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Military expenditure and economic sustainability: implications of the SAFE program

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Abstract. *This paper analyses the compatibility between the expansion of military spending generated by the SAFE (Strategy, Armament, Financing, Efficiency) programme and the long-term fiscal sustainability of the European Union Member States, with a focus on the cases of Romania, Poland and Hungary. Starting from a dual theoretical framework: the crowding-out effect versus the Keynesian multiplier, the research applies the public debt sustainability equation ($\Delta d = r - g \cdot d + pb$) and the fiscal multiplier analysis to assess the allocative efficiency of the programme. The results of the longitudinal comparison (2021–2026) demonstrate that the economic impact of the SAFE programme is non-linear and critically dependent on industrial absorption capacity: Poland transforms defence into a competitive advantage (multiplier > 1), while Romania experiences a structural deterioration in the trade balance (-1.2% of GDP). The conclusions emphasize that the economic sustainability of SAFE requires the localization of production, the implementation of the Fiscal Golden Rule, and the stimulation of public-private partnerships.*

Keywords: military expenditure, fiscal sustainability, SAFE programme, defence multiplier, crowding-out, Eastern Flank.

JEL Classification: E62, F52, H56, H62, H63.

1. Introduction

The dividend paradigm (Samuelson, 1948), which dominated European fiscal policies after 1989, has given way to the imperative of strategic security. The reconfiguration of the defense architecture through the SAFE program raises a fundamental political economy issue: the compatibility between the expansion of military spending and long-term fiscal sustainability.

Military spending can no longer be viewed exclusively as an unproductive consumption of resources, but as an “investment in institutional stability”, without which financial markets cannot operate efficiently (Hartley, 2011). However, the pressure exerted by SAFE comes at a time of post-crisis fiscal vulnerability. Economic sustainability, the capacity of a state to honor its financial obligations without compromising future growth (Blanchard, 2021), is being tested by the accelerated growth of deficits. The risk of a crowding-out effect (Benoit, 1978) coexists with evidence of positive technological externalities (Mazzucato, 2013) and the non-linear impact of military spending on growth (Dunne & Tian, 2015).

The objective of this paper is to analyze the mechanisms through which the SAFE program can be integrated into a sustainable growth model. The central hypothesis argues that, by stimulating research and development (R&D) and by creating value-added chains at European level, military spending can generate positive externalities that compensate for the initial fiscal burden. Through comparative methodology and analysis of macroeconomic indicators of Romania, Poland and Hungary in the period 2021–2026, the paper identifies the conditions under which defense investment becomes a pillar of resilience, not a source of fiscal fragility.

2. Theoretical framework

2.1. The Crowding-Out Effect: Civil Resource Eviction Mechanisms

The "crowding-out" effect postulates that an increase in budgetary allocations for defense leads to the reallocation of financial, human and technological resources from the civilian productive sectors (Smith, 1980). The primary mechanism operates through budgetary constraint: increasing military spending requires either increasing taxes or reducing other public spending, highlighting the "security-welfare trade-off" (Heo, 1998). According to the IS-LM model, financing through public debt issuance increases the demand for money, making credit more expensive for the private sector and crowding out private investment in civilian technology (Barro, 1981). Additionally, the defense sector absorbs highly skilled labor, limiting the transfer of knowledge through confidentiality barriers (Smith, 2009).

"Every dollar invested in the military-industrial complex represents a social opportunity cost, reflected in unbuilt schools or degraded civilian infrastructure (Deger, 1986)."

The sustainability of the SAFE program therefore depends on minimizing these distortions through policies supporting dual-use technologies.

2.2. The Keynesian Perspective: Multiplier and Spin-off Effects

The neo-Keynesian perspective approaches military spending as a component of countercyclical fiscal policy. State orders activate collateral sectors (metallurgy, electronics, energy), reducing unemployment and stimulating private consumption (Dunne & Smith, 1990). The multiplier is optimized if production is localized regionally, avoiding extra-community capital "leakage".

The central argument for sustainability lies in technical progress. Romer (1990) emphasizes that the stock of technical knowledge is the main engine of long-term prosperity. Historically, fundamental innovations, such as the Internet (ARPANET), GPS, emerged as a result of military financing (Mazzucato, 2013). The SAFE program, by focusing on artificial intelligence, cybersecurity and new materials, can create an "innovation ecosystem" that fuels the competitiveness of European civilian industry. The integration of dual-use technologies reduces financial risks for private firms, allowing the adaptation of military solutions for commercial markets (Vernick et al., 2017).

2.3. Economic Sustainability in the Context of the Pre-Defense Economy

In the standard literature, fiscal sustainability is the capacity of a state to maintain its spending policies without jeopardizing government solvency (Blanchard, 1990). The 2026 context requires a recalibration: in a pre-defense economy, the lack of military investment becomes, in itself, a threat to sustainability, as systemic uncertainty discourages foreign direct investment and increases the cost of capital.

"An economy cannot be considered sustainable if its critical infrastructure and trade routes are vulnerable to major external disruptions (Draghi, 2024)."

The focus shifts from allocative efficiency to resilience: maintaining surplus production capacities, strategic stocks and secure supply chains (Nordhaus, 2021). Although inefficient by traditional cost-benefit calculations, these measures ensure the survival of the system in shock conditions. However, Smith (2017) warns that "military overstretch" can generate a crisis in public finances that paradoxically weakens the defense capacity that the state is trying to strengthen.

3. The SAFE program: objectives and mechanisms

3.1. Genesis and Quadrilateral Architecture

The SAFE (Strategy, Armament, Financing, Efficiency) programme is the integrated institutional response to the need for a "defense readiness" economy. Its genesis lies in the recognition of the fragmentation of European defense markets, which generates annual inefficiencies of tens of billions of euros through the duplication of weapons systems (EPRS, 2023). SAFE goes beyond previous forms of cooperation (PESCO, EDF), synchronizing the demand of member states with the industrial supply and avoiding critical dependence on external suppliers (Biscop, 2024).

The Strategy Pillar defines long-term priorities (2030–2040), mapping the vulnerabilities of supply chains with a focus on microelectronics and autonomous systems. The Armament Pillar addresses standardization and interoperability, pursuing economies of scale through incentives for joint acquisitions, being a direct response to the historical problem of the multiplicity of European systems compared to the unitary American model (Hope & Valasek, 2021). The Financing Pillar introduces innovative mechanisms such as "Defense Bonds" and proposes "investment clauses" in European fiscal rules, allowing the partial exclusion of SAFE expenditures from the calculation of the structural deficit (European Commission, 2025). The Efficiency Pillar aims to optimize procurement through centralized digital platforms, maximizing the return on each euro invested (Draghi, 2024).

3.2. Financing Mechanisms: European Funds vs. National Budgets

SAFE's hybrid model combines the non-repayable grants and loan guarantees of the European Defence Fund (EDF) and the EDIRPA Instrument with the pressure on national budgets to reach the 2–3% of GDP target (European Commission, 2025). Centralised funding reduces entry barriers for states with smaller economies, eliminating the high fixed costs of military R&D.

"Supranational financing does not undermine sovereignty, but corrects the chronic under-investment generated by the negative externalities of uncoordinated security (Vandenbussche & Aksoy, 2023)."

The "Defense Golden Rule" proposed under SAFE would allow member states to treat capital expenditures for the program as productive investments, excluding them from the calculation of the excessive deficit (Eichengreen, 2024). Mobilizing private capital through "security bonds", with the integration of ESG criteria for the sustainable defense industry, completes the financing architecture (Credit Suisse, 2025).

3.3. Public-Private Partnerships and Industry Integration

The SAFE program marks the transition from the "client-supplier" model to a collaborative ecosystem based on PPPs, overcoming budgetary limitations by transferring operational risk to the private partner (Parker & Hartley, 2023). Long-term maintenance (Life-Cycle Costing) can represent up to 70% of the total cost of an armament program (Jones, 2025), efficiency aiming to optimize it through continuous innovation. The creation of "innovation hubs" facilitates the spin-in effect (civilian technology adopted by the military), reducing implementation time and development costs.

"Integrating the defense industry into civilian value chains through PPPs is the only sustainable method to maintain a technological advantage without depleting the state's fiscal resources (European Defence Agency, 2024)."

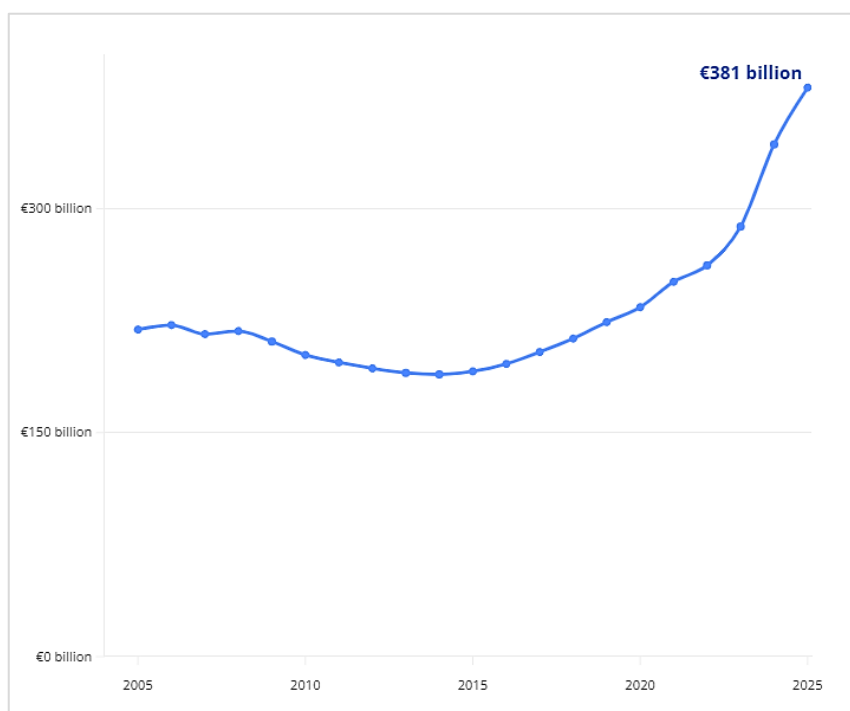
The SAFE framework imposes transparency audits and "technological sovereignty" clauses to prevent regulatory capture, ensuring that critical assets remain under the strategic control of member states (Stiglitz & Bilmes, 2023).

4. Results: evolution of defense spending and macroeconomic implications

4.1. Dynamics of Defense Spending in Europe (2005–2025)

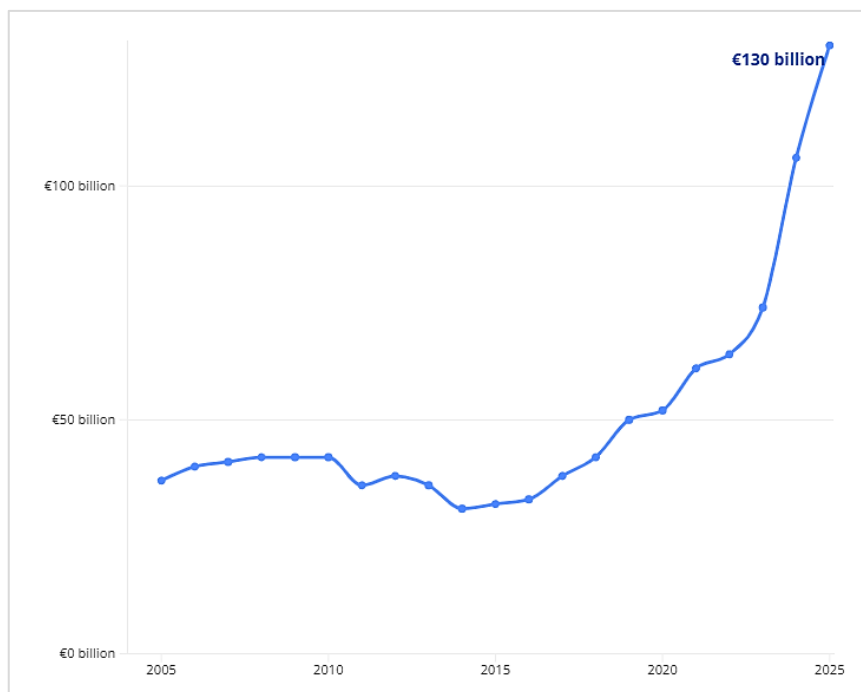
Total defense spending of European Member States followed a two-phase trajectory. Between 2005 and 2014, a reduction from ~€220 billion to ~€185–190 billion reflected post-crisis austerity policies and reduced perceptions of security risks. Starting in 2015, a sustained upward trend visibly accelerated post-2020, reaching ~€381 billion in 2025, representing a 32% increase compared to 2023. This trajectory validates the hypothesis of the “neighbourhood effect”: budgetary decisions are not isolated, but propagate in the network, generating synchronised increases in the context of a deteriorating regional security environment.

Figure 1. *Evolution of defense spending of European member states (2005–2024)*



Source: European Defence Agency

Defense investments (modernization component) have seen an even more pronounced increase: from ~30 billion euros in 2013–2014 to ~130 billion euros in 2024, a 74% increase compared to 2023. This paradigm shift, from a reactive to a proactive approach based on deterrence, justifies, from a SAFE perspective, the use of defense as a form of insurance against future risks.

Figure 2. *Defense investments (2005–2024)*

Source: European Defence Agency

4.2. The Neighborhood Effect: Analysis of Regional Interdependencies

The evolution of Romania's military spending cannot be explained by isolated internal factors, but by regional interdependencies. During the period 1990–2014, Romania followed the European model of "perceived peace balance", reducing spending from >4.5% of GDP to ~1–1.5% of GDP, a convergence facilitated by NATO and EU guarantees. The post-2014 rupture, dramatically accentuated post-2022, illustrates the mechanism of "strategic contagion": Romania reacts not only to the conflict in Ukraine, but also to the massive increase in the Polish military budget, being a signal of regional "competitive alignment".

A "geographical gradient of security" is manifested in Eastern Europe: the closer a state is to the conflict zone, the faster and more intense the budgetary reaction. Romania is positioned intermediately: more exposed than Western Europe, but less than the Baltic states or Poland, which is reflected in significant but not extreme increases. The neighborhood effect also has an anticipatory dimension: defense decisions reflect expectations regarding the future behavior of regional actors, not just retrospective reactions.

4.3. The Impact on the Deficit and Public Debt

Applying the debt sustainability equation $d_t = ((1 + r) / (1 + g)) \cdot d_{t-1} - pb$ in the context of the SAFE program allows for a rigorous assessment of Romania's fiscal trajectory (debt of ~50% GDP, $r \approx 2.5\%$, $g \approx 3.5\%$).

Figure 3. Romania's public debt sustainability scenarios under the SAFE program

Scenario	Interest rate (r)	GDP Growth (g)	Primary deficit (pb)	Est. Debt (% of GDP)
Baseline	2,5%	3,5%	2,0%	51,5%
Adverse	3,0%	1,5%	2,0%	52,75%
Favorable (spin-off)	2,5%	4,5%	2,0%	51,05%

The analysis confirms that the critical variable is the difference $r - g$: as long as economic growth exceeds the cost of financing, the SAFE program can be compatible with debt stability. In the adverse scenario, the increase in military spending amplifies the risks of fiscal slippage, highlighting the need for economic policies that support growth and limit the primary deficit.

A central element of the SAFE program is the negotiation of "flexibility clauses" within the excessive deficit procedure (EDP). Armament spending can be considered relevant mitigating factors, conceptualized as a "strategic investment" the absence of which would generate much higher economic costs in the future (Buti & Messori, 2024). However, long-term sustainability depends on the temporary versus structural nature of these exceptions (Thygesen et al., 2025).

4.4. The Defense Multiplier: Comparative Economic Efficiency

Figure 4. Comparative Fiscal Multiplier by Types of Public Expenditure

Expenditure Type	Multiplier (short-term)	Productivity Impact (long-term)
SAFE Program (Military R&D)	0,8 – 1,2	High (spin-off effects)
Civilian Infrastructure	1,0 – 1,5	High (reduction in transport costs)
Social Transfers / Consumption	0,4 – 0,6	Low (transitory impact)

The defense multiplier varies cyclically (Barro & Redlick, 2011): 0.6–0.8 in expansionary periods, >1.0 in recessionary periods. Applying $m \approx 0.7$ for an additional allocation of 1% of GDP (~3 billion euros) through SAFE, the estimated impact is $\Delta Y \approx 0.7\%$ of GDP (~2.1 billion euros). If the multiplier reaches 1.1 (underutilization conditions), $\Delta Y \approx 3.3$ billion euros, the program is partially self-financing. In comparison, infrastructure generates $\Delta Y \approx 4.5$ billion euros ($m \approx 1.5$), and education $\Delta Y \approx 2.7$ billion euros in the short term with superior effects in the long term.

However, including the "crowding-in" effect of private investment (conservatively estimated at 0.3) and reducing import losses generated by the SAFE structure (focus on domestic production) increases the effective multiplier to ~1.0–1.2, bringing it closer to the efficiency of civilian infrastructure. According to Moretti et al. (2022), public investment in military R&D stimulates private research in adjacent technological sectors, balancing the efficiency balance.

4.5. Social Sustainability: Opportunity Cost and Public Acceptance

The social sustainability of SAFE, represented by the capacity of governments to maintain cohesion in the face of resource reorientation, is analyzed through Peacock & Wiseman's (1961) hypothesis on the "displacement effect". Public acceptance is mediated by transparency and the local impact of investments: the SAFE program strengthens social

sustainability if it generates highly qualified jobs in disadvantaged regions, transforming military spending into an instrument of territorial cohesion.

Eurobarometer (2025) confirms that support for increasing defense budgets is directly proportional to the level of trust in European institutions and the perception of the efficiency of the use of funds, which gives the Efficiency pillar of SAFE a social legitimization function, not just an accounting one (Bove et al., 2023). The major risk remains "strategic fatigue": if inflationary pressure or the degradation of civil services becomes visible, the social contract may be strained (Stiglitz, 2023).

5. Comparative analysis: Romania, Poland and Hungary

5.1. Strategic Divergences on the Eastern Flank

The implementation of SAFE in the Eastern Flank generated three distinct models of economic sustainability, conditioned by the pre-existing fiscal space and industrial absorption capacity (Eurostat, 2026; SIPRI, 2025):

Figure 5. Comparative Macroeconomic Indicators: Romania, Poland, Hungary (2021–2026)

Member State	Defense % of GDP 2021	Defense % of GDP 2026 (Est.)	Debt % of GDP 2021 (Est.)	Debt % of GDP 2026 (Est.)	Industrial Multiplier (Est.)
Poland	2,20%	4,50%	53,80%	59,20%	1,15
Romania	2,00%	2,50%	48,90%	52,40%	0,85
Hungary	1,60%	2,10%	76,80%	73,10%	0,92

Poland is the "champion" of the SAFE implementation, transforming military spending into incentives for national heavy industry through massive procurement and technology transfer partnerships. Using the Armed Forces Support Fund, a financial vehicle external to the state budget, similar to the SAFE architecture, Poland maintains sustainability through an economic growth rate higher than the interest rate (Eichengreen & Panizza, 2024). Romania faced structural constraints: a significant part of the increases fueled the current account deficit through mainly foreign procurement, placing it under the pressure of the excessive deficit procedure (Fiscal Council, 2025). Hungary adopted a hybrid approach, using SAFE for regional reindustrialization (Rheinmetall factories), managing to reduce public debt by increasing value added (Hagemejer & Mućk, 2024).

5.2. Post-Implementation Macroeconomic Indicators

The military fiscal expansion generated inflationary pressures through supply bottlenecks in high-tech sectors: ECB (2025) confirms core inflation above the 2% target. In Romania, imported inflation through exchange rate depreciation during peak purchasing periods amplified structural vulnerabilities (BNR, 2025). Financial markets' perception reflects these divergences in CDS spreads:

Figure 6. Sovereign Risk Indicators (CDS Spreads and Bond Yields 2021 vs. 2026)

Member State	5Y CDS Spread – 2021	5Y CDS Spread – 2026 (Est.)	10Y Bond Yield (2026)
Poland	50 bps	85 bps	5,80%
Romania	95 bps	180 bps	7,20%
Hungary	80 bps	165 bps	6,50%

Markets penalize Romania and Hungary more severely for accumulated deficits, perceiving their fiscal space as more vulnerable to financing shocks. Poland benefits from a lower risk premium due to its solid industrial base (Eichengreen, 2024). Regarding the balance of payments, Poland managed to partially offset imports through component exports (substitution effect), Hungary stabilized its current account by localizing production (localization effect), and Romania recorded a structural deterioration of $\sim 1.2\%$ of GDP without compensating export flows (Eurostat, 2026). Therefore, the sustainability of SAFE depends on the “localization multiplier”: in states where investment remained in the domestic economy, macroeconomic pressures were absorbed more easily.

6. Discussion, limitations and research directions

6.1. Methodological Limitations

The first limitation lies in the volatility of forecast data: when analyzing the implementation of SAFE in the horizon 2024–2026, many indicators are estimates based on current trajectories, perturbed by exogenous geopolitical or energy shocks (Arslanalp & Eichengreen, 2023). The second limitation is the lack of transparency specific to the defense sector: details of offset contracts and the exact structure of R&D costs are not always public, requiring the use of econometric proxies with margins of error (Dunne & Smith, 1990). The third limitation concerns the quantification of spin-off effects: this requires an observation period of >10 years; empirical confirmation for SAFE will only be possible in the post-implementation phase (Mazzucato, 2013).

6.2. Directions for Future Research

Future research should pursue three priority directions. The transition from aggregate macroeconomic analyses to Input-Output modeling would allow for the precise identification of civilian sectors that benefit from centralized military orders (Smith, 2023). Longitudinal assessment of the inflationary impact, carried out through comparative analyses post-2026, will determine whether the military fiscal expansion generated real crowding out of private consumption or whether technological investments sufficiently increased aggregate supply (ECB, 2025). Comparative studies on the efficiency of PPPs in states that have resorted to private capital under SAFE guarantees versus those with classical budgetary financing will provide fundamental conclusions about the optimization of the cost of capital and the management of country risk (Müller & Bellmann, 2024).

7. Conclusions

The research demonstrates that the impact of the SAFE program on the economy is not univocally negative, but critically depends on the institutional architecture and industrial absorption capacity. The analysis generates three fundamental conclusions.

First, the duality of the economic impact: SAFE functions as a Keynesian stimulus in economies with solid industrial bases (the case of Poland, multiplier $md > 1$), but generates crowding-out effects and deterioration of the trade balance in import-dependent economies

(the case of Romania). Second, the reconstruction of the concept of sustainability: the 2021–2026 data suggest that financial markets accept higher levels of public debt directed towards the "Armament and Efficiency" pillars of SAFE, perceived as "insurance" against catastrophic geopolitical shocks. Third, the importance of technology transfer: the success of the program does not lie in the volume of acquisitions, but in the ability to generate spin-off effects; dual-use technologies represent the only way in which the fiscal burden can be transformed into a civil innovation dividend.

To ensure the economic sustainability of SAFE, especially for states with limited fiscal space such as Romania, three lines of action are needed: (1) Localization of production and strategic offset, by conditioning acquisitions on the integration of local companies into European supply chains, minimizing capital "leakage"; (2) Implementation of the Fiscal Golden Rule, by formalizing at EU level the exclusion of SAFE investment expenditures from the calculation of the structural deficit, subject to interoperability and R&D projects; (3) Stimulating PPPs, by reducing the pressure on public debt by attracting private capital into defense infrastructure.

The SAFE program should not be seen as an alternative to investments in social welfare, but as a necessary foundation for it in the context of 2026. The major challenge remains managing "security inflation" and preventing a new sovereign debt crisis. Deeper European integration in defense is the only solution that can provide economies of scale capable of making collective security compatible with sustainable economic prosperity.

References

- Aizenman, J., and Glick, R. (2006). Military Expenditure, Threats, and Growth. *Journal of International Trade and Economic Development*. <<https://doi.org/10.1080/09638190600680430>>
- Arslanalp, S., and Eichengreen, B. (2023). *Living with High Public Debt*. Jackson Hole Economic Symposium Proceedings.
- Auerbach, A.J., and Gorodnichenko, Y. (2024). Fiscal Multipliers in a Post-Pandemic World. *American Economic Journal: Economic Policy*.
- Banca Națională a României (BNR). (2025). *Raport asupra Inflației și Stabilității Financiare*. București.
- Barro, R.J. (1981). Output Effects of Government Purchases. *Journal of Political Economy*.
- Barro, R.J., and Redlick, C.J. (2011). Macroeconomic Effects from Government Purchases and Taxes. *Quarterly Journal of Economics*. <<https://doi.org/10.1093/qje/qjq002>>
- Benoit, E. (1978). Growth and Defense in Developing Countries. *Economic Development and Cultural Change*.
- Biscop, S. (2024). *The New European Defence Architecture: From SAFE to Strategic Autonomy*. Egmont Institute.
- Blanchard, O. (2021). *Fiscal Policy under Low Interest Rates*. MIT Press.
- Blanchard, O. (2024). *Fiscal Policy under Low-but-Rising Interest Rates*. MIT Press.
- Blanchard, O.J. (1990). *Suggestions for a New Set of Fiscal Indicators*. OECD Economic Studies.

- Bove, V., Efthyvoulou, G., and Navas, A. (2023). Political Cycles and Military Expenditure in Eurozone Countries. *Public Choice Journal*.
- Buti, M., and Messori, M. (2024). European Public Goods: The New Frontier of EU Fiscal Rules. European Policy Centre.
- Comisia Europeană. (2024). European Defence Industrial Strategy: Achieving Readiness through SAFE. Official Publications of the EU.
- Comisia Europeană. (2025). SAFE Finance: Operationalizing the Defence Investment Gap. Brussels: Official Publications Office.
- Credit Suisse Research Institute. (2025). ESG 2.0: Defense as a Social Good in the Post-Conflict Era.
- Cypher, J.M. (1987). Military Expenditures and the Performance of the Economy. *Journal of Post Keynesian Economics*.
- Deger, S. (1986). *Military Expenditure in Third World Countries: The Economic Effects*. Routledge & Kegan Paul.
- Draghi, M. (2024). The Future of European Competitiveness. Report for the European Commission.
- Dumas, L.J. (2024). *The Socio-Economics of Modern Defense Finance*. Oxford University Press.
- Dunne, J.P., and Smith, R.P. (1990). Military Expenditure and Unemployment in the OECD. Defence Economics.
- Dunne, J.P., and Tian, N. (2015). Military Expenditure and Economic Growth: A Survey. Defence and Peace Economics.
- Dunne, J.P., Smith, R.P., and Willenbockel, D. (2005). Models of Military Expenditure and Growth. Defence and Peace Economics.
- Eichengreen, B. (2024). Fiscal Rules for a New Era of Security. *Journal of European Public Policy*.
- Eichengreen, B., and Panizza, U. (2024). The Economics of Sovereign Debt in the New Geopolitical Context. *Journal of Economic Perspectives*.
- EPRS (European Parliamentary Research Service). (2023). The Cost of Non-Europe in Defence. Brussels.
- Eurobarometer. (2025). Public Perceptions on European Security and Defence Cooperation. European Commission.
- European Central Bank (ECB). (2025). Defense Spending and Price Stability in the Euro Area. Frankfurt.
- European Council. (2022). The Strategic Compass for Security and Defence. Council of the European Union.
- European Council. (2025). Revised Stability and Growth Pact: Treatment of Strategic Defence Investment. Brussels.
- European Defence Agency (EDA). (2024). *Annual Report on Defence Cooperation and Industrial Integration*. Brussels.
- Eurostat. (2026). Balance of Payments Statistics: Quarterly Data for CEE Countries. Luxembourg.
- Eurostat. (2026). General Government Expenditure by Function (COFOG) – Defence Focus 2021–2025. Luxembourg.
- Fiscal Council of Romania. (2025). *Annual Report on the Sustainability of Public Finances*. Bucharest.
- Fontanel, J., and Smith, R.P. (2024). *The Economics of Peace and Security*. Routledge.
- Gechert, S. (2025). What Drives Fiscal Multipliers? Analysis of Public Investment vs. Defense. *European Economic Review*.

- Hagemejer, J. (2025). FDI and Defense Industrial Base in Central Europe. *Journal of International Economics*.
- Hagemejer, J., and Mućk, J. (2024). Defence Spending and Global Value Chains in CEE. *World Economy Journal*.
- Hartley, K. (2011). *The Economics of Defense Policy*. Routledge.
- Heo, U. (1998). Modeling the Defense-Growth Relationship: A Reassessment. *Journal of Politics*.
- Hope, I., and Valasek, T. (2021). *Standardization and Interoperability in European Armed Forces*. Carnegie Europe.
- Jones, T.K. (2025). Life-Cycle Management in Modern Defence Procurement. *Journal of Military Economics*.
- Mamonov, M., and Pestova, A. (2023). The Impact of Military Spending on Growth. *Defence and Peace Economics*.
- Mazzucato, M. (2013). *The Entrepreneurial State*. Anthem Press.
- Moretti, E., Steinwender, C., and Van Reenen, J. (2022). The Intellectual Spoils of War? Defense R&D, Productivity and International Spillovers. NBER.
- Müller, J., and Bellmann, C. (2024). *Public-Private Partnerships in the Defence Sector*. Springer.
- Nordhaus, W. D. (2021). *The Economics of Resilience in Precarious Times*. Yale University Press.
- Parker, D., and Hartley, K. (2023). *The Economics of Public-Private Partnerships*. Routledge.
- Peacock, A.T., and Wiseman, J. (1961). *The Growth of Public Expenditure in the United Kingdom*. Princeton University Press.
- Romer, P.M. (1990). Endogenous Technological Change. *Journal of Political Economy*.
- Samuelson, P.A. (1948). *Economics*. McGraw-Hill.
- Sandler, T., and Hartley, K. (1995). *The Economics of Defense*. Cambridge University Press.
- SIPRI (Stockholm International Peace Research Institute). (2025). *Trends in World Military Expenditure*. Oxford University Press.
- Smith, R.P. (1980). Military Expenditure and Investment in OECD Countries. *Journal of Comparative Economics*.
- Smith, R.P. (2009). *Military Expenditures and Economic Outcomes*. Cambridge University Press.
- Smith, R.P. (2017). *Defense in the 21st Century: The Economics of Modern Security*. Palgrave Macmillan.
- Smith, R.P. (2023). Economic Efficiency in Cooperative Defence Procurement. *Journal of Common Market Studies*.
- Stiglitz, J.E. (2000). *Economics of the Public Sector*. W.W. Norton & Company.
- Stiglitz, J.E. (2023). Social Sustainability and the New Security State. *Journal of Policy Modeling*.
- Stiglitz, J.E., and Bilmes, L.J. (2023). *The Military-Industrial Complex and the Economics of Peace*. Columbia University Press.
- Thygesen, N., et al. (2025). Annual Report of the European Fiscal Board. *European Fiscal Board Publications*.
- Vandenbussche, H., and Aksoy, C. (2023). Public Goods and Defense: The Case for European Integration. *Economic Policy Review*.
- Vernick, J.S., et al. (2017). Dual-use Research and the Intersection of Science and Security. *Science and Engineering Ethics*.

Regional inequalities and human capital adaptability in Romania

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Abstract. *Regional disparities still impact education, employment, and access to technology in Romania. The analysis of the evolution of these discrepancies over the 2018-2023 period is carried out based on regional variables on education, labour market conditions, and digital access. GIS mapping, Moran's I, LISA cluster analysis, and PCA are used for the determination of territorial patterns and regional adaptation. The results reveal important differences between Bucharest-Ilfov and less developed regions, especially as regards the link between education, digitalization, and chances of employment. The results suggest that skill difference and technology access differences are still crucial determinants of regional development and long-term change.*

Keywords: regional disparities, human capital, adaptability, digital inclusion, spatial analysis.

JEL Classification: R11, J24.

Introduction

Even at the European level, regional disparities remain a difficult problem to address. They show how much access to education, well-paid jobs and technology matters. Research in recent years has shown that these gaps do not disappear on their own. Regions that start with a disadvantage tend to lag behind and accumulate problems that affect both the economy and people's daily lives (Rodríguez-Pose, 2018). At the same time, other studies show that where people live directly influences their perceptions and development opportunities (Dijkstra, et al., 2020).

Human capital is a central factor in these disparities. Classical theories show that investments in education lead to higher productivity and can create different economic developments from one region to another (Becker, 1993). However, it is not only the number of years of schooling that matters, but also the quality of skills (Hanushek & Woessmann, 2012). Nowadays, with digitalization, access to the internet and technology is becoming essential for a region to adapt. Territorial disparities appear consistently in the European Commission's DESI reports (2020–2023). The literature on the knowledge economy also shows that large cities attract well-trained people and generate accelerated development. This is also clearly seen in Romania, where Bucharest–Ilfov stands out strongly from other regions.

This study analyses how these disparities evolved in Romania between 2018 and 2023, with a focus on education, employment and digitalization - all related to regional adaptability. We combined several methods: GIS maps, global spatial autocorrelation (Moran's I), local cluster analysis (LISA) and PCA. The aim was to capture stable territorial patterns and the factors that separate dynamic regions from stagnant ones. The results provide an overview of how human capital and access to technology influence the ability of regions to respond to rapid change.

Literature review

Studies show that many regions lag behind for long periods. They do not attract investment, do not have good services and fail to catch up with more developed areas (McCann, 2020). These things are felt in people's lives. Those in weaker regions are more likely to say that they have fewer opportunities and feel less satisfied.

Romania is in much the same boat. Studies show that economic activity and development are concentrated in a small number of large cities. Many rural regions remain less competitive, with poorer infrastructure and weaker investment (Benedek & Kurkó, 2011)

An important factor is education. Regions where people have better skills adapt more easily and attract more jobs (Gennaioli, et al., 2013). It is not just the years of schooling that count, but what people actually know how to do. The quality of skills makes the difference (Acemoglu & Autor, 2011).

Digitalisation is also changing the situation. Areas with good internet and access to technology grow faster. Where technology is lacking, the differences deepen (Jan, 2020).

Similar empirical studies also examine digital disparities through indicators related to internet access and internet use. Vicente and López (Vicente & López, 2011), for example, showed that weaker digital connectivity is associated with lower regional development across European regions.

The literature also shows something important: big cities have a clear advantage. They attract companies, skilled people, and innovation, which helps them grow even more over time (Duranton & Puga, 2020). Societal implications of regional disparities are also identified in studies. People in less-developed areas could be excluded. They may be more skeptical of institutions. Such inequalities are often the product of a slower adaptation by some areas to economic and technological progress (Simona, et al., 2019).

In general, research shows that a place's education, technology, and economic structure strongly influence regional development. These elements explain why some areas advance rapidly while others lag behind. Previous studies focused on separately economic inequalities or digital and educational differences. The interaction of these dimensions at the regional level in Romania was studied less. This paper contributes to the literature by integrating spatial analysis and PCA. The objective is to learn more about the regional adaptability through education, employment and digitalization indicators.

Methods

The analysis began with the creation of GIS maps. These were used to show how the indicators were distributed in each region of Romania between 2018 and 2023. These maps provided a much easier visual interpretation of the differences between regions. Based on these, the first hypotheses regarding possible spatial patterns could also be identified. GIS mapping was particularly useful for identifying territorial inequalities and observing regional changes over time.

The research continued with Moran's I analysis, a widely used measure of global spatial autocorrelation (Moran, 1950). The method evaluates whether regions with similar values tend to be spatially clustered or randomly distributed. Positive Moran's I values indicate clustering, while negative values suggest spatial dispersion. The next step was the Local Indicators of Spatial Association (LISA) analysis developed by Anselin (Anselin, 1995). Unlike global Moran's I, LISA identifies local spatial clusters and spatial outliers. The method highlights high-high, low-low and asymmetric spatial combinations, helping identify regions with similar or contrasting development patterns.

After completing the spatial analysis, the study continued with the principal components analysis. PCA aimed to understand the internal structure of the data. PCA did not take geographical location into account but showed how the indicators were related to each other and which common components best described the differences between regions. This resulted in dimensions such as economic development, digitalization or social vulnerability. PCA was useful for reducing the complexity of multiple socio-economic indicators and identifying the main dimensions underlying regional disparities.

Finally, the sequence GIS - Moran's I - LISA - PCA provided a complete analysis. The maps showed the situation, Moran's I confirmed the global pattern, LISA located the

critical areas, and PCA explained the factors that underpinned these differences. Together, these methods allowed both the spatial visualization of disparities and the identification of the main socio-economic dimensions associated with regional adaptability.

The study also has limitations. The analysis only uses regional-level indicators. In this respect no regional differentiation is recorded. Additionally, the factors considered and the study timeframe limited the availability of data. PCA simplifies complex socio-economic interactions to a smaller number of components. Such simplifications may hide some particularities of an area. The results are regional generalizations, not local reality.

Results and discussions

Exploratory data analysis

The data used for this work were taken from the Eurostat database. The indicators used are explained in the table below along with the units of measurement.

The indicators were selected based on the main features of regional adjustment and socio-economic development. GDP per capita and employment indicators are used to measure economic performance and labor market conditions. Internet connectivity and internet usage are indicators for the adoption of technology and digitalization. Tertiary education and R&D people are proxies for the human capital and innovative capacity. The index of social vulnerability is the poverty index.

Table 1. Variable code, variable names of indicators and units of measurement

Variable code	Variable name	Unit of measurement
X ₁	GDP per capita	Euro per inhabitant
X ₂	R&D personnel	Full-time equivalent
X ₃	Employment rate	Percentage
X ₄	Unemployment rate	Percentage
X ₅	Internet-access households	Percentage of households
X ₆	Internet users	Percentage of individuals
X ₇	At risk of poverty	Percentage
X ₈	Tertiary students	Number

Source: Author's own research

For this analysis, only these basic indicators were selected for this paper. The basis for their selection was to take into account that they should be from various fields such as economic, educational and social. The analysis period was 2018-2023 and included the 8 regions of Romania. The table below includes the region codes and their corresponding names.

Table 2. Region code and name

Region code	Region name
RO11	North-West
RO12	Centre
RO21	North-East
RO22	South-East
RO31	South-Muntenia
RO32	Bucharest-Ilfov
RO41	South-West Oltenia
RO42	West

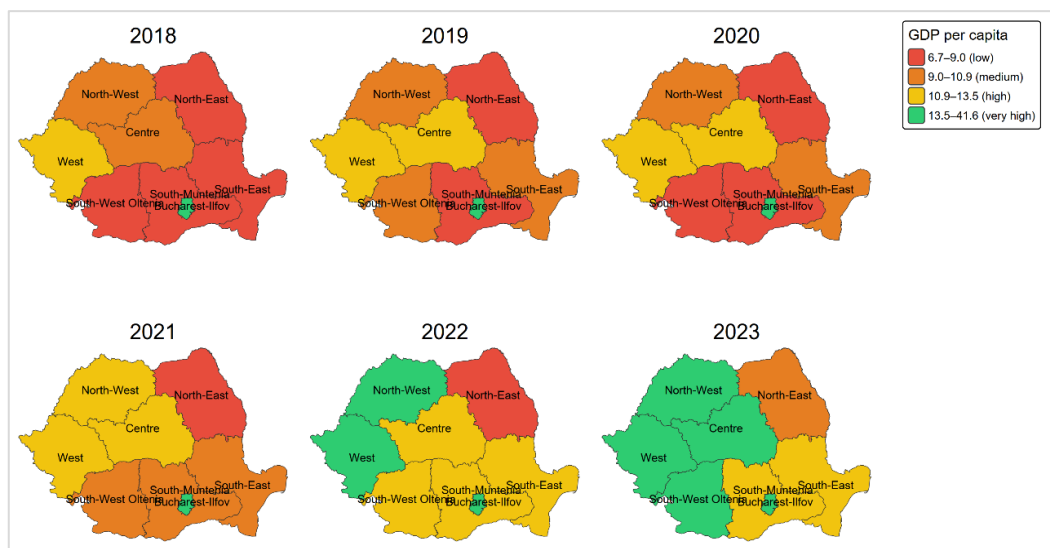
Source: Author's own research

Geographic Information System (GIS) maps

GIS maps are created for each indicator and for each year. Depending on the values of each indicator, the regions of Romania were classified each year in a certain number of classes. Similarly, considering the effect produced by that indicator, each class was represented with a certain colour. For example, for indicators that are to be maximized, in the sense of reaching a higher value, regions with low values are highlighted in red, with medium values in orange and so on until the highest values are reached, which are represented in green. The same convention was applied for indicators that are to be minimized, in the sense of reducing their values. This time, low values are represented in green, medium values in yellow up to the highest values, which are represented in red.

Regarding GDP per capita, it is observed that only in the last 2 years considered in the analysis for the North-West region are the values the highest and considered to be good. The Centre region only in 2023 ended up being green. The North-East region until 2022 had low values, with red, and only in 2023 did it move into a slightly better area, orange. The South-East and South-Muntenia regions reached an area with almost good values because it is represented with yellow in 2022 and 2023. The South-West Oltenia region in 2023 ends up having high values. The West region in the last 2 years is represented with green, and Bucharest-Ilfov throughout was the most optimal. These results are consistent with previous studies showing that Bucharest-Ilfov concentrates economic activity, infrastructure and development opportunities, while many eastern and southern regions continue to lag behind (Benedek & Kurkó, 2011).

Figure 1. GDP per capita GIS map

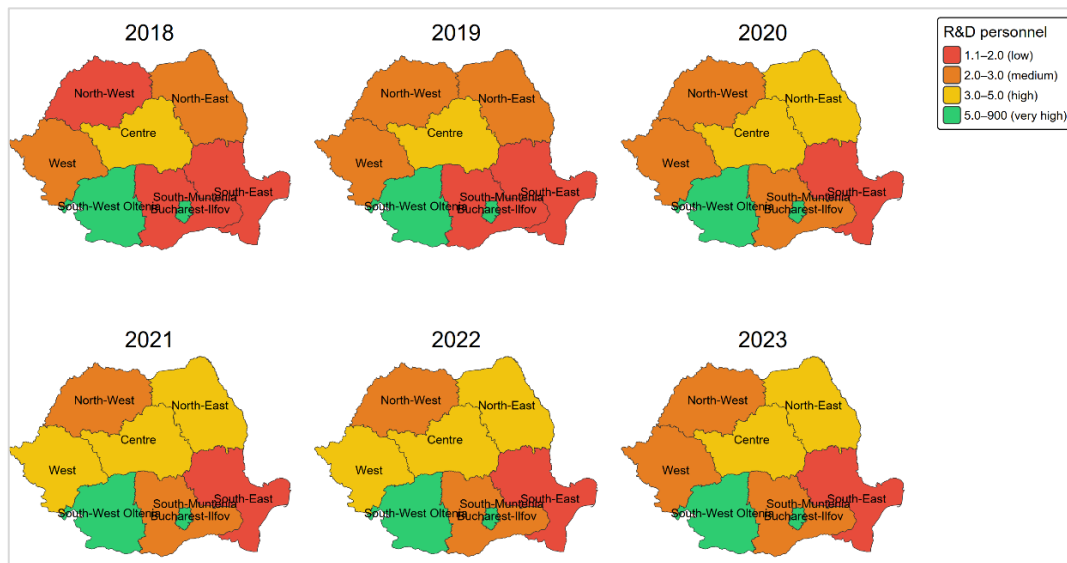


Source: Author's own research

Figure 2 illustrates the indicator regarding R&D personnel. In the first year, the North-West region had very low values, represented in red, which only increased slightly, reaching orange, even by the end of the analysed period. The North-East region was considered more

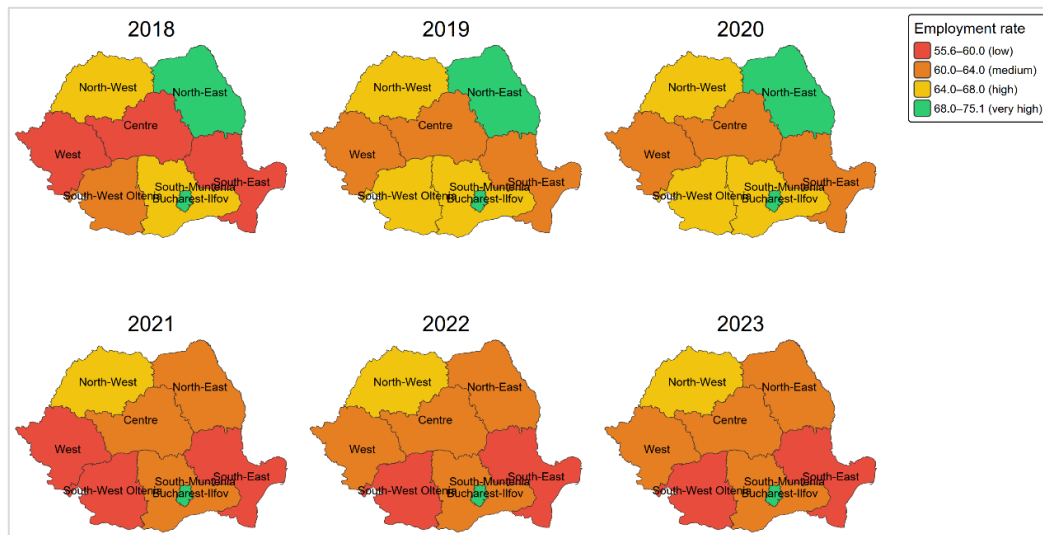
opportune because even from 2018 it had higher values, but even this did not reach the best values until 2023. The Centre region was constant over time and had quite high values. In the first 2 years, the South-Muntenia region recorded very low values and reached average values. The West region had periods when it had average values as well as quite high values. Only the 2 regions, Bucharest-Ilfov and South-West Oltenia had the highest values, and which were represented in green throughout the analysed period.

Figure 2. *R&D personnel GIS map*



Source: Author's own research

Figure 3. *Employment rate GIS map*

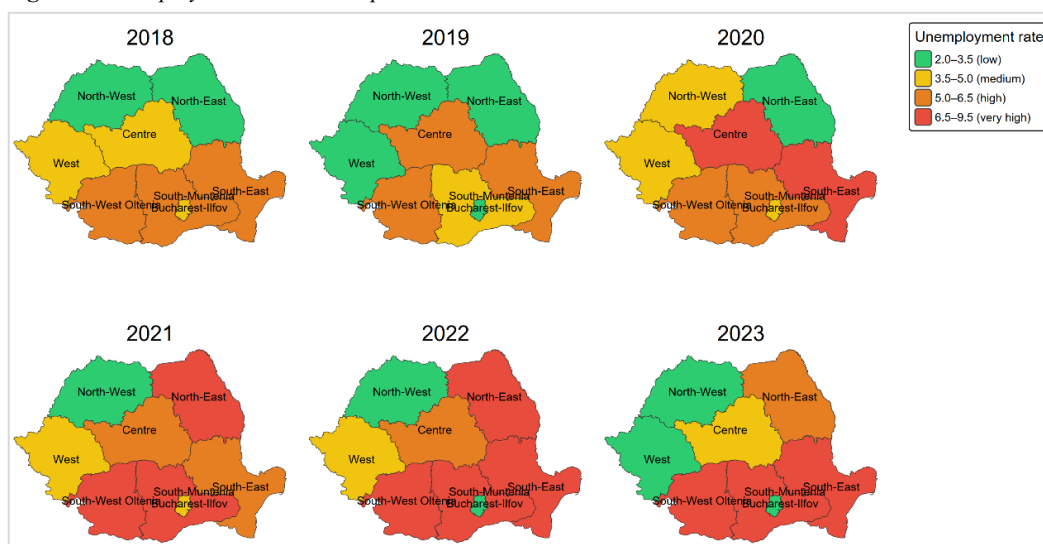


Source: Author's own research

Figure 3 contains the economic indicator regarding the employment rate. The map shows us that the North-West region has remained constant over time with quite high values. In contrast, in the first 3 years of analysis, the North-East region had very high values for this indicator and was represented in green, but then it recorded decreases that reached average values. The Centre region had low values only for 2018, in the following years it recorded average values, represented in orange on the map. The South-East region indicated average values only for 2019 and 2020, in the remaining years it had very low values, illustrated in red. The South-Muntenia region started from low values to average values. The South-West Oltenia region had both average values and quite high values, but in recent years it has reached very low values. The West region also had periods with very low but also average values. And for this indicator, the Bucharest-Ilfov region was the only one to record the highest values.

The following figure shows the unemployment rate indicator for the entire analyzed period and for each region separately. The North-West region had among the lowest values for this indicator except for 2020. The North-East region recorded low values for the first 3 years of the analysis, and then these began to gradually increase, reaching even very high values for the years 2021 and 2022. The Centre region also presented fluctuations, from very high values to average values for this indicator. Throughout the analysis period, the South-East region presented only high and very high values. The South-Muntenia region started in the first 3 years with average and high values, and in the last 3 years it had very high values. The South-West Oltenia region in the first 3 years had quite high values, and in the last 3 years very high values. The West region only for the years 2019 and 2023 recorded low values, represented in green, in the rest of the years it had average values. Even the Bucharest-Ilfov region this time for this indicator had low values only for the years 2019, 2022 and 2023, in the rest of the years the values were average.

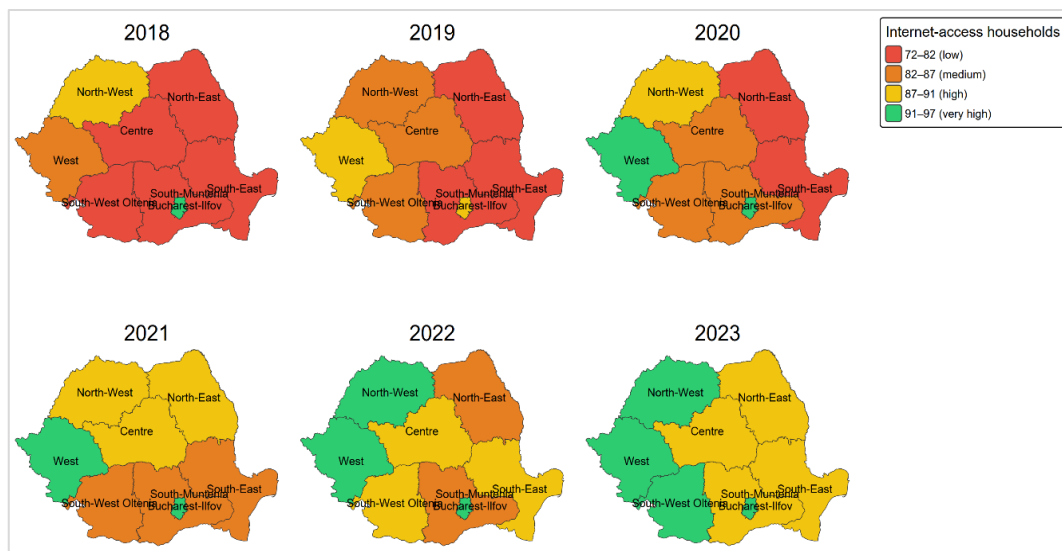
Figure 4. *Unemployment rate GIS map*



Source: Author's own research

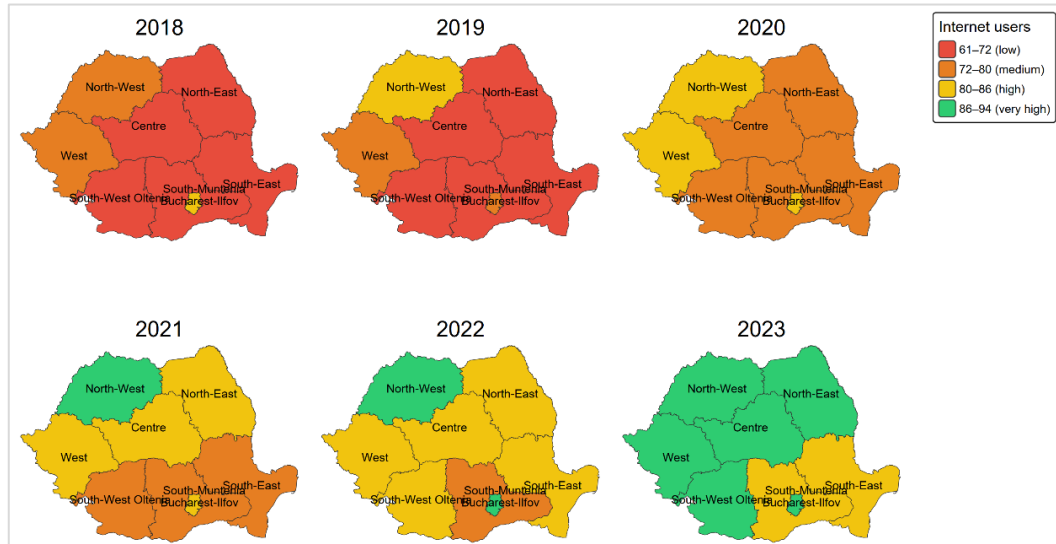
The figure below illustrates the map related to the internet access household's indicator. For the North-West region, only in the last 2 years of analysis, very high values were recorded for this indicator. The North-East region demonstrated quite high values only for the years 2021 and 2023. The Centre region started from very low values for this indicator and reached quite high values for the last 3 years of the analysed period. The South-East region recorded very low values to quite high values. The South-Muntenia region had quite high regions only for the year 2023. The South-West Oltenia region had low values at the beginning of the period, represented in red, which increased along the way and reached very high values in 2023, represented in green. In the last 3 years considered in the analysis, the West region recorded very high values for this indicator. The Bucharest-Ilfov region, apart from 2019, recorded the highest values for this indicator.

Figure 5. *Internet-access households GIS map*

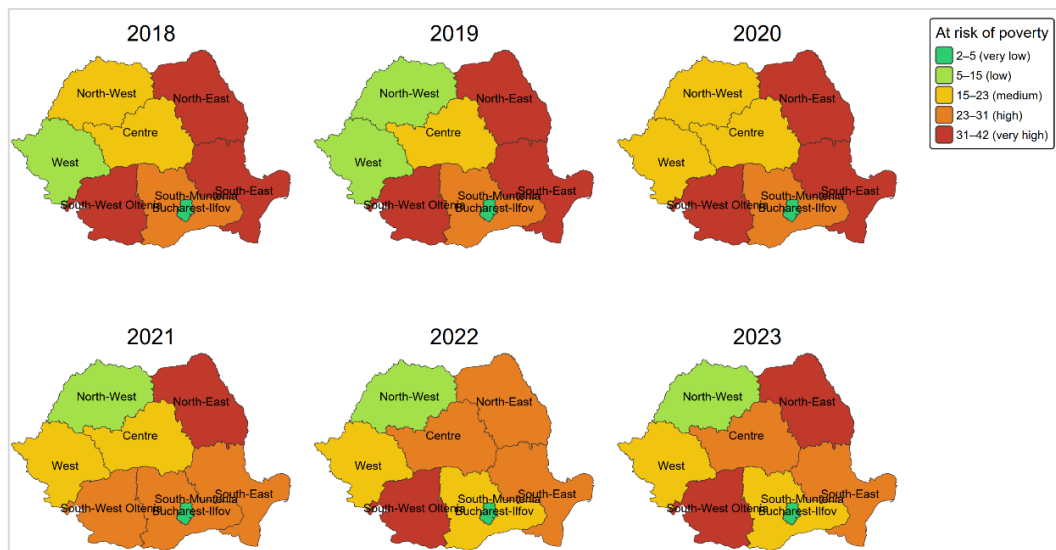


Source: Author's own research

Figure 6 shows the users who use the internet. The North-West region had very high values in the last 3 years of the analysis. The North-East region only in 2023 had very high values for this indicator. The Centre region started from very low values for this indicator for the years 2018 and 2019 and reached very high values only for the year 2023. The South-East region recorded quite high values only for the years 2022 and 2023. The South-Muntenia region illustrated quite high values for this indicator only for the year 2023, otherwise it had medium or low values. The West region had very high values also only for the year 2023. The Bucharest-Ilfov region recorded very high values only for the years 2022 and 2023.

Figure 6. *Internet users GIS map*

Source: Author's own research

Figure 7. *At risk of poverty GIS map*

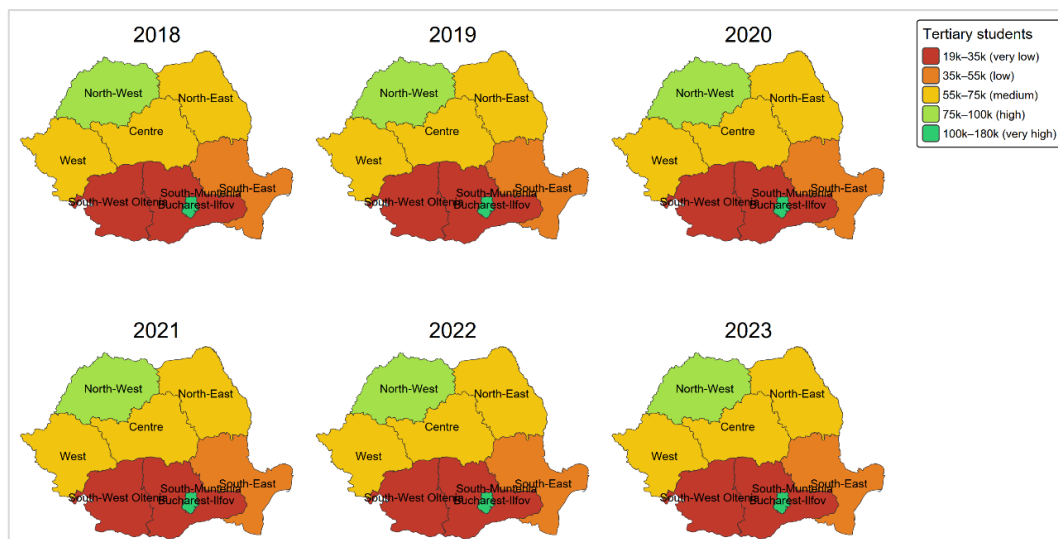
Source: Author's own research

Figure 6 shows the users who use the internet. The North-West region had very high values in the last 3 years of the analysis. The North-East region only in 2023 had very high values for this indicator. The Centre region started from very low values for this indicator for the years 2018 and 2019 and reached very high values only for the year 2023. The South-East region recorded quite high values only for the years 2022 and 2023. The South-Muntenia region illustrated quite high values for this indicator only for the year 2023, otherwise it

had medium or low values. The West region had very high values also only for the year 2023. The Bucharest-Ilfov region recorded very high values only for the years 2022 and 2023.

The map regarding students enrolled in tertiary education is illustrated in the graph below. For the North-West region, it was observed that there are high values throughout the analyzed period. The North-East, Centre and West regions remained constant for all years with average values, represented in yellow. The South-West Oltenia and South-Muntenia regions recorded very low values regarding this indicator. Bucharest-Ilfov was the only region with very high values for this indicator. The results also support the literature emphasizing the role of education and human capital in regional adaptability and labor market performance (Gennaioli, et al., 2013).

Figure 8. *Tertiary students GIS map*



Source: Author's own research

Moran's I and LISA analysis

The results for the Moran's I analysis can be seen in the appendix in table 3. The Moran's I analysis revealed that most of the socio-economic indicators have very low values. Even most of the time close to zero. Also, the p-values were not significant. This meant that there is no clear spatial pattern between the NUTS2 regions in Romania. The regions do not cluster into "high-high" or "low-low" areas, they vary quite independently of each other. It was also observed that for certain years, the Moran's I values increased slightly towards zero or positive values. This could suggest a very weak tendency of convergence between the regions, but it was not strong enough to be considered statistically significant.

Table 4 in the annexes shows the LISA results for the significant regions. The LISA results confirm what was also observed at the global level. Most regions appear as "insignificant", so they do not form clear clusters. There are certain causes for which isolated areas appear that are significant. These are of the high-high or high-low type. It is also worth mentioning

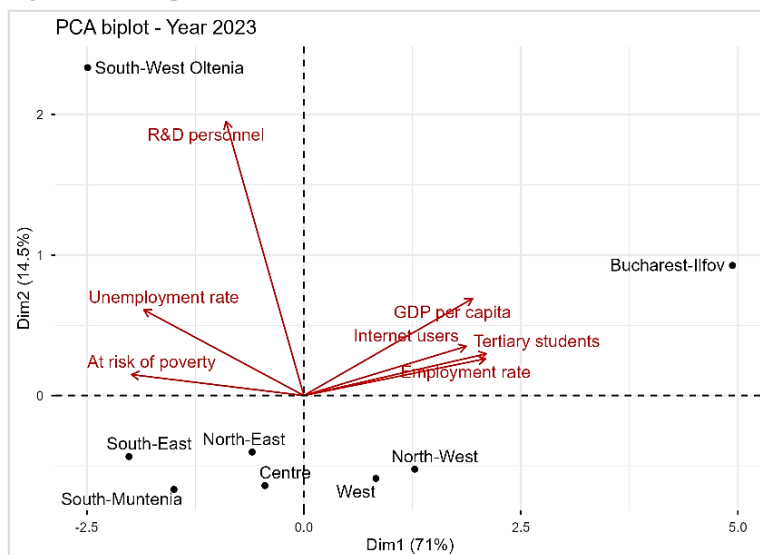
that they do not persist over time and therefore do not have a stable pattern. It was also observed that the indicators change a lot from one year to the next, and this variation makes the differences between regions difficult to put into a simple or constant pattern.

Principal component analysis

After applying the principal components analysis for all years, it was observed that the first 2 principal components could be retained. In this case, Component 1 explains about 55–76% of the total variation, and Component 2 explains between 14–21%, depending on the year. Together, the two components capture about 70–90% of the variation, which is large enough to provide a clear picture of differences between regions. Principal component 1 (Dim1) represents economic and human capital development. This structure is in line with previous studies showing that economic performance, education and digitalization tend to evolve together and shape regional competitiveness (Hanushek & Woessmann, 2012; Duranton & Puga, 2020). Principal component 2 (Dim2) captures the social and vulnerability dimension, as well as a part related to the structure of the research workforce. Also, the indicator internet access households was not considered because it was redundant. That is why the indicator internet users was kept. To illustrate this analysis, the year 2023 was selected, the rest of the graphs can be found in the appendix.

Figure 9 below shows how the regions of Romania differ in 2023 following the application of principal component analysis. It was observed that the Bucharest-Ilfov region was the most different of all because it had high values for the economy, students enrolled in university education and the internet. The eastern and southern regions appeared to be comparatively weaker, with lower values for GDP and employment rate. The South-West Oltenia region stood out with an atypical profile related to social problems but also presented very high values for R&D personnel. In contrast, the central and western regions were close to the average. Overall, the differences between the regions remained quite large.

Figure 9. PCA biplot – Year 2023



Source: Author's own research

In 2018 (figure 10), the differences between the regions were evident from the first year considered in the analysis. The Bucharest-Ilfov region was much more advanced in terms of economy, education and internet use. The North-West and West regions also presented quite good values, but more moderate compared to Bucharest-Ilfov. The regions in the South and East lagged behind because they presented lower values for GDP per capita, employment rate. They also presented high values for the poverty risk rate. Also, for this year, the South-West Oltenia region was atypical due to the high number for R&D.

In 2019 (figure 11), the structure of the regions was maintained. The Bucharest-Ilfov region remained far ahead compared to the others. The North-West region continued to have a relatively good profile. The East and South of the country lagged behind, with low values for GDP, students and employment. The North-East region continued to present a high risk of poverty.

In 2020 (figure 12), the Bucharest-Ilfov region continued to be the best of all. The North-West and West regions remained considered quite balanced. The South and East continued to be in the area with weaker performances. The North-East region remained sensitive to vulnerability indicators. This supports the broader literature arguing that weaker regions often face persistent socio-economic vulnerability and slower adaptation to structural change (Simona, et al., 2019).

In the following year (figure 13), the differences between the regions started to become increasingly evident. The Bucharest-Ilfov region became increasingly distant from the rest. The North-West and West regions remained roughly the same. The South-West Oltenia region appeared to be atypical again due to indicators such as R&D personnel and the unemployment rate. The South-East and North-East regions continued to be considered weak because they presented a high risk of poverty and a low employment rate.

The same things were observed for 2022 (figure 14). There were no major differences.

Conclusions

The results show significant regional inequalities in Romania for the period 2018-2023. Bucharest-Ilfov recorded the top economic, educational, and digital indicators. Much of the South and East were falling behind. The northwest and west areas were more evenly developed. South-West Oltenia had a more atypical profile. The focus was about the social vulnerability and the structure of R&D people.

The results highlight the differences in human capital adaptability of Romanian regions. Better educated, better connected, and with improved labour market conditions, regions were better placed to respond to economic and technological change. In contrast, those with more poverty and less secure employment conditions seemed less adaptable. They also had more socio-economic vulnerability.

The results indicated that regional inequalities were largely stable over time. There were a few indications of regional convergence. The differences did not show strong consistent spatial groupings. This means that the regional differences are more dependent on internal socio-economic factors than geographical proximity.

The study concludes that there is a strong connection between human capital, digitalization, and regional adaptability. The results are consistent with previous studies. These studies point to the importance of access to education, technology, and employment opportunities for the long-term growth of the region. Filling these gaps will take continued investment in education, digital infrastructure, innovation, and labour market opportunities. This is especially important in the less developed areas of Romania.

References

- Acemoglu, D. and Autor, D. (2011). *Skills, tasks and technologies: Implications for employment and earnings*. Handbook of Labor Economics, Volume 4, 1043–1171.
- Anselin, L. (1995). Local Indicators of Spatial Association—LISA. *Geographical Analysis*, 27(2), 93–115.
- Becker, G. (1993). *Human Capital: A Theoretical and Empirical Analysis*. University of Chicago Press.
- Benedek, J. and Kurkó, I. (2011). Evolution and Characteristics of Territorial Economic Disparities in Romania. Theory, Methodology, Practice – *Review of Business and Management*, 7(01), 5–15.
- Dijkstra, L., Poelman, H. and Rodríguez-Pose, A. (2020). The geography of EU discontent. *Regional Studies*, 54(6), 737–753.
- Duranton, G. and Puga, D. (2020). The Economics of Urban Density. *Journal of Economic Perspectives*, 34(3), 3–26.
- Gennaioli, N., La Porta, R., Lopez-de-Silanes, F. and Shleifer, A. (2013). Human Capital and Regional Development. *Quarterly Journal of Economics*, 128(1), 105–164.
- Hanushek, E. and Woessmann, L. (2012). Do better schools lead to more growth? Cognitive skills, economic outcomes, and causation. *Journal of Economic Growth*, 17(4), 267–321.
- Jan, v. D. (2020). The digital divide. *Journal of the Association for Information Science and Technology*, 72(1), 136–138.
- McCann, P. (2020). Perceptions of regional inequality and the geography of discontent: insights from the UK. *Regional Studies*, 54(2), 256–267.
- Moran, P.A.P. (1950). A Test for the Serial Independence of Residuals. *Biometrika*, 37(1/2), 178–181.
- Rodríguez-Pose, A. (2018). The revenge of the places that don't matter (and what to do about it). *Cambridge Journal of Regions, Economy and Society*, 11(1), 189–209.
- Simona, I., Rodríguez-Pose, A. and Storper, M. (2019). Regional inequality in Europe: evidence, theory and policy implications. *Journal of Economic Geography*, 19(2), 273–298.
- Vicente, M.R. and López, A.J. (2011). Assessing the regional digital divide across the European Union-27. *Telecommunications Policy*, 35(3), 220–237.

Appendix

Table 3. *Moran's I results*

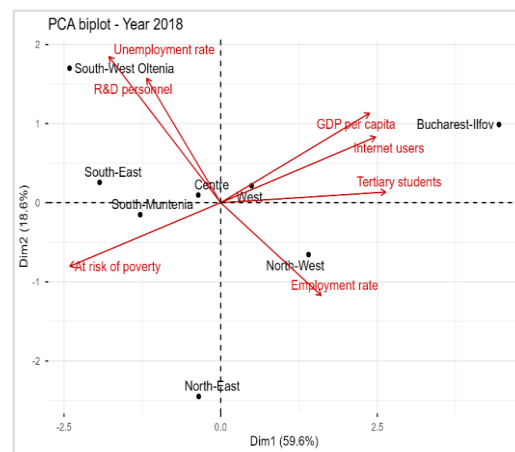
Indicator	Year	Moran_I	Expected_I	Variance	p_value
At risk of poverty	2018	-0.09	-0.14	0.05	0.41
At risk of poverty	2019	-0.07	-0.14	0.05	0.36
At risk of poverty	2020	-0.01	-0.14	0.04	0.25
At risk of poverty	2021	-0.04	-0.14	0.04	0.31
At risk of poverty	2022	0.00	-0.14	0.04	0.24
At risk of poverty	2023	0.05	-0.14	0.04	0.18
Employment rate	2018	-0.06	-0.14	0.05	0.37
Employment rate	2019	-0.08	-0.14	0.05	0.39
Employment rate	2020	-0.10	-0.14	0.05	0.42
Employment rate	2021	-0.02	-0.14	0.03	0.25
Employment rate	2022	-0.06	-0.14	0.03	0.32
Employment rate	2023	0.02	-0.14	0.03	0.17
GDP per capita	2018	-0.10	-0.14	0.01	0.36
GDP per capita	2019	-0.11	-0.14	0.01	0.39
GDP per capita	2020	-0.12	-0.14	0.01	0.41
GDP per capita	2021	-0.11	-0.14	0.01	0.38
GDP per capita	2022	-0.08	-0.14	0.01	0.29
GDP per capita	2023	-0.08	-0.14	0.01	0.28
Internet-access households	2018	-0.05	-0.14	0.05	0.33
Internet-access households	2019	-0.07	-0.14	0.05	0.38
Internet-access households	2020	-0.04	-0.14	0.05	0.32
Internet-access households	2021	-0.15	-0.14	0.05	0.51
Internet-access households	2022	-0.21	-0.14	0.04	0.62
Internet-access households	2023	-0.02	-0.14	0.04	0.27
Internet users	2018	-0.05	-0.14	0.05	0.33
Internet users	2019	0.10	-0.14	0.05	0.13
Internet users	2020	0.03	-0.14	0.06	0.23
Internet users	2021	0.04	-0.14	0.05	0.21
Internet users	2022	-0.35	-0.14	0.05	0.83
Internet users	2023	-0.24	-0.14	0.05	0.67
R&D personnel	2018	-0.11	-0.14	0.01	0.34
R&D personnel	2019	-0.11	-0.14	0.01	0.34
R&D personnel	2020	-0.11	-0.14	0.01	0.33
R&D personnel	2021	-0.11	-0.14	0.01	0.33
R&D personnel	2022	-0.11	-0.14	0.01	0.33
R&D personnel	2023	-0.11	-0.14	0.01	0.33
Tertiary students	2018	-0.23	-0.14	0.03	0.69
Tertiary students	2019	-0.23	-0.14	0.03	0.69
Tertiary students	2020	-0.23	-0.14	0.03	0.70
Tertiary students	2021	-0.23	-0.14	0.03	0.70
Tertiary students	2022	-0.24	-0.14	0.03	0.71
Tertiary students	2023	-0.24	-0.14	0.03	0.72
Unemployment rate	2018	0.05	-0.14	0.05	0.20
Unemployment rate	2019	-0.09	-0.14	0.05	0.41
Unemployment rate	2020	-0.10	-0.14	0.05	0.43
Unemployment rate	2021	-0.13	-0.14	0.05	0.48
Unemployment rate	2022	-0.10	-0.14	0.05	0.43
Unemployment rate	2023	-0.04	-0.14	0.06	0.33

Source: Author's own research

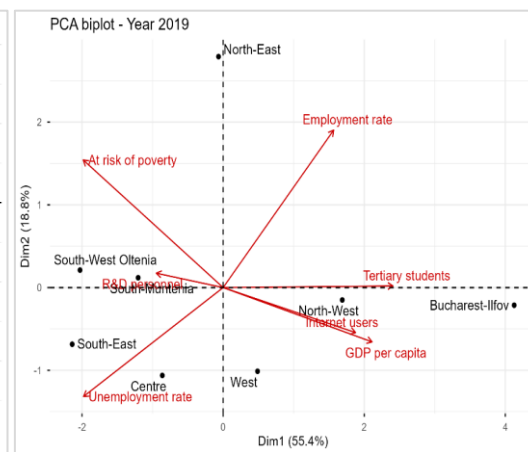
Table 4. *LISA's results*

Indicator	Year	NUTS_ID	Name	Value	li	Z_li	P value	Lag value	cluster
Employment rate	2021	RO12	Centre	60.3	0.09	2.05	0.04	60.03	Low-Low
Employment rate	2022	RO12	Centre	61.9	0.06	2.07	0.04	60.98	Low-Low
Employment rate	2023	RO12	Centre	61	0.12	2.16	0.03	61.17	Low-Low
GDP per capita	2018	RO12	Centre	10.1	0.06	2.39	0.02	8.77	Low-Low
GDP per capita	2019	RO12	Centre	10.9	0.07	2.39	0.02	9.53	Low-Low
GDP per capita	2020	RO12	Centre	10.9	0.06	2.40	0.02	9.37	Low-Low
GDP per capita	2021	RO12	Centre	11.9	0.06	2.40	0.02	10.32	Low-Low
GDP per capita	2022	RO12	Centre	13.4	0.09	2.40	0.02	12.00	Low-Low
GDP per capita	2023	RO12	Centre	15.2	0.09	2.40	0.02	13.75	Low-Low
Internet-access households	2018	RO22	South-East	72.69	0.86	1.99	0.05	75.99	Low-Low
Internet-access households	2019	RO22	South-East	78.8	0.88	1.99	0.05	81.08	Low-Low
Internet-access households	2022	RO12	Centre	90.87	-0.15	-1.99	0.05	88.14	High-Low
Tertiary students	2018	RO12	Centre	56803	0.08	2.18	0.03	50947.17	Low-Low
Tertiary students	2019	RO12	Centre	56284	0.08	2.16	0.03	50792.67	Low-Low
Tertiary students	2020	RO12	Centre	57444	0.08	2.15	0.03	51741.33	Low-Low
Tertiary students	2021	RO12	Centre	59737	0.08	2.13	0.03	53811.50	Low-Low
Tertiary students	2022	RO12	Centre	59077	0.08	2.13	0.03	53087.00	Low-Low
Tertiary students	2023	RO12	Centre	58234	0.07	2.13	0.03	51806.33	Low-Low

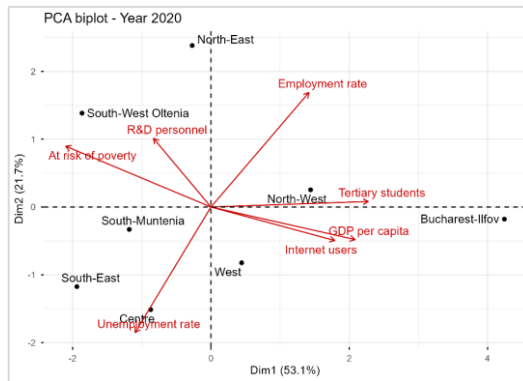
Source: Author's own research

Figure 10. *PCA biplot – Year 2018*

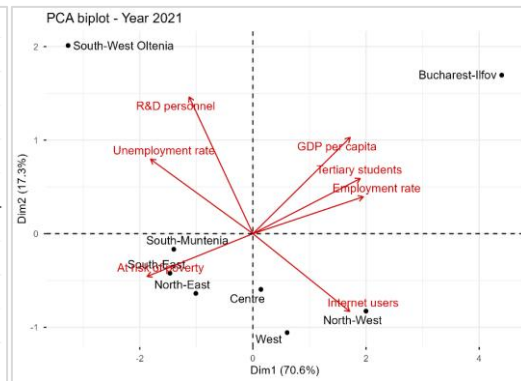
Source: Author's own research

Figure 11. *PCA biplot – Year 2019*

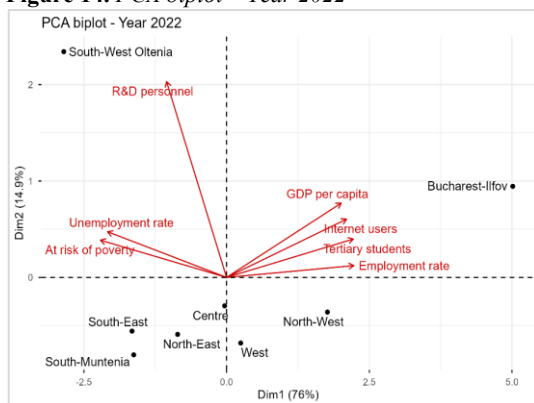
Source: Author's own research

Figure 12. *PCA biplot – Year 2020*

Source: Author's own research

Figure 13. *PCA biplot – Year 2021*

Source: Author's own research

Figure 14. *PCA biplot – Year 2022*

Source: Author's own research

Income inequality: The Resource Distribution Index (RDI)

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Abstract. *Objective: To construct a conceptual innovatory formulation of the Resource Distribution Index (RDI) integrating the distribution of income and the level of accessibility of key resources. This presents a multidimensional perspective of inequality at the micro- level the study attempts to address the issue of inequality paradox at the micro and macro perspective simultaneously.*

Study/Method: The study is of the archival type and is based on secondary data research and publications. The study constructs the RDI, and then attempts to assess empirically the relation of RDI scores to Gini Index and Palma Ratio.

Results: RDI, paradoxically, in relation to the income measure that suggests more equality, there existed a greater number of poorly accessible key resources. Next, the RDI with the measure of access to resources and income embedded ratio over-spilled limitlessly the other resources in the accessible ratio of the income metrics. Therefore, the RDI the basis of is a perfect platform in establishing the feasibility of the policy recommendations. The assumptions and results of the RDI are congruent with the prevailing, modern, and religious texts.

Study Limitations: The study is bound to a phenomenon that involves secondary data that lacks particular local data. The RDI's applicability may need to be modified to the specific circumstances of the studied population. The RDI can be enhanced by collecting primary data in the next study.

Implication: The RDI provides direct social interventions centered on fair resource distribution to policymakers, urban developers, and social community organizers. The RDI, accompanied by additional indicators, provides a framework to communities for assessing and measuring social deprivation, which goes beyond income, inequality. The RDI can be used as a benchmark for other nations, and Australia can similarly, be positioned in pursuit of its goal for Inclusive and Sustainable Development.

Novelty/value: A key element of this study is the development of a novel composite index of inequality that measures income and resource accessibility, providing additional depth to the resource inequality index, and presenting a framework for local interventions designed to achieve change at both the micro and macro levels.

Keywords: income inequality, Resource Distribution Index, resource access, social policy.

JEL Classification: D31, D63.

1. Introduction

Several studies examine income inequality using indicators such as the Gini coefficient, Palma ratio, and Theil index, which are widely used in the literature (World Bank, 2021; Palma, 2011; Conceição & Ferreira, 2000). However, these approaches mainly focus on monetary aspects of inequality and often ignore other essential dimensions such as access to healthcare, education, and food security. These elements are critical for understanding inequality in a more comprehensive way. Recent research highlights that inequality is not limited to income differences but is a multidimensional issue involving access to basic services that directly influence overall well-being (Sen, 1999). Although the Human Development Index (HDI) attempts to include non-income dimensions, the selected indicators remain limited and do not fully capture the complexity of inequality. Furthermore, much of the existing literature concentrates on measurement techniques rather than proposing practical solutions. As a result, there is a clear gap between identifying inequality and offering actionable strategies to reduce it. This limitation indicates the need for a more applied and solution-oriented framework. Based on this gap, the study addresses the following research question:

How can a novel framework effectively provide a comprehensive understanding of inequality by incorporating income and access to essential resources at the micro level to address macro-level issues?

To address this question, the study introduces the Resource Distribution Index (RDI), which integrates both income and non-income resources to provide a broader and more inclusive measure of inequality. Unlike traditional indices, the RDI focuses not only on measurement but also on practical intervention by offering actionable solutions through localized strategies. By linking measurement with problem-solving, the study contributes a framework that can support policymakers, urban planners, and stakeholders in addressing inequality more effectively. In addition, the study emphasizes a bottom-up approach, where solving issues at the micro level contributes to broader macro-level improvements. This approach allows for a more holistic understanding of inequality by combining financial and non-financial dimensions. At a broader level, the study aligns with global efforts to reduce inequality and supports the Sustainable Development Goals by extending analysis beyond income-based measures.

The study is based on secondary data, including academic publications, reports, International Labour Organization data, and books, to develop and validate the RDI. The index is applied to selected regions, and its results are compared with traditional income-based measures to highlight differences. This approach enables a deeper analysis of inequality across both income and resource-based dimensions, forming a foundation for targeted policy recommendations. The findings indicate that the RDI provides a more comprehensive understanding of inequality, especially in contexts where traditional measures fail to capture disparities. For instance, regions with high RDI scores show clear inequalities in access to education, food, shelter, and healthcare, as well as challenges in accessing basic rights. These disparities are not fully reflected in income-based indicators. The results are consistent with theories of social justice and capability, which emphasize the importance of access to resources beyond income (Rawls, 1971; Sen, 1999). Therefore, the RDI can serve as a practical tool for identifying areas that require targeted interventions.

The study suggests implementing localized solutions, focusing on resource distribution strategies tailored to specific community needs.

The proposed approach is more effective when applied initially at a small scale, such as individual villages or a limited number of households. Expanding to larger areas at the early stages may increase complexity and reduce effectiveness. An initial sample of around 100 households is recommended, with gradual expansion based on learning from earlier applications. Adaptability plays a key role in the success of the RDI, as stakeholders should continuously incorporate feedback to refine the process and improve outcomes. Lessons learned from previous challenges should guide future implementation rather than focusing solely on failures. Emphasizing solutions instead of problems can help uncover opportunities and alternative strategies. Flexibility in planning and a solution-oriented mindset are essential for effectively addressing inequality.

The contribution of this study lies not in introducing entirely new concepts but in advancing existing research to provide practical solutions. By building on previous studies and addressing identified gaps, the RDI integrates multiple perspectives into a unified framework that captures both income and access to essential resources. Unlike conventional indices, it emphasizes actionable dimensions of inequality, making it highly relevant for implementation by policymakers, planners, and researchers. By including indicators that reflect the difficulty of accessing basic needs such as food, healthcare, and shelter, the study offers a comprehensive approach to understanding and addressing inequality, and provides a foundation for more effective local-level interventions.

2. Literature Review

The literature review has three subsections: 2.1, 2.2, and 2.3. The first subsection, (2.1), “Access to Resources and the Shortcomings of Inequality Indices,” discusses the different indices that have been put forward by scholars to measure inequality, the methodologies that have been used, and the critiques. The second subsection, (2.2), “Income-based and Non-Income-based Indices,” is different from section 2.1 because it incorporates some studies where the authors either used both income-based and non-income-based approaches to address inequality or those that focused solely on non-income-based approaches to address the issue of inequality. Here, the author acknowledges the existing gaps and builds on them to arrive at “Theoretical Framework of the Study” in subsection 2.3. This framework critiques the existing indices of measuring inequality and proposes a more sophisticated approach, which is the study’s main contribution. Moreover, every element of the framework is integrated with established theories and a religious element to provide a broader explanation.

2.1. Access to Resource and Limitation of Inequality Indices

Income inequality is defined as the gap in income distribution among a given population. Evaluating inequality involves using several indices. One measure is the Gini Coefficient, one of the indices measuring the deviation of income distribution from an equal distribution (Gini, 1912). Atkinson (1970) suggests that income inequality causes economic inefficiency, social problems and political issues. The Gini Coefficient scores from 0 to 1,

0 showing complete equality and 1 showing complete inequality. This measure is the most common in determining income inequality in developed countries. Palma (2011) developed a measure known as the Palma Ratio. The Palma Ratio compares the income of the richest 10% of the population to the income of the poorest 40% of the population in attempts to reflect inequality and distribution from an equilibrium perspective. The World Bank (2022) recommends the Poverty Headcount Ratio (PHCR) as a good measure for absolute poverty. PHCR tracks poverty by measuring the percentage of a population below a stated poverty line. The Theil Index is another widely used measure. The Theil Index attempts to measure inequality within a defined population by using a logarithmic approach to the income distribution within a defined population. Although the Theil Index gives a clear representation of inequalities within a population, it is sensitive to small changes in the distribution of income among a defined population. Theil Index also has a reputation for being overly complicated for large populations.

The Atkinson Index is concerned with social welfare by adjusting its sensitivity towards income distribution which helps in identifying inequalities regarding access to fundamental resources. It captures inequalities concerning income and access in practice. Max Lorenz developed a form of wealth inequality in 1905 which is called the Lorenz curve. It represents the cumulative income of a certain population and plots the percentiles of the corresponding population on the horizontal and cumulative income or wealth on the vertical. The Quintile Ratio looks at income disparity by analyzing the income of the top 20% as compared to the bottom 20% and offers a view of the two extremes but, as a result of this, the middle income people and the resources associated with them are not factored in.

The breadth of variables such as healthcare, housing, and education, makes the Human Development Index (HDI) one of the most recognized indices. Broad wellbeing continues to be measured by Gross National Income (GNI) per capita, education (measured by the average and expected years of schooling), and life expectancy. While the HDI provides a perspective on development beyond income alone, it does not reflect the challenges people face in accessing the indicators (World Bank, 2021; Conceição & Ferreira, 2000). Given the above literature, this study attempts to provide a conceptual framework for an index that builds on existing measures by including income inequality and the accessibility (and difficulty) of fundamental resources, including healthcare, education, and housing. To illustrate, can an individual be considered to have welfare if he or she lives 99 years but has a chronic disease and does not have the adequate resources to cure it. How aligned can HDI be to the welfare of a person? This study attempts to suggest an index that measures income and resources accessibility disparities of the top 20% and the bottom 40% which can be more contextually relevant and economically practical. More comprehensive data on resource accessibility will be needed, but the index will be useful for enhancing policy development and intervention strategies. Building on these observations, the following hypothesis is put forward:

H1: Metrics like the Gini Coefficient and HDI do encapsulate inequality and the state of being, although they are partially effective as The HDI is more comprehensive because it incorporates levels of education and health. They would be stronger if they considered the varying degrees of difficulty in obtaining the resources.

2.2. Income-based and non-income-based Indices

Education, healthcare, and housing have a great impact on employment opportunities and earning potential, life expectancy and productivity, and living conditions and stability, respectively. The Human Development Index (HDI) includes these factors, while education and healthcare improve the development score. Nonetheless, the HDI may capture these dimensions without taking micro access to these resources into account for individuals or certain communities. HDI also factors in life expectancy; however, people in poor health may live for a long time and suffer, leading to concerns regarding life quality and simply living. Several scholars have suggested that for resources (education, healthcare, housing) inequality to be better understood, the metrics should be inequitable income and resources access, and the metrics should include inequitable income. For instance, in his Capability Approach (Sen, 1996), Sen emphasizes the effective demand for your right to basic needs and the right to access elements that are needed to alleviate poverty and inequality and are even beyond monetary aspects.

Bourguignon and Morrisson (2002) point out that over time, economic inequalities can be reduced through the timely and appropriate provision of essential services, including education and health care, and that income inequality requires urgent action. They illustrate that the countries with the highest income inequality consistently have the lowest levels of social mobility and the least government engagement. Along the same lines, Galbraith and Hale (2014) point out that inequality is not only about income, but also about the lack of services, including education, health care, and other social services. The authors advocate for public policy reform that results not only in income redistribution but also in the abolition of inequity in the provision of basic social services. In the same vein, Wilkinson (2010) analyzes the effect of income inequality on health, education, and crime, and other aspects of society, pointing out the more severe problems associated with the lack of equality.

The inequality developing countries face isn't just monetary; educational and health disparities fuel it. Brodie (2015) mentions how the problems developing countries face include educational inequities and health disparities. The Human Development Index (HDI) is an example of a composite measure seeking to capture human development and well-being by including income (total wealth of a state), years of education (total years of schooling), and life expectancy (which is a measure of health access). Consolidating various constituent elements, HDI manages to combine a holistic view of well-being, or human development, but it misses the ability to depict disparities of resource access through the various income brackets, and therefore is a measure limited to income inequality. Measures of access to education, health, and housing are critical to the study of inequality (Alkire & Santos, 2010; Khalid, 2015). The following hypothesis stems from the discussion above:

H2: The inequality composite measures that include access to education, health, and housing resources are more effective. Though those measures are partially effective, more localized indices would be more effective.

Among the various indices available for measuring levels of inequality, the Gini Coefficient is one of the more popular, but also one of the more problematic ones. The Gini

Coefficient focuses exclusively on income disparities, which means it pays little attention to any divides that may exist in the availability of services that are essential for the everyday functioning of human beings, such as education, health care, and housing. In fact, it is this income bias that overlooks inequalities in non-income categories which, in the aggregate, may conceal considerable disparities in the overall well-being. The Gini Coefficient, like its counterparts, is limited in what it measures, but it does suggest that policymakers and researchers should seek measures that are more multidimensional than what is typically captured by the Gini. Despite the information and disparities that the Gini Coefficient overlooks, it also fails to adequately address issues, whether intentional or not, of homelessness and food insecurity. Moreover, the health component of any Gini-type measure of a country's inequality should include factors that affect one's quality of life for the better or for the worse, and not just those that extend a life. An index for health that measures its quality by ensuring the availability and accessibility of health care resources, not just those that address life-threatening illnesses, is necessary. A high life expectancy is also not guaranteed to offer a person a healthy life. A person may endure a great deal of suffering from a chronic condition, a disability, a disease that may be manageable but is not curable, or a condition that is not lethal but does not reduce life expectancy. People suffering from such conditions may have only limited access to health care, or be entirely without access, and may have to depend on traditional medicine, dietary measures, and other self-care practices.

Using literature and other models such as Penchansky and Thomas Model of Access, which has four dimensions—affordability, availability, accessibility, and acceptability—this study attempts to measure inequality of some dimensions. Measures such as Gini coefficients ignore other dimensions apart from income, such as income and affordability of health and education. Other measures such as the Human Development Index (HDI) which are used to measure health, are also inadequate as they neglect the availability and affordability of housing, as well as the presence of chronic health conditions which are detrimental to people's health. The Penchansky and Thomas Model of Access shows that rationality (or the rationality of individuals) is the product of several, complex, multidimensional inequalities. Indirect influences on decision making and rationality behavior continue to be overlooked, and the models that apply to these refinements will continue to evolve.

H3 to propositions: Income-based and non-income-based indices look at inequality from limited perspectives. Models that address inequality will continue to develop, though no model will address every problem.

2.3. Theoretical Framework of the Study

The framework's variable relationships can be supported by a number of theories. In this case, we are dealing with the distribution of five theories (Resource Distribution Theory, Equity vs. Equality in Resource Allocation, Social Responsibility Theory, Government Intervention and Welfare Economics, and Feedback and Adaptive Systems Theory) from different domains. In addition to aligning the variable relationships of this study with theories, we aligned them with religious perspectives (Christianity, Islam, Judaism, Hinduism, and Buddhism). The primary aim of this alignment is to promote the application of the framework in multi-religious settings. The framework integrates the theories to form

a logically defensible position to bridge resource gaps. The elements of the framework, namely resources, RDI, level of intervention, community, and government actions, are configured with the theories mentioned to establish a rational sequence for the redistribution to be successful and sustain the impacts over time. The study recognizes that the problem can be approached iteratively and that the problem can be addressed over time with continued adjustments of the frameworks to the changing time, culture, and systems. This theoretical foundation outlines the relationships between the variables in the framework and provides a process for achieving equilibrium for the distribution of resources. The theory of distribution describes how unequal distribution of income and non-income resources can create disorder in the society. The RDI framework captures disparities in the access to resources (Information, Wealth, Health, Education, Food) that are destabilizing and determine the degree of inequality, thereby directing the focus of interventions to the most urgent in order to achieve a balanced society. The RDI calculated with the resources available to the top 20% and 40% of a micro-level community enables the framework to determine the degree of inequality in a community. Therefore, policy makers can adjust the degree of intervention (no, moderate, or aggressive) to create order in the society.

Adalah (Justice) also contributes to resource accessibility through Christianity, Matthew 5:3-12: “Blessed are the poor in spirit, for theirs is the kingdom of heaven”; Islam, Quran 4:29 “O you who have believed, do not consume each other’s wealth unjustly or send it [in bribery] to the rulers”; Judaism, Deuteronomy 16:20: “Justice, and only justice, you shall pursue, that you may live and inherit the land”; Buddhism, Dhammapada (Verse 223): “Better than a thousand hollow words is one word that brings peace”; and Hinduism, Rigveda 10:191.2: “Justice leads to prosperity and spiritual growth”. The theory of Equity vs Equality in the Allocation of Resources argues that rather than universally distributing a set amount of resources, the distribution of resources should be based on the individual or group needs and challenges. Resource distribution based on the “difficulty level and accessibility” of the needs is in line with this theory. The use of weighted criteria within the RDI framework is designed to address differing levels of access challenges through targeted interventions. This avoids a “one-size-fits-all” approach and focuses on the provision of opportunities to those who are disadvantaged.

Religion motivates people to fight inequality through charity (Zakat and Sadaqah). For example, Christianity has Matthew 19:21 that goes, “If you want to be perfect, go, sell your possessions, and give to the poor...”; Islam has the Quran (9:60) that states, “Zakat expenditures are only for the poor and for the needy”; in Judaism, Deuteronomy 15:7-8 states, “If there is a poor man among you... you shall generously lend him, your poor and needy brother”; In Buddhism, Dhammapada (Verse 177) states, “The gift of food, when given to one who is in need, brings great merit”; and in Hinduism, the Bhagavad Gita (3:20) states, “In the performance of one's duty, a person is free from selfish desire and is entitled to receive the rewards of his labor.” The Social Responsibility Theory highlights the importance of the community and the roles that the community has to support the individual. Within the RDI framework, community initiatives (food donation stations, recognition incentives, individual contributions) invite the thought that community support increases the ability to access different resources and the resilience of the community. Community-engineered initiatives to support resource access and sustainability. Instead of

equal distribution, addressing particular needs is in line with the Shariah principle of fairness and equity, foster social responsibility, and coincides with religious teachings.

Christianity values generosity in the New Testament. In Luke 6:38 it states, "Give, and it will be given to you... For with the measure you use, it will be measured to you." The Quran in 4:32 states "O you who have believed, do not consume one another's wealth unjustly or otherwise." In Proverbs 22:9, it reads: "The generous will themselves be blessed, for they share their food with the poor." The Dhammapada of Buddhism states "Better than a thousand hollow words is one word that brings peace." The Bhagavad Gita of Hinduism states, "Better is one's own dharma, though imperfect, than the dharma of another, performed perfectly." Through various means of taxation, subsidies, and redistribution of resources, Government Intervention and Welfare Economics aim to minimize inequity and promote social welfare. This theory matches the RDI framework, where community-driven initiatives improve resource access and sustainability for the long term.

Numerous religious traditions have said that social injustices can be alleviated through collective responsibility, community-based initiatives, and charitable giving. In Christianity, this is reflected in: Matthew 22:39: "Love your neighbor as yourself", In Islam, it is stated in the Quran 2:177: "It is not righteousness that you turn your faces to the east or west, but righteousness is in one's belief in Allah, the Last Day, and charity...",

In Judaism, it is said in Micah 6:8: "He has shown you, O mortal, what is good. And what does the Lord require of you? To act justly and to love mercy...",

In Buddhism, this is reflected in the Dhammapada 178 "One is not a true benefactor unless they offer true charity to others"

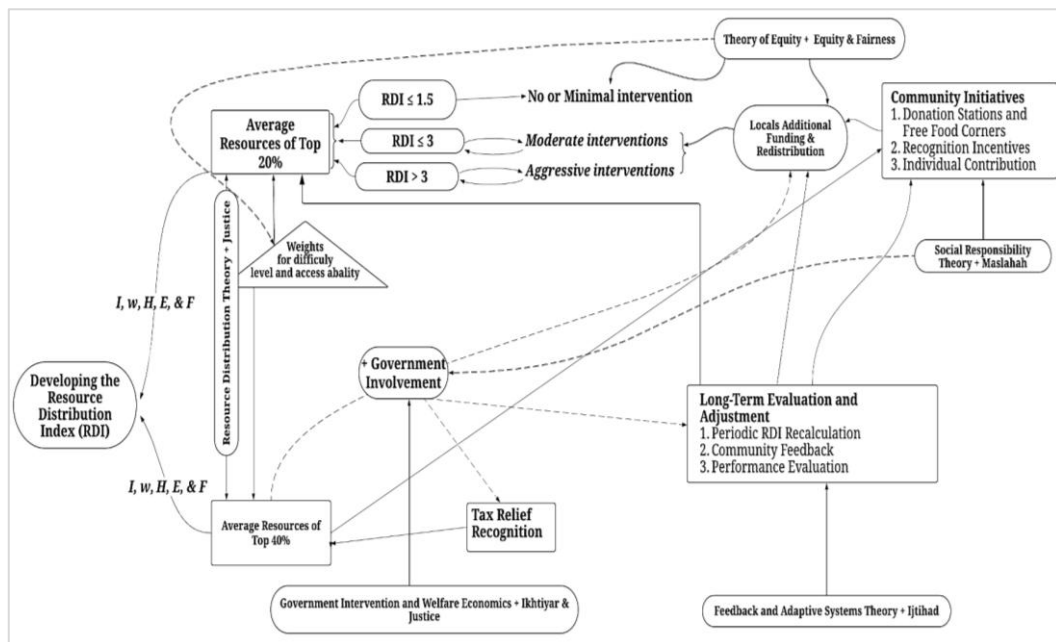
In Hinduism, this is shown in the Bhagavad Gita 3:20 "In the performance of one's duty, a person is free from selfish desire and is entitled to receive the rewards of his labor".

In addition to this, government action is also needed to ensure equitable distribution and to stop exploitation, which also helps to lessen inequalities (Ikhtiyar or Choice, and Adalah or Justice). The support of Christianity can be found in this in Romans 13:1: 'Let every soul be subject to the governing authorities'. "All authority comes from God...". Islam in the Quran (2:282), states "...And do not withhold from the people the things that are due to them..."; Judaism in the Book of Exodus 22:21 states "You shall not mistreat or oppress a foreigner, for you were foreigners in the land of Egypt"; Buddhism in the Dhammapada (verse 212) states: "Governments should govern fairly. And they should provide protection to all" and in Hinduism's Manusmriti (8:15) states "The king should make laws that are just and equitable to all".

Adaptive Systems Theory and Feedback are two concepts that align with the thinking of the importance of policies being flexible and adaptive to change. Feedback from the real-world experience is the basis on which strategies are revised and readjusted. Within the framework, there are RDI recalculation, feedback, and ongoing evaluations that are aimed at relevance and improvement of the framework. The flexibility of addressing needs of the moment would fit within the definition of feedback (Ijtihad or Independent Reasoning). This can be seen in the Christian teaching of Matthew 7:7: "Ask, and it will be given to you; seek, and you will find; knock, and the door will be opened to you"; in the Islamic

teaching of the Qur'an (65:6): "...And when they have fulfilled their term, either retain them according to what is reasonable or release them according to what is reasonable..."; in the Jewish Isaiah 1:17: "Learn to do right; seek justice. Defend the oppressed. Take up the cause of the fatherless..."; in Buddhism, Dhammapada verse 183: "The world is bound by the chains of desire, so remove them to lead a life of wisdom"; and in Hinduism, Bhagavad Gita verse 2:47: "You have a right to perform your prescribed duties, but you are not entitled to the fruits of your actions."

Figure 1. Conceptual Model of RDI.



Source: Author

3. Research Methodology

This study employs a specific type of conceptual framework construction approach to the design of the Resource Distribution Index (RDI) from the perspective of secondary data and theory. Starting from the methodology of a specific type of broad literature survey, which includes the search for empirical literature, government reports, and data from international databases, the author identifies the gaps and shortcomings of traditional measures of inequality, such as the Gini Coefficient and the Human Development Index. These gaps, especially the absence of emphasis on measuring the extent to which resources are obtainable and the levels of difficulty to access them, guide the author in the construction of the RDI. The study combines the RDI framework with both income and non-income variables such as the provision of health, education, and food, and attempts to allocate weights to the measuring variables of the resources and the corresponding level of access limitations based on the availability of such variables in the existing literature.

The RDI framework is iteratively developed and validated using secondary data from previous research, assuring its adequate development of the different aspects of inequalities of income and resource utilization across various contexts. These elements include the opencast top 20% and bottom 40% income segments, and the rest are used comparatively. The study also checks the RDI applicability by using hypothetical situations, compares the findings to previously established indices to show the RDI reliability. Using an iterative approach ensures the RDI framework development practically and theoretically leads to specific inequalities approach improvement. The secondary data reliance in the iterative process minimizes the need for primary data collection while assuring the framework to adequately address most of the traditional measures of inequalities shortcomings.

4. Findings and Discussion

The Resource Distribution Index (RDI) measures income inequality and is unique in its approach to the distribution of resources in pre-defined groups (e.g., cities, states, and communities). On the other hand, the Gini Coefficient measures overall inequality, while the RDI measures inequality in terms of wealth, resource accessibility, and ease versus difficulty in accessing resources, setting the RDI apart from the Gini Coefficient. With regard to the availability and access to basic, yet critical, services (e.g., healthcare, education, food) in addition to one's income, the RDI is an effective tool for targeted interventions at the local community level. This research proposes an RDI formula designed to measure the distribution of resources between the high-income group and the low-income group in each defined region. Here is the basic conceptual formula:

$$RDI = \frac{\text{Average Resources of the Top 20\% Group}}{\text{Average Resources of the Bottom 40\% Group}}$$

Average resources are defined as one's income, as well as access to healthcare, education, and food. The Top 20% Group is defined as the wealthiest segment of the population, and the Bottom 40% Group is defined as the segment of the population that is the least wealthy. This ratio strikes a balance between focusing solely on the middle classes and the extreme ends of income distribution.

This ratio stands out from other ratios because it captures both upper-income and lower-income dynamics. This makes it applicable in many economic situations. This ratio also gives a clearer picture of the distribution of resources which policymakers can easily understand and act upon. It is a relatively common metric which makes it easier to conduct comparisons across studies and policies.

This Index does not just measure income, it measure also the quality and accessibility of resources, aiming to capture the disparity of resources which the measure of income alone cannot. It also provides greater in-depth analysis and a clearer picture of the RDI that gives a more comprehensive perspective of the resource distribution. This research includes Basic income (BI) as the baseline income and gives consideration to the indicators of the difficulty of accessing the essential needs of food, health, education, and shelter which if applicable, should be measured at the city level by an official or a politician.

Basic income (BI) refers to the minimum income that can be considered a standard (here standard minimum income refers to the minimum requirement of income to meet everyday

expenditure, it can be monthly). The difficulty level for accessing funds for food denoted by DF_F is difficulties for accessing funds for food, DF_H shows Difficulty in accessing healthcare and house. DF_E shows difficulty in funding education and DF_S difficulty in securing shelter.

$$RDI = \frac{\alpha_1 \cdot (I_{20} + BI) + \alpha_2 \cdot W_{20} + \alpha_3 \cdot H_{20} + \alpha_4 \cdot E_{20} + \alpha_5 \cdot F_{20} - \beta_1 \cdot DF_{F_{20}} - \beta_2 \cdot DF_{H_{20}} - \beta_3 \cdot DF_{E_{20}} - \beta_4 \cdot DF_{S_{20}}}{\alpha_1 \cdot (I_{40} + BI) + \alpha_2 \cdot W_{40} + \alpha_3 \cdot H_{40} + \alpha_4 \cdot E_{40} + \alpha_5 \cdot F_{40} - \beta_1 \cdot DF_{F_{40}} - \beta_2 \cdot DF_{H_{40}} - \beta_3 \cdot DF_{E_{40}} - \beta_4 \cdot DF_{S_{40}}}$$

$I_{20}, W_{20}, H_{20}, E_{20}, F_{20}$ are average values for income, wealth, healthcare access, education access, food accessibility, and difficulty levels for the top 20% income group. While $I_{40}, W_{40}, H_{40}, E_{40}, F_{40}$ are average values for the bottom 40% income group. $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$ shows *Weights for income (including BI), wealth healthcare, education, and food accessibility* while $\beta_1, \beta_2, \beta_3$ and β_4 are *Weights for difficulty levels in accessing money for essential needs, with higher values indicating greater impact on the RDI*.

The following methodology mentions and integrates several existing theories: The Equity Theory (Adams, 1965) supports the Measuring Resource Distribution Disparities tool and focuses on measuring and addressing the disparity in the distribution of resources to promote fairness in the access to resources. Social Justice Theory (Rawls, 1971) supports RDI interventions for the equitable access to resources of the disadvantaged or underserved. Human Capital Theory (Becker, 1964) Justifies the need for the RDI to tackle education, health, and health services. The Capability Approach (Sen, 1999) aligns with RDI and focuses on the access to essential services, including health, education, and food, to broaden people's capabilities. Basic Needs Theory (Streeten, 1981) RDI supports the inclusion of the difficulty of access to food, shelter, education, and health. Institutional Theory (DiMaggio & Powell, 1983) focuses on the role of institutions in determining the control of the economy and society and the implementation of policies that control the equitable distribution of resources. The Gini Coefficient (Gini, 1921) is an index that measures the degree of income inequality in a population.

It provides a benchmark for measuring resource inequality on a larger scale than the RDI. The value of the RDI shows the level of inequality and the comparison of that value among different regions. Which regions have the most equitable distribution of resources? Regions that have a value close to 1, while the regions that have a value high above 1 shows high inequality. Therefore, the Resource Distribution Index is as follows: the table “Tabel: RDI Values and What They Mean” shows the meaning of the RDI values and the “table: Intervention Thresholds (Setting Targets for decision)” shows the values and how they are used in decision-making.

Table 1. *RDI Values and What They Mean*

RDI Value Range	Inequality Level	Description
$RDI \leq 1.5$	Low Inequality	Resources are relatively balanced between the top and bottom groups.
$RDI > 1.5$ and ≤ 3	Moderate Inequality	Noticeable but manageable inequality.
$RDI > 3$	High Inequality	Significant resource gaps, requiring targeted interventions.

Source: Author

This way provides a precise and comprehensible mean for policymakers to tailor their expectations to the attainable goals of inequality reduction by concentrating on the distribution of resources as opposed to income. Once the RDI is established, the focus can

shift to strategies. This approach uses RDI as a pathway to direct the community, empower, and involve the local government to intervene, based on the inequality level. *It is essential to formulate goal and target strategies based on the RDI.* It enables local authorities to formulate segmented goal hierarchies. Each inequality level, as indicated by the RDI, determines the type and depth of impact that is expected to be created.

Table 2. *Intervention Thresholds*

Intervention Thresholds	Description	Action
Low RDI ($RDI \leq 1.5$)	This means resource distribution is relatively balanced and equilibrium in this city.	No or Minimal intervention is needed. Emphasis on maintaining current programs and monitoring for changes.
Moderate RDI ($1.5 < RDI \leq 3$)	Need to introduce community support programs to improve healthcare, education, and food security for lower-income households.	Moderate interventions aimed at improving resource access for the bottom 40% group.
$RDI > 3$	High Inequality	Aggressive interventions, including wealth redistribution

Source: Author

With reference to the 'Intervention Thresholds' table, $RDI > 3$, warrants intensive interventions. This entails two things. First, extra financing specifically targeted to the funding of deficits; and second, an approach involving the funding of deficits through an equitable financing mechanism. It is also important to note that, No, baseline funding (B) is not always necessary or required to commence the process of assisting. The absence of initial funding means starting from an empty or null, and subsequent funding is an amount that will be determined from that point. For instance, if the total required is \$1,500, and \$500 is available, then \$500 is the baseline funding and the other \$1,000 is the rest of the total required to complete the funding. When addressing the external financing (Government or donor) to the city's income inequality, it should be considered an additional funding, not baseline funding. Baseline funding is the city's available local resources, and local's remittances; additional funding is the deficit, that is, the local resources available when $RDI > 3$. The suggested formula to calculate the necessary additional funding is as follows:

$$F_{\text{additional}} = RDI \times B$$

where $F_{\text{additional}}$ denotes additional funding required, and B denotes baseline funding. If B is baseline funding, what the above formula represents is how much additional money is required when the RDI score is multiplied by baseline funding.

For ease of understanding, let us take the example of a village with 10 people. In this village, the top group (wealthiest 2 people, 20%) has resources amounting to \$8,000, while the bottom group (least wealthy 4 people, 40%) has resources of \$1,000. The other 4 people are in the middle group, and are therefore not included in the calculation.

If the RDI is 4 (showing high inequality, as it is greater than 3), we can determine additional funding as:

$$F_{\text{additional}} = 4 \times 500 = 2000$$

While redistribution formula is as follows:

$$R_{\text{distribution}} = \frac{(R_{\text{top}} - R_{\text{bottom}})}{n}$$

Where $R_{\text{distribution}}$ is the amount of resource redistributed per individual in the bottom group, R_{top} is the resource score of the top group, R_{bottom} is the resource score of the bottom group, and n is the number of individuals in the bottom group. For easier understanding suppose, a village has The top group (2 rich people) has \$8,000 and bottom group (4 people with the least resources) has \$1,000.

$$R_{\text{distribution}} = \frac{(8000 - 1000)}{4} = \frac{7000}{4} = 1750$$

To equalize the available resources among the groups, each individual in the bottom group is to be given \$1,750 from the resources of the top group. The formula serves to equalize the bottom group's resources by taking them from the top, thereby improving the overall fairness and equality of the group's resources within the community.

Community-Driven Initiatives Based on RDI Scores

Donation Stations and Free Food Corners: Cities with a mid to high RDI are encouraged to develop community support systems to facilitate resource circulation. Donation points in large hypermarkets are an example of a resource donation system that flows from high income to low income communities. The system supports the needy and improves access to resources.

Recognition Incentives: Listing donor names on public boards at donation sites and free food corners will incentivize more people to participate. Contributors will appreciate the transparency of knowing their donations went to people in need. Trust and motivation will be built. Name recognition will also help foster a culture of giving and help decrease income disparity. Government and city management need to be more psychologically driven like religious and humanitarian obligation to activate people.

Money contribution from the Individual is also possible. Contribution Formula will as follow:

$$C_{\text{individual}} = \alpha \times I$$

This formula calculates fair contributions based on individual income $C_{\text{individual}}$ is the suggested contribution amount, α is a coefficient reflecting community needs and is individual income, and I is individual income. The aim here is to make the contributions equitable in the sense that the relatively wealthy will make a relatively higher contribution, and also to make the contributions responsive to the needs within the community.

City planners can suggest specific needs for food and other essentials, and those needs can be posted on public boards for easier and more efficient donation and consignment process to be aligned with community needs. The planners must also keep and record a proper account of the daily donated items and items given to the poorer segments of society.

Three formulas have to be applied by the city planner to reduce the city inequalities, first is Daily Need Formula which Sets the baseline daily supply. Daily Adjustments Formula is a second which the planner must adopt and even ends the supply and demand of the previous day, for example, if the previous day's supply is short or surplus, Daily Adjustment Formula is a solution to enable the planner to adjust the daily requirements to keep the supplies balanced and to control the need over demand. End-of-day Update Formula is also

used to keep the previous day's and Daily Adjustment Formula correct. This system helps keep the demand and supply balanced on the next day based on the previous day's data.

This plan will save both resources that may be wasted and resources that may be used inefficiently. This can be achieved through a Daily Supply Formula. This can be established easily by a city planner or a responsible person in order to manage daily needs and to manage a sustainable monthly supply. This will be achieved by formulating a Daily Supply Formula that can be established easily by a city planner or a responsible person in order to manage daily needs and to manage a sustainable monthly supply. This will be achieved through a balanced approach to daily supply and demand. Here is a daily supply formula that is not final, and city planners are free to modify it by adjusting the number of days or making other minor adjustments in order to meet the needs of the situation.

$$D_{\text{daily}} = \frac{M_{\text{demand}}}{30}$$

Where D_{daily} is the daily supply needed to meet monthly demand. M_{demand} is the total monthly demand (it can be explained more as it shows the number of items needed for the month). 30 is the average number of days in a month, which can be adjusted. This formula establishes the daily minimum requirement to meet the monthly demand. To respond to excess or shortages from previous days, the city planners may consider the Daily Adjustment Formula which is as follows:

$$D_{\text{adjusted}} = D_{\text{daily}} + (D_{\text{leftover}} - D_{\text{shortfall}})$$

Where D_{adjusted} shows the amount to supply on the present day, adjusted for any past surpluses or shortages. D_{leftover} is the extra supply remaining from the previous day, if any. $D_{\text{shortfall}}$ is the shortage from the previous day, if any. The third important action will be using End-of-Day Update Formula. At the end of each day, city planners have to compute the leftover or the shortfall to carry over to the next day. The formula is given as:

$$D_{\text{leftover}} = S_{\text{supplied}} - D_{\text{daily}}$$

$$D_{\text{shortfall}} = D_{\text{daily}} - S_{\text{supplied}}$$

Where S_{supplied} is the actual amount supplied on that day. D_{leftover} is positive if there is extra supply (more than needed). $D_{\text{shortfall}}$ is positive if there was a shortfall (less than needed).

Government Support and Incentive Programs

Tax Relief on Donations: Authorities in the government tax department may provide tax relief on donations, thereby encouraging individuals and companies to make regular donations to alleviate resource gaps, especially in the high-RDI zones. It also assists in the integration of individual benefits with social goals. This approach aligns with the Incentive Theory, which suggests that people take action when there is a benefit, and in the process, they help the community by reducing their own expenses. This is how the tax relief is calculated:

$$T_{\text{relief}} = C_{\text{individual}} \times \tau$$

Where T_{relief} is the tax relief amount, $C_{\text{individual}}$ is the donation, and τ is the tax rate.

Government matching donations: The government invests in high-RDI regions by matching donations from local communities. The government can provide funds to communities with high RDI gaps. The government matches community donations to add more funding in less served areas by the following formula. Whenever communities fundraise, the government can give a match. This approach benefits high need areas and encourages community participation and engagement. This fits the public good theory, where the government provides a public good that serves the community and decreases disparity. The matching funds formula is given as:

$$M_{\text{fund}} = m \times D$$

where M_{fund} = is the contribution paid by the government, m is the matching multiplier, D is the total donations, and the currency is local.

Long Term Evaluation and Adjustment

Annual RDI Even Distribution Method: Since the proposed Resource Distribution Index(RDI) is modified after each year, it can witness the effects of the interventions over time, be it improving or worsening the inequality. The RDI tracks the resource allocation/distribution concerning specific target groups or geographic areas. When analyzed over a prolonged time period, RDI reveals improved distribution/ allocation of resources concerning inequalities. The RDI also provides evaluators and program stakeholders a framework to establish whether the intended targeted interventions systematically or systematically resulted to the elimination, alleviation, or creation of new inequalities, or whether unintended new inequalities emerged. Geographical tracking of RDI provides targeted communities with access to, and distribution of, resources, positive shifts in income, or overall changes in the population.

Annual recalculation of the RDI provides areas of greatest need the ability to target communities in need, which is the essence of adjusting to inequalities.

Building Programs Based on Feedback: Programs can be adjusted to include design elements based on community member preferences. Engaging with community members allows stakeholders to gauge the interventions and their effectiveness and areas that require further efforts. If the RDI is high for the area, community feedback would address the barriers, whether a felt need or a culturally based, that is preventing improvement. Feedback is a critical resource for community-focused policy design. It fosters constructive partnership, sense of shared ownership, and helps the community feel the closure that their feedback is instrumental to the improvement of a program that is reducing the inequality in the community. Ultimately, this will lead to long-term success for the program.

Success for RDI also relies greatly on the tenacity of the stakeholders involved. Stakeholders will have to incorporate feedback from the previous rounds to tackle the challenges and improve the results for the next rounds or when increasing the target population. Stakeholders need to change the emphasis from the failures to the feedback. The more this study unraveled, the more pivotal it became to regard that the stronger the emphasis on the challenges, the more it will risk hiding the possibilities, and vice versa. While strategies may evolve, stakeholders most need to be solution-oriented when dealing with the challenges, to be able to address the problem most effectively.

Performance Evaluation Formula:

The effectiveness of a program can be quantified based on the change of the Relative Deprivation Index (RDI) from the start of a program versus the RDI at a current point in time. The formula below illustrates the change of RDI over time.

$$\Delta RDI = RDI_{\text{initial}} - RDI_{\text{current}}$$

where ΔRDI shows the change in inequality. A significant decrease in ΔRDI highlight program effectiveness.

In this formula, ΔRDI represents the measured change in inequality levels from the initial implementation period to the current evaluation point. A significant reduction in ΔRDI indicates that the program has been successful in reducing inequality within the target community. By comparing the initial RDI with the recalculated RDI, program administrators can quantitatively evaluate whether the initiatives are making a meaningful difference. If the results show minimal or no change in RDI, this signals that further adjustments or intensified interventions may be necessary. This formula offers a clear, objective measure of progress, enabling decision-makers to make data-driven adjustments to the program for enhanced impact over the long term.

How to implement RDI

This study outlines a guide to implementing the Resource Distribution Index (RDI) in several steps. First, identify key stakeholders (local government, community leaders, economists, and statisticians) who will be instrumental in this process. These stakeholders will be briefed on what RDI is and what it seeks to accomplish. Community leaders will be tasked with analyzing the degree of resource inequality in the region, which is based on the average resources of the top 20% group and the average resources of the bottom 40% group. Following the inequality analysis, the next step is to analyze the primary data at the community level. Data can be collected through community volunteers, who will conduct face-to-face surveys, interviews, and participate in online surveys. As much as possible, secondary data is to be avoided. Data accuracy is paramount, and once stakeholders have precise data, they will be able to calculate RDI scores, which will in turn help to determine tier objectives and thresholds for actions.

Programs and interventions will be established with consideration to the RDI thresholds. Seventh, activities will be developed to be community-driven, like donation stations, free food corners, and recognition incentive programs. The community is invited to contribute. The aim of these activities is to increase resource accessibility and improve community accountability. Primary government support and incentives will be tax-exempted donations and community donation matching in RDI high areas. To improve the resource flow privately and publicly funded partnerships are encouraged. RDI will be recalculated annually. The changes will determine how effective the interventions are, this will inform what changes need to be made. Finally, tenth, reporting will be the performance evaluation. The report will address the positive and negative issues, the gaps, and will further development the strategies which will be relayed to the concerned parties. The new strategies will be developed for future interventions based on the gaps.

Conclusion

This study set out to devise a model to measure income inequality by utilizing the Resource Distribution Index (RDI) for the first time relative to Australia. The RDI posits the inclusion of non-money measures to capture and analyze inequality. The RDI is a counter measure to the Gini Co-efficient and other measures of analysis. The RDI is configured to respond to the particular economic problems of unique countries. Australia, however, is unique in that it addresses all three fronts: national, sub-national, and inter-ethnic; thus, it is particularly adaptable to Australia.

To the author, the RDI is a means to explain the question, and justifiably so, to the extent that it allows for analysis of the economic concentration vis-a-vis the class elite access inequality for the upper 20 per cent and the lower 40 per cent split. The analyses highlight, although only a part, the inequitable distribution of resources available to the indigenous and non-indigenous rural Australians while the study provides a snapshot of resource access inequities situated elsewhere in non-australian rural communities in varying degrees of socio-economic development. The mere fact that RDI can be employed in devising economic policies and strategies of a targeted nature in several countries, coupled with the RDI's multi-dimensionality, provides an avenue for addressing inequities that other income measure based approaches have hitherto overlooked.

The RDI clearly demonstrates impact in the area of local and national inequities. In the Australian scenario, it demonstrates the local inequities guides policymakers, planners, and advocates in the areas of the socio-economic inequities and the community-focused financing redistribution interventions. Although it can be applied in all settings, Australia has the design features of inclusivity and sustainability the RDI is best suited for. The iterative development of the RDI is particularly relevant for research that employs local primary data and varied geopolitical applications of the RDI as this may be critical in uncovering the methodologies for effective cross-national research.

Implications for Research, Practice, and Society

The RDI is an innovative contribution to the research of inequalities in the world as it has combined the theories of income and non-income effects, modified by an accessibility and integration framework. While it has illustrated Australia and some of its unique conditions, it may serve as a structure for research that will put Australia in a comparative analysis of other countries. The research should be focused on Australia to refine the RDI before it is implemented in other countries to enhance the global efforts in addressing and finding strategies for the reduction of inequity.

The RDI helps Australian policymakers and urban planners find and address solutions to extreme inequality in specific regions. With respect to Australia's remote indigenous communities, it suggests target-based approaches in situations, contexts and environments with extenuated resource availability and accessibility. It also provides options to target such countries, with particular interest to diverse and mixed socio-economic frameworks and structures, and seeks to address resource, community, and economic development balanced inequities, in the context and relation to the wealth and economic development inequality. Additionally, it assists students in understanding inequality and the policies designed to address it.

RDI seeks to reform societal structure by improving people's living conditions Jaffari (2022), by attempting to eliminate the unequal distribution of fundamental necessities. Rural Development International (RDI), in conjunction with Australian policies of equity and inclusion, strives to close the disparities of Health care, education, and housing in rural and disadvantaged areas. Within the spectrum of the UN social development goals and the U.N SDGs, RDI operates to transform the equity and social tensions to peace. Considering RDI's capacity to instigate positive changes in the sphere of public policy and transform people's perspectives towards equity, the changes, though potentially singular, will create a robust and inclusive social climate.

References

- Adams, J.S. (1965). Inequity in social exchange. In L. Berkowitz (Ed.), *Advances in Experimental Social Psychology* (Vol. 2, pp. 267–299). Academic Press.
- Alkire, S., and Santos, M.E. (2010). Acute Multidimensional Poverty: A New Index for Developing Countries. UNDP Human Development Research Paper.
- Atkinson, A.B. (1970). On the Measurement of Inequality. *Journal of Economic Theory*, 2(3), 244–263.
- Becker, G.S. (1964). *Human capital: A theoretical and empirical analysis, with special reference to education*. University of Chicago Press.
- Bourguignon, F., and Morrisson, C. (2002). Inequality Among World Citizens: 1820–1992. *American Economic Review*, 92(4), 727–744.
- Conceição, P., and Ferreira, P. (2000). The Young Person's Guide to the Theil Index: Suggesting Intuitive Interpretations and Exploring Analytical Applications. UTIP Working Paper No. 14.
- DiMaggio, P.J., and Powell, W.W. (1983). The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. *American Sociological Review*, 48(2), 147–160.
- Galbraith, J.K., and Hale, T. (2014). *Inequality and Instability: A Study of the World Economy Just Before the Great Crisis*. Oxford University Press.
- Gini, C. (1912). Variabilità e Mutabilità. Studi Economico-Giuridici della Facoltà di Giurisprudenza della R. Università di Cagliari.
- Gini, C. (1921). Measurement of inequality of incomes. *The Economic Journal*, 31(121), 124–126.
- Palma, J.G. (2011). Homogeneous middles vs. heterogeneous tails, and the end of the 'Inverted-U': The share of the rich is what it's all about. *Development and Change*, 42(1), 87–153.
- Rawls, J. (1971). *A theory of justice*. Cambridge, MA: Harvard University Press.
- Sen, A. (1999). *Development as Freedom*. Oxford University Press.
- Streeten, P. (1981). *First things first: Meeting basic human needs in the developing countries*. Oxford University Press.
- Wilkinson, R.G., and Pickett, K.E. (2010). *The Spirit Level: Why More Equal Societies Almost Always Do Better*. Allen Lane.
- World Bank. (2021). World Development Report 2021: Data for Better Lives. Retrieved from <<https://www.worldbank.org/en/publication/wdr2021>>

Testing the weak form efficiency of green financial markets: A comparative study between developed and developing green financial markets

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Abstract. *This study examines the weak-form efficiency of developed and developing green financial markets using statistical tests, including unit root, autocorrelation, runs, and variance ratio tests. The analysis is based on weekly returns of two indices: the SRI KEHATI Index representing developing markets and the NASDAQ Clean Edge Energy Index representing developed markets. The sample is divided into two sub-periods: January 2, 2017–December 30, 2019, and March 2, 2022–December 30, 2024. Results showed that both markets exhibit weak-form efficiency, implying that abnormal returns cannot be consistently achieved.*

Keywords: Green financial markets, Weak-form efficiency, Random Walk, SRI KEHATI Index, NASDAQ Clean Edge Energy Index.

JEL Classification: G140, Q500, Q560.

1. Introduction

The efficient market hypothesis is one of the central concepts in financial literature. The efficient market hypothesis refers to markets in which prices always reflect all available information (Fama, 1970). (Fama, 1991) further has affirmed that the efficient market hypothesis is based on another fundamental hypothesis, namely the random walk of prices, i.e. prices do not follow any specific pattern, and it is impossible to identify a regular or seasonal pattern in prices.

The efficient market hypothesis is a concept of considerable importance to financial institutions, economic companies, individual investors and government regulators, as long-term investment plans are significantly influenced by market efficiency (Vochozka, et al., 2020) despite criticism due to what are known as anomalies or deviations in financial markets discovered as a result of research in behavioral finance. (Amelot, et al., 2017)

Amid growing global interest in environmental issues and sustainable development, green finance has emerged as an innovative financing mechanism for environmentally friendly projects and renewable energy. In this context, green financial markets have emerged, combining two dimensions: financial and environmental. These markets include various instruments such as green bonds, which are debt instruments issued by a government or company to raise capital from investors in order to finance projects that contribute to a low-carbon, climate- resilient economy. They are fixed-income instruments whose proceeds are allocated exclusively to supporting new and existing projects with environmental benefits (Ntsama, et al., 2021). In addition, there are green stocks, which are ownership instruments in companies active in sectors such as alternative energy, clean transport, waste management, water management and recycling, these markets have experienced significant growth since the 2015 Paris Climate Agreement, with huge capital inflows into these markets as investors seek environmentally responsible investments that also generate high returns. (Ferrer, et al., 2021) Studies testing the efficiency of financial markets in the weak form rely on a set of tools such as autocorrelation, such as (Fama, 1965), which found a positive autocorrelation between the stock returns of companies in 23 sectors. Empirical studies testing semi-strong market efficiency rely on event-specific information, such as the issuance of new securities, whereas testing strong market efficiency is based on private information. Other studies investigate whether trading strategies can generate returns that exceed expected returns derived from certain models, including the CAPM (Haugen, 2001)

Studies often focus on testing the efficiency of traditional financial markets, while studies that have attempted to test the efficiency of green financial markets have focused more on developing green financial markets such as India. This study attempts to fill this gap by testing the efficiency of green financial markets from different environments, including both developing and developed green financial markets.

The main conclusion of this study is that both SRI KEHATI Index and NASDAQ Clean Edge Energy Index are efficient in the weak form.

The rest of the study is structured as follows: Section two “Literature review” deals with relevant literature review. Section three “Data and methodology” discusses the data,

methodology, and statistical tests used in the study. After that, section four “Results and discussion” presents the empirical results and its discussion. The final section “Conclusion” covers the key findings and recommendations of the study, as well as its limitations.

2. Literature review

There are numerous studies that have attempted to test financial market efficiency in its various forms, although most studies have attempted to test financial market efficiency in the weak form. (Khanal et al., 2025) concluded that the Nepal Stock Exchange is not efficient in the weak form and therefore future prices can be predicted based on historical prices and trading volumes. (Alrabadi & Al-Qadi, 2024) explained that the Kuwait Stock Exchange, the Jordan Stock Exchange, the Saudi Stock Exchange, and the Egyptian Stock Exchange are all characterized by weak-form efficiency, while the rest of the Arab stock exchanges are not characterized by efficiency in this form during the post-COVID-19 pandemic period. (Akbar & Bhutto, 2023) concluded that there is no weak-form efficiency for a sample of developing and emerging countries represented by China, Malaysia, the Philippines, Pakistan, India, and Indonesia using unit root tests, the GARCH (1.1) model, and the variance ratio test. (Gurung & Sarkar, 2023) also proved that the daily, weekly and monthly returns of the BSE Green Index of the Indian Stock Exchange do not conform to the weak form of financial market efficiency hypothesis (Dias et al., 2023) also showed that the returns of green financial market indices represented by the Clean Energy Fuels Index, S&P Global Clean Energy Index and iShares Global Energy (SWX) ETF, are not considered to be weak-form efficient due to the predictability of returns, especially in periods of instability such as the coronavirus pandemic and Russia's war on Ukraine, which constituted structural breaks. as the tests used revealed autocorrelations between returns, as well as for traditional financial market indices represented by gold, crude oil and natural gas. Meanwhile, (Goel & Sahay, 2023) concluded that the Greenex and Carbonex indices, which represent socially responsible investment indices in India, exhibit weak-form. Consequently, their future prices cannot be predicted based on historical prices, implying that abnormal or excess returns cannot be achieved by the investors. (Sharma, 2022) also pointed out that the returns of the BSE GREENEX index were stable, confirming that it does not follow a random path and is therefore inefficient in the weak form. (Nelmda, 2020) clarified that the Indonesian financial market is efficient in the semi- strong form. (Dias et al., 2020) found that the weak-form market efficiency hypothesis is not satisfied in the Chinese Shanghai Stock Exchange, the US Stock Exchange as represented by the Dow Jones Index, and the Portuguese Stock Exchange, and is only partially satisfied in the Belgian Stock Exchange, the French stock exchange, the Greek stock exchange and the German stock exchange, while it is fully achieved on the Spanish stock exchange and the Irish stock exchange. (Kumar et al., 2020) explained that pharmaceutical companies and the Indian stock market in general are efficient in the weak-form and are not in the strong and semi- strong form. (Agustin, 2019) concluded that the Sharia-compliant stock index in Indonesia is inefficient in the weak form, which was confirmed by the ARMA (1.1.1) model, which was able to provide predictions for the index based on its historical data. (Angelovska, 2018) confirmed that the Macedonian financial market is not efficient in the

weak form. (Tokić et al., 2018) concluded that the Croatian, Slovenian and Slovak stock exchanges are efficient in the weak form, whereas this hypothesis does not hold for the Serbian stock exchange. (Chaker & Sabah, 2018) also confirmed that the stock exchanges of the Gulf Cooperation Council countries, with the exception of Qatar, are not efficient in the weak form. (Cagli, 2018) concluded that the Turkish Istanbul Stock Exchange exhibits weak-form efficiency, as the prices of the BIST-100, BIST-Financials, BIST- Industrials, BIST- Service and BIST-Technology indices all appear to follow a random walk. (Lawal et al., 2017) concluded that the financial markets of seven African countries, including Egypt, Nigeria and South Africa, are all considered inefficient in a weak form. (Njuguna, 2016) demonstrated that the Nairobi (Kenya) financial market does not conform to the weak-form efficiency hypothesis. (Al-Khazali et al., 2015) conducted a study on nine conventional indices and nine Islamic indices, the findings showed that during the entire study period, the conventional European, Japanese and British indices were efficient in the weak form, while their Islamic counterparts were not. During the bearish market, traditional indices in Asia-Pacific, Canada, the United States and Japan stood out with weak efficiency, as did the Islamic indices in these countries. During the bullish market, the traditional indices of Asia- Pacific, Europe and Japan stood out with weak efficiency. During the 2009 financial crisis, Islamic indices performed better than conventional indices, while during the recovery period, conventional indices in Asia-Pacific, Europe, the United Kingdom and Japan, a period in which Islamic indices for Europe, the United Kingdom and the United States also performed well. (Mbululu et al., 2013) also proved that the returns on the US dollar exchange rate against the Zambian kwacha contradict the financial market efficiency hypothesis, which means that investors can achieve abnormal returns by relying on technical and fundamental analysis. Meanwhile, (Potocki & Świst, 2012) concluded that the Warsaw financial market is efficient in the strong form. (Gimba, 2012) affirmed that the Nigerian financial market is not efficient in the weak form, and argues that there are some anomalies in this market. (Al-Ajmi & Kim, 2011) confirmed that the stock markets in the Gulf Cooperation Council countries are not efficient in the weak form, whether using daily or weekly returns, especially daily returns, which are strong evidence of the inefficiency of these markets in the weak form. (Guidi et al., 2011) concluded that the autocorrelation test indicates that the returns of financial market indices in Central and Eastern European countries do not follow a random pattern and are therefore not weak-form efficient, particularly following their accession to the European Union. The runs tests revealed that these markets improved in efficiency after European Union accession, further the analysis of the variance ratio revealed that, with the exception of the returns of the SAX16 index of the Slovak Stock Exchange and the returns of the SOFIX index of the Bulgarian Stock Exchange, which do not follow random pattern after European Union accession. (Borges, 2010) concluded that the Portuguese and Greek stock exchanges are inefficient due to the existence of a positive first-order correlation between returns on these two exchanges. A similar pattern was observed for the French and UK stock exchanges. In contrast, The German and Spanish stock exchanges are efficient in the weak form. (Asiri, 2008) found that the stock prices of all companies listed on the Bahrain Stock Exchange follow a random walk, which means that the Bahrain Stock Exchange exhibits weak-form efficiency. (Pele & Voineagu, 2008) concluded that the Romanian financial market is efficient in the weak form. (Chen, 2008) showed that the euro-US dollar exchange

market is efficient in the weak form. (Smith & Ryoo, 2003) concluded that the stock exchanges of Greece, Hungary, Poland and Portugal contradict the weak-form financial market efficiency hypothesis due to the presence of autocorrelation between returns, whereas the returns of the Turkish stock exchange are consistent with this hypothesis reflecting a random walk.

3. Data and Methodology

The data and methodology information are presented as follows.

3.1. Data and its source

The study examined two green financial market indices: the SRI KEHATI Index of the Indonesia Stock Exchange, representing developing financial markets, and the NASDAQ Clean Edge Energy Index, representing developed financial markets. The study period was divided into two sub-periods: The first sub-period, from 2 January 2017 to 30 December 2019, which is the pre-COVID-19 period, while the second sub-period, from 2 March 2022 to 30 December 2024, which is the post-COVID-19 period. This division is due to the fact that financial markets are highly sensitive to external circumstances, including health events, were affected by this pandemic, as returns during that period experienced high volatility. Therefore, this phase may not accurately reflect of the efficiency or inefficiency of these markets. Data on the two indices was collected from Investing.

4. Results and Discussion

A series of statistical tests were conducted to determine whether the hypothesis of market efficiency in a weak form for these two indices was valid. These tests included: autocorrelation tests, variance ratio tests, unit root tests, and runs tests.

4.1. Normality Test

A range of statistical tests can be employed to assess the normality of return distributions; however, this study focuses on the results reported in Table 1. The findings indicate that, over the 2017–2019 period, both indices exhibit negative skewness, suggesting a left-skewed distribution and a deviation from normality (where skewness equals zero). From a financial perspective, this implies a higher frequency of extreme negative returns, reflecting exposure to downside risk. In contrast, during the 2022–2024 period, the SRI KEHATI Index remains slightly left-skewed, whereas the NASDAQ Clean Edge Energy Index shifts to a mild positive skewness, indicating a relative increase in positive return occurrences.

Regarding kurtosis, both indices display values exceeding 3 during 2017–2019, consistent with a leptokurtic distribution. This implies fat tails and a higher probability of extreme outcomes, highlighting elevated tail risk and pronounced market volatility. Similar patterns persist in the 2022–2024 period, confirming the continued presence of non-normal distributional characteristics.

Finally, the Jarque–Bera test results reinforce these findings, as p-values remain below the 5% significance level across both indices and sub-periods. Accordingly, the null hypothesis of normality is rejected, confirming that returns are not normally distributed. This outcome is consistent with the skewness and kurtosis evidence, jointly indicating persistent departures from normality in both markets.

Table 1. *Normality Test*

	SRI KEHATI Index	NASDAQ Clean Edge Energy Index
First sub-period: 2017-2019		
Skewness	-0.228284	-0.359629
Kurtosis	4.688875	4.471887
Jarque-Bera	92.07771	84.20369
P-value	0.000000	0.000000
Observations	722	753
Second sub-period: 2022-2024		
Skewness	-0.612395	0.123213
Kurtosis	6.344493	3.437825
Jarque-Bera	361.5437	7.509379
P-value	0.000000	0.023408
Observations	684	714

Source: Results from data analysis

4.2. Autocorrelation Test

Table 2 reports the autocorrelation function (ACF) correlogram, together with the Ljung–Box Q-statistics used to test for serial dependence in returns. For the 2017–2019 sub-period, the SRI KEHATI Index exhibits autocorrelation coefficients that fluctuate around zero, although some statistically noticeable deviations appear at short lags (notably lags 2 and 3). More importantly, the Ljung–Box test at lag 36 yields a p-value below the 5% significance threshold, leading to the rejection of the null hypothesis of no serial correlation. This indicates the presence of statistically significant autocorrelation in returns, implying that price changes do not follow a random walk. From an efficiency perspective, these results suggest that the SRI KEHATI market was not weak-form efficient during this sub-period.

In contrast, for the 2022–2024 period, the autocorrelation coefficients for the SRI KEHATI Index are very small and remain close to zero across all lags. Consistently, the Ljung–Box test statistics produce p-values exceeding the 5% significance level, even at lag 36, indicating that the null hypothesis cannot be rejected. This suggests the absence of statistically significant serial dependence, supporting the conclusion that the SRI KEHATI market is weak-form efficient during this later period.

Regarding the NASDAQ Clean Edge Energy Index, the correlogram similarly shows autocorrelation coefficients fluctuating closely around zero across both sub-periods (2017–2019 and 2022–2024). In addition, the Ljung–Box Q-statistics remain statistically insignificant at conventional levels for all examined lags. Consequently, the null hypothesis of no autocorrelation cannot be rejected throughout both periods, indicating that returns follow a random walk process. These findings collectively suggest that the NASDAQ

Clean Edge Energy Index exhibits weak-form market efficiency over the entire study period.

Table 2. *Autocorrelation Test*

First sub-period: 2017-2019					
Nasdaq Clean Edge Energy Index			SRI KEHATI Index		
ACF	Q-Stat	Prob	ACF	Q-Stat	Prob
-0.016	0.1900	0.663	0.011	0.0901	0.764
-0.040	1.3817	0.501	-0.089	5.8492	0.054
0.016	1.5672	0.667	-0.037	6.8328	0.077
0.014	1.7088	0.789	-0.028	7.4145	0.116
-0.045	3.2728	0.658	-0.027	7.9409	0.160
-0.007	3.3127	0.769	-0.012	8.0431	0.235
0.050	5.2496	0.630	0.043	9.4055	0.225
-0.103	13.326	0.101	-0.015	9.5638	0.297
-0.030	13.996	0.122	-0.013	9.6894	0.376
0.018	14.235	0.163	-0.077	14.089	0.169
0.009	14.294	0.217	-0.049	15.833	0.147
-0.035	15.257	0.228	0.083	20.957	0.051
0.056	17.686	0.170	0.039	22.078	0.054
-0.073	21.817	0.082	-0.017	22.288	0.073
-0.052	23.878	0.067	0.046	23.853	0.068
0.025	24.350	0.082	-0.005	23.872	0.092
0.042	25.726	0.080	-0.038	24.917	0.097
-0.004	25.737	0.106	-0.042	26.216	0.095
-0.041	27.021	0.104	-0.087	31.836	0.033
-0.016	27.226	0.129	0.027	32.365	0.040
0.017	27.441	0.157	-0.002	32.367	0.054
-0.060	30.194	0.114	0.081	37.226	0.022
0.023	30.621	0.132	0.031	37.948	0.026
-0.038	31.750	0.133	-0.058	40.466	0.019
-0.027	32.340	0.148	-0.049	42.247	0.017
-0.019	32.624	0.173	-0.021	42.565	0.021
-0.017	32.862	0.202	-0.001	42.566	0.029
0.031	33.609	0.214	0.004	42.576	0.038
-0.064	36.839	0.150	0.006	42.603	0.050
0.033	37.673	0.158	0.032	43.353	0.055
-0.007	37.713	0.189	0.000	43.353	0.069
-0.028	38.341	0.204	-0.044	44.798	0.066
0.020	38.656	0.229	0.061	47.612	0.048
-0.010	38.732	0.265	-0.006	47.644	0.060
-0.003	38.738	0.305	0.106	56.155	0.013
0.020	39.070	0.334	0.010	56.226	0.017
Second sub-period: 2022-2024					
NASDAQ Clean Edge Energy Index			SRI KEHATI Index		
ACF	Q-Stat	Prob	ACF	Q-Stat	Prob
-0.005	0.0147	0.903	-0.034	0.7930	0.373
-0.010	0.0932	0.954	0.005	0.8112	0.667
-0.028	0.6402	0.887	0.0056	2.9763	0.395
-0.010	0.7162	0.949	0.029	3.5436	0.471
-0.039	1.8256	0.873	-0.010	3.6101	0.607
-0.013	1.9464	0.925	-0.029	4.1755	0.653
0.046	3.4573	0.840	-0.079	8.4958	0.291
-0.020	3.7392	0.880	0.047	10.017	0.264
0.062	6.4972	0.689	0.001	10.018	0.349
-0.031	7.1752	0.709	-0.057	12.317	0.264
0.049	8.9151	0.630	0.056	14.489	0.207
-0.034	9.7501	0.638	-0.066	17.512	0.131
-0.016	9.9284	0.700	0.062	20.164	0.091

Second sub-period: 2022-2024					
NASDAQ Clean Edge Energy Index			SRI KEHATI Index		
0.027	10.461	0.728	-0.018	20.385	0.118
-0.039	11.574	0.711	0.044	21.752	0.114
-0.061	14.281	0.578	0.010	21.817	0.149
0.075	18.395	0.364	-0.013	21.935	0.187
0.044	19.835	0.342	-0.058	24.311	0.145
-0.048	21.512	0.309	0.006	24.333	0.184
0.064	24.493	0.222	0.031	25.021	0.201
-0.035	25.418	0.230	-0.008	25.062	0.244
-0.030	26.093	0.248	0.029	25.659	0.267
-0.031	26.789	0.265	-0.003	25.665	0.317
0.009	26.846	0.312	0.050	27.438	0.284
-0.020	27.146	0.349	-0.010	27.506	0.331
-0.074	31.220	0.220	-0.007	27.543	0.381
0.037	32.224	0.224	-0.002	27.546	0.435
-0.006	32.248	0.265	0.045	29.025	0.411
0.006	32.273	0.308	-0.003	29.031	0.463
-0.058	34.793	0.250	0.007	29.071	0.514
-0.076	39.081	0.151	0.030	29.704	0.533
0.013	39.209	0.178	-0.049	31.405	0.496
0.017	39.433	0.204	0.031	32.085	0.512
0.006	39.461	0.239	-0.029	32.672	0.533
0.013	39.589	0.273	0.003	32.679	0.581
0.061	42.381	0.215	0.024	33.083	0.608

Source: Results from data analysis

4.3. Unit Root Test

Table 3 presents the results of unit root tests, namely the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests, conducted at levels under different deterministic specifications (constant, constant with trend, and without deterministic components). These tests are widely used in financial econometrics to examine the presence of unit roots in time series data and to evaluate weak-form market efficiency.

The results show that, across both sub-periods and under all specifications, the p-values of the ADF and PP tests are below the 5% significance level. Accordingly, the null hypothesis of a unit root is rejected in all cases, indicating that both return series are stationary at levels. This suggests that the dynamics of returns are mean-reverting rather than consistent with a random walk process. From an informational efficiency perspective, these findings provide evidence inconsistent with weak-form market efficiency for both indices over the study period.

Table 3. Unit Root Test

First sub-period: 2017-2019								
SRI KEHATI Index					NASDAQ Clean Edge Energy Index			
Status	Prob	PP t-stat	Prob	ADF t-stat	Prob	PP t-stat	Prob	ADF t-stat
Constant	0.0000	-26.9098	0.0000	-26.5159	0.0000	-27.8926	0.0000	-27.8703
Constant and trend	0.0000	-25.9167	0.0000	-26.5060	0.0000	-27.8748	0.0000	-27.8528
No Constant and trend	0.0000	-26.8501	0.0000	-26.5055	0.0000	-27.8323	0.0000	-27.8208

Second sub-period: 2022-2024								
SRI KEHATI Index					NASDAQ Clean Edge Energy Index			
Status	Prob	PP t-stat	Prob	ADF t-stat	Prob	PP t-stat	Prob	ADF t-stat
Constant	0.0000	-27.0194	0.0000	-27.0221	0.0000	-26.8102	0.0000	-26.7800
Constant and trend	0.0000	-27.0827	0.0000	-27.0838	0.0000	-26.7905	0.0000	-26.7612
No Constant and trend	0.0000	-27.0387	0.0000	-27.0415	0.0000	-26.7964	0.0000	-26.7716

Source: Results from data analysis

4.4. Runs Test

Autocorrelation-based tests and unit root procedures, when considered in isolation, do not provide a comprehensive assessment of market efficiency. For this reason, additional non-parametric evidence is required, particularly the runs test. Table 4 presents the results of the runs test for both the SRI KEHATI Index and the NASDAQ Clean Edge Energy Index over the two sub-periods under study.

The results show that, in all cases, the p-values exceed the 5% significance level. Accordingly, the null hypothesis of randomness in the sequence of returns cannot be rejected for either index or sub-period. This indicates that the ordering of positive and negative returns does not deviate significantly from randomness, implying an absence of systematic patterns in return sequences. Taken together, these findings are consistent with the weak-form efficiency hypothesis for both markets over the study period.

Table 4. Runs Test

First sub-period: 2017-2019			
SRI KEHATI Index		NASDAQ Clean Edge Energy Index	
Z	0.637	Z	0.727
Number of Runs	370	Number of Runs	383
Prob	0.524	Prob	0.467
Second sub-period: 2022-2024			
SRI KEHATI Index		NASDAQ Clean Edge Energy Index	
Z	0.498	Z	1.145
Number of Runs	349	Number of Runs	372
Prob	0.619	Prob	0.252

Source: Results from data analysis

4.5. Variance Ratio Tests

In order to test the variance ratio, two fundamental tests were employed. The first was the (Wright, 2000) test, which is an individual variance ratio test. The second was the (Chow & Denning, 1993) test, which is a multiple variance ratio test. The difference between the individual and multiple variance ratio tests is that the latter based on testing the null hypothesis that the variance ratio for all lags (k) is equal to 1, while individual tests rely on testing the null hypothesis of a single time lag, i.e., the variance ratio for a single lag is equal to one (Charles & Darné, 2009).

4.5.1. Wright Test

The following two tables present the results of the Wright variance ratio test for both the SRI KEHATI Index and the NASDAQ Clean Edge Energy Index. Table 5 displays the findings for the SRI KEHATI Index across different holding periods.

During the first sub-period, the findings indicate that the null hypothesis of a random walk cannot be rejected for most holding periods (2, 4, and 16) at the 5% significance level. However, for the holding period of 8, the results point to a rejection of the null hypothesis, suggesting statistically significant deviations from random walk behavior at this specific horizon. In the second sub-period, the null hypothesis is not rejected across all examined holding periods, indicating more pronounced departures from randomness and, therefore, evidence against weak-form efficiency during this period.

Table 6 presents the corresponding results for the NASDAQ Clean Edge Energy Index. The results show that, for all holding periods (2, 4, 8, and 16), the null hypothesis of a random walk cannot be rejected at the 5% significance level. This implies that price dynamics are consistent with a random walk process, supporting the presence of weak-form market efficiency for this index over the study period.

Table 5. *Wright Test for the SRI KEHATI Index*

		Number of lags (k)			
Time Period		k=2	k=4	k=8	k=16
First sub-period: 2017-2019	R1	-0.2122508	-1.8194544	-2.0698880	-1.6706644
	R2	-0.05432039	-1.64005206	-2.06478303	-1.85731578
	S1	-0.6698906	-1.5715365	-1.5349252	-1.2301938
Second sub-period: 2022-2024	R1	-1.13470608	-0.21071194	0.28020526	-0.02735622
	R2	-0.9048418	-0.2322908	0.1132584	-0.2014763
	S1	-0.5353034	0.3883216	0.9888476	0.5754889

Source: Results from data analysis

Table 6. *Wright Test for NASDAQ Clean Edge Energy Index*

		Number of lags (k)			
Time Period		k=2	k=4	k=8	k=16
First sub-period: 2017-2019	R1	-0.2122508	-1.8194544	-2.0698880	-1.6706644
	R2	-0.05432039	-1.64005206	-2.06478303	-1.85731578
	S1	-0.6698906	-1.5715365	-1.5349252	-1.2301938
Second sub-period: 2022-2024	R1	-1.13470608	-0.21071194	0.28020526	-0.02735622
	R2	-0.9048418	-0.2322908	0.1132584	-0.2014763
	S1	-0.5353034	0.3883216	0.9888476	0.5754889

Source: Results from data analysis

4.5.2. Chow & Denning Test

Table 7 presents the results of the Chow–Denning multiple variance ratio test for both the SRI KEHATI Index and the NASDAQ Clean Edge Energy Index, applied across several holding periods and sub-periods. This test provides a joint assessment of the random walk hypothesis by evaluating whether variance ratios across multiple horizons differ significantly from unity.

The empirical results indicate that the calculated test statistics remain below their corresponding critical values for both indices in each of the two sub-periods. As a result, the null hypothesis of a random walk cannot be rejected at the 5% significance level. This implies that the variance ratios are not statistically different from one, suggesting the absence of linear dependence in returns across the examined horizons.

From an economic perspective, these findings indicate that price changes incorporate available information efficiently, and past return patterns do not provide reliable predictive power for future movements. Consequently, the evidence supports the presence of weak-form market efficiency for both the SRI KEHATI Index and the NASDAQ Clean Edge Energy Index throughout the study period.

Table 7. *Chow & Denning Test*

SRI KEHATI Index					
Time Period	Critical value at significance level of 1%	Critical value at significance level of 5%	Critical value at significance level of 10%	CD 1	CD 2
First sub-period: 2017-2019	3.022202	2.490915	2.226268	1.858761	1.538644
Second sub-period: 2022-2024	3.022202	2.490915	2.226268	0.9161586	0.8600458
NASDAQ Clean Edge Energy Index					
Time Period	Critical value at significance level of 1%	Critical value at significance level of 5%	Critical value at significance level of 10%	CD 1	CD 2
First sub-period: 2017-2019	3.022202	2.490915	2.226268	1.324492	1.138388
Second sub-period: 2022-2024	3.022202	2.490915	2.226268	0.8763	0.8053585

Source: Results from data analysis

The findings of this study are broadly consistent with prior literature on market efficiency. For instance, (Goel & Sahay, 2023) concluded that the Greenex and Carbonex indices in India are exhibited weak-form efficiency. Similarly, (Kumar et al., 2020) found that the Indian financial market, in general, and firms within the pharmaceutical sector, in particular, were characterized by weak-form efficiency. A comparable conclusion was reported by (Asiri, 2008), who showed that the Bahraini stock market satisfied the weak-form efficiency hypothesis.

This evidence was further supported by (Al-Khazali et al., 2015), who examined nine conventional and nine Islamic indices across different regions and market conditions. Their results indicated that, over the full sample period, conventional indices in Europe, Japan, and the United Kingdom were not weak-form efficient, whereas their Islamic counterparts exhibited relatively stronger efficiency. During bearish market conditions, conventional indices in Asia-Pacific, Canada, the United States, and Japan displayed weak-form efficiency, alongside their Islamic counterparts in the same regions. In contrast, under bullish market, weak-form efficiency was primarily observed in conventional indices across Asia-Pacific, Europe, and Japan.

However, other empirical studies that examined the efficiency of green financial markets reported findings that were not aligned with those of the present study. For example (Dias et al., 2023) found that the returns of green financial market indices, namely the Clean Energy Fuels Index, the S&P Global Clean Energy Index, and the iShares Global Clean Energy ETF, did not exhibit weak-form efficiency, as return predictability persisted, particularly during periods of heightened uncertainty such as the COVID-19 pandemic and the Russia–Ukraine conflict. Similarly, (Sharma, 2022) showed that the returns of the BSE GREENEX Index did not follow a random walk process, thereby rejecting the weak-form efficiency hypothesis.

This study contributed to the literature by providing new empirical evidence on the weak-form efficiency of both developing and developed green financial markets. Nevertheless, several limitations should be acknowledged. First, the analysis was constrained by a relatively short sample period, which may limit the generalizability of the findings. Second, the study did not incorporate a broader set of green financial markets, which could provide a more comprehensive assessment. Finally, commonly used econometric models for testing return predictability, such as ARMA and GARCH-type models, were not employed, suggesting potential avenues for future research.

5. Conclusion

The market efficiency hypothesis has attracted considerable attention in the financial economics literature, as numerous studies have examined the behavior of asset prices and returns to determine whether they follow predictable patterns based on historical, public, or private information. Conversely, the absence of such predictability supports the validity of the Efficient Market Hypothesis (EMH) in its various forms.

Within this framework, the present study provided new empirical evidence on the weak-form efficiency of green financial markets by applying a series of statistical tests to the SRI KEHATI Index, representing a developing market, and the NASDAQ Clean Edge Energy Index, representing a developed market. The empirical findings indicated that both markets exhibited characteristics consistent with weak-form efficiency.

Despite the differences in economic and regulatory environments across the sampled markets, the results remain specific to the selected indices and time frame. Accordingly, they provide a basis for future research incorporating a broader set of green financial markets and a longer observation period. Further extensions may also include testing semi-strong and strong forms of efficiency, as well as employing more advanced econometric techniques to deepen the analysis of market efficiency.

References

- Agustin, I.N. (2019). Testing Weak Form of Stock Market Efficiency at The Indonesia Sharia Stock Index. *Muqtasid Journal of Islamic Economics and Banking*, 10(01), 17-29.
- Akbar, S.U. and Bhutto, N.A. (2023). Weak Form Market Efficiency: Evidence from Developing and Emerging Markets. *International Research Journal of Management and Social Sciences*, 04(03), 211-224.
- Al-Ajmi, J. and Kim, J.H. (2011). Are Gulf Stock Markets Efficient? Evidence from New Multiple Variance Ratio Tests. *Applied Economics*, 44(14), 1737–1747.
- Al-Khazali, O.M., Leduc, G. and Alsayed, M.S. (2015). A Market Efficiency Comparison of Islamic and Non-Islamic Stock Indices. *Emerging Markets Finance and Trade*, 52(07), 1587–1605.
- Alrabadi, H.W. and Al-Qadi, N.S. (2024). Testing the weak-form efficiency of Arab stock markets after the Covid-19 pandemic. *Investment Management and Financial Innovations*, 21(2), 381-388.
- Amelot, L.M.M., Ushad, S.A. and Lamport, M. (2017). Testing The Efficient Market Hypothesis in An Emerging Market: Evidence from Forex Market in Mauritius. *Theoretical Economics Letters*, Volume 07, 2104-2122.
- Angelovska, J. (2018). Testing Weak Form of Stock Market Efficiency at The Macedonian Stock Exchange. *UTMS Journal of Economics*, 09(02), 133-144.
- Asiri, B. (2008). Testing Weak-Form Efficiency in The Bahrain Stock Market. *International Journal of Emerging Markets*, 03(01), 38-53.
- Borges, M.R. (2010). "Efficient Market Hypothesis in European Stock Markets". *The European Journal of Finance*, 16(07), pp. 711-726.
- Cagli, E.C. (2018). Re-visiting The Turkish Stock Market Efficiency: Evidence from Adaptive Wild Bootstrap Testing Procedures. *Press Academia Procedia*, Volume 08, 38-42.
- Chaker, M.N. and Sabah, A. (2018). Testing The Weak Form of Efficiency of The Stock Markets in Gulf Cooperation Council Countries. *J. Global Business Advancement*, 11(03), 376-391.
- Charles, A. and Darné, O. (2009). Variance Ratio Tests of Random Walk: An Overview. *Journal of Economic Surveys*, 23(03), 503-527.
- Chen, J.-H. (2008). Variance Ratio Tests of Random Walk of The Euro Exchange Rate. *International Business & Economics Research Journal*, 07(12), 97-106.
- Chow, K.V. and Denning, K.C. (1993). A Simple Multiple Variance Ratio Test. *Journal of Econometrics*, Volume 58, 385-401.
- Dias, R., Horta, N. and Chambino, M. (2023). Clean Energy Action Index Efficiency: An Analysis in Global Uncertainty Contexts. *Energies*, 16(09), 01-18.
- Dias, R. et al. (2020). Random Walks and Market Efficiency Tests: Evidence on US, Chinese and European Capital Markets within The Context of The Global Covid-19 Pandemic. *Oeconomia Copernicana*, 11(04), 585-608.
- Fama, E.F. (1965). The Behavior of Stock-Market Prices. *The Journal of Business*, 38(01), 34-105.
- Fama, E.F., (1970). Efficient Capital Markets: A Review of Theory and Empirical Work. *The Journal of Finance*, 25(02), 383-417.
- Fama, E.F. (1991). Efficient Capital Markets: II. *The Journal of Finance*, 46(05), 1575-1617.
- Ferrer, R., Benítez, R. and Bolós, V.J. (2021). Interdependence between Green Financial Instruments and Major Conventional Assets: A Wavelet-Based Network Analysis. *Mathematics*, 09(08), 01-20.

- Gimba, V.K. (2012). Testing The Weak-Form Efficiency Market Hypothesis: Evidence from Nigerian Stock Market. *CBN Journal of Applied Statistics*, 03(01), 117-136.
- Goel, A. and Sahay, N. (2023). Investigating the Market Efficiency of Socially Responsible Indices: Evidence from India. *International Journal of Finance, Economics and Business*, 02(04), 301-312.
- Guidi, F., Gupta, R. and Maheshwari, S. (2011). Weak-Form Efficiency and Calendar Anomalies for Eastern Europe Equity Markets. *Journal of Emerging Market Finance*, 10(03), 337-389.
- Gurung, P. and Sarkar, S. (2023). Testing of Market Efficiency of BSE GREENEX: An Empirical Analysis. *SDMIMD Journal of Management*, 14(01), 91-106.
- Haugen, R.A. (2001). *Modern Investment Theory*. New Jersey: Prentice Hall.
- Khanal, M., Thapa, K.B. and Bhandari, M. (2025). Weak Form of Market Efficiency in Nepalese Stock Market. *Journal of Business and Econometrics Studies*, 02(01), 01-10.
- Kumar, A. et al. (2020). The Testing of Efficient Market Hypotheses: A Study of Indian Pharmaceutical Industry. *International Journal of Economics and Financial Issues*, 10(03), 208-216.
- Lawal, A.I., Somoye, R.O. and Babajide, A.A. (2017). Are African Stock Markets Efficient? Evidence From Wavelet Unit Root Test for Random Walk. *Economics Bulletin*, 37(04), 2665-2679.
- Mbululu, D., Auret, C. and Chiliba, L. (2013). Do Exchange Rates Follow Random Walks? A Variance Ratio Test of The Zambian Foreignexchange Market. *Southern African Business Review*, 17(02), 45-66.
- Nelmida, N. (2020). Is Indonesia Stock Exchange Semi-Strong Form Efficiency? *Jurnal Manajemen*, 24(02), 313-326.
- Njuguna, J. (2016). Testing The Efficient Market Hypothesis on The Nairobi Securities Exchange". *Investment Management and Financial Innovations*, 13(03), 75-83.
- Ntsama, U.Y.O., Yan, C., Nasiri, A. and Mboungam, A.H.M. (2021). Green Bonds Issuance: Insights in Low- and Middle-Income Countries. *International Journal of Corporate Social Responsibility*, 06(02), 02-09.
- Pele, D.T. and Voineagu, V. (2008). Testing Market Efficiency via Decomposition of Stock Return: Application to Romanian Capital Market. *Romanian Journal of Economic Forecasting*, Volume 03, 63-79.
- Potocki, T. and Świst, T. (2012). Empirical Test of The Strong Form Efficiency of The Warsaw Stock Exchange: The Analysis of WIG 20 Index Shares. *South-Eastern Europe Journal of Economics*, Volume 02, 155-172.
- Sharma, S. (2022). BSE Greenex: A Pre & Post Covid-19 Empirical Study. *Procedia Computer Science*, Volume 214, 149-155.
- Smith, G. and Ryoo, H.-J. (2003). Variance Ratio Tests of The Random Walk Hypothesis. *The European Journal of Finance*, 09(03), 290-300.
- Tokić, S., Bolfek, B. and Peša, A.R. (2018). Testing Efficient Market Hypothesis in Developing Eastern European Countries. *Investment Management and Financial Innovations*, 15(02), 281-291.
- Vochozka, M., Horák, J. and Krulický, T. (2020). Innovations in Management Forecast: Time Development of Stock Prices with Neural Networks. *Marketing and Management of Innovations*, Volume 02, 324-339.
- Wright, J.H. (2000). Alternative Variance-Ratio Tests Using Ranks and Signs. *Journal of Business & Economic Statistics*, 18(01), 01-09

Exploring symmetry and asymmetry in evacuation dynamics: A comprehensive bibliometric and computational analysis

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Abstract. *This study presents a comprehensive bibliometric analysis of evacuation research, focusing on the integration of symmetry and asymmetry elements. By analyzing a dataset of scholarly papers from the ISI Web of Science database spanning 2000 to 2023, we reveal a sustained annual growth rate of 8.1% in academic interest. Key contributors, influential publications, and leading journals in the field are identified. The analysis highlights the importance of considering information symmetry/asymmetry, symmetric/asymmetric Hausdorff distance, evacuation layout symmetry/asymmetry, and symmetry-breaking behaviors of evacuees. We show that N-gram analysis techniques uncover various applications of symmetry and asymmetry in evacuation research, emphasizing their significance in addressing evacuation challenges and enhancing strategies.*

Keywords: evacuation, bibliometric analysis, network analysis, information symmetry, symmetry-breaking behavior.

JEL Classification: C88, C63, R58, R41.

1. Introduction

Evacuation research is an increasingly critical field, attracting considerable attention from both scholars and policymakers. This growing interest reflects the evolving dynamics of modern society, particularly the complexities of expanding urban environments that present new challenges for emergency management (Perry and Lindell, 2003; Kapucu, 2008). The urgency of efficient evacuation strategies has been underscored by natural disasters, industrial accidents, and unforeseen crises such as pandemics. In this context, the science of evacuating populations safely and efficiently has become more vital than ever.

The present study seeks to advance our understanding of evacuation research by providing a comprehensive overview of the field. However, what sets our approach apart is its emphasis on exploring evacuation dynamics through the lens of symmetry and asymmetry. This distinctive perspective uncovers deeper insights into evacuation behaviors, patterns, and underlying factors that may have been overlooked by traditional studies (Che et al., 2015). While symmetry and asymmetry are often examined in other scientific disciplines, their application to evacuation research is uniquely significant. Evacuation is not simply the movement of individuals out of a space in a uniform manner; it involves a complex interplay of factors such as information asymmetry, the geometry of the evacuation environment, and the varied behaviors exhibited by evacuees themselves. Understanding these elements is crucial for optimizing evacuation strategies and improving their effectiveness across diverse real-world scenarios (Cotfas et al., 2023; Delcea et al., 2020). To investigate this topic, we have employed a bibliometric approach - an increasingly valuable tool for analyzing the evolution of research fields. Bibliometric analysis allows us to trace the trajectory of evacuation research by examining key trends, influential authors, institutions, and journals, while also identifying shifts in terminology and conceptual focus (Delcea et al., 2023). Bibliometrics, with its inherent capabilities, offers valuable insights into key stakeholders, academic institution affiliations, influential publications, and leading journals in the field, while also highlighting common terminologies and their frequencies of use (Li et al., 2020; López Belmonte et al., 2020; Lou and Hung, 2023).

Our study draws upon the ISI Web of Science database, covering a period of more than two decades (2000–2023), and focuses specifically on publications related to evacuation that integrate symmetry and asymmetry elements. By leveraging this method, we can provide a detailed and nuanced view of how these elements have shaped the field. Our analysis reveals a compelling narrative, demonstrating a steady and substantial interest in evacuation research that incorporates symmetry and asymmetry. Notably, the data reveals an 8.1% annual growth rate in publications related to this niche, indicating the increasing recognition of its importance. This growth not only reflects the growing body of literature but also suggests that this unique angle is resonating with scholars and practitioners alike. Beyond quantitative analysis, our study provides an in-depth exploration of emerging trends, crucial keywords, and evolving research trajectories. By examining author collaboration networks, academic affiliations, and the global distribution of research, we offer new insights into how evacuation modeling, with a focus on symmetry and

asymmetry, is being applied worldwide. Additionally, our use of advanced computational techniques, such as n-gram analysis of titles, keywords, abstracts, and keyword-plus fields, reveals the diverse applications of these concepts within the evacuation domain.

The findings from our study significantly contribute to the broader discourse on evacuation research by integrating computational and bibliometric methods to investigate a previously underexplored dimension of the field. The study not only highlights the continued relevance of symmetry and asymmetry in evacuation scenarios but also offers a comprehensive review of globally cited documents, positioning our approach as a unique and valuable addition to existing literature.

2. Materials and Methods

For extracting the publications discussing the symmetry / asymmetry aspects to the field of evacuation, the Web of Science platform (WoS platform) was employed. The data collection is only applicable to papers published until the end of 2023. The bibliometric analysis has been conducted in accordance with the most recent works from the field which have considered the same analysis technique, but on a different topic – please consider the following works for similar bibliometric analysis on various topics (Gorski et al., 2023; Stefanis et al., 2023; Delcea and Cotfas, 2023; Fatma and Haleem, 2023). As suggested by Marin-Rodriguez et al. (Marín-Rodríguez et al., 2023), the bibliometric analysis incorporates two main parts: de identification of the dataset of articles from the evacuation area that take into account elements related to symmetry/asymmetry along with other elements that might derive from modeling such a complex situation (e.g. the occurrence of obstacles, evacuating with a friend, elevated floors, etc.), and the analysis of the extracted dataset. A similar approach is conducted by Anac et al. (Anaç et al., 2023).

Regarding the first part related to dataset extraction, a search action carried out on the WoS platform using a list of keywords that includes "evacuation" words like "evacuation" and "evacuations" as well as "symmetry"-related words like "symmetry", "asymmetry", "symmetric" and "asymmetric" on the papers' title, abstract, and keywords. This search is represented in the exploration steps 1 through 3 presented in Table 1. This method was chosen since a straightforward search using only the key words "evacuation" and "symmetry" would have produced a significant number of publications, the majority of which would not have been relevant to the chosen research area. This problem is brought about by the widespread use of the word "evacuation" and "symmetry" in several areas covered in scientific studies. As a result, 14 papers were identified as having both the searched keywords in the title, 202 papers had both the searched keywords in the abstract, and 9 papers in the keywords - Table 1. When searching for only one of the selected words, the result of the query amounts to a much larger number of papers, finding thousands more than when using both the keywords. A merging operation was performed in step 4 to create a total of 206 papers on evacuation research containing "symmetry" related words, because most of the papers contained the chosen keywords in more than one of the three sections of the article (title, abstract, or keywords).

Based on the language requirement, which specifies that the articles need to be written in English, 198 of these papers have been kept for analysis (please see step 5). Since most readers and researchers can easily understand English, this exclusion criterion has been used to eliminate papers written in languages other than English. Another exclusion criterion has been the document type. Only the papers designated as articles were kept for analysis. This action has the effect of bringing the number of papers down to 166 (step 6). Further, another exclusion criterion has been used (step 8) for the 162 papers. The publications that only discuss the subjects of evacuation were chosen based on this final criterion. The papers were chosen manually by reading their titles, abstracts, and keywords because the action couldn't be completed using the filtering tools provided by the WoS platform and we have observed that some of the papers included in the database, even though feature the use of evacuation specific keyword and symmetry / asymmetry specific keywords were not referring to the crowd evacuation but rather to other fields of study such as chemistry, biology or medicine (e.g. the gas particles evacuation). A total of 46 papers were retained for examination because of this action, and the results are reviewed and examined in the sections that follow. **Table 1** contains a list of the procedures required to extract the papers.

Table 1. *Queries used for extracting the database*

Exploration steps	Questions on Web of Science	Description	Query	Query number	Count
1	Title	Contains evacuation specific keyword	(TI=(evacuation)) OR TI=(evacuations)	#1	10,204
		Contains one of the symmetry / asymmetry specific keywords	((TI=(symmetry)) OR TI=(asymmetry)) OR TI=(symmetric) OR TI=(asymmetric)	#2	274,610
		Contains #1 and #2	#2 AND #1	#3	14
2	Abstract	Contains evacuation specific keyword	(AB=(evacuation)) OR AB=(evacuations)	#4	31,079
		Contains one of the symmetry / asymmetry specific keywords	((AB=(symmetry)) OR AB=(asymmetry)) OR AB=(symmetric) OR AB=(asymmetric)	#5	933,461
		Contains #4 and #5	#4 AND #5	#6	202
3	Keywords	Contains evacuation specific keyword	(AK=(evacuation)) OR AK=(evacuations)	#7	7370
		Contains one of the symmetry / asymmetry specific keywords	((AK=(symmetry)) OR AK=(asymmetry)) OR AK=(symmetric) OR AK=(asymmetric)	#8	151,840
		Contains #7 and #8	#7 AND #8	#9	9
4	Title/ Abstract/ Keywords	Contains evacuation specific keyword and one of the symmetry / asymmetry specific keywords	#3 OR #6 OR #9	#10	206
5	Language	Limit to English	(#10) AND LA=(English)	#11	198
6	Document Type	Limit to Article	(#11) AND DT=(Article)	#12	166
7	Publication year	Limit to 2023	(#12) NOT PY=(2024)	#13	162
8	Select the papers discussing evacuation and symmetry / asymmetry aspects	Limit to the papers dealing with evacuation and discussing aspects related to symmetry or asymmetry	Manually selected papers based on titles and abstracts	#14	46

For the dataset overview, a series of indicators have been discussed in accordance to other papers which have used the same analysis approach: the number of sources, papers' annual growth rate, number of authors, number of authors of single-authored document, co-authors per document, international co-authorship rate, number of authors' keywords, the average

years from publication, the average number of citations per document, the average citations per year per document, the number of references – all these on the purpose of having an overview over the selected papers. Sources analysis provides information related to the most relevant journals in terms of number of articles related to symmetry/asymmetry aspects, along with the sources located in the top peer according to Bradford's law, the most relevant journals form the point of view of H-index, and the growth of the number of papers for the top-ranked journals over time. Authors' analysis depicts the most prominent authors from both the number of authored papers and number of citations, discuss their affiliations, and their residence countries. Also, in this analysis a collaboration network is identified and discussed, along with the clusters of authors.

Papers analysis provides the list of top 10 most cited papers, along with their main indicators (total citations, total citations per year, normalized total citations per year indicator). In this analysis, a review of the top 5 most cited papers is provided along with information related to the main elements discussed in the paper, the type of data used, and theories considered. Besides these elements, a review of the symmetry / asymmetry elements is provided for all the papers included in the dataset. Words analysis discusses the top 10 n-grams (unigrams and bigrams) from various sections of the papers (e.g. title, abstract, authors' keywords). Based on these words and the evolution of the number of papers, a further analysis is conducted with the purpose of extracting the main themes that have occurred over time and their evolution. Mixed analysis connects the authors with their countries, with the journals in which they have published, or with their affiliations and keywords used for giving more insight on this area of research related to considering symmetry/asymmetry elements in evacuation problems.

As discussed in the previous section, evacuation is a complex process influenced by many different factors. In this study, we focus specifically on the role of symmetry and asymmetry in evacuation research. These aspects are particularly important because they can significantly affect the safety and efficiency of the evacuation process. By considering such factors, researchers can develop models that more accurately reflect real-world evacuation dynamics. A review of the selected literature also shows that many authors emphasize the importance of incorporating symmetry and asymmetry considerations when analyzing evacuation scenarios.

Bibliographic analysis, content analysis, visualization, and citation analysis have all been used to examine the data. Through the usage of the Biblioshiny program created by Aria and Cuccurullo from the Federico II University and University of Campania Luigi Vanvitelli, several visualizations have been carried out (Aria and Cuccurullo, 2017). This software was chosen as it offers a number of visually appealing graphics that demonstrate the links between the items under consideration. From a methodological point of view, the Bibliometrix package has been loaded in the RStudio console window using the *biblioshiny()* command. However, the program has recently been used in numerous research projects that suggest author networks and paper analyses (Delcea and Cotfas, 2023; Zardari et al., 2023; Marín-Rodríguez et al., 2023).

3. Dataset Analysis

The following section includes a discussion that includes authors, sources and citations for the extracted publications in the field of evacuation.

3.1. Dataset Overview

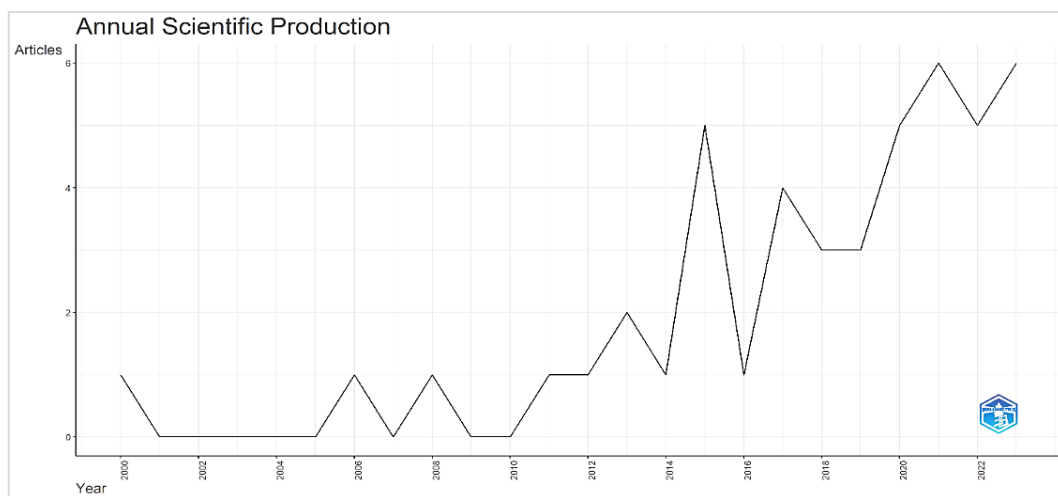
Table 2 provides the values for a set of variables and describe the characteristics of the data set made up of the 46 publications. The time period for the papers that have been published is 2000 to 2023, and the journals that the articles have been published in total 30 sources. Due to the low value for the average years from publication indicator, which is equal to 6.15 years, the majority of the publications included in the dataset are recent papers. According to the information in **Table 2**, the published articles have attracted more attention from the scientific community, as evidenced by an average of 21.89 citations per document.

Table 2. Main information about data

Indicator	Value
Timespan	2000:2023
Sources	30
Documents	46
Annual growth rate	8.1%
Authors	149
Authors of single-authored docs	3
Co-authors per document	3.52
International co-authorship	23.91%
Author's keywords	174
Average years from publication	6.15
Average citations per documents	21.89
References	1741

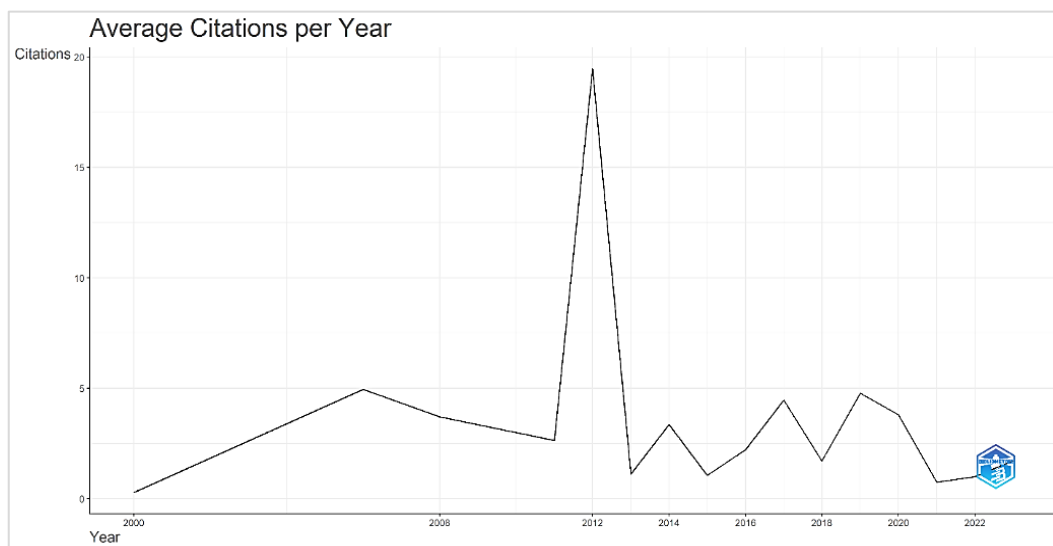
The annual scientific production has shown an increase in the number of papers, with an annual growth rate of 8.1%. This can be seen in **Figure 1**, reaching a number of 46, respectively 6 articles in year 2023. The first major spike was recorded in 2015, growing from 1 article per year, to a number of 5.

Figure 1. Annual scientific production evolution



The evolution of the average value of article citations has been between 3.7 and 4.95 since 2005, varying from year to year, indicating a good visibility of papers written in the field of evacuation research. Almost null values were recorded between 2000–2005. The year in which most references were made is 2012, when it reached a value of 19.46, a significant difference from other years (**Figure 2**).

Figure 2. Annual average article citations per year evolution



When using “keywords plus” in our analysis, we have reached a value of identified words (a number of 150) relatively lower than when using the authors’ keywords, (174 occurrences). A total of 149 researchers have been uniquely identified. It can be said that the collaboration network among the authors of the papers written in the evacuation research area is predicted to be dense because the number of authors of single-authored documents is quite low in comparison to the number of extracted documents (3 versus 146). The fact that there is a comparable number of authors on multi-authored publications than there are overall (146 versus 149).

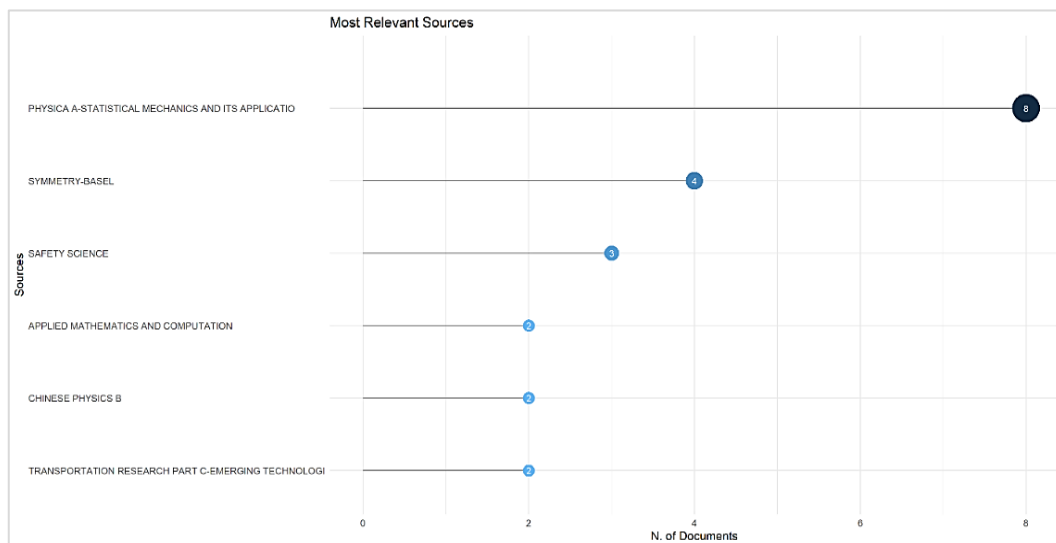
Table 3 presents key indicators of author collaboration within the scope of this study. The data reveals that out of the documents analyzed, only three were authored by a single individual, indicating a prevalent culture of collaboration in this research domain. On average, each author contributed to approximately 0.307 documents, highlighting the widespread involvement of multiple authors in each publication. Furthermore, the documents in the dataset had an average of 3.239 authors, showcasing the cooperative nature of scholarly work in the field. With an average of 3.52 co-authors per document, it's evident that many papers were the result of collective efforts. The collaboration index, calculated at 3.395, underscores the degree of cooperation among authors, emphasizing the importance of teamwork and shared expertise in advancing the study of evacuation incorporating symmetry/asymmetry elements.

Table 3. *Authors collaboration*

Indicator	Value
Single-authored documents	3
Documents per author	0.307
Authors per document	3.239
Co-authors per documents	3.52
Collaboration index	3.395

3.2. Sources

When looking at the most relevant publications where the chosen papers have been published, it is clear that the journal “Physica A-Statistical Mechanics and its Applications”, with 8 papers, is the top spot. Places second and third are close to each other, each having 4 and 3 papers published in the following journals: “Symmetry-Basel”, and “Safety Science”. The following place is held by three journals, each having 2 of the selected articles (“Applied Mathematics and Computation”, “Transportation Research Part C-Emerging Technologies” and “Chinese Physics B”). This ranking can be seen as a graphical interpretation in **Figure 3**.

Figure 3. *Top 6 most relevant journals*

When applied to the chosen paper, Bradford's law places a total of four sources (“Physica A-Statistical Mechanics and its Applications”, “Symmetry Basel”, “Safety Science” and “Applied Mathematics and Computation”) in zone 1 - please refer to **Figure 4**. The image illustrates the concept of "Core Sources" as defined by Bradford's Law, a principle in bibliometrics that describes the distribution of relevant literature across journals. The graph plots the number of articles against the logarithmic rank of sources, highlighting a steep decline in the number of articles as the rank increases. The shaded region represents the "Core Sources," which are a small subset of journals that publish the majority of relevant articles in a given field. This visualization underscores the idea that a few key journals dominate the dissemination of significant research, with diminishing returns observed in

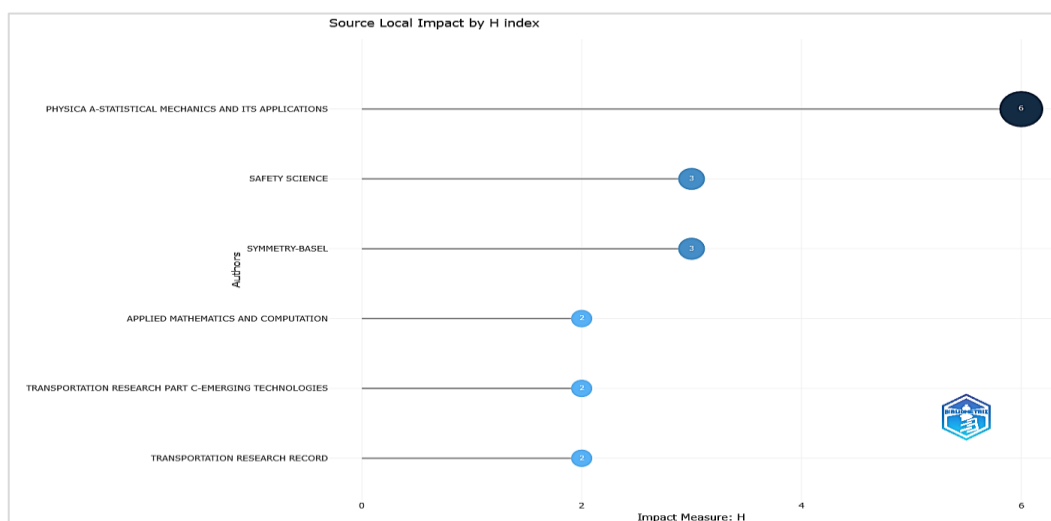
journals of lower rank. The graph effectively demonstrates the concentration of scholarly output, emphasizing the importance of identifying and focusing on these core sources for comprehensive literature reviews.

Figure 4. *Bradford's law on source clustering*



The H-index statistics have also been used to analyze the impact of the journals. This index, as known, is a measurement of the proportion of a journal's papers that have received H or more citations overall. Regarding the chosen articles, the journal “Physica A-Statistical Mechanics and its Applications” receives the greatest H-index score, with 6 works in the field of evacuation research, having received at least 6 citations (please see **Figure 5**). With H-index values ranging from 2 to 6, the journals designated as zone 1 according to Bradford's law are among the best (“Symmetry” and “Safety Science”).

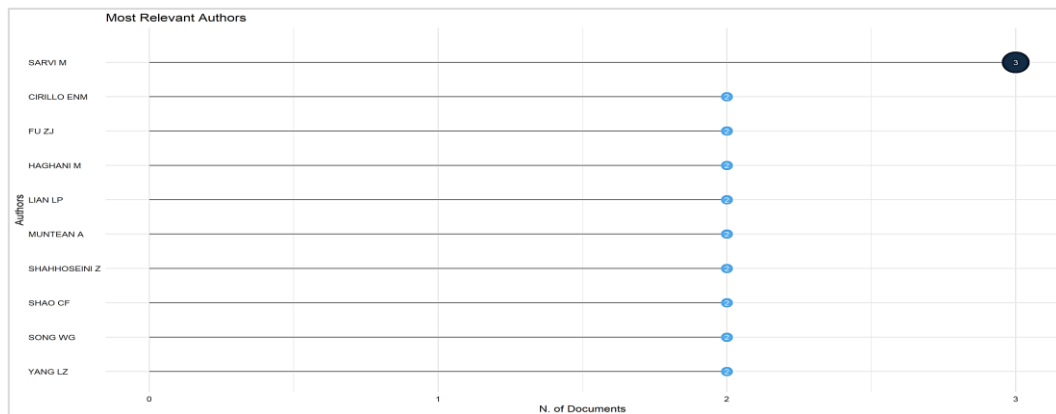
Figure 5. *Journals' impact based on H-index*



3.3. Authors

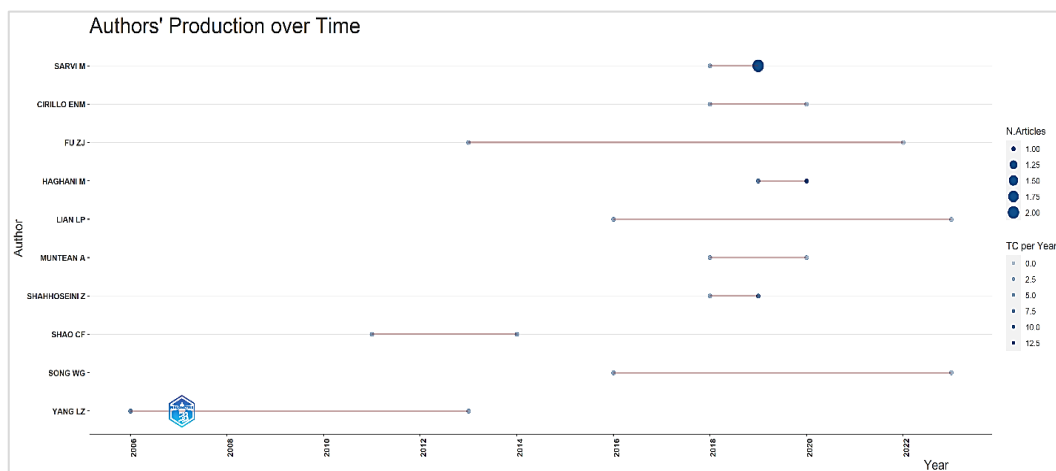
In the evacuation research field, the authors with the most prominent activity based on the number of published articles in this area can be seen in **Figure 6**. The author with the largest number of articles published in this research area is Sarvi M, counting 3 documents. Authors with fewer documents are Cirillo ENM, Fu ZJ, Haghani M, Lian LP, Muntean A, Shahhoseini Z, Shao CF, Song WG and Yang LZ, all having a number of 2 articles per author.

Figure 6. Top-10 authors based on number of documents



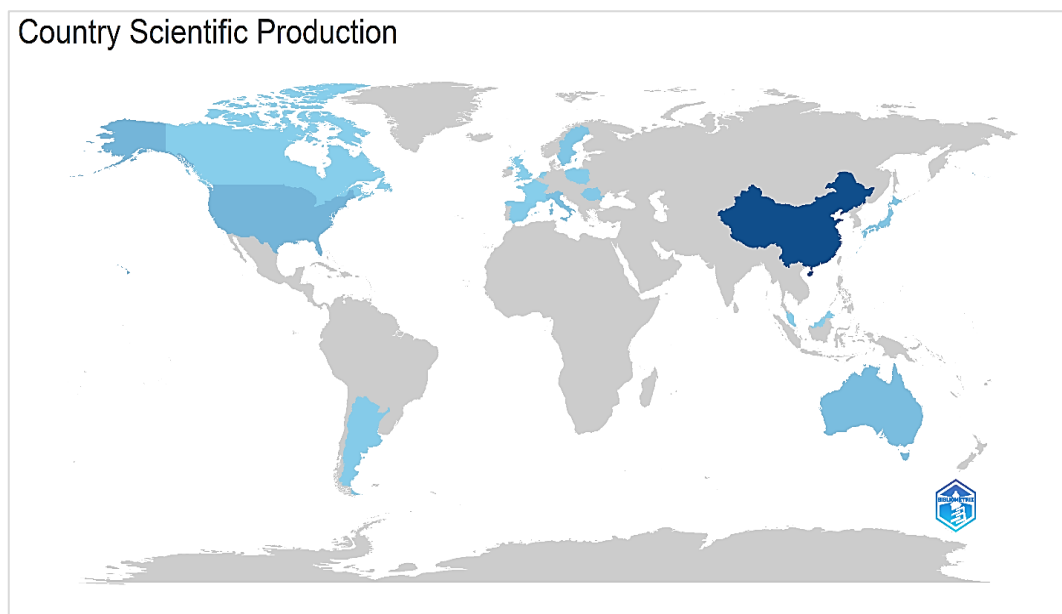
As for the most recent papers, the top 10 most prolific authors in terms of the number of documents they have published can be seen in **Figure 7**. Most of the articles have been published after 2018. Each dot signifies a published article, with the size of the dots corresponding to the number of articles produced in a given year. The brown horizontal lines indicate the span of an author's contributions over time. Additionally, the color intensity of the dots reflects the total citations per year, with darker shades indicating higher citation impact. Notably, Sarvi M and Cirillo ENM exhibit high-impact contributions, as indicated by the larger, darker blue dots around 2018. The graph provides insights into both the longevity and citation influence of key researchers in this domain.

Figure 7. Top-10 authors' production over time



A map of global visualization makes it simple to see how each nation has contributed. The scientific contribution made by each author to the papers under consideration based on their home country is shown in **Figure 8**. The figure's colors are varied. From dark blue, denoting a significant contribution, as in the case of China, to grey, denoting a lack of publications in the fields of evacuation research. As a result of the trend established by scientific production, it can be seen that China has received 409 citations for the publications, which is the most of any nation. The following nation is USA with 274 citations, followed by Australia in close third with 227 citations.

Figure 8. *Scientific production based on country*



In **Figure 9** are presented the collaboration networks of the top 50 authors for the selected papers used in this study. This network visualization represents collaborative relationships among authors in the field of evacuation research involving symmetry and asymmetry. Each node corresponds to an author, with larger nodes indicating higher publication output and thicker connecting lines representing stronger co-authorship ties. The different colors signify distinct research clusters, highlighting groups of authors who frequently collaborate. Notably, Sarvi M, Cirillo ENM, and Muntean A form a tightly connected group (green), while Lian LP and Song WG (orange) also exhibit strong collaboration. Similarly, Fu ZJ (red) appears as a central figure in another major research cluster. This visualization provides insights into the structure of academic collaborations, identifying key contributors and research communities within the field.

In this part, we have chosen the top ten publications that have received the most citations and examined them from the perspective of the data that accompanied the papers.

Table 4 provides detailed information about the top ten most cited articles in the world, including the article's number of authors, area, total citations (TC), total citations per year (TCY), and normalized TC (NTC), which describes the number of citations for each author who cites the document.

No.	Paper (First Author, Year, Journal, Reference)	Number of authors	Region	Total citations (TC)	Total citations per year (TCY)	Normalized TC (NTC)
1	Weina Ge, 2012, IEEE Transactions on Pattern Analysis and Machine Intelligence	3	USA	253	19.46	1.00
2	Zhao Daoliang, Yang Lizhong, 2006, Physica A: Statistical Mechanics and its Applications	3	China	94	4.95	1.00
3	Nirajan Shiwakoti, 2017, Safety Science	4	Australia	69	8.63	1.93
4	Milad Haghani, 2020, Safety Science	1	Australia	64	12.8	3.37
5	Ren-Yong Guo, 2008, Journal of Physics A: Mathematical and Theoretical	2	China	63	3.71	1.00
6	Zahra Shahhoseini, 2019, Transportation Research Part B: Methodological	2	Australia	45	7.50	1.57
7	Yue Hao, 2014, Chinese Physics B	4	China	37	3.36	1.00
8	Yue Hao, 2011, Physica A: Statistical Mechanics and its Applications	4	China	37	2.64	1.00
9	Huang Keke, 2016, Applied Mathematics and Computation	4	China	37	4.63	1.03
10	Milad Haghani, 2019, Safety Science	2	Australia	35	5.83	1.22

No.	Paper (First Author, Year, Journal, Reference)	Number of authors	Region	Total citations (TC)	Total citations per year (TCY)	Normalized TC (NTC)
1	Weina Ge, 2012, IEEE Transactions on Pattern Analysis and Machine Intelligence	3	USA	253	19.46	1.00
2	Zhao Daoliang, Yang Lizhong, 2006, Physica A: Statistical Mechanics and its Applications	3	China	94	4.95	1.00
3	Nirajan Shiwakoti, 2017, Safety Science	4	Australia	69	8.63	1.93
4	Milad Haghani, 2020, Safety Science	1	Australia	64	12.8	3.37
5	Ren-Yong Guo, 2008, Journal of Physics A: Mathematical and Theoretical	2	China	63	3.71	1.00
6	Zahra Shahhoseini, 2019, Transportation Research Part B: Methodological	2	Australia	45	7.50	1.57
7	Yue Hao, 2014, Chinese Physics B	4	China	37	3.36	1.00
8	Yue Hao, 2011, Physica A: Statistical Mechanics and its Applications	4	China	37	2.64	1.00
9	Huang Keke, 2016, Applied Mathematics and Computation	4	China	37	4.63	1.03
10	Milad Haghani, 2019, Safety Science	2	Australia	35	5.83	1.22

3.4.2. Top 5 Most Cited Papers – Review

The top ten most cited papers are reviewed briefly in the sections that follow, along with a brief synopsis of each work.

In the most cited article, "Vision-based Analysis of Small Groups in Pedestrian Crowds" by Weina Ge, Robert T. Collins, and R. Barry Ruback (Weina Ge et al., 2012), the authors introduce an innovative approach to automatically detect small groups within pedestrian crowds using state-of-the-art algorithms for pedestrian detection and multi-object tracking. Their method, based on hierarchical clustering and a generalized Hausdorff distance, demonstrates substantial statistical agreement with human-perceived group structures, providing a novel methodology for empirical studies of social behavior. This research not only advances the field of computer vision but also offers practical applications in crowd management, evacuation planning, and crowd simulation, with potential extensions exploring diverse social events and the incorporation of spatial group configurations into tracking algorithms.

The second ranking article "Exit Dynamics of Occupant Evacuation in an Emergency" by Zhao Daoliang, Yang Lizhong, and Li Jian (Daoliang et al., 2006) presents a two-dimensional Cellular Automata model to simulate occupant evacuation dynamics. The study offers valuable insights into exit design for safety, emphasizing the importance of exit width exceeding a critical value and door separation being neither too small nor too large. It highlights that increasing exit width improves overall evacuation flow, and the optimal door separation remains consistent regardless of exit width. Additionally, the study underscores the importance of symmetry in exit layout for optimal performance in building design. Overall, this research contributes to a better understanding of occupant evacuation dynamics and provides guidance for performance-based building design considerations.

In the article "Likely Behaviors of Passengers Under Emergency Evacuation in Train Stations" by Nirajan Shiwakoti, Richard Tay, Peter Stasinopoulos, and Peter Jarrod Woolley (Shiwakoti et al., 2017), the authors investigate various aspects of passenger behavior during emergency evacuations in train stations. Through a survey of 1134 train passengers, the study reveals that passengers exhibit diverse behaviors, with a tendency toward reactive responses (waiting for instructions) rather than proactive ones (moving to exit independently) during emergencies. Furthermore, cooperative behavior (helping others) is more common than competitive behavior (pushing others), and while some symmetry-breaking behavior is observed (following others), it's not as pronounced as previous mathematical models assumed. Passengers also tend to avoid using escalators, lifts, and train tunnels during evacuations. The findings contribute valuable insights for developing mathematical models, emergency response strategies, training programs, and design solutions to enhance evacuation effectiveness in train stations. Overall, this research provides crucial insights into passenger behavior during emergency situations, particularly within complex and confined transport hubs.

In the article "Empirical Methods in Pedestrian, Crowd, and Evacuation Dynamics: Part II - Field Methods and Controversial Topics" by Milad Haghani (Haghani, 2020), the author

provides a comprehensive review of field data collection methods in pedestrian dynamics from April 2017 to July 2019. The article discusses the increasing popularity of field observations in natural settings for calibrating and validating simulation models. Additionally, the review identifies nine controversial topics in crowd dynamics, shedding light on recent experiments that challenge long-held assumptions. This article, notable for being single-authored, underscores the rapid growth in the field of pedestrian and evacuation dynamics, reflecting the expanding interest and research efforts in this area. It sets the stage for further investigation into and clarification of the inconsistencies surrounding these controversial topics in the years to come.

The fifth article "A Modified Floor Field Cellular Automata Model for Pedestrian Evacuation Simulation" by Ren-Yong Guo and Hai-Jun Huang (Guo and Huang, 2008) introduces an innovative approach to simulate pedestrian evacuations in high-density crowds. The authors address the asymmetric, accumulative, and transferable nature of pedestrian interactions by discretizing the evacuation space into smaller cells and considering individual inertia and forces imposed on others. Through numerical simulations, they explore the effects of pedestrian movement styles and model parameters on evacuation efficiency. The results reveal that unorganized movements and stronger push and bump interactions among pedestrians increase evacuation times. The modified model outperforms the original floor field model in terms of evacuation time, offering flexibility in adjusting parameters to match real-world scenarios. This research represents a promising development in understanding and optimizing pedestrian evacuation processes in various contexts, including buildings with multiple obstacles and multiple exits.

Table 5 provides information related to the elements considered from the evacuation research field, the type of data used in the analysis, the main purpose of the paper, the presence of a theoretical and/or practical application of the methodology, and the presence/absence of a hybrid approach, along with the name of the paper and a brief description based on the first author's name.

Table 5. *Brief summary of the content of top 5 most global cited documents*

No.	Paper (First Author, Year, Journal, Reference)	Title	Main elements	Data	Purpose	Hybrid approach / Theories considered
1	Weina Ge, 2012, IEEE Transactions on Pattern Analysis and Machine Intelligence	Vision-Based Analysis of Small Groups in Pedestrian Crowds	Detecting and tracking individuals	Field data	Automatically detection of small groups within pedestrian crowds	Algorithms for detecting pedestrians and multi-object tracking; hierarchical clustering; generalized Hausdorff distance
2	Zhao Daoliang, Yang Lizhong, 2006, Physica A: Statistical Mechanics and its Applications	Exit dynamics of occupant evacuation in an emergency	Exit design safety	Synthetic data	Simulation of occupant evacuation dynamics	Cellular Automata model
3	Nirajan Shiwakoti, 2017, Safety Science	Likely behaviors of passengers under emergency evacuation in train station	Analyzing passengers' behaviors	Survey	Investigation of various aspects of passenger behavior during emergency evacuations in train stations	-

No.	Paper (First Author, Year, Journal, Reference)	Title	Main elements	Data	Purpose	Hybrid approach / Theories considered
4	Milad Haghani, 2020, Safety Science	Empirical methods in pedestrian, crowd and evacuation dynamics: Part II. Field methods and controversial topics	Review of field data collection methods	Field data	Review of field data collection methods in pedestrian dynamics	-
5	Ren-Yong Guo, 2008, Journal of Physics A: Mathematical and Theoretical	A modified floor field cellular automata model for pedestrian evacuation simulation	Discretization of the evacuation space into smaller cells; consideration of individual inertia and forces imposed on others	Synthetic data	Simulation of pedestrian evacuations in high-density crowds	Numerical simulations

3.4.3. Symmetric/Asymmetric Elements Overview

In the context of articles pertaining to evacuation, an analysis of the inherent symmetry and asymmetry attributes within the selected papers has been conducted, with a focus on discerning the primary elements thereof. The outcomes of this scrutiny have been succinctly synthesized and are presented in Table 8. Upon initial inspection, it becomes evident that a substantial majority of the included articles emphasize the examination and discourse surrounding asymmetry considerations, with 33 out of the 40 papers explicitly addressing and delving into the subject of "asymmetry" in relation to the evacuation process. In contrast, a comparatively lesser proportion, specifically 16 out of the 40 papers, engage in discussions revolving around "symmetry"-related issues in the context of evacuations. Consequently, there emerges a subset of 9 papers that undertake a comprehensive examination of evacuation dynamics, concurrently exploring both symmetry and asymmetry facets.

Based on the categories presented in the final column of **Table 6**, three main themes emerge in the discussion of symmetry and asymmetry within evacuation research. The first and most common theme, addressed in 17 of the 40 selected papers, focuses on the symmetry or asymmetry of exit designs and layout configurations. Another important topic, explored in 8 papers, relates to the presence or absence of symmetry in evacuee behavior, including symmetry-breaking phenomena during evacuations. In addition, 6 papers examine the role of symmetric and asymmetric information in evacuation scenarios. Furthermore, within the remaining subset of papers, several distinctive and individualized themes are discerned. These include discussions on topics such as the utilization of Hausdorff distance as a means to simulate evacuation behavior, the occurrence of asymmetric flow patterns, and the assumption of asymmetric weight distributions within the simulation models, among others. For further elaboration on these specific themes, please refer to **Table 6**.

Table 6. Summary of the symmetry/asymmetry content of the selected articles included in the analysis

No.	Paper (First Author, Year, Journal, Reference)	Symmetry / Asymmetry Elements		Considered Symmetry / Asymmetry Elements and Brief Explanation
		Symmetry	Asymmetry	
1	Weina Ge, 2012, IEEE Transactions on Pattern Analysis and Machine Intelligence	✓		Small Groups in Pedestrian Crowds are discovered by bottom-up hierarchical clustering using a generalized Symmetric Hausdorff distance.
2	Zhao Daoliang, Yang Lizhong, 2006, Physica A: Statistical Mechanics and its Applications	✓		The exits' layouts are considered symmetrical.
3	Nirajan Shiwakoti, 2017, Safety Science	✓	✓	Trains passengers' behaviors considering various aspects, including symmetry breaking behavior, such as following other passengers, or symmetry behavior such as choose least crowded exit.
4	Milad Haghani, 2020, Safety Science		✓	Controversial topics discussion, including the symmetry breaking phenomenon
5	Ren-Yong Guo, 2008, Journal of Physics A: Mathematical and Theoretical		✓	Pedestrian evacuation considering a high-density crowd asymmetric interaction.
6	Zahra Shahhoseini, 2019, Transportation Research Part B: Methodological	✓	✓	Experimental scenarios for pedestrian crowd flows in shared spaces with symmetric and non-symmetric layouts.
7	Yue Hao, 2014, Chinese Physics B		✓	Exit selection in pedestrian evacuation is made by taking into account the asymmetry of exits or of pedestrian layout.
8	Yue Hao, 2011, Physica A: Statistical Mechanics and its Applications		✓	Pedestrian evacuation simulations for a room with asymmetrical exit layout.
9	Huang Keke, 2016, Applied Mathematics and Computation	✓	✓	Pedestrian evacuation from a room with symmetrically located exits; the occurrence of a symmetry breaking behavior.
10	Milad Haghani, 2019, Safety Science		✓	Symmetry breaking is observed in less substantial degrees of information uncertainty situations.
11	Zhijian Fu, 2013, Physica A: Statistical Mechanics and its Applications		✓	A cellular automata model, as an extension to the Asymmetric Simple Exclusion Process is considered.
12	Shujie Wang, 2016, Physica A: Statistical Mechanics and its Applications		✓	Ants demonstrate a symmetry breaking behavior when confronted with a stressful situation.
13	Hidalgo Rc, 2017, Physical Review E		✓	The use of spherocylindrical particles in evacuation simulation rather than the traditional symmetric disks.
14	Tomasz Gwizdalla, 2015, Physica A: Statistical Mechanics and its Applications		✓	Rooms with different asymmetries are considered when building the evacuation model.
15	Yuan-Kai Chung, 2017, Plos One		✓	Symmetry breaking study by considering heat-induced platform and ants.
16	Li Wang, 2020, Computers & Industrial Engineering		✓	Information asymmetry in evacuation planning.
17	Zahra Shahhoseini Z, 2018, Transportation Research Record: Journal of the Transportation Research Board	✓	✓	Symmetric layouts outperform the asymmetric counterparts in evacuation process.
18	Alessandro Ciallella, 2018, Mathematical Models and Methods in Applied Sciences	✓	✓	Asymmetry in the positioning of the obstacles with respect to the center of the corridor and a variation of simple symmetric random walk on the considered square lattice in the case of confined and darkened spaces.
19	Jonatan Gehandler, 2015, Fire Technology	✓		The one-dimensional symmetry of a tunnel in evacuation situation.
20	Xiaodong Che, 2015, Visual Computer		✓	Information asymmetry in evaluating evacuation plan.
21	ManWo Ng, 2015, Transportation Research Part C: Emerging Technologies	✓		The inclusion of an optional symmetry assumption in evacuation planning.
22	Huan-huan Tian, 2018, Physica A: Statistical Mechanics and its Applications		✓	Asymmetric rules for changing evacuees' strategies are considered.

No.	Paper (First Author, Year, Journal, Reference)	Symmetry / Asymmetry Elements		Considered Symmetry / Asymmetry Elements and Brief Explanation
		Symmetry	Asymmetry	
23	Camelia Delcea, 2020, Symmetry-Basel	✓	✓	Symmetric and asymmetric exits' impact on classroom and lecture halls evacuation.
24	Wenhan Wu, 2023, Tsinghua Science and Technology		✓	The state of the pedestrian parameters is affected by visual information, causing asymmetry in evacuees' acceleration behavior.
25	Rodrigo Martinez-Val, 2000, Journal of Aircraft		✓	The uneven longitudinal distribution of exits and lack of left to right symmetry in airplane evacuation impacts the difficulties in evacuation process.
26	Guofeng Ma, 2021, Advances in Civil Engineering	✓	✓	An even symmetry is determined to be more efficient than an asymmetric distribution of exits.
27	Gino J Lim, 2019, IISE Transactions	✓		Demand distribution (number of actual evacuees) is symmetric.
28	Fengqiang Gao, 2023, Applied Mathematics and Computation		✓	Asymmetric-exit evacuation is considered.
29	Emilio NM Cirillo, 2020, Mathematical Bioscience and Engineering	✓	✓	Symmetric random walk for the passive particles; asymmetric (drift guiding) for the active particles in pedestrian escape from an obscure room.
30	Razieh Khaksari, 2021, Symmetry-Basel		✓	Asymmetric smoke propagation in tunnel during contraflow traffic operations.
31	Zhenfei Wang, 2021, Symmetry-Basel	✓		Multi-exit symmetrical facilities are considered for pedestrian evacuation simulation.
32	Maha El-Metwally, 2015, Transportation Research Record: Journal of the Transportation Research Board		✓	Discussions related to crossing elimination when evacuation flow is asymmetric.
33	Junji Urata, 2021, Transportation Research Part C: Emerging Technologies		✓	The consideration of asymmetric weights of interaction in the evacuation departure choice.
34	Klaas Fiete Krutein, 2023, Transportation Research Part E: Logistics and Transportation Review		✓	Introduces a highly asymmetric Isolated Community Evacuation Problem.
35	Rongyong Zhao, 2021, IEEE Transactions on Intelligent Transportation Systems		✓	Asymmetric pedestrian merging layout is proposed for a T-shaped street junction.
36	Yan Mao, 2020, IEEE Access		✓	Asymmetric intimacy is considered when building the evacuation model.
37	Sikora W, 2013, Acta Physica Polonica A	✓	✓	Symmetry conditions of allowed space are considered. the times of evacuation and average presses acting on individuals during the evacuation are determined and compared for situations with and without symmetry considerations.
38	Atsuo Murata, 2023, Symmetry-Basel		✓	Information asymmetry is considered in delayed evacuation after disaster.
39	Li Y, 2021, Fresenius Environmental Bulletin	✓		Symmetrical inverse layout merger to the rescue path dynamic planning of refuge buildings.
40	Zhijian Fu, 2023, Physica A: Statistical Mechanics and its Applications		✓	Cellular automaton for pedestrian dynamics when asymmetry and bipedal features of rotation are considered.
41	Ming Zhang, 2023, Journal of Building Engineering	✓	✓	The influence of two typical crowd flow modes are used (symmetric split and asymmetric split)
42	Yang-Hui Hu, 2023, Chinese Physics B		✓	Asymmetric building and obstacles are used for simulations
43	Ken Chen, 2023, Physica A: Statistical Mechanics and its Applications	✓		A symmetric flip enlargement of the sample for aisle widths is used in the study
44	Enrico Q, 2023, Heritage	✓	✓	Large and symmetric squares used for evacuation simulations determine higher differences in evacuation indicators
45	Mengkai Liu, 2023, Fire	✓	✓	A symmetric building structure is studied in this paper with the asymmetry of the stairwell
46	Huaxian Wan, 2023, International Journal of Thermal Sciences		✓	A model for flame length of two asymmetric fires in a tunnel is developed

3.4.4. Words Analysis

In order to determine the methodologies that the authors employed in their articles or the scope of the applicability of their study, an analysis of the most frequently used words in the selected papers was conducted as follows in the section below. The keywords plus, authors' keywords, titles, and abstracts have all been used in the search.

Regarding the keywords plus, we have observed that the top-10 keywords refer to “simulation” (with 14 appearances), “dynamics” (with 14 appearances), “behavior” (11), “evacuation” (with 8), “flow” (with 7), “model” (with 6), “escape” (with 6), “pedestrian evacuation” (with 5) and “crowd” and “social force model” (with 4 appearances each). It is clear from **Table 7** that the majority of the top 10 keywords plus are related to the field of evacuation research.

Table 7. Top 10 most frequent words in keywords plus

Words	Occurrences
simulation	14
dynamics	14
behavior	11
evacuation	8
flow	7
model	6
escape	6
pedestrian evacuation	5
crowd	4
social force model	4

When using the authors' keywords, the situation from **Table 8** is somewhat different (please see **Table 7**). This time, the top 10 most frequent words are as follows: “evacuation” (with 8 appearances); “cellular automata”, “crowd dynamics”, “pedestrian dynamics”, “crowd evacuation”, “emergency evacuation” (with 4 appearances each); “pedestrian evacuation” (with 3 appearances); “analytical models”, “dynamic parameters” and “crowd flow” (with 2 appearances each).

Table 8. Top 10 most frequent words in authors' keywords

Words	Occurrences
evacuation	8
cellular automata	4
crowd dynamics	4
pedestrian dynamics	4
crowd evacuation	4
emergency evacuation	4
pedestrian evacuation	3
analytical models	2
dynamic parameters	2
crowd flow	2

In **Figure 10**, two clusters are created inside the visualization: Cluster A, which concentrates on keywords plus, and Cluster B, which concentrates on authors' keywords. In the first cluster, A, which focuses on keywords plus, we can observe a Word Cloud formed of the most indicative words such as “simulation”, “dynamics”, “behavior”, “evacuation”, “model”, “flow”, “escape”, “crowd”, “pedestrian evacuation” and so on (please see the left side of Figure 16 for more information). These words and phrases

capture the key ideas and topics that have emerged from this study. The second word cluster, B, that focuses on authors' keywords, has a Word Cloud formed of the following: "evacuation", "cellular automata", "crowd dynamics", "pedestrian dynamics", "pedestrian evacuation", "crowd evacuation", "emergency evacuation", "symmetry breaking" and so forth (please refer Figure 16, right side for more).

Figure 10. Top 50 words based on keywords plus (A) and authors' keywords (B)

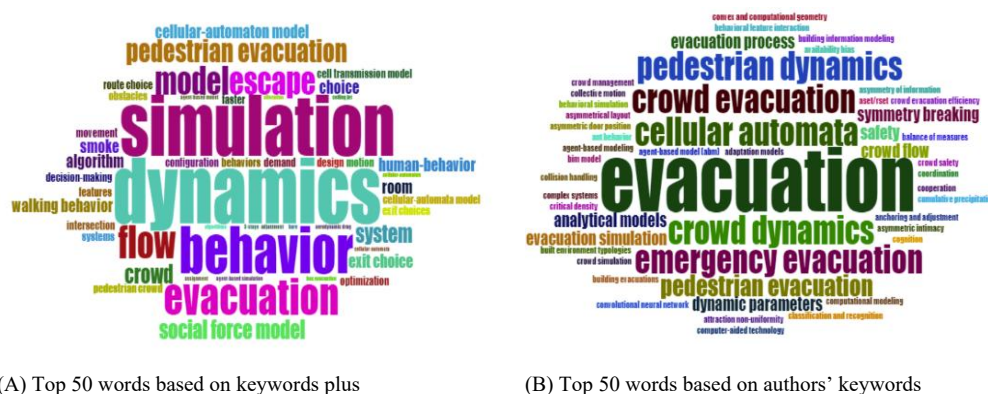


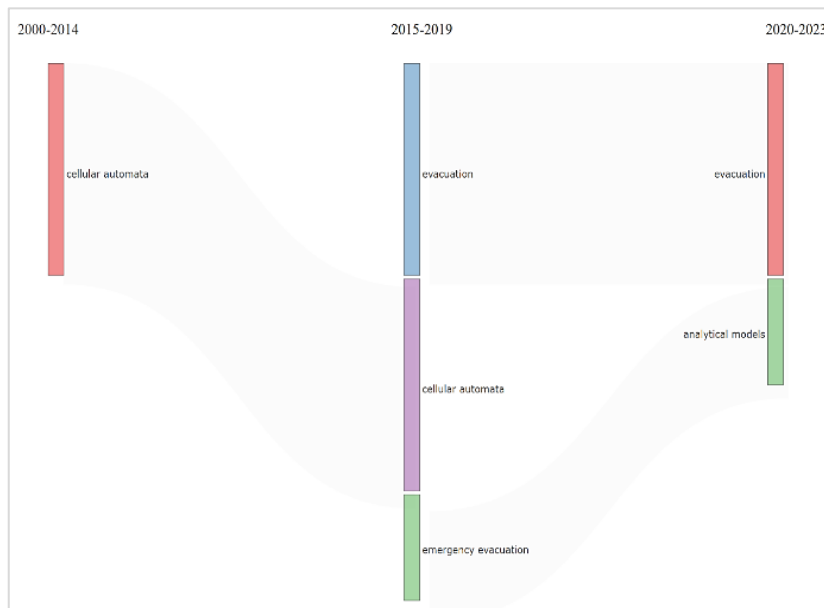
Table 9 provides valuable insights into the recurring bigrams found in both the abstracts and titles of scholarly works related to evacuation research. In the realm of abstracts, it is evident that phrases such as "evacuation time" and "evacuation efficiency" stand out, occurring 21 and 16 times, respectively. These bigrams underline the crucial importance of enhancing evacuation procedures for better safety and efficiency. Additionally, "crowd evacuation" and "refuge building" appear prominently, demonstrating a keen interest in addressing the challenges posed by evacuating large groups of people, particularly within refuge structures. Meanwhile, in the titles, bigrams like "cellular automaton" and "crowd evacuation" hold prominence, indicating the significance of computational models and crowd dynamics in the study of evacuation. The prevalence of bigrams like "evacuation planning" and "pedestrian evacuation" highlights the multifaceted nature of research in this field, which encompasses both strategic planning and individual-level behaviors. These recurring bigrams not only reflect the current research trends but also serve as valuable pointers for understanding the key themes and concepts driving scholarly discourse in evacuation research.

Table 9. *Top 10 most frequent bigrams in abstracts and titles*

Bigrams in abstracts	Occurrences	Bigrams in titles	Occurrences
evacuation time	21	crowd evacuation	4
evacuation efficiency	16	cellular automaton	3
crowd evacuation	10	evacuation planning	3
evacuation process	9	field cellular	3
refuge building	9	floor field	3
exit selection	8	pedestrian evacuation	3
symmetry breaking	8	cellular automata	2
flame length	7	evacuation model	2
exit width	7	emergency evacuation	2
experimental results	7	evacuation behavior	2

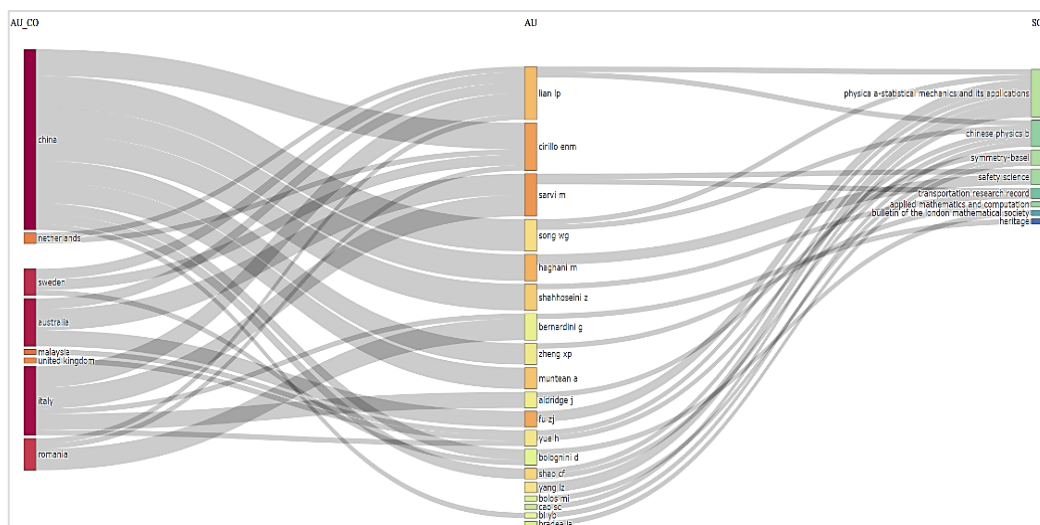
Considering the entire time-period, the use of cellular automata for both the 2000-2014 and 2015-2019 periods is highlighted in **Figure 11**, while the general evacuation theme emerges from the 2015-2019 and continues in the 2020-2023 period. Overall, the image illustrates a progression from a singular focus on cellular automata to a broader exploration of evacuation dynamics and analytical modeling, reflecting the evolving interests and methodologies in the research community over time.

Figure 11. *Thematic evolution*



3.5. Mixed Analysis

Figure 12. *Three-fields plot: countries (left), authors (middle), journals (right)*



As the importance of the evacuation research field has grown in recent years, it is crucial to investigate the complex connections between authors, journals, and nations while examining scholarly publications. Three-fold plots, like the one in **Figure 12**, are used to depict these complex interactions.

The triadic arrangement provides insights into the working relationships between authors from various nations and their connections to particular journals. Sweden, Italy, and Romania are the top three nations in terms of collaborations in **Figure 12**, which highlights their active participation in global research projects. The fact that "Physica A-Statistical Mechanics and its Applications" stands out as the main venue for publishing these collaborative works highlights the journal's crucial role in fostering international research collaborations.

4. Limitations

While emphasizing the incorporation of symmetry and asymmetry features, this analysis aims to find the most relevant publications within the fields of evacuation research. However, it is important to recognize some inherent limits that constrain the scope of this study.

First off, the only publications included in our analysis are those found in ISI Web of Science-indexed journals. As a result, it excludes information that could be found in research papers or conference proceedings that are available in other databases, like Scopus or PubMed. This restriction might unintentionally leave out important contributions from these alternate sources. Secondly, due to linguistic restrictions, we could only review papers that were written in English. Therefore, despite their potential value, papers written in other languages were not included in our study. In addition to the previously mentioned constraints, it's essential to acknowledge another limitation regarding the specific time period selected for this analysis, spanning from 2000 to 2023. This period has been a result of the selection keywords used in the paper, of the linguistic restriction and of the selected database. By considering other databases, keywords, types of paper and language, it is possible that someone could identify some papers before the year 2000.

As shown in **Table 1**, a predefined list of terms related to our subject of interest ("evacuation" and "symmetry" / "asymmetry") further defined the scope of our study. It's possible that this selected list of keywords unintentionally left out relevant publications that use other languages or cover related subfields.

We understand that various software packages may give unique perspectives and insights, thus while we used the Biblioshiny library inside the R programming language to help our study, our findings are constrained by the particular tools used.

5. Conclusions

Research in evacuation has evolved significantly since the year 2000, reflecting the growing complexity of urban environments and the increasing need for efficient emergency response strategies. Our study employed the well-established ISI Web of Science database (WoS platform) to gather and analyze the most influential authors, journals, and publications within this domain from 2000 to 2023. By leveraging advanced bibliometric techniques available in the Biblioshiny library, we were able to systematically examine key research trends and contributions over this period.

This investigation involved a comprehensive analysis of publication trends, identifying leading nations and prolific re-searchers, assessing the impact of individual papers, and mapping citation networks across journals, countries, and authors. Notably, we highlighted the top five most-cited papers that have played a pivotal role in shaping the field. This in-depth examination not only facilitated a better understanding of the evolution of evacuation research but also provided valuable insights into the diverse methodologies employed and their real-world applications. The findings reinforce the growing importance of evacuation modeling, especially in the context of increasing global risks, including natural disasters, industrial accidents, and large-scale public events.

To present our key findings effectively, we utilized a variety of graphical representations, including Collaboration Networks, Word Clouds, Thematic Maps, and Collaboration Maps. These visual tools offered a clearer perspective on the research landscape, shedding light on emerging trends and influential works. Additionally, recent advancements in crowd simulation and evacuation modeling have significantly enriched this field. For instance, Sun et al. (2024) introduced a novel multi-agent deep reinforcement learning approach to enhance crowd cooperation for formation maintenance and collision avoidance, providing valuable insights into realistic crowd behaviors under emergency conditions. Furthermore, Khan and Deng (2024) conducted an extensive survey on agent-based crowd simulation, identifying critical factors influencing heterogeneous behavior, thus improving our understanding of individual and collective movement dynamics (Khan, 1993).

In addition to these contributions, agent-based simulation techniques continue to play a crucial role in advancing evacuation research. Recent studies have integrated hierarchical agent models with physics-based character control to enhance the realism of evacuation scenarios, allowing for more accurate predictions of crowd behavior in dynamic environments. Similarly, knowledge-driven dynamic perception models have been introduced to refine scene simulations, improving both decision-making accuracy and evacuation efficiency. These advancements highlight the growing sophistication of computational models and their potential to enhance real-world evacuation planning and emergency preparedness.

Given the rapid advancements in this field, we recommend that future research broaden its scope by incorporating additional databases such as Scopus and other relevant public repositories. Expanding the analysis to include conference proceedings alongside journal

publications would also provide a more comprehensive view of the evolving research landscape. Furthermore, integrating interdisciplinary approaches - such as artificial intelligence, virtual reality, and real-time sensor data - may further enhance the effectiveness and applicability of evacuation models.

Ultimately, evacuation research remains an exciting and continuously evolving domain, driven by its critical real-world implications. As global urbanization accelerates and new challenges emerge, this field will undoubtedly continue to capture the interest of academics and practitioners worldwide. The ongoing advancements in simulation technologies and data-driven methodologies will further strengthen our ability to design safer, more efficient evacuation strategies for the future.

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References

- Anaç, M., Gumusburun Ayalp, G. and Erdayandi, K. (2023). Prefabricated Construction Risks: A Holistic Exploration through Advanced Bibliometric Tool and Content Analysis. *Sustainability*, 15, 11916, <doi:10.3390/su15111916>
- Aria, M. and Cuccurullo, C. (2017). Bibliometrix: An R-Tool for Comprehensive Science Mapping Analysis. *Journal of Informetrics*, 11, 959–975, <doi:10.1016/j.joi.2017.08.007>
- Che, X., Niu, Y., Shui, B., Fu, J., Fei, G., Goswami, P. and Zhang, Y. (2015). A Novel Simulation Framework Based on Information Asymmetry to Evaluate Evacuation Plan. *Vis Comput*, 31, 853–861, <doi:10.1007/s00371-015-1119-6>
- Chen, K., Li, F., Ji, Q., You, Q., and Feng, Z. (2023). Emergency Evacuation Behaviour Characteristics Classification of Aircraft Cabin Passengers Based on Deep Learning Network Model SMCNN-LSTM. *Physica A: Statistical Mechanics and its Applications*, <10.1016/j.physa.2023.129097>
- Chung, Y.-K. and Lin, C.-C. (2017). Heat-Induced Symmetry Breaking in Ant (Hymenoptera: Formicidae) Escape Behavior. *PLoS ONE*, 12, e0173642, <doi:10.1371/journal.pone.0173642>
- Ciallella, A., Cirillo, E.N.M., Curşeu, P.L. and Muntean, A. (2018). Free to Move or Trapped in Your Group: Mathematical Modeling of Information Overload and Coordination in Crowded Populations. *Math. Models Methods Appl. Sci.*, 28, 1831–1856, <doi:10.1142/S0218202518400079>
- Cirillo, E.N.M., Colangeli, M., Muntean, A. and Thieu, T.K.T. (2020). A Lattice Model for Active-Passive Pedestrian Dynamics: A Quest for Drafting Effects. *Mathematical Biosciences and Engineering*, 17, 460–477, <doi:10.3934/mbe.2020025>

- Cotfas, L.-A., Delcea, C., Iancu, L.-D., Ioanas, C., and Ponsiglione, C. (2023). Large Event Halls Evacuation Using an Agent-Based Modeling Approach. *IEEE Access*, 10, 49359–49384, <doi:10.1109/ACCESS.2023.3172285>
- Daoliang, Z., Lizhong, Y., and Jian, L. (2006). Exit Dynamics of Occupant Evacuation in an Emergency. *Physica A: Statistical Mechanics and its Applications*, 363, 501–511, <doi:10.1016/j.physa.2005.08.012>
- Delcea, C., and Cotfas, L.-A. (2023). “Hybrid Approaches Featuring Grey Systems Theory.” In *Advancements of Grey Systems Theory in Economics and Social Sciences*; Series on Grey System; Springer Nature Singapore: Singapore, 281–333 ISBN 978-981-19993-1-4.
- Delcea, C., and Cotfas, L.-A. (2023). “State of the Art in Grey Systems Research in Economics and Social Sciences.” In *Advancements of Grey Systems Theory in Economics and Social Sciences*; Series on Grey System; Springer Nature Singapore: Singapore, 1–44 ISBN 978-981-19993-1-4.
- Delcea, C., Cotfas, L.-A., Bradea, I.-A., Boloș, M.-I., and Ferruzzi, G. (2020). Investigating the Exits’ Symmetry Impact on the Evacuation Process of Classrooms and Lecture Halls: An Agent-Based Modeling Approach. *Symmetry*, 12, 627, <doi:10.3390/sym12040627>
- Delcea, C., Cotfas, L.-A., Craciun, L., and Molanescu, A.G. (2020). An Agent-Based Modeling Approach to Collaborative Classrooms Evacuation Process. *Safety Science*, 121, 414–429, <doi:10.1016/j.ssci.2019.09.026>
- Delcea, C., Javed, S.A., Florescu, M.-S., Ioanas, C., and Cotfas, L.-A. (2023). 35 Years of Grey System Theory in Economics and Education. *K*, <doi:10.1108/K-08-2023-1416>
- El-Metwally, M., and Murray-Tuite, P. (2015). Selecting Four-Leg Intersections for Crossing Elimination in Evacuations. *Transportation Research Record*, 2532, 141–153, <doi:10.3141/2532-16>
- Fatma, N., and Haleem, A. (2023). Exploring the Nexus of Eco-Innovation and Sustainable Development: A Bibliometric Review and Analysis. *Sustainability*, 15, 12281, <doi:10.3390/su151612281>
- Fu, Z., Xiong, X., Luo, L., Yang, Y., Feng, Y., and Chen, H. (2023). Influence of Rotation on Pedestrian Flow Considering Bipedal Features: Modeling Using a Fine Discrete Floor Field Cellular Automaton. *Physica A: Statistical Mechanics and its Applications*, 605, 128027, <doi:10.1016/j.physa.2023.128027>
- Fu, Z., Yang, L., Chen, Y., Zhu, K., and Zhu, S. (2013). The Effect of Individual Tendency on Crowd Evacuation Efficiency under Inhomogeneous Exit Attraction Using a Static Field Modified FFCA Model. *Physica A: Statistical Mechanics and its Applications*, 392, 6090–6099, <doi:10.1016/j.physa.2013.07.062>
- Gao, F., Yan, Y., Chen, Z., Zheng, L., and Ren, H. (2023). Effect of Density Control in Partially Observable Asymmetric-Exit Evacuation under Guidance: Strategic Suggestion under Time Delay. *Applied Mathematics and Computation*, 418, 126838, <doi:10.1016/j.amc.2021.126838>
- Gehandler, J., Eymann, L., and Regeffe, M. (2015). Limit-Based Fire Hazard Model for Evaluating Tunnel Life Safety. *Fire Technol*, 51, 585–614, <doi:10.1007/s10694-014-0406-5>

- Gorski, A.-T., Ranf, E.-D., Badea, D., Halmaghi, E.-E., and Gorski, H. (2023). Education for Sustainability – Some Bibliometric Insights. *Sustainability*, 15, 14916, <doi:10.3390/su152014916>
- Guo, R.-Y., and Huang, H.-J. (2008). A Modified Floor Field Cellular Automata Model for Pedestrian Evacuation Simulation. *J. Phys. A: Math. Theor.*, 41, 385104, <doi:10.1088/1751-8113/41/38/385104>
- Gwizdała, T.M. (2015). Some Properties of the Floor Field Cellular Automata Evacuation Model. *Physica A: Statistical Mechanics and its Applications*, 419, 718–728, <doi:10.1016/j.physa.2014.10.070>
- Haghani, M. (2020). Empirical Methods in Pedestrian, Crowd and Evacuation Dynamics: Part II. *Field Methods and Controversial Topics. Safety Science*, 129, 104760, <doi:10.1016/j.ssci.2020.104760>
- Haghani, M., and Sarvi, M. (2019). ‘Herdin’ in Direction Choice-Making during Collective Escape of Crowds: How Likely Is It and What Moderates It? *Safety Science*, 115, 362–375, <doi:10.1016/j.ssci.2019.02.034>
- Hidalgo, R.C., Parisi, D.R., and Zuriguel, I. (2017). Simulating Competitive Egress of Noncircular Pedestrians. *Phys. Rev. E*, 95, 042319, <doi:10.1103/PhysRevE.95.042319>
- Hu, Y., Bi, Y., Zhang, J., Lian, L., Song, W., and Gao, W. (2023). Effect of a Static Pedestrian as an Exit Obstacle on Evacuation. *Chinese Physics B*, 32, 018901, <doi:10.1088/1674-1056/ac9605>
- Huang, K., Zheng, X., Cheng, Y., and Yang, Y. (2017). Behavior-Based Cellular Automaton Model for Pedestrian Dynamics. *Applied Mathematics and Computation*, 292, 417–424, <doi:10.1016/j.amc.2016.07.002>
- Kapucu, N. (2008). Planning for Disasters and Responding to Catastrophes: Error of the Third Type in Disaster Policy and Planning. *IJPP*, 3, 313, <doi:10.1504/IJPP.2008.020985>
- Khaksari, R., Harun, Z., Fielding, L., and Aldridge, J. (2021). Numerical Simulation of the Evacuation Process in a Tunnel during Contraflow Traffic Operations. *Symmetry*, 13, 2392, <doi:10.3390/sym13122392>
- Khan, S., and Deng, Z. (1993). Agent-based crowd simulation: an in-depth survey of determining factors for heterogeneous behavior. *Vis Comput* 40, –5004, <https://doi.org/10.1007/s00371-024-03503-2>
- Krutein, K.F., and Goodchild, A. (2023). The Isolated Community Evacuation Problem with Mixed Integer Programming. *Transportation Research Part E: Logistics and Transportation Review*, 161, 102710, <doi:10.1016/j.tre.2023.102710>
- Li, B., Xu, Z., Zavadskas, E.K., Antuchevičienė, J., and Turskis, Z. (2020). A Bibliometric Analysis of Symmetry (2009–2019). *Symmetry*, 12, 1304, <doi:10.3390/sym12081304>
- Li, Y., and Liu, P. (2021). A Novel Dynamic Planning Method for Rescue Routes of Refuge Buildings in Response to Geological Environmental Disasters Based on Spatial Layout Theory. *Fresenius Environ. Bull.*, 30, 8491–8497.
- Lim, G.J., Rungta, M., and Davishan, A. (2019). A Robust Chance Constraint Programming Approach for Evacuation Planning under Uncertain Demand Distribution. *IIE Transactions*, 51, 589–604, <doi:10.1080/24725854.2018.1533675>

- Liu, M., and Wang, G. (2023). Indoor Fire Simulation in Low-Rise Teaching Buildings Based on BIM-FDS. *Fire*, 6(5), 203, <doi:10.3390/fire6050203>
- Lou, T.-F., and Hung, W.-H. (2023). Revival of Classical Algorithms: A Bibliometric Study on the Trends of Neural Networks and Genetic Algorithms. *Symmetry*, 15, 325, <doi:10.3390/sym15020325>
- López Belmonte, J., Segura-Robles, A., Moreno-Guerrero, A.-J., and Parra-González, M.E. (2020). Machine Learning and Big Data in the Impact Literature. *A Bibliometric Review with Scientific Mapping in Web of Science*. *Symmetry*, 12, 495, <doi:10.3390/sym12040495>
- Ma, G., Wang, Y., and Jiang, S. (2021). Optimization of Building Exit Layout: Combining Exit Decisions of Evacuees. *Advances in Civil Engineering*, 2021, 1–16, <doi:10.1155/2021/6622661>
- Mao, Y., Fan, Z., Mao, H., and He, W. (2020). Asymmetric Intimacy Based Positive Emotions Contagion Peer Public Safety Evacuation Behavior. *IEEE Access*, 8, 185253–185265, <doi:10.1109/ACCESS.2020.3030339>
- Martinez-Val, R., and Hedo, J.M. (2000). Analysis of Evacuation Strategies for Design and Certification of Transport Airplanes. *Journal of Aircraft*, 37, 440–447, <doi:10.2514/2.2617>
- Marín-Rodríguez, N.J., González-Ruiz, J.D., and Botero Botero, S. (2023). Dynamic Co-Movements among Oil Prices and Financial Assets: A Scientometric Analysis. *Sustainability*, 14, 12796, <doi:10.3390/su141912796>
- Marín-Rodríguez, N.J., González-Ruiz, J.D., and Valencia-Arias, A. (2023). Incorporating Green Bonds into Portfolio Investments: Recent Trends and Further Research. *Sustainability*, 15, 14897, <doi:10.3390/su152014897>
- Murata, A., Doi, T., Hasegawa, R., and Karwowski, W. (2021). Delayed Evacuation after a Disaster Because of Irrational Prediction of the Future Cumulative Precipitation Time Series under Asymmetry of Information. *Symmetry*, 14, 6, <doi:10.3390/sym14010006>
- Ng, M., and Lin, D.-Y. (2015). Sharp Probability Inequalities for Reliable Evacuation Planning. *Transportation Research Part C: Emerging Technologies*, 60, 161–168, <doi:10.1016/j.trc.2015.08.003>
- Perry, R.W., and Lindell, M.K. (2003). Preparedness for Emergency Response: Guidelines for the Emergency Planning Process. *Disasters*, 27, 336–350, <doi:10.1111/j.0361-3666.2003.00237.x>
- Quagliarini, E., Bernardini, G., and D'Orazio, M. (2023). How Could Increasing Temperature Scenarios Alter the Risk of Terrorist Acts in Different Historical Squares? A Simulation-Based Approach in Typological Italian Squares. *Heritage*, 6(7), 5151–5186, <doi:10.3390/heritage6070274>
- Shahhoseini, Z., and Sarvi, M. (2018). Traffic Flow of Merging Pedestrian Crowds: How Architectural Design Affects Collective Movement Efficiency. *Transportation Research Record*, 2672, 121–132, <doi:10.1177/0361198118796714>
- Shahhoseini, Z., and Sarvi, M. (2019). Pedestrian Crowd Flows in Shared Spaces: Investigating the Impact of Geometry Based on Micro and Macro Scale Measures. *Transportation Research Part B: Methodological*, 122, 57–87, <doi:10.1016/j.trb.2019.01.019>
- Shiwakoti, N., Tay, R., Stasinopoulos, P., and Woolley, P.J. (2017). Likely Behaviours of Passengers under Emergency Evacuation in Train Station. *Safety Science*, 91, 40–48, <doi:10.1016/j.ssci.2016.07.017>

- Sikora, W., and Malinowski, J. (2013). Crowd Behavior as an Example of the Evolution of a Complex System - Evacuation Models Proposal Based on the Symmetry Analysis Approach. *Acta Phys. Pol. A*, 124, 1005–1012.
- Stefanis, C., Giorgi, E., Tselemonis, G., Voidarou, C., Skoufos, I., Tzora, A., Tsigalou, C., Kourkoutas, Y., Constantinidis, T.C., and Bezirtzoglou, E. (2023). Terroir in View of Bibliometrics. *Stats*, 6, 956–979, <doi:10.3390/stats6040060>
- Sun, L., Yan, J., and Qiu, Y. et al. (2024). The crowd cooperation approach for formation maintenance and collision avoidance using multi-agent deep reinforcement learning, *Vis Comput.* <<https://doi.org/10.1007/s00371-024-03647-1>>
- Tang, K., Zhang, J, Shen, Y., Li, C., and He, G. (2024), KDPM: Knowledge-driven dynamic perception model for evacuation scene simulation, *Computer Animation & Virtual Worlds*, Volume 35, Issue 3, <<https://doi.org/10.1002/cav.2279>>
- Tian, H., Wei, Y., Dong, L., Xue, Y., and Zheng, R. (2018). Resolution of Conflicts in Cellular Automaton Evacuation Model with the Game-Theory. *Physica A: Statistical Mechanics and its Applications*, 503, 991–1006, <doi:10.1016/j.physa.2018.08.140>
- Urata, J., and Hato, E. (2021). Dynamics of Local Interactions and Evacuation Behaviors in a Social Network. *Transportation Research Part C: Emerging Technologies*, 125, 103056, <doi:10.1016/j.trc.2021.103056>
- Wan, H., Xiao, Y., Wei, S., Zhang, Y., and Oka, T. (2023). Experimental study on multiple fire hazards in a naturally ventilated tunnel: Assessment of the flame interaction and extension of two unequal fires. *International Journal of Thermal Sciences*, 187, 108209, <10.1016/j.ijthermalsci.2023.108209>
- Wang, L. (2020). A Two-Stage Stochastic Programming Framework for Evacuation Planning in Disaster Responses. *Computers & Industrial Engineering*, 145, 106458, <doi:10.1016/j.cie.2020.106458>
- Wang, S., Cao, S., Wang, Q., Lian, L., and Song, W. (2016). Effect of Exit Locations on Ants Escaping a Two-Exit Room Stressed with Repellent. *Physica A: Statistical Mechanics and its Applications*, 457, 239–254, <doi:10.1016/j.physa.2016.03.083>
- Wang, Z., Zhang, C., Wang, J., Zheng, Z., and Li, L. (2021). Research on Path Planning Algorithm for Crowd Evacuation. *Symmetry*, 13, 1339, <doi:10.3390/sym13081339>
- Weina, Ge., Collins, R.T., and Ruback, R.B. (2012). Vision-Based Analysis of Small Groups in Pedestrian Crowds. *IEEE Trans. Pattern Anal. Mach. Intell.*, 34, 1003–1016, <doi:10.1109/TPAMI.2011.176>
- WoS Web of Science Available online: <webofknowledge.com> [accessed on 5 May 2026].
- Wu, W., Chen, M., Li, J., Liu, B., Wang, X., and Zheng, X. (2023). Visual Information Based Social Force Model for Crowd Evacuation. *Tsinghua Sci. Technol.*, 27, 619–629, <doi:10.26599/TST.2021.9010023>
- Ye, J., Liu, Z., Liu, T, Wu, Y., and Wang, Y. (2024). Crowd evacuation simulation based on hierarchical agent model and physics-based character control, *Computer Animation & Virtual Worlds*, Volume 35, Issue 3, <<https://doi.org/10.1002/cav.2263>>
- Yue, H., Guan, H., Shao, C., and Zhang, X. (2011). Simulation of Pedestrian Evacuation with Asymmetrical Exits Layout. *Physica A: Statistical Mechanics and its Applications*, 390, 198–207, <doi:10.1016/j.physa.2010.10.003>

- Yue, H., Zhang, B.-Y., Shao, C.-F., and Xing, Y. (2014). Exit Selection Strategy in Pedestrian Evacuation Simulation with Multi-Exits. *Chinese Phys. B*, 23, 050512, <doi:10.1088/1674-1056/23/5/050512>
- Zardari, S., Alam, S., Al Salem, H.A., Al Reshan, M.S., Shaikh, A., Malik, A.F.K., Masood Ur Rehman, M., and Mouratidis, H. (2023). A Comprehensive Bibliometric Assessment on Software Testing (2016–2021). *Electronics*, 11, 1984, <doi:10.3390/electronics11131984>
- Zhang, M., Xu, R., Siu, M., and Luo, X. (2023). Human Decision Change in Crowd Evacuation: A Virtual Reality-Based Study. *Journal of Building Engineering*, 68, 106041, <10.1016/j.jobbe.2023.106041>
- Zhao, R., Liu, Q., Hu, Q., Dong, D., Li, C., and Ma, Y. (2021). Lyapunov-Based Crowd Stability Analysis for Asymmetric Pedestrian Merging Layout at T-Shaped Street Junction. *IEEE Trans. Intell. Transport. Syst.*, 22, 6833–6842, <doi:10.1109/TITS.2020.2995275>

AI-driven marketing models as a competitive advantage in global markets

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Abstract. *The proliferation of artificial intelligence technologies has fundamentally transformed marketing practices in global markets, shifting organizational paradigms from intuition-based decision-making toward data-driven strategic frameworks. This study investigates how AI-driven marketing models function as sources of sustained competitive advantage in contemporary global commerce. Employing a systematic analysis of theoretical frameworks, empirical evidence, and organizational implementations, the research examines mechanisms through which machine learning algorithms, predictive analytics, and autonomous optimization systems enhance marketing effectiveness across heterogeneous market contexts. Findings reveal that AI-driven marketing models generate competitive advantages through superior customer targeting precision, real-time resource allocation optimization, enhanced attribution accuracy, and continuous adaptive learning capabilities. However, competitive advantage sustainability depends critically on organizational capabilities spanning data infrastructure maturity, analytical talent acquisition, ethical governance frameworks, and cultural adaptability. The study contributes theoretical insights regarding the resource-based foundations of AI-driven competitive advantage while providing practical implications for marketing leaders navigating digital transformation imperatives in global markets.*

Keywords: artificial intelligence, marketing models, competitive advantage, machine learning, predictive analytics, global markets, digital transformation.

JEL Classification: M31, O33.

Introduction

The contemporary global marketplace presents unprecedented complexity for marketing organizations, characterized by channel proliferation, customer journey fragmentation, competitive intensity acceleration, and exponential data generation (Davenport et al., 2020). Traditional marketing approaches predicated on demographic segmentation, periodic campaign optimization, and intuition-based resource allocation demonstrate insufficient responsiveness to dynamic market conditions where consumer preferences shift rapidly and competitive actions demand immediate strategic responses. Within this turbulent environment, artificial intelligence technologies have emerged as transformative capabilities enabling organizations to process vast data volumes, identify complex behavioral patterns, forecast future outcomes, and execute autonomous optimization with precision unattainable through manual approaches (Huang & Rust, 2021; Verhoef et al., 2021). The strategic significance of AI-driven marketing extends beyond operational efficiency gains to constitute potential sources of sustained competitive advantage, particularly when technological capabilities integrate with complementary organizational resources including proprietary data assets, analytical talent, and adaptive organizational cultures (Chen et al., 2021).

AI-driven marketing models encompass integrated systems employing machine learning algorithms (Herhausen et al., 2024), predictive analytics frameworks, and autonomous decision engines to enhance marketing effectiveness across customer acquisition, engagement optimization, and lifetime value maximization. These systems transcend simple automation by incorporating adaptive learning mechanisms that continuously refine performance through feedback loops connecting implemented strategies with observed outcomes (Verhoef et al., 2021). Unlike rule-based automation that executes predefined instructions without contextual understanding or improvement capability, AI systems discover patterns autonomously, generate probabilistic predictions about future behaviors, and optimize decisions based on accumulated experience while adapting to evolving market conditions (Chen et al., 2021; Kannan, 2017).

The resource-based view of competitive advantage, originating in Barney's seminal work (1991), posits that sustainable superior performance derives from valuable, rare, inimitable, and non-substitutable resources that organizations possess and deploy effectively within their strategic contexts. AI-driven marketing models potentially satisfy these criteria when organizations develop proprietary algorithmic capabilities tailored to specific market contexts, accumulate unique customer data repositories through extended interaction histories, cultivate specialized analytical expertise combining statistical sophistication with domain knowledge, and embed AI systems within organizational routines that prove resistant to imitation due to social complexity and causal ambiguity (Teece, 2018). The theoretical challenge centers on whether these capabilities constitute genuine sources of sustained advantage or merely temporary advantages subject to rapid competitive erosion as rivals observe successful implementations and replicate technical architectures using increasingly accessible commercial AI platforms and standardized machine learning frameworks (Puntoni et al., 2021; Grewal et al., 2020).

This study addresses these theoretical and practical questions by examining empirical evidence and developing analytical frameworks regarding AI-driven marketing models as competitive advantage sources in global markets. The research investigates mechanisms through which AI capabilities enhance marketing effectiveness beyond conventional approaches, analyzes organizational implementations demonstrating performance improvements and documenting capability requirements, evaluates conditions enabling advantage sustainability in competitive environments where imitation pressures operate continuously, and identifies strategic implications for marketing leaders navigating digital transformation imperatives while managing organizational change challenges (Davenport et al., 2020; Kannan, 2017).

Methodology

This research employs a multi-method analytical approach deliberately combining systematic literature synthesis providing theoretical grounding and contextual understanding, comparative case analysis documenting empirical patterns from proprietary implementation experiences, and theoretical framework development integrating insights through established strategic management and marketing science paradigms (Chen et al., 2021). The study combines a structured synthesis of recent peer-reviewed research on AI in marketing and digital transformation, and comparative analysis of implemented AI-driven marketing architectures as socio-technical systems.

The unit of analysis is an AI-driven marketing model implemented as an integrated architecture that links data integration, predictive modeling, attribution, optimization, and execution. For each implementation, the analysis captured data layer characteristics (sources, identity resolution logic, data quality controls), modeling layer choices (propensity/CLV prediction, sequence modeling, ensemble logic), decision layer logic (objective functions, constraints, and budget reallocation rules), and governance layer elements (human override thresholds, anomaly detection, rollback, and compliance constraints).

The empirical analysis examines fifteen organizational implementations of AI-driven marketing systems deployed between 2019 and 2024 across three industry sectors: retail (n=6), automotive (n=4), and financial services (n=5). Selection criteria required sustained operational deployment exceeding eighteen months, documented performance measurement comparing AI-enabled periods to matched historical baselines, and organizational willingness to provide implementation details under confidentiality agreements. Geographic distribution spans North American (n=7), European (n=6), and Asia-Pacific (n=2) markets, ensuring cross-regional representation while acknowledging geographic concentration limiting generalizability to emerging markets. For each implementation, data collection employed three complementary methods. First, structured technical documentation reviews extracted architectural specifications, algorithm families, data sources, integration patterns, and governance mechanisms from internal system documentation. Second, semi-structured interviews with implementation teams elicited tacit knowledge regarding design rationale, encountered challenges, and organizational

adaptation processes not captured in formal documentation. Third, performance metric analysis examined quantitative outcomes including conversion rates, customer acquisition costs, return on advertising spend, and attribution accuracy, with data aggregated at the implementation level to preserve confidentiality while enabling cross-case pattern identification.

The comparative analysis proceeded iteratively. Initial descriptive coding of architectural elements identified recurring components (data ingestion subsystems, feature engineering modules, ensemble prediction engines, multi-objective optimization modules, autonomous execution subsystems, and continuous learning mechanisms) that formed the basis for a typology of AI marketing architectures. Performance outcome analysis employed matched-period comparisons, pairing each AI-enabled operational period with a historical control period of equivalent duration, calendar timing, and macroeconomic conditions. Statistical significance testing used paired t-tests for continuous metrics and chi-square tests for categorical outcomes, with alpha set at 0.01 to account for multiple comparisons. Mechanism tracing linked observed performance changes to specific architectural capabilities through logical inference supported by interview evidence and technical documentation.

Several measures addressed potential threats to validity. Construct validity was strengthened through triangulation across multiple data sources (documentation, interviews, performance metrics) and member checking where preliminary findings were shared with implementation teams for accuracy verification. Internal validity benefited from matched-period comparisons controlling for temporal confounds, though acknowledging that unobserved variables may influence outcomes. External validity remains constrained by sampling from successful implementations in developed markets, potentially limiting generalizability to failed deployments or different geographic contexts. Reliability was enhanced through systematic documentation of analytical decisions and maintenance of detailed audit trails enabling independent verification of interpretations.

Results

Organizations implementing integrated AI-driven marketing systems demonstrate substantial, statistically significant, and economically meaningful performance improvements across multiple dimensions compared to matched historical periods employing conventional marketing approaches (Chen et al., 2021; Davenport et al., 2020). All quantitative comparisons employ carefully matched historical control periods selected to exhibit similar characteristics regarding seasonality with equivalent calendar timing to account for holiday effects and seasonal demand patterns, competitive dynamics matching periods with comparable rival promotional intensity, and macroeconomic conditions controlling for consumer confidence shifts and discretionary spending patterns that might confound treatment effect attribution (Kannan, 2017).

Across examined implementations, AI-driven marketing systems exhibited consistent architectural patterns despite industry-specific customizations. The core architecture comprised five interconnected layers. The data integration layer aggregated heterogeneous

signals from web analytics platforms, paid advertising networks, CRM systems, email service providers, and offline transaction databases into unified customer profiles, resolving identity across devices through probabilistic matching algorithms achieving 78-85% linkage accuracy. The predictive modeling layer employed ensemble architectures combining gradient boosting decision trees for structured tabular data, recurrent neural networks for sequential behavioral patterns, and transformer models for contextual relevance assessment, generating individual-level predictions for conversion probability, customer lifetime value, and churn risk refreshed hourly. The attribution layer implemented multi-touch attribution using Shapley value calculations allocating credit across touchpoints based on marginal contribution to conversion outcomes. The optimization layer formulated budget allocation as constrained mathematical programs balancing multiple objectives (short-term revenue, long-term customer value, cost efficiency) solved via reinforcement learning policies trained through interaction with simulated and real marketing environments. The execution layer translated optimization decisions into platform-specific API calls implementing bid adjustments, budget reallocations, and creative rotations with end-to-end latency below 500 milliseconds.

Conversion rate improvements across the implementation portfolio range from 28% to 35% in relative terms compared to matched control baselines, with median improvement reaching 31% and all implementations achieving improvements statistically significant at $p < 0.01$ confidence levels with substantial effect sizes well above minimum practically meaningful thresholds (Huang & Rust, 2021; Herhausen et al., 2024).

A European fashion retailer implementation achieved 34% conversion rate gains operating primarily through customer lifetime value predictions that enabled sophisticated resource allocation concentrating acquisition spending on behavioral micro-segments predicted to generate high long-term value while reducing investment in segments exhibiting favorable immediate conversion propensities but poor retention characteristics and low repeat purchase rates (Davenport et al., 2020). The AI system identified 847 distinct micro-segments exhibiting dramatic variation in predicted lifetime value ranging from €47 to €734 despite similar demographic profiles that previous segmentation approaches would classify identically (Chen et al., 2021; Grewal et al., 2020). Young urban professionals in their late twenties exhibited 10-15x variation in predicted lifetime value based on subtle behavioral signals including cross-category purchase diversity, price point preferences, browsing depth, email engagement consistency, and mobile app usage patterns that demographic analysis collapsed into single homogeneous segments.

Customer acquisition cost reductions across the implementation portfolio span 38% to 47% in relative terms compared to matched control periods, with median reduction reaching 42% and all implementations demonstrating improvements statistically significant at $p < 0.01$ confidence levels (Verhoef et al., 2021; Kannan, 2017). These substantial efficiency gains result from improved resource allocation that directs marketing investments toward high-efficiency channels and customer segments exhibiting favorable cost-to-conversion ratios while systematically reducing or eliminating expenditure on low-conversion audiences and inefficient channels. An automotive manufacturer case revealed particularly dramatic acquisition cost reductions of 47% through reinforcement learning-based budget

allocation optimization that discovered complex channel interaction effects and synergies that manual optimization approaches systematically missed despite experienced marketing managers possessing deep industry expertise (Huang & Rust, 2021; Herhausen et al., 2024).

Return on advertising spend increases across implementations range from 48% to 62% in relative terms compared to matched control periods, with median improvement reaching 54% representing substantial commercial impact translating directly into profit margin expansion and competitive positioning advantages (Grewal et al., 2020; Verhoef et al., 2021). The ROAS improvements result from multiplicative effects where conversion rate gains and acquisition cost reductions compound to generate substantial profitability enhancements (Huang & Rust, 2021; Herhausen et al., 2024).

Four primary mechanisms explain the documented performance gains. Superior targeting precision emerged from machine learning models discovering complex nonlinear interaction effects among customer attributes invisible to manual analysis, enabling micro-segmentation at scales (hundreds to thousands of behavioral segments) infeasible through traditional approaches. Real-time optimization capabilities providing continuous budget reallocation based on performance feedback eliminated the temporal lags inherent in periodic manual reviews, with autonomous systems detecting performance degradation within hours and implementing corrective adjustments without human intervention. Enhanced attribution accuracy corrected systematic biases in last-click models that chronically underinvested in upper-funnel activities, with Shapley value calculations revealing that initial awareness touchpoints contributed 18-24% of conversion value despite receiving minimal credit under conventional attribution. Continuous adaptive learning generated compounding improvements as systems accumulated experience, with conversion rates improving 3-5% quarter-over-quarter over sustained periods as models refined behavioral segment definitions and discovered previously undetected seasonal patterns through multi-year observation.

Enhanced attribution accuracy revealing true channel contributions through sophisticated multi-touch modeling enables optimal resource allocation across marketing mix elements by correcting systematic distortions in simplistic last-click attribution that chronically undervalues awareness-building and consideration-development activities despite their essential causal roles in conversion generation (Herhausen et al., 2024). Conventional last-click attribution assigns full conversion credit to final touchpoints preceding purchases based on temporal proximity rather than causal contribution, systematically over-crediting lower-funnel activities that capture demand other channels created while under-crediting upper-funnel activities that generate awareness and consideration but rarely receive last-click credit due to their earlier positions in customer journeys (Chen et al., 2021; Puntoni et al., 2021). Sophisticated multi-touch attribution employing game-theoretic Shapley value calculations that fairly allocate credit based on marginal contributions, Markov chain models that estimate channel transition probabilities, and causal inference techniques quantifies actual contributions more accurately (Davenport et al., 2020; Verhoef et al., 2021).

Analysis of modeling approaches revealed that ensemble architectures combining multiple algorithm families consistently outperformed single-model implementations. Implementations employing ensemble prediction engines (combining gradient boosting, recurrent neural networks, and transformer models) achieved 14-18% lower prediction error rates on hold-out test sets compared to implementations using single algorithm families. The performance advantage stemmed from complementary strengths: gradient boosting excelled at capturing interactions among structured tabular features, recurrent networks effectively modeled sequential dependencies in customer journey data, and transformers provided superior contextual relevance assessment. Model aggregation through learned weighting schemes (where meta-learner models combined base model predictions) further improved accuracy by 5-8% compared to simple averaging approaches, with dynamic weighting adapting to recent performance enabling systems to emphasize models demonstrating superior accuracy for specific customer segments or prediction tasks.

Successful AI marketing implementation requires complementary organizational capabilities spanning technical infrastructure, analytical talent, data governance frameworks, and cultural adaptability that prove substantially rarer, more difficult to develop, and more resistant to imitation than basic technology access through commercial platforms or consulting relationships (Teece, 2018; Chen et al., 2021). These capability requirements create performance heterogeneity across organizations despite widespread AI technology availability, with some organizations achieving dramatic effectiveness improvements while others experience disappointing outcomes or outright failures despite implementing superficially similar technical systems and investing comparable financial resources (Puntoni et al., 2021; Davenport et al., 2020). Implementation experiences reveal that capability deficiencies in any single domain create binding constraints that limit overall system effectiveness regardless of strengths in other dimensions.

Technical infrastructure requirements encompass cloud computing platforms providing elastically scalable processing capacity for model training and real-time inference, comprehensive data warehouses enabling unified customer data integration across historically siloed systems, and robust API connectivity facilitating bidirectional real-time data exchange with external marketing execution platforms (Huang & Rust, 2021; Verhoef et al., 2021). While these infrastructure requirements sound straightforward in abstract discussions, actual implementation proves extraordinarily challenging and time-consuming due to accumulated technical debt in legacy systems, organizational politics around data ownership and access, and fundamental architectural incompatibilities across systems built independently without integration foresight (Kannan, 2017). A European fashion retail implementation invested eighteen months and approximately €3.2 million establishing foundational data infrastructure before any algorithmic development or model training commenced, a timeline that initially frustrated executive sponsors expecting rapid deployment and visible results but proved absolutely essential for downstream success (Grewal et al., 2020; Herhausen et al., 2024).

Analytical talent requirements span multiple specialized roles with distinct skill profiles rarely concentrated in single individuals, creating organizational challenges in recruitment, team composition, and collaboration facilitation (Chen et al., 2021). Data scientists with

machine learning expertise develop and maintain predictive models through algorithm selection, feature engineering, hyperparameter tuning, and validation testing, requiring deep technical knowledge of statistical methods, computational algorithms, and software engineering practices (Davenport et al., 2020). Marketing technologists bridge business requirements and technical implementations by translating marketing strategies into algorithmic specifications, interpreting model outputs for marketing audiences, and designing experimentation frameworks measuring business impact. The talent landscape presents persistent challenges given competitive labor markets where experienced machine learning engineers command compensation premiums reaching 40-60% above traditional software developer salaries, data scientists with relevant domain expertise combining statistical sophistication with marketing understanding prove exceptionally scarce, and cultural gaps between technical and marketing professionals create communication barriers even when talented individuals exist on both sides (Puntoni et al., 2021; Verhoef et al., 2021).

Cultural adaptability encompassing organizational willingness to embrace data-driven decision-making that potentially conflicts with hierarchical authority and experienced intuition, tolerance for experimentation including acceptance that systematic testing inevitably produces some failed experiments, and cross-functional collaboration breaking down traditional silos between marketing, technology, and analytics functions proves surprisingly difficult despite widespread rhetorical commitment to data-driven approaches (Huang & Rust, 2021; Kannan, 2017). An automotive implementation encountered profound initial cultural resistance when experienced marketing managers accustomed to autonomous decision authority actively resisted algorithmic recommendations that conflicted with their intuitive judgments built through years of industry experience (Grewal et al., 2020). Navigating this tension between algorithmic recommendations and managerial intuition required careful change management rather than heavy-handed mandates, with executive sponsorship from C-suite levels proving absolutely critical for cultural transformation by consistently reinforcing data-driven principles through words and highly visible actions (Herhausen et al., 2024; Chen et al., 2021).

Discussion

The empirical findings regarding AI-driven marketing model performance, implementation patterns, and organizational requirements illuminate fundamental theoretical mechanisms through which these technological capabilities generate competitive advantages, examined systematically through resource-based view and dynamic capabilities theoretical lenses (Barney, 1991; Teece, 2018). The analysis distinguishes between surface-level technical features that competitors can observe and imitate relatively easily through reverse engineering, vendor relationships, or talent recruitment versus deep organizational capabilities, accumulated assets, and socially complex routines that resist rapid replication despite transparency regarding their existence and general characteristics, with this distinction proving crucial for understanding why some AI marketing implementations generate sustained multi-year advantages while others produce only temporary performance improvements (Verhoef et al., 2021; Puntoni et al., 2021).

AI marketing systems satisfy several classical resource-based view criteria for sustainable competitive advantage sources when implemented effectively with appropriate complementary capabilities, though the sustainability duration, mechanisms, and boundary conditions differ substantially from traditional strategic resources (Davenport et al., 2020; Chen et al., 2021). The systems demonstrate unambiguous value creation through substantial performance improvements documented consistently across diverse implementations, with conversion rate gains of 28-35%, customer acquisition cost reductions of 38-47%, and ROAS increases of 48-62% representing economically meaningful advantages that translate directly into superior financial performance (Huang & Rust, 2021; Kannan, 2017). However, rarity analysis proves substantially more nuanced than superficial technology access considerations might suggest, requiring careful distinction between widely available technological artifacts versus genuinely scarce organizational capabilities and accumulated assets (Grewal et al., 2020; Herhausen et al., 2024).

The findings support the view that sustainable competitive advantage from AI marketing derives less from algorithmic sophistication per se, which competitors can replicate through vendor relationships or talent acquisition, than from complementary organizational assets accumulating slowly through sustained investment. Proprietary customer data repositories built through years of interaction histories constitute the most defensible asset, as competitors cannot rapidly acquire equivalent datasets without comparable customer relationships. The fashion retailer case illustrates this principle: the 847 micro-segments identified by the AI system required three years of granular behavioral data collection that new market entrants or competitors with less mature data infrastructure could not replicate quickly. Similarly, organizational routines embedding AI insights into operational decision processes develop through extended cultural transformation, not mere technology deployment. The automotive manufacturer case revealed that achieving cultural acceptance of algorithmic recommendations required 18 months of change management, executive sponsorship, and iterative trust-building, organizational capabilities far more resistant to imitation than technical architectures competitors can observe and copy. This interpretation aligns with Barney's (1991) VRIN framework: while AI algorithms are increasingly non-rare due to commercial platform availability, the complementary assets enabling effective deployment remain rare, inimitable due to social complexity and causal ambiguity, and non-substitutable in achieving comparable performance outcomes.

Dynamic capabilities perspectives prove essential for understanding advantage sustainability in turbulent AI marketing environments where static resources erode through competitive imitation and environmental change (Teece, 2018; Grewal et al., 2020). Sensing capabilities detect emerging patterns and threats through continuous monitoring systems tracking prediction accuracy metrics, feature distribution shifts identifying changes in customer population characteristics, competitive intelligence monitoring rival capabilities, and technological landscape tracking identifying emerging algorithmic innovations (Herhausen et al., 2024; Verhoef et al., 2021). Seizing capabilities enable rapid exploitation of sensed opportunities through automated retraining pipelines, experimentation frameworks testing proposed improvements, rapid development processes prototyping innovations, and flexible technical architectures accommodating new data

sources and model families (Chen et al., 2021; Puntoni et al., 2021). Transforming capabilities address fundamental organizational evolution requirements when strategic priorities shift substantially through organizational restructuring, resource reallocation, cultural evolution, and leadership development (Davenport et al., 2020; Huang & Rust, 2021).

The transition from retrospective performance measurement to predictive analytics represents a fundamental shift in how marketing creates competitive advantage. Traditional measurement systems operated as diagnostic tools documenting past performance, introducing temporal lags between strategic decisions and corrective adjustments that allowed competitors to observe and respond to successful initiatives. The implementations examined demonstrate that predictive analytics transforms measurement into a prescriptive system enabling preemptive optimization. The continuous learning mechanisms documented, where conversion rates improved 3-5% quarter-over-quarter through accumulated experience, exemplify what Teece (2018) terms dynamic capabilities: organizational capacities to sense environmental changes, seize opportunities through resource reconfiguration, and transform operations as conditions evolve. Organizations achieving this prospective orientation establish moving-target advantages: by the time competitors replicate current capabilities, leaders have advanced further through continuous learning cycles. However, this advantage remains contingent on sustained investment in sensing mechanisms (monitoring prediction accuracy, feature drift, competitive actions), seizing capabilities (automated retraining pipelines, experimentation frameworks), and transforming capabilities (organizational willingness to evolve processes as AI systems uncover new insights). Organizations lacking these dynamic capabilities risk advantage erosion as static AI implementations depreciate through environmental change and competitive diffusion.

Conclusion

This comprehensive investigation reveals that AI-driven marketing models constitute significant sources of competitive advantage in contemporary global markets when organizations develop integrated capabilities combining algorithmic sophistication with complementary organizational resources including proprietary customer data assets, specialized analytical talent, adaptive organizational cultures, and robust governance frameworks (Barney, 1991; Teece, 2018). The empirical evidence demonstrates substantial, statistically significant, and economically meaningful performance improvements spanning conversion rate gains of 28-35%, customer acquisition cost reductions of 38-47%, and marketing return on advertising spend increases of 48-62% compared to conventional marketing approaches, with improvements documented consistently across diverse implementations spanning retail, automotive, financial services, and technology sectors in North American, European, and Asia-Pacific markets (Davenport et al., 2020; Huang & Rust, 2021; Verhoef et al., 2021).

Competitive advantage sustainability depends critically on complementary organizational capabilities that prove substantially rarer, more difficult to develop, and more resistant to

competitive imitation than basic AI technology access through commercial platforms or consulting relationships (Chen et al., 2021; Puntoni et al., 2021). Proprietary customer data accumulated through years of interaction histories provides essential foundation for accurate prediction and personalization that competitors lacking comparable relationships cannot rapidly replicate (Kannan, 2017). Specialized analytical talent combining machine learning expertise with marketing domain knowledge enables effective algorithm customization and continuous optimization (Grewal et al., 2020). Organizational routines embedding AI insights into operational decision processes develop through cultural transformation requiring 18-24 months of sustained leadership effort (Herhausen et al., 2024). These capabilities create sustained advantages persisting over multi-year horizons rather than temporary performance improvements that competitive imitation rapidly erodes.

Organizations establishing these complementary capabilities position themselves for sustained competitive advantages through continuous capability development and strategic renewal rather than resting on initial deployment successes (Teece, 2018; Verhoef et al., 2021). The dynamic capabilities perspective proves essential for understanding advantage sustainability, with sensing capabilities detecting emerging patterns and threats, seizing capabilities enabling rapid adaptation, and transforming capabilities evolving organizational routines as strategic priorities shift (Huang & Rust, 2021; Chen et al., 2021). The transformation toward AI-driven marketing represents fundamental evolution in how organizations understand customers, formulate strategies, execute campaigns, and measure performance rather than mere incremental improvement to existing approaches through better tools or increased automation (Davenport et al., 2020; Kannan, 2017). Marketing leadership in this environment requires new competency portfolios combining analytical literacy, technological fluency, strategic vision, change management capability, and ethical judgment balancing commercial optimization against privacy protection, fairness, transparency, and broader social responsibilities (Puntoni et al., 2021; Grewal et al., 2020).

References

- Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), 99-120.
- Chen, Y., Wang, Y., Nevo, S., Benitez, J., and Kou, G. (2021). Improving strategic flexibility with information technologies: Insights for firm performance in an emerging economy. *Journal of Information Technology*, 36(2), 152-171.
- Davenport, T.H., Guha, A., Grewal, D., and Bressgott, T. (2020). How artificial intelligence will change the future of marketing. *Journal of the Academy of Marketing Science*, 48(1), 24-42.
- Dwivedi, Y.K., Ismagilova, E., Hughes, D.L., Carlson, J., Filieri, R., Jacobson, J., Jain, V., Karjaluoto, H., Kefi, H., Krishen, A.S., Kumar, V., Rahman, M.M., Raman, R., Rauschnabel, P.A., Rowley, J., Salo, J., Tran, G.A., and Wang, Y. (2022). Artificial intelligence (AI) applications for marketing: A literature-based study. *International Journal of Information Management*, 63, 102434. <<https://doi.org/10.1016/j.ijinfomgt.2022.102434>>

- Grewal, D., Hulland, J., Kopalle, P.K., and Karahanna, E. (2020). The future of technology and marketing: A multidisciplinary perspective. *Journal of the Academy of Marketing Science*, 48(1), 1-8.
- Hasan, M.M., and Wafik, H.A. (2025). The role of artificial intelligence in marketing: A thematic review of AI applications and consumer engagement. *Open Access Research Journal of Science and Technology*, 5(2), 65–78.
- Herhausen, D., Miocevic, D., Morgan, R.E., and Kleijnen, M.H. (2024). The digital marketing capabilities gap. *Industrial Marketing Management*, 90, 276-290.
- Huang, M.H., and Rust, R.T. (2021). A strategic framework for artificial intelligence in marketing. *Journal of the Academy of Marketing Science*, 49(1), 30-50.
- Jackson, R., and Loffredo, L. (2023). Predictive analysis in marketing: Forecasting consumer behavior for strategic advantage. *International Journal of Research Publication and Reviews*, 6(2), 123–131.
- Jain, R., and Kumar, A. (2024). Artificial intelligence in marketing: Two decades review. *Journal of Business Perspective*, 28(3), 145–168. <<https://doi.org/10.1177/09711023241272308>>
- Kannan, P.K. (2017). Digital marketing: A framework, review and research agenda. *International Journal of Research in Marketing*, 34(1), 22-45.
- Puntoni, S., Reczek, R.W., Giesler, M., and Botti, S. (2021). Consumers and artificial intelligence: An experiential perspective. *Journal of Marketing*, 85(1), 131-151.
- Teece, D.J. (2018). Business models and dynamic capabilities. *Long Range Planning*, 51(1), 40-49.
- Verhoef, P.C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J.Q., Fabian, N., and Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, 122, 889-901.
- Verma, S., Sharma, R., Deb, M., and Maitra, D. (2021). Artificial intelligence in marketing: Systematic review and future research directions. *Journal of Business Research*, 129, 902–919. <<https://doi.org/10.1016/j.jbusres.2021.01.041>>

Does institutional quality promote economic growth in West Africa?

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Abstract. *This research examines the effect of institutional quality on economic growth in West Africa. Several dimensions of institutional quality are used: the composite index of institutional quality, three aggregate indicators (economic, political, and institutional governance), and the World Bank's six governance indicators. Using a sample of 15 countries, we estimate a panel data model using the Augmented Mean Group method, whose robustness is reconfirmed by the Driscoll-Kraay method over the period 2000-2023. We obtain three main results: first, the composite institutional quality index promotes economic growth. Second, economic, political, and institutional governance stimulate economic growth. Ultimately, the six governance indicators have a positive influence on economic growth. The results suggest a general improvement in the quality of institutions. In particular, these countries must fight corruption, have sound and robust regulations, strengthen the principles of the rule of law, have qualified administrative staff, maintain political stability, and promote democratic principles.*

Keywords: institutional quality, economic growth, AMG, Driscoll–Kraay, West Africa.

JEL Classification: C23, 011, 043, 047.

1. Introduction

Since Smith (1776), the debate on the origins and disparities of wealth between nations has remained a controversial topic. It is generally accepted that disparities in countries' development are largely linked to productivity, which determines their economic performance. It took observing the differences in per capita income between developed and developing countries for new ideas to emerge about the determinants of economic growth. As a result, the analysis of the determinants of economic growth has been the subject of numerous developments in economic literature.

On a theoretical level, following the failure of exogenous growth theory to explain stable growth at equilibrium, authors such as Romer (1986), Lucas (1988), and Barro (1990) developed new growth theories in the 1980s, known as endogenous growth theories. These authors suggest that economic growth results from a combination of technology, physical capital, public capital, and human capital. However, these models explain only part of the differences in growth and development around the world.

Thus, over the past two decades, the issue of economic growth has remained a major challenge for leaders in developing countries, given the inability of traditional theories to explain long-term growth and after years of macroeconomic adjustment. In order to catch up with developed countries in terms of economic growth and kick-start development, African countries in general, and the West African sub-region in particular, have embarked on a vast program of reforms. The aim is to create conditions conducive to the emergence of a market economy, to clean up the political and social landscape, and to establish the rules of good governance. However, the economic growth announced after the restoration of the major balances has not always been sufficient to drive development in the countries that have embarked on these adjustments.

This highlights the fact that quantitative factors alone are not sufficient to explain differences in per capita income between countries. As a result, since the 1990s, most research on development economics has focused on studying the contribution of other factors, particularly institutional quality. Since then, spurred on by the pioneering work of North (1993) and Williamson (2000), institutional economics has enjoyed a resurgence of interest. Economic literature reveals that the quality of institutions is one of the fundamental causes of differences in countries' growth rates (Acemoglu et al., 2001). This is because the effectiveness of any economic policy is highly dependent on the institutional and political environment in which it is implemented (Rodrik et al., 2004).

North (1990) defines institutions as the rules of the game in a society. They represent constraints that determine human interactions. High institutional quality reduces uncertainty and transaction costs in exchanges and, as a result, optimizes the expectations of economic agents in a country (Coase, 1937; North, 1990; Acemoglu and Robinson, 2010). In addition, better quality private property rights institutions stimulate investment and ensure better allocation of economic resources, which promotes economic growth (North and Thomas, 1973, and North, 1981). Thus, the key to economic growth is the development of quality institutions that promote economic and political competition (Acemoglu and Robinson, 2012). As such, economic institutions, due to their ability to coordinate economic activities and optimize the investment decisions of economic actors, determine long-term economic growth (Acemoglu et al., 2005).

Empirically, several studies have concluded that institutional quality has a positive effect on economic growth (Vianna and Mollick, 2018; Salman et al., 2019; Dirir, 2023; Hussen, 2023; Liko, 2024), while others have hypothesized a nonlinear relationship between institutional quality and economic growth (Thi Tran, 2021). A third group of authors highlights a bidirectional causality between institutional quality and economic growth (Law et al., 2013; Jaunky, 2013).

For West African countries, the debate concerning the effect of institutional quality on economic growth remains relevant. According to World Bank statistics, the average annual GDP growth rate in this region stood at 4.4% between 2000 and 2023. Estimated at 4.54% in 2000, the average annual growth rate reached 5.7% in 2010. It fell sharply to -0.43% in 2020, then rose in 2022 to 5.87% and fell again in 2023 to an average annual rate of 4.74%. In addition, West African countries have lower GDP growth compared to South Asian countries, which recorded an average growth of 5.3% between 2000 and 2023 (World Bank, 2024a). These statistics suggest that growth is volatile in the countries of the West African subregion. This situation is partly due to the impact of the global COVID-19 pandemic and also to the low level of institutional quality.

For example, the average institutional quality indices, measured by the World Bank's governance indicators, are recorded at -0.596 for control of corruption, -0.8 for government effectiveness, -0.54 for political stability and absence of violence, -0.649 for regulatory quality, -0.672 for rule of law, and -0.357 for citizen voice and accountability. The value of these indices ranges from -2.5 (very poor performance) to 2.5 (very good performance). This reflects the poor quality of institutions in West Africa, as the average values of the six governance indicators are negative (World Bank, 2024b).

In light of the above, what is the effect of institutional quality on economic growth in West Africa? The objective of this research is to empirically analyze the effect of institutional quality on economic growth in West Africa. The research hypothesis is that institutional quality stimulates economic growth in West Africa.

This research is part of recent literature on the effects of institutional quality. The contribution of this research to the literature is threefold. Unlike previous research, this study uses several institutional dimensions to comprehensively analyze the effect of institutional quality on economic growth in West Africa. First, a composite index of institutional quality is calculated using principal component analysis (PCA). Next, three aggregate indicators of institutional quality (economic, political, and institutional governance) and individual indicators of institutional quality are considered. This makes it possible to capture the overall effect and the differentiated effects of institutional quality. Finally, our methodological approach is robust, as this research uses estimation techniques that have the advantage of resolving several econometric problems such as cross-sectional dependence, heterogeneity of slopes, endogeneity, and non-stationarity of variables.

The rest of the article is organized as follows: Section 2 reviews the theoretical and empirical literature. Section 3 presents the stylized facts. Section 4 describes the methodology. Section 5 presents the results and their discussion.

2. Literature review

Economic literature shows that an economy's growth rate can be explained by its endowment of natural resources, investment, technology, and human capital (Ricardo, 1817; Solow, 1956; Romer, 1986; Lucas, 1988). However, in the 1990s, the literature was renewed with the introduction of institutions as a necessity in the process of economic growth (North, 1990; Williamson, 1994). In essence, this is the institutional explanation of economic growth within the framework of the New Institutional Economics.

Thus, the New Institutional Economics consists of a development of neoclassical tools for analyzing the role of institutions in the coordination and implementation of economic activities (North, 1993; Williamson, 2000). Unlike Solow's model (1956), which attributes a key role in growth to capital accumulation and technical progress, North (1991) emphasizes that these factors are not the causes of economic growth, but rather its manifestations.

An examination of economic theory shows that institutions can affect economic growth through a number of channels. The first is the transaction cost channel. According to the transaction cost theory of Coase (1937) and Williamson (1975), these costs are defined as the expenses associated with exchanges between economic agents, in addition to the prices of the goods themselves. These include the costs of negotiation, information gathering, and contract enforcement. According to North (1991), commercial exchanges develop if transaction costs are limited and uncertainty is reduced. Institutions are therefore designed to reduce uncertainty in exchanges and define transaction costs that are profitable for economic activity (North, 1991). Consequently, institutional quality through the reduction of transaction costs is essential for economic growth. The second is the property rights channel. A property rights system that provides effective protection and reduces uncertainty helps maximize the profitability of economic activity. In addition, private property allows individuals to make decisions that lead to economic efficiency (North, 1990).

Empirically, several studies have concluded that the quality of institutions has a positive effect on economic growth. For example, Liko (2024) applied fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) methods to a sample of eight Balkan countries over the period 2000-2022. He found a positive and significant effect of institutional quality on economic growth. Ha et al. (2023) used the generalized method of moments (GMM) for their study on Vietnam between 2010 and 2020. The results of the study indicated the overall positive effect of institutional quality on total factor productivity. Thi Tran et al. (2021) investigated the impact of institutional quality on economic growth in 48 Asian countries from 2005 to 2018. The results of the estimates using quantile regression methods show that institutional quality promotes economic growth. Similarly, Uddin et al. (2023), considering a sample of 70 developing countries between 2002 and 2018, found, using the CS-ARDL (cross-sectional augmented autoregressive distributed lag) estimator, that the quality of institutions has a positive impact on economic development.

Regarding the effects of disaggregated institutional quality indicators, Dirir (2023) indicated, through the application of FMOLS and DOLS, that political stability, citizen voice and accountability have a favorable effect on the economic development of countries torn by war over the past 20 years. Misi Lopes et al. (2023) considered a sample of five emerging economies and three developed economies between 1996 and 2018 and found, using OLS, FE, and RE techniques, that regulatory quality has a positive and significant effect on economic growth. Destek et al. (2023), using cross-sectional data estimates for countries in the MENA region over the period 1996 to 2019, found, using the generalized system of moments method, that institutional quality, measured by control of corruption, political stability, the rule of law, and voice and accountability, contributes significantly to increased GDP growth. Jaunky (2013) analyzed the link between democracy and economic development for 28 sub-Saharan African countries over the period 1980-2005. Estimates made using the generalized method of moments in a VAR causality test panel system reveal the existence of a bidirectional causality between democracy and economic growth.

Regarding the literature on African countries, Hussien (2023), considering a sample of 31 countries in sub-Saharan Africa from 1991 to 2015, and using the Generalized Moments Method (GMM) technique, found that the quality of institutions has a positive and significant effect on economic growth. In particular, the results show that democratic and regulatory institutions promote economic growth. Bannor et al. (2023) analyze data from a sample of 39 African countries during the period 1996-2019 using the PMG method and find that indicators of political stability and government efficiency have a direct positive and significant impact on economic growth. Iheonu et al. (2017) use panel data from 13 West African countries covering the period 1996 to 2015. Data estimated by the double-least-squares method show that government efficiency has a positive and significant impact on countries' economic performance. Similarly, Atangana Ondo (2013) applied the Generalized System Moments (GMM) method and found that political stability and the quality of regulation have a positive influence on economic growth in Africa. On the other hand, the control of corruption and the rule of law do not have a significant influence on economic growth.

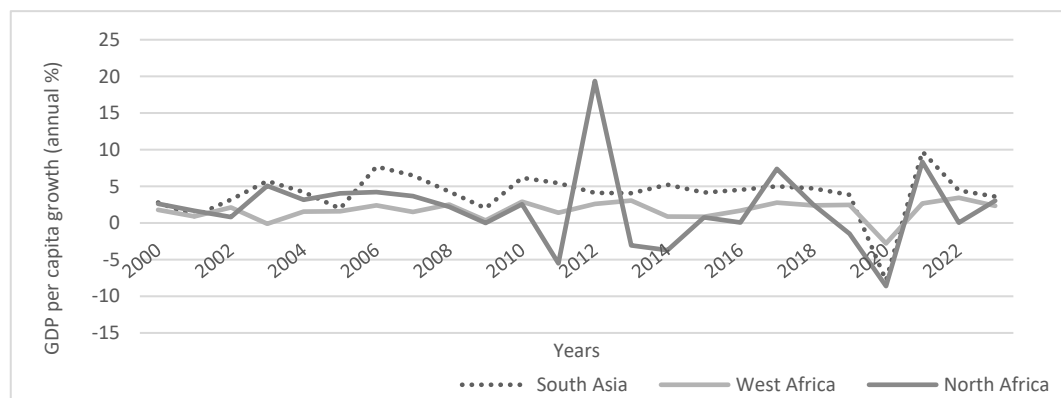
Most of these studies have analyzed either the effect of the composite index or the disaggregated indicators of institutional quality on economic growth. This research aims to fill a gap in the literature by analyzing not only the effect of the composite index and the three aggregate indicators (economic, political, and institutional governance), but also the six World Bank governance indicators on economic growth in West Africa.

3. Institutional Quality and Economic Growth in West Africa: Stylized Facts

Figure 1 shows the average growth rates of GDP per capita in different regions of Africa over the period 2000-2023. Average growth rates are generally very volatile, as can be seen from the significant fluctuations in Figure 1. For example, the years 2003, 2009, and 2020 are characterized by significant declines in GDP per capita growth rates in West Africa. In addition, the average annual GDP per capita growth rate from 2000 to 2023 is 1.70% in West Africa, compared with 1.80% in North Africa and 4% in South Asia. The explanatory

factors are, on the one hand, the effects of the subprime crisis and the volatility of commodity prices, and, on the other hand, the economic impact of the COVID-19 pandemic, as well as the insecurity caused by terrorism.

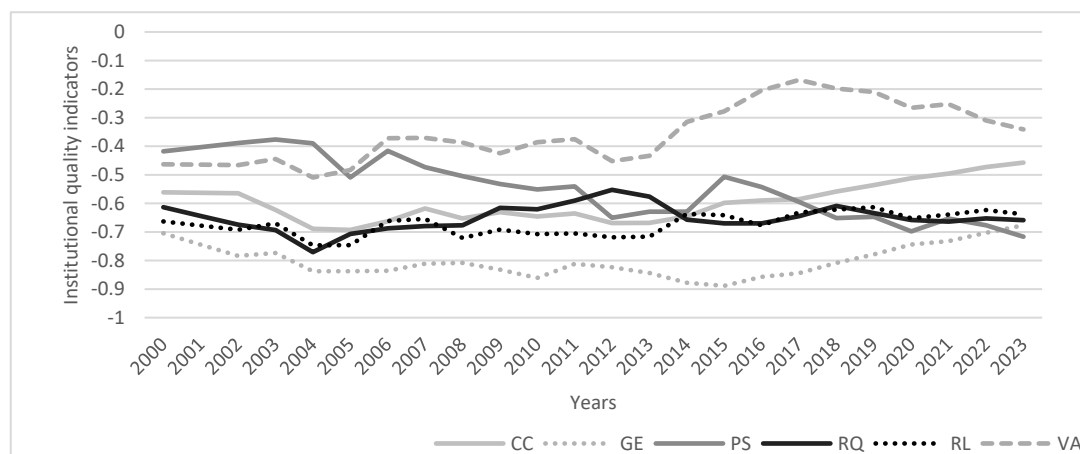
Figure 1. Change in GDP per capita growth (% annual) in regions between 2000 and 2023



Source: Authors

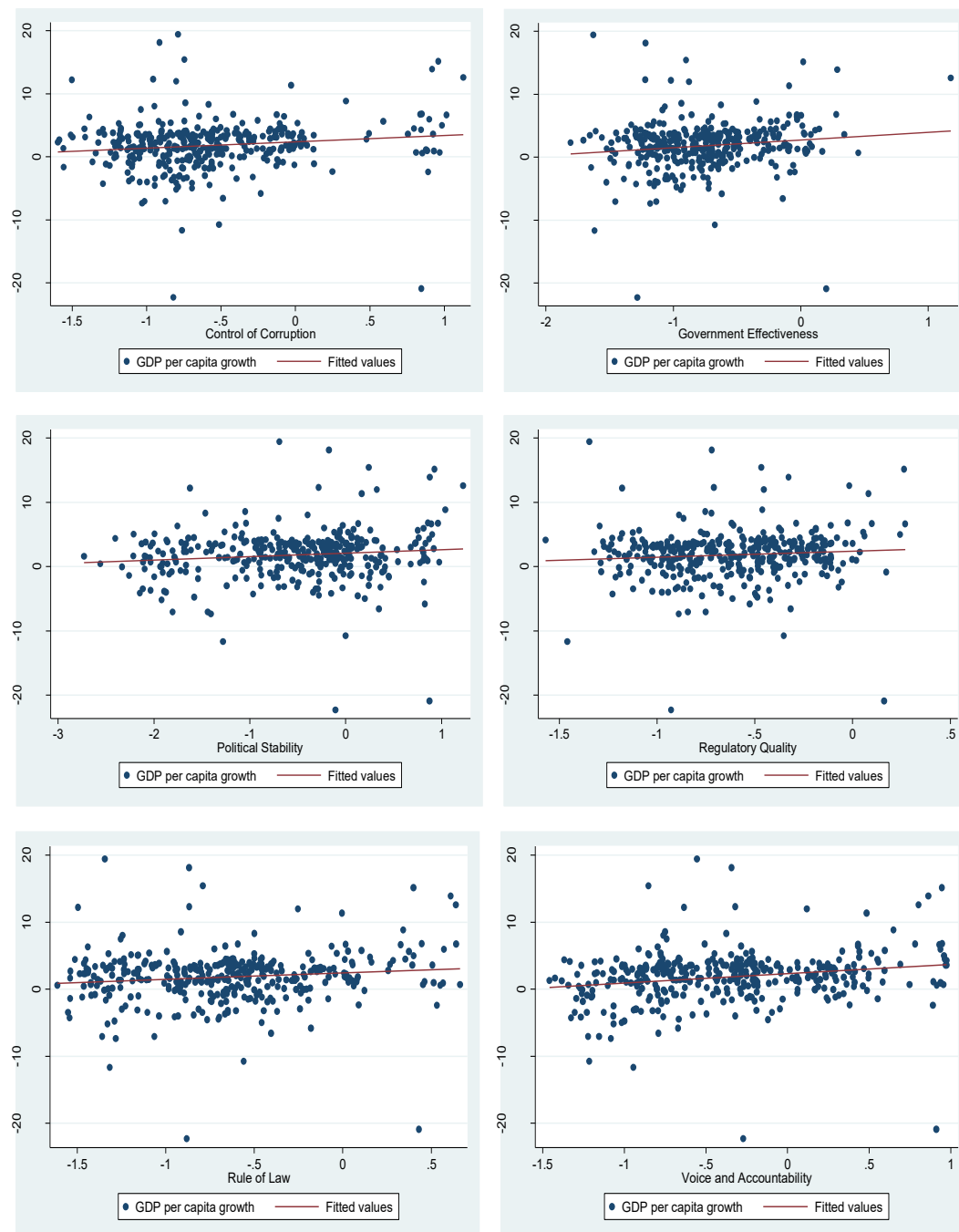
Economic growth in West African countries has taken place against a backdrop of poor institutional performance. Figure 2 shows the average change in institutional quality indicators in West Africa over the period 2000-2023. All indicators have negative values, and some show a downward trend, such as political stability and regulatory quality. This can be explained, on the one hand, by the numerous coups d'état that have taken place in recent years in the subregion, causing political instability. This is the case in Burkina Faso, Guinea, Mali, and Niger. On the other hand, this trend can be explained by the numerous terrorist activities that have shaken the West African subregion in recent years, creating insecurity and political instability. However, the other indicators have improved in recent years.

Figure 2. Evolution of institutional quality indicators, 2000-2023



CC: control of corruption; GE: governance effectiveness; PS: political stability; RQ: regulatory quality; RL: rule of law; VA: voice and accountability.

Source: Authors

Figure 3. *Correlation between institutional quality and economic growth*

This figure shows a positive relationship between per capita GDP growth and institutional quality indicators in West Africa. This means that West African countries with high institutional quality indicators are likely to have high economic growth rates. However, correlation analysis only illustrates the nature of the correlations and not the actual effect of institutional quality on economic growth. Therefore, it is relevant to conduct an empirical analysis.

4. Methodology and data

4.1. Specification of the econometric model

This research examines the effect of institutional quality on economic growth. To do so, a growth model derived from that of Mankiw et al. (1992) was specified, introducing institutional indicators into the regressors. In our model, we assume that institutional quality, as measured by indicators such as control of corruption, government effectiveness, political stability and absence of violence, regulatory quality, rule of law, and voice and accountability, plays a key role in economic growth by promoting investment and innovation. The basic model of Mankiw et al. (1992) is given by:

$$Y_{it} = F(K_{it}, H_{it}, A_{it}, L_{it}) = K_{it}^{\alpha} H_{it}^{\beta} (A_{it} L_{it})^{1-\alpha-\beta} \quad (1)$$

Where Y represents production, K: physical capital stock, H: human capital stock, L: labor, and A: technological level. Thus, technological improvements are the result of high-quality institutions (North, 1990, 1991), which increase the efficiency of the productive sector and improve economic growth.

After transforming equation (1) into logarithmic form, we obtain:

$$\ln(y) = \ln A_0 + g t + \alpha / (1 - \alpha) \ln(s_k) - \alpha / (1 - \alpha) \ln(n + g + \delta) + \beta / (1 - \alpha) \ln(h^*) \quad (2)$$

Where δ is the depreciation rate, L and A are assumed to grow exogenously at rates n and g, s_k is the share of income invested in physical capital, h^* is the equilibrium state of human capital toward which the economy converges, and the term A_0 reflects technology, natural resources, and institutional quality.

Thus, equation (2) can be rewritten in matrix form as follows:

$$y_{it} = \alpha + \beta IQ_{it} + \gamma X_{it} + \varepsilon_{it} \quad (3)$$

Where y_{it} is the per capita GDP growth rate; IQ_{it} is institutional quality, which can represent either the composite index, the three aggregate indicators, or the six World Bank governance indicators; X_{it} is a vector of control variables; ε_{it} is the error term; i represents a West African country ($i = 1, 2, 3, \dots, 15$) and t denotes the year ($t = 2000, 2001, 2002, \dots, 2023$). Institutional quality indicators include control of corruption, government effectiveness, political stability and absence of violence, regulatory quality, rule of law, and voice and accountability. Several empirical studies have established a positive and significant influence of institutional quality on economic growth (Atangana Ondo, 2013;

Hussen, 2023; Liko, 2024). Therefore, we anticipate a positive and significant result for institutional quality on economic growth.

In line with recent literature on institutional quality (Acheampong et al., 2021; Diallo and Ouoba, 2023; Bayili and Maiga, 2025), our research first uses principal component analysis (PCA) to create the composite index of institutional quality. PCA is a statistical analysis that seeks to reduce a large amount of information to a limited number of major dimensions (called principal components). The results of the principal component analysis are presented in Table A5 in Appendix A. The criteria used to validate the PCA are those of Bartlett's sphericity test, where the overall KMO index is significant at the 1% threshold. Then, with reference to Diallo and Ouoba (2023) and Bayili and Maiga (2025), the three aggregate indicators of economic, political, and institutional governance are obtained as follows: economic governance is the simple average of two indicators of institutional quality, namely government effectiveness and regulatory quality. Political governance is the simple average of institutional quality indicators such as political stability and absence of violence, citizen voice, and accountability. Institutional governance is the simple average of indicators such as control of corruption and rule of law. Finally, to facilitate interpretation, all institutional quality indices are normalized using the min-max method. Thus, a value close to 0 implies poor performance, while a value close to 1 indicates very good institutional quality performance.

Based on the literature, the vector of control variables X includes potential determinants of economic growth: natural resources are measured by total rents from natural resources as a percentage of GDP. While some authors find a positive effect of natural resources on economic growth (Miamo and Achuo, 2021; Sharma and Paramati, 2022), others highlight a negative effect (Avom et al., 2022; Achuo, 2023). The sign is ambiguous. In line with Atangana Ondo (2013), human capital is measured by the gross enrollment rate in primary education. This is a variable frequently used to quantify human capital (Hall and Jones, 1999). According to endogenous growth theory, human capital is considered to be the driver of economic growth (Lucas, 1988). We expect human capital to have a positive impact on economic growth. According to Achuo (2023), trade openness is measured by the sum of exports and imports as a percentage of gross domestic product. Trade liberalization promotes long-term economic growth through increased productivity (Iyke, 2016). It generates economies of scale and technology transfer. Several empirical studies show that trade liberalization has a positive effect on economic growth (Zahonogo, 2017; Manwa et al., 2019; Liko, 2024; Votsoma et al., 2024). We anticipate a positive result. Table A2 in Appendix A presents the definition and source of the different variables.

4.2. Data

Data on macroeconomic variables are taken from World Development Indicators (2024). Data on institutional quality variables are taken from Worldwide Governance Indicators (2024). The sample comprises 15 West African countries, listed in Table A1 in Appendix A. The study period covers 2000 to 2023. Descriptive statistics and the correlation matrix for the analysis variables are presented in Tables A3 and A4 in Appendix A. The correlations between the different variables are not high enough, suggesting an absence of multicollinearity. Furthermore, the correlation matrix indicates that economic growth

remains positively linked to the institutional quality index, human capital, trade openness, and natural resources. These positive relationships demonstrate the role of these variables in increasing economic growth.

4.3. Estimation technique

4.3.1. Cross-sectional dependency test

When analyzing panel data, it is essential to perform a cross-sectional dependence test due to the specific characteristics of the countries in the sample. We therefore apply three tests: the Pesaran CD test (2004), the Friedman test (1937), and the LM test adjusted for bias by Pesaran, Ullah, and Yamagata (2008). The null hypothesis of these tests is the absence of cross-sectional dependence. Table 1 presents the results of the three tests. They reveal the rejection of the null hypothesis. Consequently, West African countries are dependent on each other and thus share common factors.

Table 1. *Results of the cross-sectional dependence tests*

Tests	Statistics	p-value
Pesaran CD test	3.108	0.0019
Friedman test	45.957	0.0000
LM adjusted	3.964	0.0001

Source: Authors

4.3.2. Slope heterogeneity test

The slope heterogeneity test is essential when dealing with panel data (Aladejare and Nyiputen, 2023). The objective is to examine whether the slopes are homogeneous or different between the panel units. Therefore, this research applies the Pesaran and Yamagata test (2008). In this test, the null hypothesis is that the slope coefficients are homogeneous. Table 2 presents the results of the heterogeneity test. The results reject the null hypothesis that the slope coefficients are homogeneous.

Table 2. *Results of the slope heterogeneity test*

Test	Value	p-Value
Adj Delta test	16.084	0.000
Adj Delta test	18.572	0.000

Source: Authors

4.3.3. Unit root test

After confirming the heterogeneity of the slope and the existence of cross-sectional dependence between the units in the panel, it is essential to use second-generation unit root tests, which are appropriate for resolving the above-mentioned problems. We therefore apply Pesaran's (2007) stationarity test to verify the order of integration. A variable is stationary when the statistic is less than the critical value of the distribution at the 5% threshold. Otherwise, there is a unit root. The results in Table 3 show that variables such as per capita GDP growth, natural resource rents, government efficiency, and political stability are stationary in level. However, variables such as human capital, trade openness, institutional quality index, control of corruption, regulatory quality, rule of law, and citizen voice and accountability are stationary in first difference.

Table 3. Results of the unit root test

Variables	Level		First difference		Decision
	Intercept	Intercept and Trend	Intercept	Intercept and Trend	
GDP per capita growth	-4.044***	-4.443***			I (0)
Human capital	-1.598	-2.102	-3.799***	-4.200***	I (1)
Trade openness	-2.050	-2.424	-4.478***	-4.478***	I (1)
Natural resource	-2.441**	-2.708*			I (0)
Institutional quality index	-1.540	-2.399	-3.944***	-4.115***	I (1)
Control of Corruption	-1.908	-2.623	-4.403***	-4.327***	I (1)
Government Effectiveness	-2.409**	-3.220***			I (0)
Political stability	-2.560***	-2.832**			I (0)
Regulatory Quality	-1.509	-2.159	-4.628***	-4.745***	I (1)
Rule of Law	-1.681	-2.251	-4.392***	-4.553***	I (1)
Voice and Accountability	-1.927	-2.112	-4.151***	-4.237***	I (1)

Note. *** p<0.01, ** p<0.05, * p<0.1, respectively. The critical values of the CIPS test at 10%, 5% and 1% levels of significance are -2.14, -2.25, and -2.45 for constant, and -2.66, -2.76, and -2.96 for constant plus trend, respectively.

Source: Authors

4.3.4. Cointegration test

Given the cross-sectional dependence observed in West African countries, Westerlund's (2007) test is used to describe the long-term relationship between variables. This test is based on the second-generation error correction model and assumes the null hypothesis of no cointegration. The results are presented in Table 4. The results support the rejection of the null hypothesis of no cointegration and confirm the presence of a long-term relationship between the variables.

Table 4. Cointegration test

Statistic	Value	Z-value	P-value
Gt	-4.716***	-7.907	0.000
Ga	-13.584	1.694	0.955
Pt	-17.596***	-7.425	0.000
Pa	-12.199	0.760	0.776

Source: Authors

4.3.5. Long-Run Estimation

In practical terms, estimating our models poses two main problems: slope heterogeneity and cross-sectional dependence. To correct these problems, this research uses the Augmented Mean Group (AMG) estimator developed by Eberhardt and Teal (2010). The AMG technique takes into account structural breaks and shocks (Dahmani et al., 2022). In addition, the AMG method uses time indicator variables and treats the unobservable factor not as a nuisance but as a common dynamic process (Eberhardt, 2012). This technique also solves the problem of endogeneity between variables and the non-stationarity of certain variables (Zuo et al., 2022). The AMG estimator is carried out in two stages. The first stage is expressed by the following equation:

$$\Delta Y_{it} = \alpha_i + \beta_i \Delta X_{it} + \varphi_i \delta_t + \sum_{t=1}^T \theta_t D_t + \varepsilon_{it} \quad (4)$$

Where β_i denotes the slope, δ_t the unobserved common factor, φ_i the heterogeneous factor loadings, D_t the annual dummy variables, and θ_t the coefficients. In the second step, we

add a unit coefficient for each unit in the group to the group-specific regression specification, then calculate the mean of the group-specific parameters across the entire panel.

$$AMG = \frac{1}{N} \sum_{i=1}^N \hat{\beta}_i \quad (5)$$

5. Presentation and discussion of results

5.1. Effect of institutional quality on economic growth in West Africa

First, we estimate the models relating to the effect of the composite institutional quality index and the three aggregate institutional quality indicators on economic growth. Second, we estimate the effect of the six disaggregated institutional quality indicators on economic growth in West Africa.

Overall, institutional quality has positive and statistically significant effects on economic growth at the 5% and 1% thresholds (Table 5). Thus, an improvement in the composite index of institutional quality, as well as the aggregate indicators of institutional quality, stimulates economic growth in West Africa. These results are consistent with the predictions of New Institutional Economics, which states that institutions are one of the determining factors of long-term economic growth (Williamson, 1975; North, 1990). Indeed, New Institutional Economics suggests that institutional quality encourages economic agents to invest and innovate, which increases productivity and, consequently, improves economic growth.

These results also indicate that economic growth is promoted by a high-quality institutional framework that creates an environment conducive to economic activity. Economic growth is thus stimulated by economic governance through respect for private property rights and contractual rights. For example, good economic institutions assure investors that they will be able to enjoy the fruits of their investments, which encourages them to increase their investments and allocate the resources necessary to stimulate economic growth. This result is consistent with the findings of Lassoued et al. (2019), according to which economic governance has an indirect positive effect on economic growth. Second, political governance supports economic growth because it improves the credibility of states and reduces uncertainty, which encourages economic activity. Good political governance ensures sound resource management, macroeconomic stability, and the implementation of growth policies. Finally, institutional governance is a factor in economic growth in that it protects investments and allows economic agents to optimize their expectations. These results are expected and confirm those of Thi Tran et al. (2021) and Uddin et al. (2023).

With regard to other exogenous variables, the results in Table 5 reveal a positive and significant effect of human capital on economic growth. The positive effects of human capital are stable across all estimates. Thus, a 1% improvement in human capital stimulates GDP per capita growth by 0.0658 to 0.108%. This result is expected and consistent with endogenous growth theory, which states that the accumulation of human capital improves

the quality of work and stimulates research and development, thereby increasing productivity and, consequently, positively influencing economic growth. This result is consistent with the conclusions of Ouoba (202) and Destek et al. (2023).

The coefficients relating to the trade openness variable are positive and statistically significant at the 1% threshold. Thus, a 1% increase in trade openness leads to an increase in the GDP per capita growth rate from 4.218% to 5.661%. Trade openness creates more opportunities for local economies in terms of product variety, market size, and economies of scale. In addition, trade openness allows West African economies to benefit from technology transfer, which boosts productivity. Thus, economic growth in the West African subregion is driven in part by exports of natural resources (African Development Bank, 2025). This result corroborates the findings of Atangana Ondo (2013) and Votsoma et al. (2024).

Table 5. *Effects of institutional quality on economic growth in West Africa*

Dependent variable:		GDP per capita growth (annual %)		
Estimation method:		Augmented Mean Group (AMG)		
Explanatory variables	Institutional quality index	Economic governance index	Political governance index	Institutional governance index
Human capital	0.0658** (0.0286)	0.108*** (0.0389)	0.0782** (0.0392)	0.0970*** (0.0341)
Trade openness (log)	5.494*** (1.766)	4.218*** (1.518)	5.661*** (1.652)	4.371** (1.716)
Total natural resources rents	-0.0868 (0.146)	-0.0425 (0.0991)	-0.0864 (0.0921)	0.0108 (0.0985)
Institutional quality index	15.02** (6.568)			
Economic governance index		8.640** (3.472)		
Political governance index			15.54*** (5.518)	
Institutional governance index				9.296** (4.275)
Constant	-36.78*** (11.15)	-29.87*** (7.617)	-39.68*** (12.53)	-30.36*** (7.867)
Number of observations	360	360	360	360
Number of groups	15	15	15	15
Wald chi2 (P-value)	19.98 (0.0005)	38.28 (0.0000)	17.89 (0.0013)	63.80 (0.0000)

Source: Authors

Table 6 presents the results of the analysis in terms of disaggregated institutional quality indicators. These results show that the coefficient of the institutional quality variable controlling for corruption is positive and statistically significant at the 10% threshold. A 1% increase in corruption control leads to a 6.748% improvement in the GDP per capita growth rate. This result implies that economic growth in these countries is stimulated by the fight against corruption. Indeed, low levels of corruption reduce uncertainty and transaction costs associated with economic activities, which encourages investment. The fight against corruption helps to clean up management and ensures the optimal allocation of financial resources to fund productive investments. These results corroborate those of Atangana Ondo (2013) and Destek et al. (2023), who found that corruption control promotes economic growth.

The results of the estimates indicate that economic growth is influenced by the quality of institutions as measured by government efficiency. The coefficient of this institutional variable is positive and statistically significant at the 5% threshold. Thus, a 1% improvement in government efficiency translates into a 9.138% increase in the GDP per capita growth rate. Indeed, economic growth increases when government officials are competent, public services are of high quality, and public authorities fulfill their commitments. Our results are consistent with the findings of Mtiraoui (2020), according to which effective governance has a positive impact on economic growth.

The results in Table 6 indicate that political stability stimulates economic growth. This variable has a positive and statistically significant effect on economic growth at the 1% level. A 1% improvement in political stability increases the GDP per capita growth rate by 11.82%. This result shows that economic growth is important in politically stable countries. Indeed, political stability creates a predictable and secure environment, which encourages investors to invest in long-term projects. For example, a politically stable country has easy access to the financing necessary for the development of economic activities. Political stability promotes competitiveness through investment in worker training. This result is in line with those of Atangana Ondo (2013) and Dirir (2023).

The results show that the coefficient associated with the quality indicator of regulation is positive and statistically significant at the 10% level. A 1% increase in the quality of regulation leads to a 5.878% increase in the GDP per capita growth rate. Indeed, the ability of governments to develop and implement good regulatory policies conducive to private sector development allows for the development of private initiatives that stimulate economic growth. This result confirms that of Atangana Ondo (2013) and Dirir (2023).

The rule of law has a positive and statistically significant effect on economic growth at the 10% threshold. Thus, a 1% improvement in the rule of law translates into an 8.208% increase in the GDP per capita growth rate. These results show that economic growth is linked to the principles of the rule of law. Indeed, when citizens have confidence in the laws of society and are committed to respecting them, and above all, when the jurisdiction of the judiciary is established, economic agents are willing to invest, innovate, and produce, which are essential factors for long-term economic growth.

The citizen voice and responsibility variable has a positive and statistically significant effect on economic growth at the 5% threshold. A 1% improvement in democratic principles is associated with a 10.08% increase in economic growth. Indeed, countries with democratic regimes have high growth rates. Democracy improves the credibility of states through the separation of powers, which promotes private investment. It enables citizen participation in the formulation of development programs, which enhances economic performance. This finding is consistent with the findings of Adika (2020), who found that democracy is one of the necessary prerequisites for promoting economic growth in sub-Saharan Africa.

Table 6. *Effects of Institutional Quality on Economic Growth in West Africa*

Dependent variable:		GDP per capita growth (annual %)				
Estimation method:		Augmented Mean Group (AMG)				
Explanatory variables	CC	GE	PS	RQ	RL	VA
Human capital	0.104*** (0.0337)	0.0864** (0.0392)	0.0809** (0.0396)	0.129*** (0.0439)	0.0571 (0.0354)	0.0773** (0.0356)
Trade openness (log)	5.160*** (1.907)	4.508*** (1.304)	5.120*** (1.358)	3.750** (1.581)	4.787*** (1.269)	5.697*** (1.969)
Total natural resources rents	-0.0430 (0.109)	-0.0151 (0.0980)	-0.0981 (0.0975)	-0.121 (0.115)	-0.0828 (0.163)	-0.0793 (0.112)
Control of corruption (CC)	6.748* (4.039)					
Government effectiveness (GE)		9.138** (3.884)				
Political stability (PS)			11.82*** (3.747)			
Quality of regulation (RQ)				5.878* (3.246)		
Rule of law (RL)					8.208* (4.270)	
Voice and accountability (VA)						10.08** (3.982)
Constant	-33.96*** (11.21)	-28.52*** (5.532)	-35.43*** (8.951)	-28.38*** (8.183)	-27.70*** (5.978)	-34.19*** (8.775)
Number of observations	360	360	360	360	360	360
Number of groups	15	15	15	15	15	15
Wald chi2 (P-value)	29.00 (0.0000)	55.58 (0.0000)	25.21 (0.0000)	23.04 (0.0001)	45.03 (0.0000)	43.37 (0.0000)

Source: Authors

5.2. Analysis of the robustness of the results

In order to ensure the robustness of our results, we change our estimation technique. Thus, the technique of Driscoll and Kraay proposed by Driscoll and Kraay (1998) was used. This method is robust for addressing issues of cross-sectional dependence, heteroscedasticity, endogeneity, and serial correlation (Aladejare and Nyiputen, 2023; Diallo and Ouoba, 2024). Table 7 presents the results of the Driscoll and Kraay (1998) estimate. Subsequently, this research uses GDP per capita expressed in constant prices (PPP, 2021 US dollars) as an alternative measure of economic growth. This indicator has been widely used in the literature to measure economic growth (Henry, 2019; Achuo, 2023; Mahran, 2023). The results show the stability of the coefficients of the base model. Thus, all disaggregated institutional-quality indicators still have a positive and significant influence on economic growth. Similarly, human capital and trade openness continue to have a positive and significant impact on economic growth. The results corroborate those of the basic model in terms of signs and significance. In summary, our baseline results are therefore robust.

Table 7. *Results of the robustness analyses*

Dependent variable:		GDP per capita (log)				
Estimation method:		Driscoll and Kraay (1998)				
Variables	CC	GE	PS	RQ	RL	VA
Human capital	0.00469*** (0.000839)	0.00523*** (0.000727)	0.00386*** (0.00129)	0.00561*** (0.000784)	0.00472*** (0.000777)	0.00400*** (0.00110)
Trade openness (log)	0.377*** (0.0749)	0.304*** (0.0739)	0.440*** (0.0872)	0.357*** (0.0672)	0.408*** (0.0841)	0.467*** (0.0671)

Dependent variable:		GDP per capita (log)				
Estimation method:		Driscoll and Kraay (1998)				
Variables	CC	GE	PS	RQ	RL	VA
Total natural resources rents	0.00274 (0.00302)	0.00635** (0.00274)	0.00287 (0.00378)	0.00625** (0.00284)	0.00405 (0.00307)	0.00262 (0.00378)
Control of corruption (CC)	0.624*** (0.124)					
Government effectiveness (GE)		1.147*** (0.180)				
Political stability (PS)			0.349** (0.168)			
Quality of regulation (RQ)				0.665*** (0.102)		
Rule of law (RL)					0.427** (0.184)	
Voice and accountability (VA)						0.377** (0.150)
Constant	5.849*** (0.320)	5.890*** (0.278)	5.744*** (0.387)	5.699*** (0.256)	5.761*** (0.314)	5.614*** (0.291)
R2	0.300	0.351	0.268	0.304	0.278	0.277
Fisher test statistic (P-value)	566.65 (0.0000)	158.09 (0.0000)	138.87 (0.0000)	275.42 (0.0000)	206.73 (0.0000)	141.72 (0.0000)
Number of observations	360	360	360	360	360	360
Number of countries	15	15	15	15	15	15

Source: Authors

6. Conclusion and policy implications

This research examined the effect of institutional quality on economic growth using a sample of 15 West African countries from 2000 to 2023. For empirical application, we used several dimensions of institutional quality: the composite index of institutional quality, the aggregate indicators of economic, political, and institutional governance, and the six World Bank governance indicators. The empirical strategy is the Augmented Mean Group (AMG) method on panel data.

Three main findings emerge:

- First, the overall institutional quality index drives economic growth.
- Second, the three aggregate indicators of economic, political, and institutional governance have a positive influence on economic growth.
- Third, each of the World Bank's six governance indicators drives economic growth.

Based on these results, we suggest that West African countries build strong and credible institutions. In particular, institutions with exceptional power to better fight corruption, put in place sound policies and strong regulations that are favorable to the private sector. These countries must also promote freedom of association and freedom of the press, and strengthen political stability through transparency and participation. Finally, they must strengthen the efficiency of public administration through competent civil servants, the provision of quality public services, and also respect the principles of the rule of law.

References

- Acemoglu, D., and Robinson, J.A. (2010). Why is Africa poor? *Economic history of developing regions*, 25(1), 21-50.
- Acemoglu, D., and Robinson, J.A. (2012). *Why Nations Fail: The Origins of Power, Prosperity, and Poverty*. Crown Business, New York.
- Acemoglu, D., Johnson, S., and Robinson, J.A. (2001). The colonial origins of comparative development: An empirical investigation. *American Economic Review*, 91(5), 1369-1401.
- Acemoglu, D., Johnson, S., and Robinson, J.A. (2005). Institutions as a fundamental cause of long-run growth. *Handbook of economic growth*, 1, 385-472.
- Acheampong, A.O., Dzator, J., and Savage, D.A. (2021). Renewable energy, CO₂ emissions and economic growth in sub-Saharan Africa: Does institutional quality matter? *Journal of Policy Modeling*, 43(5), 1070-1093.
- Achuo, E. (2023). Resource wealth and the development dilemma in Africa: The role of policy syndromes. *Resources Policy*, 83, 103644. <<https://doi.org/10.1016/j.resourpol.2023.103644>>
- Adika, G. (2020). Economic growth dynamics between resource-rich and resource-poor countries in sub-Saharan Africa: The role of politics and institutions. *African Development Review*, 1-13. <<https://doi.org/10.1111/1467-8268.12440>>
- African Development Bank Group. (2025). African economic outlook report: Making Africa's capital work better for Africa's development. *Abidjan, Ivory Coast*.
- Aladejare, S.A., and Nyiputen, I.R. (2023). Ecological response to industrialisation drivers in Africa. *Environmental Development*, 47, 100896. <<https://doi.org/10.1016/j.envdev.2023.100896>>
- Atangana Ondo, H. (2013). Gouvernance et croissance économique en Afrique. *African Development Review*, 25(2), 130-147.
- Avom, D., Keneck-Massil, J., Njangang, H., and Nvuh-Njoya, Y. (2022). Why are some resource-rich countries more sophisticated than others? The role of the regime type and political ideology. *Resources Policy*, 103067. <<https://doi.org/10.1016/j.resourpol.2022.103067>>
- Bannor, F., Magambo, I., Mubenga-Tshitaka, J.L., Mduduzi, B., and Osei-Acheampong, B. (2023). Do effective governance and political stability facilitate the promotion of economic growth through natural resource rents? *Evidence from Africa. MPRA Paper No. 116651*. <<https://mpa.ub.uni-muenchen.de/id/eprint/116651>>
- Barro, R.J. (1990). Government Spending in a Simple Model of Endogenous Growth. *The Journal of Political Economy*, 98(5), 103-125.
- Bayili, P.A-R., and Maiga, W.H.E. (2025). Does dependence on natural resource rents reduce the quality of institutions in Africa? *Région et Développement*, 61, 72-95.
- Coase, R.H. (1937). The Nature of the Firm. *Economica*, 16 (4), 386-405.
- Dahmani, M., Mabrouki, M., and Ben Youssef, A. (2022). The Information and Communication Technologies-Economic Growth Nexus in Tunisia: A Cross-Section Dynamic Panel Approach. *Montenegrin Journal of Economics*, 18 (2), 155-168.
- Destek, M.A., Adedoyin, F., Bekun, F.V., and Aydin, S. (2023). Converting a resource curse into a resource blessing: The function of institutional quality with different dimensions. *Resources Policy*, 80, 103234.
- Diallo, S., and Ouoba, Y. (2023). Effect of renewable energy on economic growth in sub-Saharan Africa: Role of institutional quality. *Sustainable Development*, 1-16. <<https://doi.org/10.1002/sd.2855>>

- Diallo, S., and Ouoba, Y. (2024). Effect of energy policies on industrial development in sub-Saharan African countries. *International Journal of Technology Management & Sustainable Development*, 23(1), 105–122. <https://doi.org/10.1386/tmsd_00087_1>
- Dirir, S.A. (2023). The Effect of Institutional Quality on Economic Growth: Evidence from Tripartite Approaches in the Context of War-Torn Countries. *Organizations and Markets in Emerging Economies*, 14(29), 508–535. <<https://doi.org/10.15388/omee.2023.14.3>>
- Driscoll, J.C., and Kraay, A.C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Rev. Econ. Stat.*, 80 (4), 549–560.
- Eberhardt, M. (2012). Estimating panel time-series models with heterogeneous slopes. *Stata J*, 12 (1), 61–71.
- Eberhardt, M., and Teal, F. (2010). Productivity Analysis in Global Manufacturing Production. Department of Economics, University of Oxford. *Discussion Paper* 515. <<http://www.economics.ox.ac.uk/research/WP/pdf/paper515.pdf>>
- Friedman, M. (1937). The use of ranks to avoid the assumption of normality implicit in the analysis of variance. *Journal of the American Statistical Association*, 32(200), 675–701.
- Ha, V., Andre, J., Kim, A.T., and Thi Thu, H.N. (2023). Total factor productivity and institutional quality in Vietnam: which institutions matter most? *Asia-Pacific Journal of Regional Science*, 8, 705–736. <<https://doi.org/10.1007/s41685-024-00343-9>>
- Hall, R.E., and Jones, C.I. 1999. Why Do Some Countries Produce so Much More Output per Worker Than Others? *The Quarterly Journal of Economics*, 114 (1): 83–116. <<https://doi.org/10.1162/003355399555954>>
- Henry, A. (2019). Transmission channels of the resource curse in Africa: A time perspective. *Economic Modelling*, 82, 13-20. <<https://doi.org/10.1016/j.econmod.2019.05.022>>
- Hussen, M.S. (2023). Institutional quality and economic growth in Sub-Saharan Africa: a panel data approach. *Journal of Economics and Development*. <<https://doi.org/10.1108/JED-11-2022-0231>>
- Iheonu, C.O., Ihedimma, G.I., and Onwuanaku, C.S. (2017). Institutional Quality and Economic Performance in West Africa. *MPRA Paper No.* 82212. <<https://mpra.ub.uni-muenchen.de/id/eprint/82212>>
- Iyke, N.B. (2016). Does Trade Openness Matter for Economic Growth in the CEE Countries? *MPRA Paper* n°78869, posted 1.
- Jaunky, V.C. (2013). Democracy and economic growth in Sub-Saharan Africa: a panel data approach. *Empirical Economics*, 45, 987-1008. Retrieved from <[https:// link.springer.com/article/10.1007/s00181-012-0633-x](https://link.springer.com/article/10.1007/s00181-012-0633-x)>
- Lassoued, T., Hamida, A., and Hadhek, Z. 2019. Les effets de la gouvernance sur la croissance économique. Conference Paper. <<https://www.researchgate.net/publication/332108225>>
- Law, S.H., Lim, T.C., and Ismail, N.W. 2013. Institutions and economic development: A Granger causality analysis of panel data evidence. *Economic Systems*, 37, 610-624. <<https://doi.org/10.1016/j.ecosys.2013.05.005>>
- Liko, E. (2024). Institutional quality and economic growth: Evidence from developing countries. *Journal of Governance & Regulation*, 13(2), 395–402. <<https://doi.org/10.22495/jgrv13i2siart15>>
- Lucas, R. (1988). On the Mechanics of Economic Development. *Journal of Monetary Economics*, 22, 3-42.

- Mahran, H. (2023). The impact of governance on economic growth: spatial econometric approach. *Review of Economics and Political Science*, 8(1), 37-53. <<https://doi.org/10.1108/REPS-06-2021-0058>>
- Mankiw, G., Romer, D., and Weil, D. 1992. A Contribution to the Empirics of Economic Growth. *Q. J. Econ*, 107(2), 407–437.
- Manwa, F., Wijeweera, A., and Kortt, M.A. 2019. Trade and growth in SACU countries: A panel data analysis. *Economic Analysis and Policy*, 63, 107-118.
- Misi Lopes, L.E., Packham, N., and Walther, U. 2023. The effect of governance quality on future economic growth: an analysis and comparison of emerging market and developed economies. *SN Bus Econ*, 3(6). <<https://doi.org/10.1007/s43546-023-00488-3>>
- Mtiraoui, A. (2020). Qualité institutionnelle et croissance économique: application sur données de panel dynamique (GMM). *Qualité institutionnelle et croissance économique*. hal-02740504. <<https://hal.science/hal-02740504v1>>
- North, D. (1990). Institutions, Institutional Change and Economic Performance. *Cambridge University Press, Cambridge, UK*.
- North, D. (1993). Institutions and Credible Commitment. *Journal of Institutional and Theoretical Economics*. 149, 11-23.
- North, D., and Thomas, R. 1973. The Rise of the Western World: A New Economic History. *Cambridge University Press, New York*. <<https://doi.org/10.1017/CBO9780511819438>>
- North, D.C. (1981). Structure and Change in Economic History. New York and London: W. W. Norton & Co. *Politics & Society*, 11, 4: 511-512. <<https://doi.org/10.1177/003232928201100416>>
- North, D.C. (1991). Institutions. *Journal of Economic Perspectives*, 5 (1): 97–112.
- Ouoba, Y. (2020). Natural resources fund types and capital accumulation: A comparative analysis. *Resources Policy*, 66, <<https://doi.org/10.1016/j.resourpol.2020.101635>>
- Pesaran, M. (2004). General Diagnostic Tests for Cross-Section Dependence in Panels. *Discussion Paper No.* 1240.
- Pesaran, M.H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, 22(2), 265-312. <<https://doi.org/10.1002/jae.951>>
- Pesaran, M.H., and Yamagata, T. (2008). Testing slope homogeneity in large panels. *J. Econom.* 142 (1), 50–93.
- Pesaran, M.H, Ullah, A., and Yamagata, T. (2008). (2008) A bias-adjusted LM test of error cross-section independence. *Econ J*, 11, 105–127. <<https://doi.org/10.1111/j.1368.423X.2007.00227.x>>
- Ricardo, D. (1817). On the Principles of Political Economy and Taxation, London. *Cambridge University Press, Cambridge: In: Sraffa, P., Ed., The Works and Correspondence of David Ricardo*, 1.
- Rodrik, D., Subramanian, A., and Trebbi, F. (2004). Institutions Rule: The Primacy of Institutions Over Geography and Integration in Economic Development. *Journal of Economic Growth*, 9, 131-165.
- Romer, P. (1986). Increasing Returns and Long Run Growth. *Journal of Political Economy*, 94(5), 1002-1037.
- Salman, M., Long, X., Dauda, L., and Mensah, C.N. (2019). The impact of institutional quality on economic growth and carbon emissions: Evidence from Indonesia, South Korea, and Thailand. *Journal of Cleaner Production*, 241, 118331. <<https://doi.org/10.1016/j.jclepro.2019.118331>>

- Smith, A. (1776). Recherches sur la nature et les causes de la richesse des nations. *Paris: Adolphe Blanqui* en 1843.
- Solow, R.M. (1956). A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics*, 70(1): 65-94.
- Thi Tran, O.K., Le, H.D., and Viet Nguyen, A.H. (2021). Role of institutional quality in economic development: A case study of Asian countries. *Problems and Perspectives in Management*, 19(2), 357-369. <[http://dx.doi.org/10.21511/ppm.19\(2\).2021.29](http://dx.doi.org/10.21511/ppm.19(2).2021.29)>
- Uddin, I., Ahmad, M., Ismailov, D., Balbaa, M.E., Akhmedov, A., Khasanov, S., and Haq, M.U. (2023). Enhancing institutional quality to boost economic development in developing nations: New insights from CS-ARDL approach. *Research in Globalization*, 7, 100137. <<https://doi.org/10.1016/j.resglo.2023.100137>>
- Votsoma, P., Djekna, V., and Mwa Ndjokou, I.M.M. (2024). Ouverture commerciale et croissance économique dans la Communauté économique et monétaire des États de l'Afrique centrale: le réexamen des preuves empiriques a-t-il de l'importance? *Mondes en Développement*, 205 (1), 51-70. 10.3917/med.205.0051. <<https://hal.science/hal-04560475v1>>
- Westerlund, J. (2007). Testing for error correction in panel data. *Oxford Bulletin of Economics and Statistics*, 69(6), 709-748. <<https://doi.org/10.1111/j.1468-0084.2007.00477.x>>
- Williamson, O. (1994). Visible And Invisible Governance. *American Economic Review*. 84(2), 323-326.
- Williamson, O. (2000). The New Institutional Economics: Taking Stock, Looking Ahead. *Journal of Economic Literature*, 38 (3), 595-613.
- Williamson, O. E. (1975). Markets and Hierarchies: Analysis and Antitrust Implications. *A Study in the Economics of Internal Organization*, New York: The Free Press.
- World Bank. (2024a). World Development Indicators. Washington, D.C. <<https://databank.worldbank.org/source/world-development-indicators>>
- World Bank. (2024b). *World Governance Indicators*. Washington, D.C.
- World Development Indicators. (2025). *Base de données de la Banque Mondiale*, Washington, D.C.
- Zahonogo, P. (2017). Trade and economic growth in developing countries: Evidence from Sub-Saharan Africa. *Journal of African Trade*, 3, 41-56. <<http://dx.doi.org/10.1016/j.joat.2017.02.001>>
- Zuo, S., Zhu, M., Xu, Z., Oláh, J., and Lakner, Z. (2022). The Dynamic Impact of Natural Resource Rents, Financial Development, and Technological Innovations on Environmental Quality: Empirical Evidence from BRI Economies. *Int. J. Environ. Res. Public Health*, 19, 130. <<https://doi.org/10.3390/ijerph19010130>>

Appendix A

Table A 1. *List of countries*

1. Benin	6. Ghana	11. Niger
2. Burkina Faso	7. Guinea	12. Nigeria
3. Cape Verde	8. Guinea-Bissau	13. Senegal
4. Ivory Coast	9. Mali	14. Sierra Leone
5. Gambia	10. Mauritania	15. Togo

Source: Authors

Table A2. *Variables, definitions, and sources*

Variables	Definition	Source
Economic growth	Gross Domestic Product (GDP) per capita growth (annual %)	WDI (2024)
Human capital	Gross primary school enrolment	WDI (2024)
Trade openness	The sum of exports and imports (% of GDP)	WDI (2024)
Total natural resources rents	Sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents.	WDI (2024)
Control of corruption	Reflects perceptions of the extent to which public power is exercised for private gain.	WGI (2024)
Government effectiveness	Reflects perceptions of the quality of public services, civil service, and the degree of its independence from political pressures.	WGI (2024)
Political stability and absence of violence	Measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism.	WGI (2024)
Quality of regulation	Reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.	WGI (2024)
Rule of law	Reflects perceptions of the extent to which agents have confidence in and abide by the rules of society.	WGI (2024)
Voice and accountability	Reflect perceptions of the extent to which a country's citizens can participate in selecting their government, as well as freedom of speech and association, and an independent media.	WGI (2024)
Institutional quality		Author's calculations

Source: Authors

Table A3. *Descriptive statistics*

Variables	Obs	Mean	Std. Dev.	Min	Max
GDP per capita growth	360	1.810	3.975	-22.313	19.4307
Institutional quality index	360	0.386	0.204	0	1
Economic governance index	360	0.416	0.177	0	1
Political governance index	360	0.499	0.217	0	1
Institutional governance index	360	0.389	0.207	0	1
Control of corruption	360	0.373	0.196	0	1
Government effectiveness	360	0.350	0.148	0	1
Political stability	360	0.558	0.207	0	1
Quality of regulation	360	0.520	0.194	0	1
Rule of law	360	0.426	0.224	0	1
Voice and accountability	360	0.454	0.242	0	1
Human capital	360	90.001	20.078	31.847	156.802
Trade openness	360	4.007	0.355	2.794	4.769
Total natural resources rents	360	9.731	6.777	1.972	49.206

Source: Authors

Table A4. *Correlation matrix*

	GDP per capita growth	Institutional quality index	Human capital	Trade openness	Total natural resources rents
GDP per capita growth	1				
Institutional quality index	0,154	1			
Human capital	0,125	0,111	1		
Trade openness	0,136	0,358	0,246	1	
Total natural resources rents	0,140	0,010	0,200	0,332	1

Source: Authors**Table A5:** *Results of the principal component analysis (PCA)*

Component	Eigenvalue	Proportion	Cumulative			
1	4.6659	0.7777	0.7777			
2	0.5756	0.0959	0.8736			
3	0.3411	0.0568	0.9304			
4	0.1765	0.0294	0.9599			
5	0.1427	0.0238	0.9836			
6	0.0981	0.0164	1			
Indicators	CC	GE	PS	RQ	RL	VA
KMO Index	0.9231	0.9096	0.9290	0.9109	0.8676	0.9365
Bartlett test		Statistics of χ^2 (p-value)		Average KMO index		
		2169.190 (0.000)		0.909		

Source: Authors

A dynamic panel data analysis of the asymmetric impact of labour cost on intra-EU migration

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Abstract. *This paper investigates the main factors influencing migration inflows within the European Union over the 2013-2024 period. Using a dynamic panel data approach based on the Arellano-Bond GMM estimator, it accounts for persistence in migration patterns and potential endogeneity in socio-economic indicators. The research focuses on the differences between high- and low-inflow countries regarding “push” and “pull” migration factors. Primary results show that labour cost increases act as a significant “pull” factor in high-immigration states, whereas in low-immigration countries it loses statistical significance. Notably, the NEET rate emerges as the strongest inhibitor of immigration across the EU-27, having a substantial negative impact in the low-inflow country model. Moreover, the old age dependency ratio behaves like a “push” factor, while GDP per capita growth positively shapes migration dynamics. These findings suggest that EU migration policies should address the asymmetrical influence of labour cost on intra-EU migration through targeted interventions.*

Keywords: labour cost, intra-EU migration, dynamic panel data analysis, high versus low immigration, EU-27 countries.

JEL Classification: F22, C23, J30.

1. Introduction

The context of intra-European labour migration has undergone important transformations in the last three decades regarding proactive integration of labour force. The evolution towards a united labour market was first signalled by the adoption of the Citizens' Right Directive 2004/38/EC (European Parliament & Council of the European Union, 2004) and later by the introduction of the Regulation 492/2011 on Freedom of Movement for Workers within the European Union (EU) (European Parliament & Council of the European Union, 2011). These two constitute the pillars of free movement and residence of people and workers across the European Economic Area (EEA), thus eliminating work permit and residency restrictions and helping promote more migration between the founding countries of the EU and newer member states. However, only on January 1st, 2014, were the last obstacles removed, workers from Romania and Bulgaria receiving full rights (European Commission, 2014), followed by the progressive integration of Croatian labour force through 2020 (European Commission, 2015).

Given the absence of formal barriers between the EU countries, labour force is spatially reallocated mainly through the interaction of "push" and "pull" socio-economic factors, as conceptualized by Lee (1966). Therefore, migrants selectively respond either to factors affecting their country of origin or to those influencing their destination. This behaviour is then explored by Harris and Todaro (1970), treating migrants as rational actors who take into consideration the costs and benefits of their choice of migration, especially regarding the levels of wages and job opportunities. However, their choice of destination could often be shaped by interpersonal income comparisons to their reference group rather than individualistic reasons, as suggested by Stark and Bloom (1985). Thereby, low-income individuals who decide to move may trigger another migration round since the relative income deprivation of those remaining increases, creating a self-perpetuating migration cycle. This dynamic is further on reinforced in the study of Massey et al. (1993), stating that existing migration stocks in the destination countries act like a "pull" factor because the expansion of migrants' networks lowers the risks and costs of newcomers.

Building upon the above-mentioned legislative and theoretical framework, the aim of this paper consists in investigating the main factors that trigger or inhibit migration inflows around the European Union, by considering "pull" factors like GDP per capita growth or labour cost, along with "push" factors like the NEET rate and old age dependency ratio among others. As methodological approach, several Arellano-Bond dynamic panel models were estimated for the period 2013-2024 at the following territorial levels: (1) the EU-27; (2) the European country sub-sample with higher-than-average immigration flows; and (3) the European country sub-sample with lower-than-average immigration flows, respectively. As main research question (RQ), the paper aims to answer the following question:

RQ: Are there any divergences in terms of "pull" and "push" factors on intra-EU migration between the high versus low inflow countries?

The structure of the paper is the following: Section 2 briefly tackles the literature review on the topic of migration factors, while Section 3 is dedicated to the methodology and data

description. Section 4 summarizes the main results and discusses the implications of the main findings, while the last section concludes.

2. Literature review

The landscape of empirical research on European migration has traditionally been dominated by macro-econometric frameworks, primarily gravity-type or “push and pull” models. In these early specifications, bilateral migration flows were typically regressed against a foundational set of variables, including GDP per capita, wage gaps, unemployment differentials, and proxies for migration costs such as geographic distance and colonial ties (Mayda, 2010). Panel data estimations within this tradition consistently identified income levels and labour market conditions as the primary predictors of intra-EU mobility (Afonso et al., 2025).

However, the last decade has witnessed a significant evolution in both the conceptualization of migration drivers and the analytical toolkit employed by scholars. Methodologically, the field has transitioned from static gravity equations (Belu et al., 2025) toward more sophisticated dynamic panel models and instrumental-variable approaches designed to mitigate endogeneity between migration and economic performance (Åslund, 2005). Theoretically, this shift reflects a move away from viewing migration as a mere response to isolated economic signals, moving instead toward a complex interaction of individual aspirations, capabilities, and structural constraints (de Haas, 2021). This multi-layered perspective is often categorized through the distinction between predisposing, proximate, precipitating, and mediating factors (Van Hear et al., 2012; Manafi & Roman, 2022), allowing for a more nuanced inclusion of institutional variables such as welfare-state generosity and labour market regulations (De Giorgi & Pellizzari, 2009).

Parallel to these theoretical advances, recent literature has increasingly adopted data-driven classification and dimensionality-reduction techniques. Methods like cluster analysis are now frequently used to move beyond simple linear relationships, allowing researchers to identify distinct typologies of migration regimes and multidimensional driver profiles (Kumpikaitė-Valiūnienė et al., 2025; Rosińska, 2024). These approaches are particularly effective at detecting latent patterns within combined economic, demographic, and socio-political factors (Manafi & Roman, 2022).

Despite this broadening, a critical gap persists in capturing the dynamic nature of migration triggers, especially when accounting for the inherent endogeneity and persistence of flows within the EU-27. While previous studies often rely on static frameworks, they frequently overlook the “Nickell bias” and the complex feedback loops between immigration and labour market indicators. This study addresses these shortcomings by employing a dynamic panel data approach based on the Arellano-Bond estimator. By incorporating a lagged dependent variable and transforming regressors through first differencing, we provide a more robust estimation of how factors like GDP growth, labour costs, and NEET rates shape immigration dynamics. Furthermore, we differentiate the analysis by categorizing EU states into high- and low-inflow groups, allowing for a comparative investigation into how these drivers vary across different migratory regimes.

3. Data description and methodology

For this research, yearly data for the period 2013-2024 regarding the EU-27 countries was used. The following indicators collected from the Eurostat database were taken into consideration: intra-EU immigration (*immig*) as dependent variable, GDP per capita growth (*gdp_cap_growth*), labour cost change (*lab_cost_c*), NEET rate (*neet_r*), old age dependency ratio (*old_age_dep*), Gini coefficient (*gini_coef*), net earnings (*net_earn*), corruption perception index (*corrupt_i*), and life expectancy at birth (*life_exp*) as independent variables.

Intra-EU immigration is represented by the number of immigrants whose origin residence country belongs to the EU and destination country is also an EU member state. Immigration flows are aggregated for the EU-28 for the period 2013-2019, and for the EU-27 for the period 2020-2024, after the Brexit, with a missing value for Portugal in 2024.

GDP per capita growth is expressed in chain linked volumes as percentage change on previous period, showing the growth in real terms. Labour cost change represents the percentage change on previous period of nominal unit labour cost based on hours worked. NEET is an abbreviation coming from young persons neither in employment nor in education. Its rate is calculated as the number of youth aged 15-29 in one of the situations previously mentioned in relation to the total number of youth aged 15-29. Old age dependency ratio is expressed as the total population aged 65+ in relation to the total population aged 15-64. A missing value of this indicator exists for Greece in 2024.

Further on, Gini coefficient of equivalised disposable income is measured on a scale from 0 to 100, where 0 means perfect equality, while 100 means maximum inequality. For this indicator, there are missing values in 2013. Net earnings represent the difference between gross earnings and social security contributions and income taxes for a single person without children earning 50% of the average wage, being expressed in purchasing power standard. Missing values were found for Cyprus in 2013, 2015 and 2016. Corruption perception index is a composite indicator highlighting people's perception of how corrupt the public sector is. It can take values between 0 (very high level of corruption) and 100 (very low level of corruption). Finally, life expectancy at birth is the mean number of years expected for a newborn to live, given specific mortality conditions. For comparability reasons, variables expressed in other units of measurement than percentage points or values between 0 to 100 were transformed by applying the logarithm.

The econometric analysis was mainly based on dynamic panel data estimations, using R and RStudio, consisting of Arellano-Bond models. Developed by Arellano and Bond (1991), this type of model employs a generalized method of moments (GMM) estimator, focusing on individual effects, a lagged dependent variable and no strictly exogenous variables. The general equation of the standard dynamic specification follows the form:

$$y_{it} = \alpha y_{i,t-1} + \beta x'_{it} + \eta_i + \epsilon_{it}$$

where y_{it} is the dependent variable, $y_{i,t-1}$ represents the first-order lag of the dependent variable, x'_{it} comprises the explanatory factors, while η_i and ϵ_{it} account for the unobserved effects, respectively the individual fixed effect and the idiosyncratic error.

The Arellano-Bond model was designed to address the dynamic panel bias, also known as the “Nickell bias”, which appears when the correlation between the lagged dependent variable and the unobserved effects exists, resulting in inconsistent estimations (Nickell, 1981; Bond, 2002). Thus, all model regressors are usually first differenced to eliminate the fixed effect (Anderson & Hsiao, 1981), building a GMM system composed of the standard dynamic panel equation and the transformed one. Apart from this, instruments are introduced by using the lags of the dependent and independent variables to control for endogeneity. However, it should be noted that the Arellano-Bond model ought to be applied to datasets in which the number of cross-sectional units (N) is larger than the number of time periods (T), and that the number of instruments used should be limited because it tends to increase depending on T (Roodman, 2009).

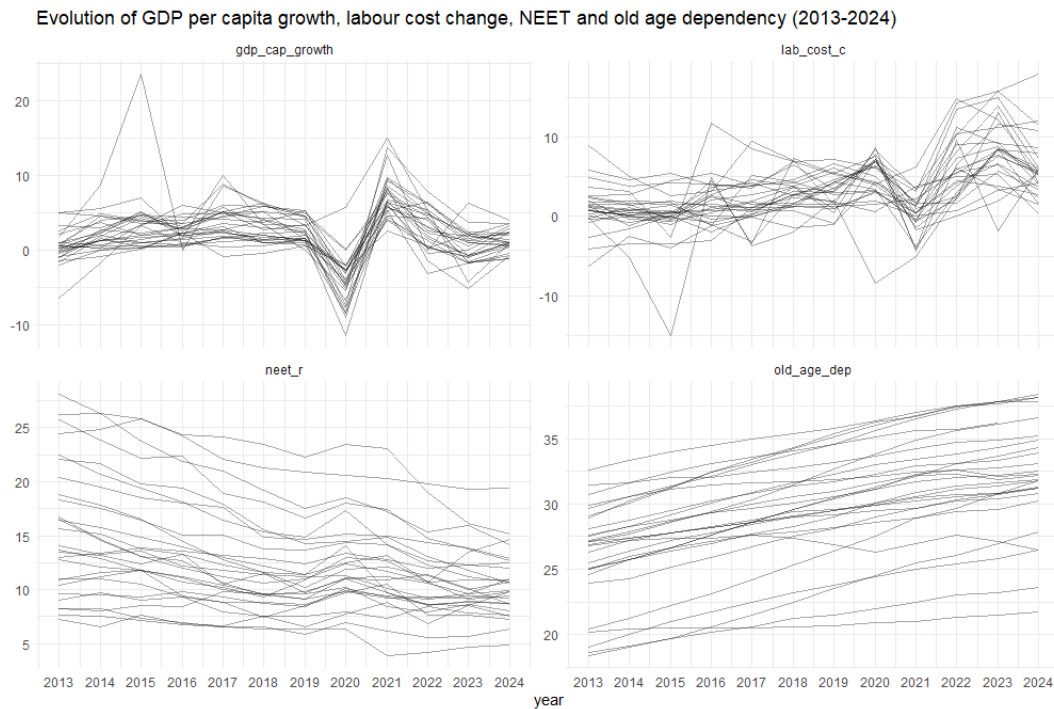
To validate the Arellano-Bond estimations, a suite of diagnostic tests can be used. The Wald test adapted for the GMM estimation checks the joint significance of explanatory factors, whereas the Sargan test indicates the validity of the instruments introduced in the model (Sargan, 1958). Other important tests include the ones for the presence of autocorrelation: AR(1) test which looks for first-order serial correlation in the differenced error term, and AR(2) test which checks the exogeneity of instruments. The expected results of these two tests should indicate first-order serial correlation in differenced residuals, with exogenous instruments, along with no second-order serial correlation of errors.

4. Results and discussion

Based on the initial dataset, the Arellano-Bond model was estimated by also incorporating the first lag of intra-EU immigration into the model. The estimations showed that the Gini coefficient, net earnings, corruption perception index and life expectancy at birth were statistically insignificant, while GDP per capita growth, labour cost change, NEET rate and old age dependency ratio significantly shaped immigration. Moreover, as expected, the first lag of immigration was influential, emphasizing the importance of previous year immigration flow in explaining its dynamic.

Figure 1 illustrates the evolution of the significant independent variables for the period 2013-2024. GDP per capita recorded visible volatility throughout the chosen time interval, showing relative moderate growth in the pre-pandemic years, followed by a sharp contraction in 2020 caused by the COVID-19 crisis. This decline was then succeeded by a notable recovery in 2021, and a stabilization afterwards. In the case of labour cost changes, the fluctuations were moderate, presenting an upward trend in the later years of the period, which may reflect wage adjustments during the post-pandemic economic rebound.

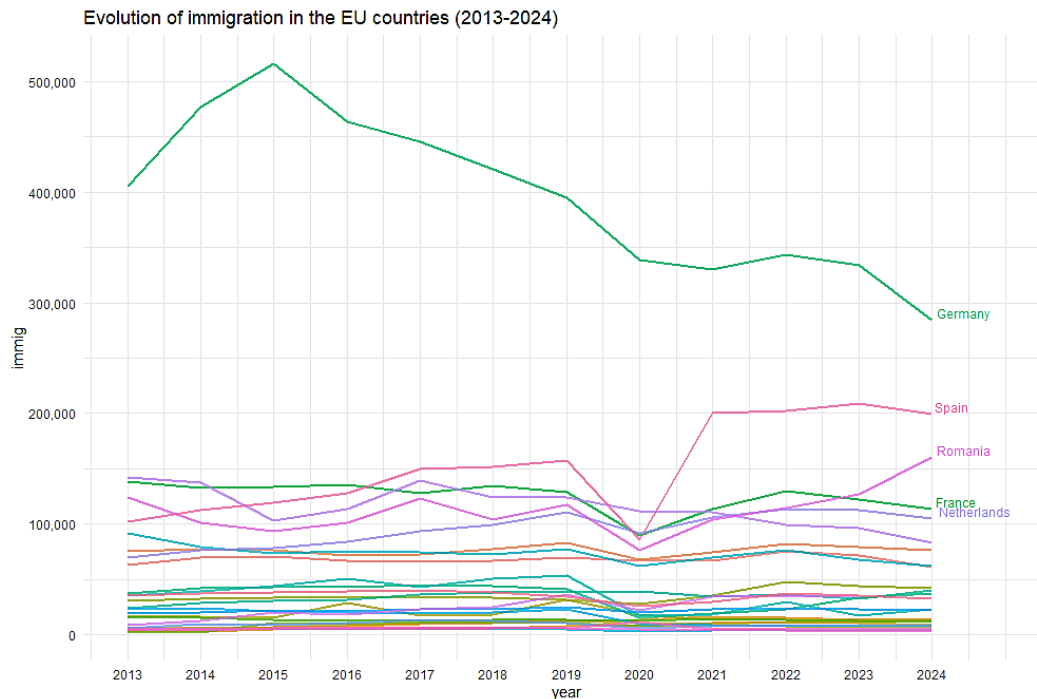
In contrast, the NEET rate presented a general downward trend across most EU-27 states, highlighting improvements in the youth integration regarding labour market and education. However, there was a temporary increase concerning the year 2020, indicating a disruption caused by the pandemic. By the end of the period, the rates were considerably lower than at the beginning of it. Finally, old age dependency ratio had a consistent upward trajectory across almost all countries, emphasizing a long-term structural demographic ageing.

Figure 1. *Evolution of significant independent variables (2013-2024)*

Source: authors' own computation in RStudio.

Figure 2 presents the evolution of the number of intra-EU immigrants across the EU-27 states between 2013 and 2024, highlighting a substantial cross-country heterogeneity in both the level and dynamics of the phenomenon. Germany represented the primary destination state throughout the entire period, reaching a peak of more than 500,000 immigrants in 2015, being mostly associated with the European migration crisis. Even though the flows gradually decreased afterwards, this country continued to receive the highest number of immigrants, remaining above 250,000 in 2024. Being the second major destination country with around 200,000 immigrants in 2024, Spain recorded an increase in immigration until 2019, followed by a sudden drop in 2020, then a strong recovery and a stabilization from 2021 on. In contrast, Romania showed an upward trend in recent years after presenting moderate inflows. In 2024, this country placed on the third position, with around 160,000 immigrants. Compared to Germany and Spain, France and Netherlands exhibited more stable levels of immigration throughout the period. The remaining EU states had lower numbers of immigrants, with temporary declines at the beginning of pandemic across most of them.

Overall, the figure emphasizes noticeable and persistent differences between the EU-27 states regarding intra-EU immigration. Structural factors, such as economic development, labour market conditions, youth integration and demographic pressure, are likely to contribute to these cross-country disparities, thus the need of including individual effects in the empirical model.

Figure 2. *Evolution of immigration in the EU-27 member states (2013-2024)*

Source: authors' own computation in RStudio.

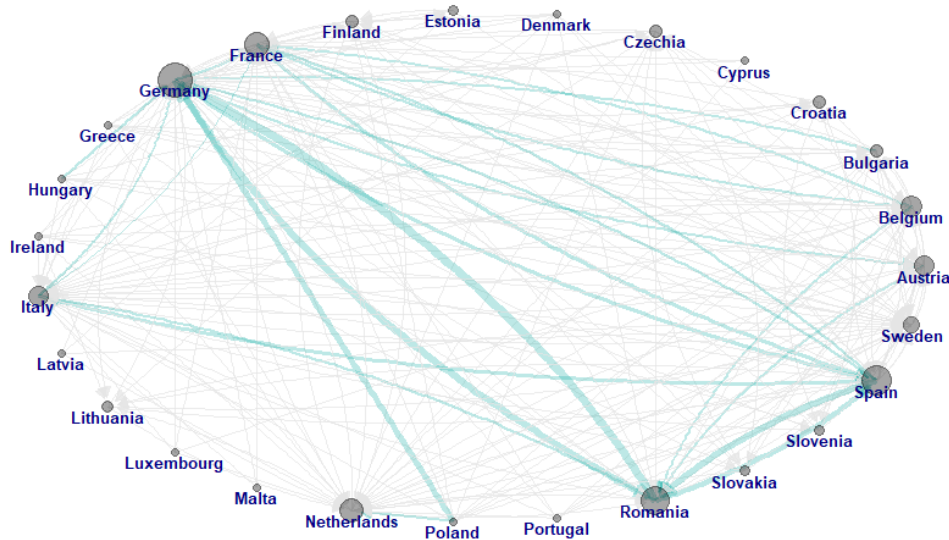
Further on, the EU-27 states were divided into two groups regarding the number of immigrants registered in 2024: states with higher-than-average immigration flows (Austria, Belgium, France, Germany, Italy, Netherlands, Poland, Romania, Spain) and states with lower-than-average immigration flows. Figure 3 shows the social network of immigrants between the EU countries in 2024, where the states are the nodes, while migration flows are depicted as directed edges. The magnitude of the flows is given by the thickness of links, whereas the node size signifies the in-strength of a country, represented by the total incoming volume of migrants. For clarity, only the top 50% of flows are displayed, the strongest ones being highlighted.

Concerning the states with higher-than-average immigration flows, the in-strength of Poland is underrepresented due to missing data. Apart from this, the network reveals a highly concentrated migration system, with a few countries being important immigration destinations. Germany emerges as the central node, attracting migrants from many EU states, but the most dominant edges come from Romania (22.6% of total volume), Poland (15.6%), Italy (8.2%) and Bulgaria (8%). Spain is another crucial destination, receiving migrants especially from Romania (19.3%), France (15.7%), Italy (15.6%) and Germany (14.1%). Romania represents not only an important source of immigration towards Western and Southern Europe, but also an attractive destination for migrants from Germany (36%), Spain (29.3%), Austria (9.8%) and Belgium (9.6%). France and Netherlands occupy an

intermediate position, with fewer migrants absorbed. In this case, among the origin countries are Belgium, Spain, Germany, Poland and Italy.

Figure 3. Immigration network between the EU-27 member states (2024)

Immigration network between the EU countries (2024)



Source: authors' own computation in RStudio.

Next, two more distinct Arellano-Bond models were built at the following territorial levels: (1) the high immigration flow countries; and (2) the low immigration flow countries, respectively. Together with the general UE-27 model, the validity of the joint significance of explanatory factors was checked for all three models by applying the Wald test, with p-value being under the 1% threshold. The autocorrelation tests confirmed the presence of the first-order autocorrelation and the absence of the second-order one, while the Sargan test indicated that the instruments used were appropriate.

For the EU-27 model, the coefficient of the first lag of immigration was positive, suggesting that a 1% increase in the previous period immigration would lead to a 0.58% increase in the current period. Also, GDP per capita growth presented a positive influence on the flows of immigrants, a one-percentage-point rise in the independent variable conducting to a 2.39% surge in immigration. Labour cost exerted a positive impact on the number of immigrants, a one-percentage-point higher labour cost producing a 1.02% higher immigration. Unlike the rest, the NEET rate and old age dependency ratio presented a negative effect on attracting immigrants. A one-percentage-point increase in NEET rate would inflict a 5.39% decrease in immigration, the strongest impact of all independent variables, while a one-percentage-point surge in old age dependency ratio would have a 5.33% decline in the number of immigrants.

Comparing high-immigration country model with the low-immigration country one, labour cost change was considerably significant in the first model, but insignificant in the second one. Regarding the previous period immigration, both models have a lower impact on the

current dynamics of immigrants, with weaker significance in the high immigration flow model. The effect of the GDP per capita growth is strongest in the high immigration flow model specification, emphasizing that migrants better responded to economic expansion in preferred destination countries. In the case of labour cost change, its influence gained importance in the model with countries with high immigration, a one-percentage-point increase in this variable determining a 1.35% decrease in the number of immigrants. As an exception, NEET rate was kept in the high-immigration model, having a p-value of 0.15. In comparison with the EU-27 model, this indicator presented a higher impact in the low-immigration model, becoming its strongest factor. Finally, old age dependency ratio had a significant influence on both models but lost a part of its significance. However, this indicator exerted the most substantial effect on immigration in the high-immigration model, a one-percentage-point surge in old age dependency ratio leading to a 3.77% decline in the number of immigrants.

Table 1. Results of Arellano-Bond models

Variable	EU-27 model	High immigration flow model	Low immigration flow model
<i>lag (log_immig, 1)</i>	0.5875*** (0.1207)	0.3798* (0.2276)	0.4999*** (0.118)
<i>gdp_cap_growth</i>	0.0239*** (0.0056)	0.0289*** (0.0059)	0.014** (0.0059)
<i>lab_cost_c</i>	0.0102** (0.004)	0.0135** (0.0041)	
<i>neet_r</i>	-0.0539*** (0.0177)	-0.0305 (0.0216)	-0.075*** (0.0213)
<i>old_age_dep</i>	-0.0533*** (0.0186)	-0.0377* (0.0214)	-0.0595** (0.0273)
Sargan test p-value	0.153	0.437	0.159
Autocorrelation test (1) p-value	0.014	0.041	0.042
Autocorrelation test (2) p-value	0.546	0.4	0.804
Wald test p-value	0.000	0.000	0.000
Number of observations	268	90	178
Number of countries	27	9	18
Number of years	12	12	12

Note: *** significant at a threshold of 1%, ** significant at a threshold of 5%, * significant at a threshold of 10%.

Source: authors' own computation in RStudio.

The most notable finding of this study consists in the asymmetric impact of labour cost changes on intra-EU migration between the high versus low inflow countries. Based on the two comparative models, we found that for countries with high immigration flows, labour cost plays as a significant driver in the EU-27, while it becomes statistically irrelevant for the low-immigration group. On the one hand, the positive elasticity in high-immigration flow model might seem counter-intuitive from a firm's perspective, but could suggest that from a migrant's perspective, rising labour costs act as a "pull" factor, as it signals prosperity and better compensation packages in the destination countries. This is particularly the case of Germany or Spain, which dominate the immigration network and where the upward trend in labour costs in the post-pandemic rebound reflects attractive wage adjustments for migrant EU workers.

On the other hand, in the low-immigration flow model, labour cost changes were found to be insignificant, suggesting that for these countries, the migrant's decision is governed by

structural barriers rather than marginal cost or wage changes. Specifically, the high negative impact of the NEET rate and old age dependency in this group indicates that labour market rigidity and demographic decline are far more critical factors for potential immigrants than the nominal labour cost dynamic.

5. Conclusions

Through this paper we intended to investigate the main factors that trigger or inhibit migration inflows around the European Union using Arellano-Bond dynamic panel models. Our findings highlight as the main significant “pull” factor the GDP per capita growth and labour cost changes, while as “push” factors the NEET rate and old age dependency ratio.

As main research question of the paper we were particularly interested in finding out the presence of any divergences in terms of “pull” and “push” factors on intra-EU migration between the high versus low inflow countries. Our findings underscore that the factors attracting migrants are not uniform across the Union. The most striking finding of this divergence lies in the role of labour cost changes. In high-immigration countries, rising labour costs act as a significant “pull” factor, as it might positively signal wage growth and market vitality in the destination countries. Conversely, in low-immigration countries, this factor loses its significance, suggesting that markets in this group of countries are governed by more rigid structural barriers.

Moreover, the research highlights the network persistence, as the presence of the lagged dependent variable across models underscores the path-driven phenomenon of migration, where previous flows facilitate future ones through already established social and economic networks. In terms of economic context, GDP per capita growth remains a universal “pull” factor, with its strongest influence observed in preferred destination countries. Finally, in terms of structural inhibitors, the NEET rate and old age dependency ratio act as powerful negative factors to immigration. The particularly high negative impact of the NEET rate in low-immigration states suggests that poor youth integration and demographic ageing create a “push” effect that nominal economic gains cannot easily offset.

In conclusion, EU migration policy should address the asymmetric impact of labour costs on intra-EU migration through targeted interventions: high-inflow states must manage the integration challenges of rapid growth, while low-inflow states should focus on domestic structural reforms aiming to reduce NEET rates and to improve their overall attractiveness and labour market resilience.

The main limitations of the study are twofold. First, there is the issue of data availability and the methodological restrictions of the Arellano-Bond model to use only a limited number of instruments in the analysis. Second, dynamic panel data estimators are highly sensitive to the specific model specification and the choice of instruments, leading us to a trade-off between having a panel model with higher explanatory power by including the lagged dependent variable in the explanatory list, and dealing with the “Nickell bias” on samples with relatively balanced panels in terms of cross-units and time periods.

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References

- Afonso, A., Alves, J., and Beck, K. (2025). Drivers of migration flows in the European Union: earnings or unemployment? *International Labour Review*, 164(2), 1-23.
- Anderson, T.W., and Hsiao, C. (1981). Estimation of Dynamic Models with Error Components. *Journal of the American Statistical Association*, 76(375), 598-606.
- Arellano, M., and Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *The Review of Economic Studies*, 58(2), 277-297.
- Åslund, O. (2005). Now and forever? Initial and subsequent location choices of immigrants. *Regional Science and Urban Economics*, 35(2), 141-165.
- Belu, M.B., Cimpoeu, S., Popescu, M.E., and Cristescu, A. (2025). Mapping Regional Employment Divergences in North-South Europe Through Spatial Models. *Economies*, 13(12), 345.
- Bond, S.R. (2002). Dynamic panel data models: a guide to micro data methods and practice. *Portuguese Economic Journal*, 1(2), 141-162.
- De Giorgi, G., and Pellizzari, M. (2009). Welfare migration in Europe. *Labour Economics*, 16(4), 353-363.
- de Haas, H. (2021). A theory of migration: the aspirations-capabilities framework. *Comparative Migration Studies*, 9, 8(2021).
- European Commission (2014). *End of restrictions on free movement of workers from Bulgaria and Romania - statement by László Andor, European Commissioner for Employment, Social Affairs and Inclusion*. Retrieved from <https://ec.europa.eu/commission/presscorner/detail/en/memo_14_1>
- European Commission (2015). *Commission report on transitional arrangements regarding free movement of workers from Croatia*. Retrieved from <https://ec.europa.eu/commission/presscorner/detail/hr/memo_15_5068>
- European Parliament, and Council of the European Union (2004). *Directive 2004/38/EC on the right of citizens of the Union and their family members to move and reside freely within the territory of the Member States*. Retrieved from <<https://eur-lex.europa.eu/eli/dir/2004/38/oj/eng>>
- European Parliament, and Council of the European Union (2011). *Regulation (EU) No 492/2011 on freedom of movement for workers within the Union Text with EEA relevance*. Retrieved from <<https://eur-lex.europa.eu/eli/reg/2011/492/oj/eng>>
- Harris, J.R., and Todaro, M.P. (1970). Migration, unemployment and development: a two-sector analysis. *The American Economic Review*, 60(1), 126-142.

- Kumpikaitė-Valiūnienė, V., Žičkutė-Daugelavičienė, I., Glińska, E., Rollnik-Sadowska, E., and Mockaitis, A.I. (2025). Exploring pull migration drivers to the European Union: A systematic literature review and future research agenda. *International Journal of Intercultural Relations*, 109, 102296.
- Lee, E.S. (1966). A Theory of Migration. *Demography*, 3(1), 47-57.
- Manafi, I., and Roman, M. (2022). A Way to Europe: New Refugees' Migration Patterns Revealed. *Sustainability*, 14(2), 748.
- Massey, D.S., Joaquin, A., Hugo, G., Kouaouci, A., Pellegrino, A., and Taylor, J.E. (1993). Theories of International Migration: A Review and Appraisal. *Population and Development Review*, 19(3), 431-466.
- Mayda, A.M. (2010). International migration: A panel data analysis of the determinants of bilateral flows. *Journal of Population Economics*, 23, 1249-1274.
- Nickell, S. (1981). Biases in Dynamic Models with Fixed Effects. *Econometrica*, 49(6), 1417-1426.
- Roodman, D. (2009). How to do xtabond2: An introduction to difference and system GMM in Stata. *The Stata Journal*, 9(1), 86-136.
- Rosińska, A. (2024). *Drivers of Migration: Dimensions and Indicators. A Policy-Oriented Literature Review*. Publications Office of the European Union. Retrieved from <<https://data.europa.eu/doi/10.2760/5771973>>
- Sargan, J.D. (1958). The Estimation of Economic Relationships using Instrumental Variables. *Econometrica*, 26(3), 393-415.
- Stark, O., and Bloom, D.E. (1985). The New Economics of Labor Migration. *The American Economic Review*, 75(2), 173-178.
- Van Hear, N., Bakewell, O., and Long, K. (2012). *Drivers of Migration*. The Institute of Development Studies and Partner Organisations. Retrieved from <<https://hdl.handle.net/20.500.12413/14821>>

Determinants of CO₂ emissions in ASEAN-5: The role of human development, renewable energy, and economic growth

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Abstract. *Environmental pressures in the ASEAN-5 region have intensified alongside accelerated human development and rising carbon emissions driven by industrialization. This study examines the impact of human development, renewable energy consumption, and economic growth on CO₂ emissions in ASEAN-5 countries. Using annual panel data from 2000–2019, the Autoregressive Distributed Lag (ARDL) approach is employed to analyze both short-run and long-run relationships. The results show that, in the long run, human development significantly increases CO₂ emissions, while renewable energy consumption and economic growth contribute to emission reductions. In the short run, human development and renewable energy consumption have no significant effect, whereas economic growth exerts a positive and significant impact on CO₂ emissions. The findings also support the Environmental Kuznets Curve (EKC) hypothesis in the ASEAN-5 region. These results underscore the importance of promoting clean energy transitions and strengthening human development policies to achieve sustainable economic growth and carbon emission mitigation.*

Keywords: CO₂ emissions, human development, renewable energy, economic growth, ASEAN-5.

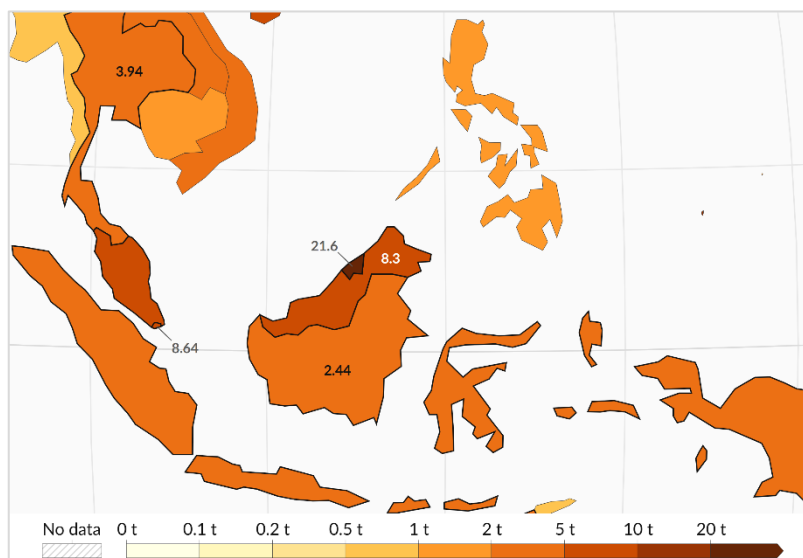
JEL Classification: O13, F64, Q56.

1. Introduction

Environmental issues in the ASEAN region have become an increasingly important concern alongside rapid economic growth and intensified industrialization. The region is characterized by substantial economic diversity, where fast-paced economic expansion and intensive industrial activities are often accompanied by rising carbon emissions resulting from fossil energy consumption. These carbon emissions contribute to various forms of environmental degradation, including air pollution, land degradation, and declining ecosystem quality (Shahbaz et al., 2015). Unsustainable energy utilization may exceed the Earth's capacity to absorb CO₂ emissions, thereby exacerbating environmental damage (Khan et al., 2025). According to the Environmental Kuznets Curve (EKC) hypothesis, however, environmental degradation is expected to decline once income reaches a certain threshold (Grossman & Krueger, 1995). The EKC theory posits an inverted U-shaped relationship between economic growth and environmental degradation.

Building upon this theoretical framework, numerous empirical studies suggest that human development, renewable energy consumption, and economic growth are closely associated with CO₂ emissions. The ASEAN region contributes significantly to carbon emissions, primarily originating from production activities such as the manufacturing sector (IEA, 2024). Despite ongoing development efforts, economic growth in ASEAN countries remains largely dependent on fossil fuel consumption. Rapid economic expansion, population growth, and excessive reliance on fossil energy have collectively contributed to the persistent increase in CO₂ emissions across the region (Sugiharti et al., 2025).

Figure 1. Map of CO₂ Emissions in ASEAN, 2019



Source: Our World in Data

High per capita emissions in countries such as Brunei Darussalam and Singapore reflect economic structures that are heavily reliant on oil, gas, and energy-intensive industries. High-income economies with strong dependence on fossil energy sectors tend to generate

higher per capita CO₂ emissions due to substantially greater individual energy consumption (Stern, 2007). Among ASEAN countries, the five highest-income economies Brunei Darussalam, Singapore, Malaysia, Thailand, and Indonesia, also record the highest levels of per capita CO₂ emissions, as illustrated in Figure 1.

Human beings, as the primary drivers of production activities, play a crucial role in promoting economic growth; however, they also contribute to increased carbon emissions through production processes (Haini, 2021; Shahbaz et al., 2012; Todaro & Smith, 2020). This occurs because rising economic activity is accompanied by greater energy demand (Onozaki, 2009). Nevertheless, C. C. Lee & Zhao (2023) argue that at higher income levels, human development can contribute to reducing carbon emissions by fostering innovation and facilitating the adoption of renewable energy. Renewable energy consumption is generally found to have an inverse relationship with CO₂ emissions, indicating that environmentally oriented renewable energy policies can help mitigate total CO₂ emissions (Ali et al., 2025).

Several studies have been conducted in the ASEAN region to analyze the relationship between economic growth, renewable energy, and CO₂ emissions (Munir et al., 2020; Sudarmaji et al., 2022; Vo et al., 2019). However, studies incorporating human development into the analysis in this region remain limited. Meanwhile, the relationship between CO₂ emissions and human development has been examined by Azam et al., (2023); Gu et al., (2024); Haini, (2021). Specifically, previous studies suggest that human development, renewable energy, economic growth, and CO₂ emissions are interrelated within the framework of sustainable economic development.

The urgency of this research is increasingly evident as the ASEAN region faces dual pressures: the need to accelerate human and economic development while simultaneously reducing rising carbon emissions resulting from industrial activities and rapid urbanization (IEA, 2024). ASEAN is projected to experience increasing carbon emissions if such growth is not accompanied by an energy transition and effective regulatory policies (Lee & Brahmaasrene, 2014). Under these conditions, research on the determinants of CO₂ emissions is crucial for formulating sustainable development strategies that not only maintain economic stability but also ensure a clean energy transition and the achievement of the Sustainable Development Goals (SDGs).

The research gap lies in the limited number of studies that simultaneously examine human development, renewable energy, and economic growth in ASEAN countries with the highest GDP, as well as in the lack of analysis comparing the emission dynamics between developed ASEAN countries, namely Singapore and Brunei, and developing ASEAN countries namely Indonesia, Malaysia, and Thailand. Therefore, this study aims to examine the impact of human development, renewable energy, and economic growth on CO₂ emissions in ASEAN-5 countries in order to provide a deeper understanding of the determinants of CO₂ emissions in ASEAN, as well as to offer balanced policy recommendations that integrate economic development, improvements in quality of life, and clean energy transition.

2. Literature Review

Human development plays a crucial role in energy use and carbon emissions. As a key driver of production activities, human capital influences productivity and energy demand. Improvements in human development are often accompanied by increased mobility, industrialization, and urbanization, which lead to higher fossil fuel consumption (Todaro & Smith, 2020). However, other studies argue that higher levels of human development can foster environmental awareness, promote renewable energy adoption, and enhance energy efficiency (Canh et al., 2020; Rahman et al., 2021; Shabani, 2024). Empirical evidence from Chen et al. (2022) further indicates that human capital increases carbon emissions in the short term but contributes to emission reductions in the long term when combined with clean energy innovation. These mixed findings suggest that the impact of human development on CO₂ emissions may vary across time horizons and levels of economic development.

Renewable energy represents an alternative to fossil fuel consumption (IRENA, 2024). It can substitute conventional energy sources in industrial and transportation activities. Empirical studies indicate that long-run renewable energy consumption contributes to CO₂ emission reductions, particularly in developed economies (Apergis & Payne, 2010). However, Maftoon et al. (2025) suggest that during the early stages of adoption, renewable energy consumption and human capital may initially increase carbon emissions before contributing to long-term reductions. This phenomenon occurs because renewable energy implementation may remain inefficient and coexist with continued fossil fuel use. Infrastructure development, renewable energy technology production, and structural dependence on fossil fuels delay the realization of environmental benefits.

The contribution of renewable energy in developing countries remains limited due to the continued dominance of fossil fuels in the national energy mix (Sugawana & Managi, 2016). Furthermore, Sadorsky (2009) explains that in developing countries, renewable energy consumption faces capital, technological, and policy constraints in its implementation. In the ASEAN region, economic growth has been found to increase emissions, while renewable energy use has not demonstrated a statistically significant effect on emission reductions at the aggregate level (Lee & Brahma-srene, 2014).

The Environmental Kuznets Curve (EKC) hypothesis posits that economic growth initially contributes to environmental degradation. The relationship between economic growth and environmental quality is characterized as an inverted U-shape. At the early stages of industrial economic growth, environmental quality deteriorates; however, once income reaches a certain threshold, environmental quality begins to improve alongside the implementation of environmentally friendly policies. This is consistent with the findings of Musyarof & Qomari (2023), who argue that economic growth in its initial stages increases CO₂ emissions through production processes that contribute to environmental degradation.

Empirical findings from Santana & Maria, (2024); Widyawati et al., (2021), who tested the Kuznets hypothesis in ASEAN countries, indicate that Singapore and Brunei Darussalam have passed the turning point and structural effect phases of the EKC, whereas other

ASEAN countries remain on the left side of the curve. This outcome depends on whether a country has reached the EKC turning point. Similarly, Sugiharti et al. (2025) find that economic growth continues to exert a positive effect on CO₂ emissions in the ASEAN region. The Kuznets hypothesis suggests that as income increases, economic growth eventually reduces environmental degradation after reaching a certain threshold (Wang et al., 2024). However, Burki & Tahir (2022) report an N-shaped relationship between economic growth and environmental degradation in the ASEAN region, deviating from the traditional EKC framework.

3. Data and Methods

This study employs secondary data obtained from the World Bank and Our World in Data. The dataset consists of panel data covering the period from 2000 to 2019 for five ASEAN countries Brunei Darussalam, Indonesia, Malaysia, Singapore, and Thailand. The variables used in this study include CO₂ emissions per capita (CO₂), Human Development Index (HDI), renewable energy consumption (REN), and economic growth (GGDP).

Table 1. *Measurement of Variables*

Variable	Metadata	Symbol	Source
CO₂ Emissions	CO ₂ emissions per capita are measured in metric tons per person per year.	CO ₂	Our World in Data
Human Development	The HDI represents the contribution of health, education, and living standards to human development and is expressed as an index value.	HDI	World Bank, UNDP
Renewable Energy	Renewable energy consumption is measured as the percentage of total renewable energy consumption relative to total final energy consumption.	REN	Our World in Data, World Bank
Economic Growth	Economic growth is calculated as the annual percentage change in gross domestic product (GDP), computed as: $(GDP_t - GDP_{t-1}) / GDP_{t-1} \times 100$	GGDP	World Bank

To examine both short-run and long-run relationships among variables, this study applies the Autoregressive Distributed Lag (ARDL) model. The ARDL approach is appropriate when variables are integrated at level I(0), first difference I(1), or a combination of both, provided none are integrated at order two I(2). The general ARDL specification is presented in Equation (1):

$$CO_{2it} = a_0 + a_1HDI_{it} + a_2REN_{it} + a_3GGDP_{it} + e_{it}$$

CO_{2it} : Carbon Emissions

HDI_{it} : Human Development Index

REN_{it} : Renewable Energy

$GGDP_{it}$: Economic Growth

i : Cross Section

t : Time Series

Subsequently, the ARDL model in Equation (1) is reformulated into the Error Correction Model (ECM) representation shown in Equation (2):

$$\Delta CO_{2it} = Y_0 + a_0 CO_{2it-1} + a_1 HDI_{it} + a_2 REN_{it} + a_3 GGD P_{it} + \Delta_{it-1} + \sum_{i=1}^n p_1 HDI_{it-1} + \sum_{i=1}^n p_2 REN_{it-1} + \sum_{i=1}^n p_3 GGD P_{it-1} + e_{it}$$

In this specification, t denotes the time period, and ε_t represents the error term. The long-run coefficients are denoted by $\beta_0, \beta_1, \beta_2, \dots$, while the short-run coefficients are represented by $\alpha_0, \alpha_1, \alpha_2, \dots$. The error correction term (ECT) is derived from the cointegration equation and is presented in Equation (3):

$$\Delta CO_{2it} = \vartheta_0 + \sum_{i=1}^n Y_{0i} \Delta CO_{2it-1} + \sum_{i=1}^n Y_{1i} HDI_{it-1} + \sum_{i=1}^n Y_{2i} REN_{it-1} + \sum_{i=1}^n Y_{3i} GGD P_{it-1} + \vartheta ect_{it}$$

The coefficient of the error correction term, denoted by θ , measures the speed of adjustment toward long-run equilibrium following short-run disequilibrium. A statistically significant and negative ECT coefficient confirms the existence of a long-run relationship among variables. The lagged error correction term ECT_{t-1} captures the magnitude of disequilibrium from the previous period. The ARDL model enables the estimation and analysis of dynamic adjustments among variables, distinguishing between short-run effects and long-run equilibrium relationships, while holding other factors constant.

4. Results

Descriptive statistics are employed to provide an overview of the characteristics of the research data, which include human development (HDI), renewable energy consumption (REN), economic growth (GGDP), and CO₂ emissions. Table 2 presents the descriptive statistical results for all variables. The average value of CO₂ emissions per capita is 8.108 metric tons, indicating a moderate level of emissions across the ASEAN-5 countries during the observation period. The minimum value of 1.302 suggests that, in certain countries and periods, emissions were relatively low. This variation reflects differences in energy consumption patterns and levels of industrialization across countries.

Table 2. *Statistic Descriptive*

	CO ₂	HDI	REN	GGDP
Mean	8.108	0.783	14.127	4.020
Median	6.967	0.792	8.750	4.524
Maximum	24.263	0.942	45.600	14.520
Minimum	1.302	0.600	0.300	-3.901
Std. Dev.	6.399	0.092	13.432	3.046
Observations	100	100	100	100

Source: Eviews (Processed Data, 2025)

The human development variable (HDI) records an average value of 0.780, indicating that the ASEAN-5 countries are generally classified within the high human development category. The median value of 0.792 suggests a relatively stable distribution of HDI across

countries and time, with no substantial extreme deviations. Renewable energy consumption (REN) shows an average value of 14.127 percent and a maximum value of 45.600 percent, indicating considerable variation in the contribution of renewable energy to the national energy mix among ASEAN-5 countries. The minimum value of 0.300 percent reflects that some countries rely heavily on conventional fossil fuels, resulting in a limited share of renewable energy in total energy consumption.

The economic growth variable (GGDP) has an average value of 4.020 percent, suggesting moderate long-term growth across the sample countries. The median value of 4.524 percent is slightly higher than the mean, indicating that growth observations are moderately concentrated in the mid-to-upper range. The minimum value of -3.901 percent reflects periods of economic contraction. The standard deviation of 3.046 indicates a relatively high degree of fluctuation in economic growth over time, which may be associated with external economic shocks and macroeconomic dynamics affecting the ASEAN region.

Unit Roots Test

The unit root test is conducted to examine the stationarity properties of the variables and to ensure that the series do not exhibit stochastic trends. A stationary series fluctuates around a constant mean and variance over time. Table 3 presents the results of the unit root tests using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) approaches.

Table 3. *Unit Root Tests Results*

Variable	Augmented Dickey-Fuller		Phillips-Perron	
	Level	First Difference	Level	First Difference
HDI	14.091	34.323	25.129	34.080
REN	1.744	60.077	2.324	68.087
GGDP	52.997	85.743	54.339	615.076
CO ₂	6.362	55.956	6.367	58.622

Source: Eviews (Processed Data, 2025)

The results indicate that most variables are non-stationary at level but become stationary after first differencing. Specifically, the CO₂ emissions variable is not statistically significant at level based on the ADF test but becomes significant after first differencing, indicating that it is integrated of order one, I(1). Similarly, the human development (HDI) variable is non-stationary at level and becomes stationary at first difference.

The renewable energy (REN) variable also shows a non-stationary result at level but becomes stationary after first differencing. In contrast, the economic growth (GGDP) variable is already stationary at level, suggesting that it is integrated of order zero, I(0), and remains stationary after first differencing. The results of the Phillips-Perron (PP) test are consistent with the ADF findings. Overall, the unit root tests confirm that the variables are integrated at either I(0) or I(1), and none are integrated at order two I(2). Therefore, the use of the ARDL approach is appropriate. Stationarity is confirmed when the p-value is less than 0.05.

Cointegration Test

A cointegration test is conducted to determine the existence of a long-run equilibrium relationship among the research variables. This study employs the Fisher-type cointegration test to examine whether a stable long-term relationship exists within the panel data. The results are presented in Table 4.

Table 4. *Cointegration Test Results*

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	31.19	0.0005	25.07	0.0052
At most 1	13.82	0.1811	10.86	0.3688
At most 2	10.51	0.3972	7.564	0.6713
At most 3	17.21	0.0370	14.21	0.0698

Source: Eviews (Processed Data, 2025)

Based on the Fisher test results, the trace statistic (31.19) and the max-eigenvalue statistic (25.07) are associated with joint probability values below the 5% significance level. These results indicate the rejection of the null hypothesis of no cointegration at the 1% significance level, suggesting the presence of at least one cointegrating vector.

At the “At most 1” to “At most 3” levels, most probability values are statistically insignificant, indicating that no additional cointegrating vectors are detected beyond the first. The max-eigenvalue results further support this conclusion. Overall, the Fisher cointegration test confirms the existence of a stable long-run relationship among the variables in the panel.

Violation of Classical Assumptions

Heteroskedasticity Test

The heteroskedasticity test is performed to examine whether the variance of the regression residuals is constant across observations. The presence of heteroskedasticity may lead to inefficient estimates and biased standard errors. In this study, heteroskedasticity is addressed using robust standard errors. The results presented in Table 5 indicate that the probability values for most variables exceed the 5% significance level, suggesting that there is no evidence of serious heteroskedasticity in the model. Therefore, the estimated coefficients can be considered reliable for inference.

Table 5. *Heteroscedasticity Test Results*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.2032	0.3265	0.6224	0.0000
HDI	0.9729	4.3953	2.2274	0.5352
REN	0.0031	0.0062	0.5180	0.6057
GGDP	0.0128	0.0085	1.4981	0.1375

Source: Eviews (Processed Data, 2025)

These findings indicate that the regression model satisfies the homoscedasticity assumption, implying that the variance of the residuals remains constant across observations and does not systematically depend on the independent variables. Specifically, the probability value for human development (HDI) is 0.5352, for renewable energy (REN) is 0.6057, and for economic growth (GGDP) is 0.1375. Since all probability values exceed the 5% significance level, the null hypothesis of homoscedasticity cannot be rejected. Therefore, the residual variances can be considered constant, indicating that the model does not suffer from heteroskedasticity and that the estimated standard errors are reliable for statistical inference.

Cross-Sectional Dependence Test

The Cross-Sectional Dependence (CD) test is employed to examine whether cross-sectional units in the panel data are correlated with one another. In this study, the cross-sectional units refer to the ASEAN-5 countries. The presence of cross-sectional dependence may lead to biased standard errors and unreliable statistical inference if not properly addressed.

Table 6. *Cross-Sectional Dependence Test*

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	40.147	45	0.0000
Pesaran scaled LM	6.741		0.0000
Bias-corrected scaled LM	6.609		0.0000
Pesaran CD	-1.949		0.0513

Source: Eviews (Processed Data, 2025)

The results presented in Table 6 indicate evidence of cross-sectional dependence based on several test statistics. The null hypothesis of no cross-sectional dependence is rejected at the 5% significance level according to the Breusch–Pagan LM test, the Pesaran scaled LM test, and the Bias-corrected scaled LM test. The respective test statistics are 40.147, 6.741, and 6.609, with probability values of 0.0000, all below the 5% significance threshold. However, the Pesaran CD test reports a statistic of -1.949 with a probability value of 0.0513, which is slightly above the 5% significance level. This result suggests that, under the Pesaran CD test, the null hypothesis of no cross-sectional dependence cannot be rejected.

Overall, given that the majority of the test statistics indicate the presence of cross-sectional dependence, this study addresses the issue by employing robust standard errors in the ARDL estimation. The use of robust standard errors ensures that the estimated coefficients remain consistent and that the statistical inference is reliable despite potential cross-sectional dependence among the ASEAN-5 countries.

Model Criteria Selection

Model selection criteria are applied to evaluate and determine the most appropriate specification of the Autoregressive Distributed Lag (ARDL) model. The selection is based on several information criteria, namely the Log Likelihood (LogL), Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Hannan–Quinn Criterion (HQ). These criteria are commonly used to identify the optimal lag structure by balancing model goodness-of-fit and parsimony.

Table 7. *Model Criteria Selection*

Model	LogL	AIC*	BIC	HQ	Specification
6	62.359	0.015	1.826	0.743	ARDL(2, 3, 3, 3)
3	44.768	0.311	1.978	0.982	ARDL(1, 3, 3, 3)
1	11.058	0.399	1.203	0.722	ARDL(1, 1, 1, 1)
5	28.524	0.458	1.838	1.023	ARDL(2, 2, 2, 2)
2	19.282	0.558	1.794	1.055	ARDL(1, 2, 2, 2)
4	6.054	0.634	1.582	1.015	ARDL(2, 1, 1, 1)

Source: Eviews (Processed Data, 2025)

Based on Table 7, the model with the lowest AIC value is considered the most optimal, as it provides the best trade-off between explanatory power and model complexity. The ARDL (2, 3, 3, 3) specification yields the lowest AIC value of 0.015, along with a BIC

value of 1.826 and an HQ value of 0.743. Therefore, this specification is selected as the most appropriate model for the empirical analysis.

ARDL Model Estimation Results

Based on the ARDL estimation, the selected ARDL (2, 3, 3, 3) specification reveals varying relationships between the independent variables and CO₂ emissions as the dependent variable.

Table 8. *ARDL Estimation Results*

Dependent Variabel = CO ₂ Selected Model: ARDL (2, 1, 1, 1,)				
Variable	Coef.	Std. error	t-Stat.	Prob.
Jangka Panjang				
HDI	15.621	1.469	11.317	0.0000
REN	-0.157	0.038	-4.081	0.0002
GGDP	-0.114	0.039	-2.899	0.0063
Jangka Pendek				
C	-0.387	1.322	-0.293	0.7712
Δ (HDI)	16.430	28.958	0.567	0.5739
Δ (REN)	-0.095	0.153	-0.623	0.5372
Δ (GGDP)	0.065	0.031	2.078	0.0447

Source: Eviews (Processed Data, 2025)

Referring to the results presented in Table 8, human development (HDI) exhibits a positive and statistically significant effect on CO₂ emissions. This finding indicates that a 1 percent increase in HDI is associated with an approximately 15 percent increase in CO₂ emissions in the long run. In contrast, renewable energy consumption (REN) and economic growth (GGDP) show negative and statistically significant effects on CO₂ emissions. Specifically, a 1 percent increase in renewable energy consumption reduces CO₂ emissions by approximately 0.157 percent, while a 1 percent increase in economic growth decreases CO₂ emissions by about 0.114 percent in the long term.

In the short run, the ARDL estimation shows that the constant term has a negative but statistically insignificant coefficient, implying that when all explanatory variables are held constant, CO₂ emissions tend to decline by approximately 0.387 percent, although the effect is not statistically significant. The human development variable has a positive but insignificant short-run effect, suggesting that a 1 percent increase in HDI may increase CO₂ emissions by approximately 16 percent; however, this relationship lacks statistical significance. Renewable energy consumption shows a negative but insignificant short-run effect, indicating that its immediate impact on reducing CO₂ emissions is limited. Meanwhile, economic growth demonstrates a positive and insignificant short-run effect on CO₂ emissions, implying that short-term economic expansion may increase emissions, although the effect is not statistically significant.

5. Discussion

The findings indicate that human development has a significant positive effect on CO₂ emissions in the long run. This result is consistent with Haini (2021), who argues that human capital plays a substantial role in increasing carbon emissions. Human development

is closely associated with economic expansion, as improvements in education, health, and living standards enhance labor productivity and stimulate economic activity. Consequently, higher levels of human capital may intensify energy consumption and production activities, leading to increased carbon emissions (Akpola & Bakırtaş, 2024; Rahman et al., 2021). However, Maftoon et al. (2025) suggest that at more advanced stages of development, higher human development may also promote the adoption of environmentally friendly energy sources, thereby supporting sustainable development objectives.

Human capital also contributes to improving the effectiveness and adoption of renewable energy technologies. In the long term, a more educated and skilled population facilitates technological innovation and environmental awareness, which may help mitigate environmental degradation (Sadiq et al., 2022; Zhang et al., 2024). In the ASEAN-5 context, improvements in human development have been accompanied by rising energy demand and expanding economic activities in both household and industrial sectors. As living standards improve, demand for transportation, goods, services, and mobility increases. When these demands are largely met through fossil fuel-based energy sources, carbon emissions tend to rise alongside human development (Haq et al., 2025).

The short-run results show that human development (HDI) has an insignificant effect on CO₂ emissions. This suggests that annual fluctuations in HDI do not immediately translate into changes in emissions within the same period. The impact of human development appears to be structural and cumulative, becoming more evident over the long term rather than in the short term. In the short run, the relationship may be influenced by transitional dynamics, policy adjustments, and macroeconomic conditions that moderate the immediate effect of human development on environmental outcomes.

Furthermore, renewable energy consumption (REN) demonstrates a consistent role as a long-term mitigating factor of CO₂ emissions. The results confirm that renewable energy significantly reduces emissions in the ASEAN-5 region in the long run. This finding aligns with previous studies Honma et al., (2025); Rahman et al., (2021); Zhang et al., (2024), which emphasize that renewable energy improves environmental quality by substituting fossil fuels and reducing carbon intensity. The results imply that the energy transition process in ASEAN has begun to generate measurable long-term environmental benefits, although structural changes in energy systems and clean energy investments require time before producing stable and sustained reductions in emissions.

Renewable energy is widely recognized as an environmentally sustainable energy source due to its renewable nature and lower environmental impact compared to fossil fuels (Amer et al., 2024). In the ASEAN-5 region, the findings suggest that the substitution mechanism of renewable energy for fossil-based energy has gradually begun to operate, as reflected in its long-term contribution to reducing CO₂ emissions. However, in the short run, renewable energy does not exhibit a statistically significant effect on CO₂ emissions. This indicates that the adoption of renewable energy remains in a phase of structural transition, where its immediate impact on carbon intensity is still limited and subject to adjustment dynamics within the regional energy system.

In contrast to the previous variables, economic growth (GGDP) demonstrates distinct dynamics between the long and short run. In the long term, economic growth has a significant negative effect on CO₂ emissions, implying that higher levels of economic growth in the ASEAN-5 region are associated with lower emission intensity. This finding suggests that economic expansion in these countries has increasingly aligned with sustainable development objectives, reflecting structural transformation and improved efficiency in production processes. Such results are consistent with previous studies (Amar Ben et al., 2025; Bozatli et al., 2025; Gazik et al., 2025), which argue that beyond a certain income threshold, economic growth contributes to environmental improvement. This outcome also provides empirical support for the Environmental Kuznets Curve (EKC) hypothesis in the ASEAN-5 context.

The observed long-term negative relationship indicates that structural adjustments have taken place within the ASEAN-5 economies, including shifts toward less emission-intensive sectors and greater efficiency in energy utilization. At more advanced stages of development, economic activity tends to incorporate cleaner technologies and renewable energy sources, thereby increasing demand for environmental quality (Magazzino et al., 2025). However, in the short run, economic growth exerts a positive and significant effect on CO₂ emissions, suggesting that immediate economic expansion leads to higher emissions. This pattern may occur because increases in production, energy consumption, and aggregate demand materialize more rapidly than the adoption of clean technologies and adjustments in the energy mix (Raza et al., 2025). These findings are consistent with Jahanger et al., (2023); Munir et al., (2020), who confirm the EKC hypothesis in the ASEAN region, indicating that environmental degradation initially rises with economic growth before declining after the turning point is reached.

6. Conclusion

This study examines the relationship between human development (HDI), renewable energy consumption (REN), and economic growth (GGDP) on CO₂ emissions in the ASEAN-5 region over the period 2000–2019 using the ARDL approach. The findings indicate that, in the long run, human development has a significant positive effect on CO₂ emissions, suggesting that improvements in living standards and productivity in the ASEAN-5 countries remain closely associated with fossil fuel-based energy consumption. In contrast, renewable energy consumption and economic growth demonstrate significant negative effects on CO₂ emissions in the long term. These results confirm the role of renewable energy as an effective mechanism for emission reduction through the substitution of fossil fuels. Moreover, the negative long-run relationship between economic growth and emissions suggests the presence of structural transformation toward more environmentally sustainable economic activities, indirectly supporting the Environmental Kuznets Curve (EKC) hypothesis. This study also contributes empirically by highlighting the short-run and long-run dynamics of the relationships among human development, renewable energy, economic growth, and CO₂ emissions in the ASEAN-5 context.

The policy implications of these findings emphasize the importance of integrating human development strategies with the green energy transition. Improvements in education, health, and overall quality of life should be accompanied by enhanced energy literacy and the adoption of efficient, environmentally friendly technologies in both household and industrial sectors. In addition, sustainable and low-carbon economic growth can be promoted through policies that decouple economic expansion from carbon emissions. Such efforts may include strengthening energy efficiency regulations in the industrial and transportation sectors, as well as implementing carbon pricing mechanisms or incentives for low-carbon technologies.

Based on the empirical evidence, ASEAN governments are encouraged to align carbon emission control policies with human development and sustainable energy agendas. Human development initiatives should be positioned as part of broader climate change mitigation strategies. Furthermore, the acceleration of renewable energy deployment requires continued regulatory support, financial incentives, and investment facilitation, given its demonstrated long-term effectiveness in reducing emissions. Economic development strategies should prioritize energy efficiency and environmentally sustainable growth to ensure that development objectives and environmental sustainability are achieved simultaneously.

Future research is recommended to explore sectoral emission dynamics within each ASEAN-5 country, considering differences in economic structure and energy policy frameworks. Further studies may also examine potential non-linear relationships between economic growth and emissions using more advanced econometric models to provide stronger evidence regarding the existence of the EKC hypothesis in the region.

References

- Akpolat, A.G., and Bakırtaş, T. (2024). The Nonlinear Impact of Renewable Energy, Fossil Energy and CO₂ Emissions on Human Development Index for The Eight Developing Countries. *Energy*, 312. <<https://doi.org/10.1016/j.energy.2024.133466>>
- Ali, M., Xiaoying, L., Mehmood, S., Khan, M.A., and Oláh, J. (2025). Assessing the impact of FDI, CO₂ emissions, economic growth, and income inequality on renewable energy consumption in Asia. *Energy Strategy Reviews*, 58. <<https://doi.org/10.1016/j.esr.2025.101653>>
- Amar Ben, A., Kharbach, M., and Lmasrar, B. (2025). Agricultural CO₂ emissions in India, China, and the United States. *Development and Sustainability in Economics and Finance*, 8. <<https://doi.org/10.1016/j.dsef.2025.100078>>
- Amer, E.A.A.A., Meyad, E.M., Meyad, A.M., and Mohsin, A.K.M. (2024). Impacts of renewable and disaggregated non-renewable energy consumption on CO₂ emissions in GCC countries: A STIRPAT model analysis. *Heliyon*, 10(9). <<https://doi.org/10.1016/j.heliyon.2024.e30154>>
- Apergis, N., and Payne, J.E. (2010). Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy*, 38(1), 656–660. <<https://doi.org/https://doi.org/10.1016/j.enpol.2009.09.002>>

- Azam, A., Shafique, M., Rafiq, M., and Ateeq, M. (2023). Moving toward sustainable agriculture: The nexus between clean energy, ICT, human capital and environmental degradation under SDG policies in European countries. *Energy Strategy Reviews*, 50, 1–12. <<https://doi.org/10.1016/j.esr.2023.101252>>
- Bozatli, O., Degirmenci, T., Can Serin, S., and Aydin, M. (2025). Two centuries of carbon emissions (1800–2022): The role of government spending, economic growth, and population density in the United States. *Journal of Environmental Management*, 394. <<https://doi.org/10.1016/j.jenvman.2025.127725>>
- Burki, U., and Tahir, M. (2022). Determinants of environmental degradation: Evidenced-based insights from ASEAN economies. *Journal of Environmental Management*, 306. <<https://doi.org/10.1016/j.jenvman.2022.114506>>
- Canh, N.P., Thanh, S.D., and Nasir, M.A. (2020). Nexus Between Financial Development & Energy Intensity: Two Sides of a Coin? *Journal of Environmental Management*, 270, 110902. <<https://doi.org/10.1016/j.jenvman.2020.110902>>
- Chen, Z., Wang, H., Wang, M., Liu, L., and Wang, X. (2022). Investigation of Cooling Processes of Molten Slags to Develop Multilevel Control Method for Cleaner Production in Mineral Wool. *Journal of Cleaner Production*, 339, 130548. <<https://doi.org/10.1016/j.jclepro.2022.130548>>
- Gazik, A.N., Yousefi, H., and Abdoos, M. (2025). Sustainability under the threat: The nexus of economic growth, energy consumption, and CO₂ emission during COVID-19 pandemic (case study: United Kingdom). *Environmental Challenges*, 20. <<https://doi.org/10.1016/j.envc.2025.101285>>
- Grossman, G.M., and Krueger, A.B. (1995). Economic Growth and the Environment. *The Quarterly Journal of Economics*, 110(2), 353–377. <<https://doi.org/10.2307/2118443>>
- Gu, X., Baig, I.A., Shoaib, M., and Zhang, S. (2024). Examining the natural resources-ecological degradation nexus: The role of energy innovation and human capital in BRICST nations. *Resources Policy*, 90, 104782. <<https://doi.org/10.1016/j.resourpol.2024.104782>>
- Haini, H. (2021). Examining the impact of ICT, human capital and carbon emissions: Evidence from the ASEAN economies. *International Economics*, 166, 116–125. <<https://doi.org/10.1016/j.inteco.2021.03.003>>
- Haq, W., Ahmad, I., Arshad, A., and Alvi, S. (2025). The role of human capital and innovation in reducing carbon emissions in OECD and BRICS countries. *Sustainable Futures*, 10. <<https://doi.org/10.1016/j.sftr.2025.101475>>
- Honma, S., Ushifusa, Y., Taghizadeh-Hesary, F., and Vandercamme, L. (2025). How do energy efficiency and renewable energy impact carbon emissions in Asian economies? *Energy Strategy Reviews*, 62. <<https://doi.org/10.1016/j.esr.2025.101993>>
- IEA. (2024). *Southeast Asia Energy Outlook 2024*. <www.iea.org>
- IRENA. (2024). *World Energy Transitions Outlook 2024: 1.5°C pathway*. <www.irena.org>
- Jahanger, A., Zaman, U., Hossain, M.R., and Awan, A. (2023). Articulating CO₂ emissions limiting roles of nuclear energy and ICT under the EKC hypothesis: An application of non-parametric MMQR approach. *Geoscience Frontiers*, 14(5). <<https://doi.org/10.1016/j.gsf.2023.101589>>
- Khan, M.R., Khan, I., Umar, M., Ghouri, A.M., Hooi, K.K., and Lim, A.F. (2025). Analyzing the Impact of Socio-economic Factors on Environmental Degradation: Empirical Insights from Emerging Economy. *Sustainable Futures*, 10. <<https://doi.org/10.1016/j.sftr.2025.100967>>

- Lee, C.C., and Zhao, Y.N. (2023). Heterogeneity Analysis of Factors Influencing CO₂ Emissions: The Role of Human Capital, Urbanization, and FDI. In *Renewable and Sustainable Energy Reviews* (Vol. 185). Elsevier Ltd. <<https://doi.org/10.1016/j.rser.2023.113644>>
- Lee, J.W., and Brahmasrene, T. (2014). ICT, CO₂ Emissions and Economic Growth: Evidence from a Panel of ASEAN. *Global Economic Review*, 43(2), 93–109. <<https://doi.org/10.1080/1226508X.2014.917803>>
- Maftoon, A.S., Razzaq, A., Arfeen, M.I., and Khan, K. (2025). The Interplay of Renewable Energy and Human Capital: Unveiling the Moderating Pathways to Carbon Emission Mitigation in a Global Panel Study. *Sustainable Futures*, 10, 101108. <<https://doi.org/10.1016/j.sftr.2025.101108>>
- Magazzino, C., Gattone, T., Pakrooh, P., and Destek, M.A. (2025). The Impact of Energy Prices and Socio-Economic Factors on CO₂ Emissions in OECD Countries: A STIRPAT and Machine Learning Analysis. *Energy Strategy Reviews*, 62. <<https://doi.org/10.1016/j.esr.2025.101920>>
- Munir, Q., Lean, H.H., and Smyth, R. (2020). CO₂ emissions, energy consumption and economic growth in the ASEAN-5 countries: A cross-sectional dependence approach. *Energy Economics*, 85. <<https://doi.org/10.1016/j.eneco.2019.104571>>
- Musyarof, Z., and Qomari, I.N. (2023). Pengaruh Pertumbuhan Ekonomi terhadap Emisi Gas Karbon Dioksida (CO₂): Data Panel Negara ASEAN Tahun 2000-2019. *Ecoplan*, 6(2), 87–99. <<https://doi.org/10.20527/ecoplan.v6i2.624>>
- Onozaki, K. (2009). Population Is a Critical Factor for Global Carbon Dioxide Increase. *Journal of Health Science*, 55(1), 125–127. <<https://doi.org/10.1248/jhs.55.125>>
- Rahman, M.M., Nepal, R., and Alam, K. (2021). Impacts of Human Capital, Exports, Economic Growth and Energy Consumption on CO₂ Emissions of a Cross-Sectionally Dependent Panel: Evidence from The Newly Industrialized Countries (NICs). *Environmental Science and Policy*, 121, 24–36. <<https://doi.org/10.1016/j.envsci.2021.03.017>>
- Raza, A., Alharthi, M., Shakeel, M., and Khan, M.I. (2025). Nexus between CO₂ emissions, economic growth, and energy consumption with special reference to BRICS: A panel data approach. *Energy Nexus*, 20. <<https://doi.org/10.1016/j.nexus.2025.100556>>
- Sadiq, M., Shinwari, R., Usman, M., Ozturk, I., and Maghyereh, A.I. (2022). Linking nuclear energy, human development and carbon emission in BRICS region: Do external debt and financial globalization protect the environment? *Nuclear Engineering and Technology*, 54(9), 3299–3309. <<https://doi.org/10.1016/j.net.2022.03.024>>
- Sadorsky, P. (2009). Renewable Energy Consumption and Income in Emerging Economies. *Energy Policy*, 37(10), 4021–4028. <<https://doi.org/10.1016/j.enpol.2009.05.003>>
- Santana, F.R., and Maria, N.S.B. (2024). Determinan Emisi CO₂ pada Negara Anggota ASEAN Tahun 2015-2022. *Diponegoro Journal of Economics*, 13(2), 53–68. <<https://doi.org/10.14710/djoe.44589>>
- Shabani, Z.D. (2024). Renewable energy and CO₂ emissions: Does human capital matter? *Energy Reports*, 11, 3474–3491. <<https://doi.org/10.1016/j.egyr.2024.03.021>>
- Shahbaz, M., Lean, H.H., and Shabbir, M.S. (2012). Environmental Kuznets Curve Hypothesis in Pakistan: Cointegration and Granger causality. *Renewable and Sustainable Energy Reviews*, 16(5), 2947–2953. <<https://doi.org/10.1016/j.rser.2012.02.015>>
- Shahbaz, M., Solarin, S.A., Sbia, R., and Bibi, S. (2015). Does Energy Intensity Contribute to CO₂ Emissions? A Trivariate Analysis in Selected African Countries. *Ecological Indicators*, 50, 215–224. <<https://doi.org/10.1016/j.ecolind.2014.11.007>>

- Stern, Nicholas. (2007). *The Economics of Climate Change: Stern Review on the Economics of Climate Change*. Cambridge University Press.
- Sudarmaji, E., Achsani, N.A., Arkeman, Y., and Fahmi, I. (2022). Determinants of Carbon Emission and Rebound Effect in Asean Countries: Kaya and LMDI Decomposition. *Indonesian Journal of Business and Entrepreneurship*. <<https://doi.org/10.17358/ijbe.8.2.240>>
- Sugiawan, Y., and Managi, S. (2016). The Environmental Kuznets Curve in Indonesia: Exploring the Potential of Renewable Energy. *Energy Policy*, 98, 187–198. <<https://doi.org/10.1016/j.enpol.2016.08.029>>
- Sugiharti, L., Akter, S., Das, M.K., Pattak, D.C., Esquivias, M.A., and Akter, S. (2025). Population Dynamics, Economic Growth, Energy Mix, and Environmental Pollution in ASEAN: Exploring the Role of Renewable, Nuclear, and Nonrenewable Energy Using the CCEMG Approach. *Environmental and Sustainability Indicators*, 26, 100598. <<https://doi.org/10.1016/j.indic.2025.100598>>
- Todaro, M.P., and Smith, S.C. (2020). *Economic Development* (13th ed.). Pearson.
- Vo, A., Vo, D., and Le, Q. (2019). CO2 Emissions, Energy Consumption, and Economic Growth: New Evidence in the ASEAN Countries. *Journal of Risk and Financial Management*, 12(3), 1–20. <<https://doi.org/10.3390/jrfm12030145>>
- Wang, Q., Wang, X., Li, R., and Jiang, X. (2024). Reinvestigating the Environmental Kuznets Curve (EKC) of Carbon Emissions and Ecological Footprint in 147 Countries: a Matter of Trade Protectionism. *Humanities and Social Sciences Communications*, 11(1), 1–17. <<https://doi.org/10.1057/s41599-024-02639-9>>
- Widyawati, R.F., Hariani, E., Ginting, A.L., and Nainggolan, E. (2021). Pengaruh Pertumbuhan Ekonomi, Populasi Penduduk Kota, Keterbukaan Perdagangan Internasional Terhadap Emisi Karbon Dioksida (CO2) di Negara ASEAN. *JAMBURA: Agribusiness Journal*, 3(1), 37–47.
- Zhang, S., Xie, W., Sun, S., Wu, F., and Xue, Y. (2024). Nexus of green energy innovation, governance quality, and CO2 emissions in natural resource sector: The role of sustainable human development. *Resources Policy*, 88. <<https://doi.org/10.1016/j.resourpol.2023.104493>>

Effects of digital economy on economic growth: Evidence from low- and middle-income countries in Africa

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Abstract. *This paper aims to analyze the effects of the digital economy on economic growth in low- and middle-income countries in Africa. We use a sample of 52 countries, comprising 21 low-income countries (LICs) and 31 middle-income countries (MICs), over the period 2004–2022. The two-stage generalized method of moments (GMM) estimation technique, corrected to finite sample bias of Windmeijer's (2005), is applied to a panel model. The main results show that the digital economy has a more positive influence on economic growth in LICs than in MICs. This supports the argument that these countries are "leapfrogging" in terms of growth thanks to digitization. Otherwise, our results highlight that "Internet access" remains the dimension of the digital economy with the greatest impact on economic growth in both types of countries. Governments in African countries may invest in digital infrastructure and support to increase internet access.*

Keywords: digital economy, economic growth, low- and middle-income countries, Africa.

JEL Classification: O11, O33, O47, O55.

1. Introduction

In Africa, traditional development models have yet to produce sustained growth. Indeed, in most African countries, the real GDP per capita growth rate is unstable and low (single digits). According to the African Economic Outlook 2023, Africa's real GDP growth, which was estimated at 4.8% in 2021, fell by 1% (3.8%) in 2022 and is expected to rebound to 4% in 2023. The continent experienced its worst recession in half a century, with real GDP contracting by 2.1% in 2020 due to the COVID-19 pandemic (AfDB⁽¹⁾, 2021). Inclusive growth is out of reach for most African countries (UNCTAD⁽²⁾, 2021). In fact, according to this report, growth was inclusive in only 17 of the 49 African countries surveyed over the period 2000-2020.

Moreover, although the poverty rate⁽³⁾ has fallen at a higher rate than in other regions of the world, the (absolute) number of poor people has increased in the region. Indeed, according to Calderon et al. (2019), the number of people living on less than 1.9 USD a day increased from around 278 million in 1990 to 416.4 million in 2015, and the poverty rate fell from 54% to 41.4%. Similarly, forecasts indicate that poverty will soon become a predominantly African phenomenon, as Africa's share of global poverty will rise from 55% in 2015 (compared with 15% in 1990) to 90% in 2030 (Calderon et al., 2019). In addition, the UNDP⁽⁴⁾ report (2023) indicates that almost two-thirds of all poor people live in middle-income countries and 35% in low-income countries, the majority of which are African. In other words, lack of economic growth and poverty are just some of the economic problems plaguing the African continent.

However, the spread of digital technologies across the continent has the potential to reinvigorate economic growth and reduce poverty. Indeed, digital technologies can broaden access to global markets, change business models, and bring significant productivity gains. According to Acemoglu and Robinson (2013), technological change, including that related to information and communication technologies (ICT), is seen as one of the indispensable drivers of prosperity among many, and for countries to benefit from other growth drivers, they need to use ICT. In the same vein, a World Bank study (2012) states that: "ICTs hold great promise for reducing poverty, increasing productivity, stimulating economic growth (...)". For example, according to a World Bank report (2009), access to telecommunications and the Internet stimulates global economic growth, and for developing countries, every 10% increase in broadband Internet connection corresponds to a 1.38% increase in economic growth. What's more, poor countries could leapfrog rich ones thanks to the advent of ICTs (Steinmueller, 2001).

In theory, several authors have shown that digital diffusion should be a key stimulus for economic growth (Aghion & Howitt, 1992; Lucas, 1988; Romer, 1986, 1990; Solow, 1956, 1957; Swan, 1956). Indeed, according to the neoclassical theory of exogenous growth (Solow, 1957; Swan, 1956), growth is stimulated by exogenous technological change. Technological progress is said to be a godsend that augments the factors (capital and labor) of production. Similarly, for endogenous growth theory (Lucas, 1988; Romer, 1986, 1990), the sources of growth lie in investment in human capital and technological innovation. Technical progress results from the voluntary decisions of companies, which are obliged

to innovate in their quest for maximum profit. Consequently, technical progress is endogenous rather than exogenous.

Following these theoretical studies, several empirical studies have been carried out on the relationship between the digital economy and economic growth. Some of these studies have confirmed Solow's paradox (1957) that ICT diffusion has no effect on economic growth (Gordon, 2000; Greenan & L'Horty, 2000). Others, however, have refuted this, i.e., that ICT is a key determinant of economic growth (Adeleye & Eboagu, 2019; Haftu, 2019; Pradhan et al., 2018; Toader et al., 2018).

In addition to the aforementioned empirical studies, some have shown that the contribution of the digital economy to economic growth can differ according to a country's level of development (Karlsson & Liljevern, 2017; Niebel, 2018; Yousefi, 2011). Indeed, according to the law of diminishing marginal returns, the return on capital is higher in poor economies than in rich ones. To this end, the marginal effect of digital investments must be higher in poor countries than in rich ones. As a result, low- and middle-income countries could leapfrog traditional methods of increasing productivity through digital diffusion (Steinmueller, 2001), and thus catch up with rich (high-income) countries. In addition, low-income countries may lack absorptive factors such as an appropriate level of human capital, or other complementary factors such as Research and Development spending and digital investment (Caselli & Coleman, 2001; Dewan & Kraemer, 2000; Keller, 2001, 2004), and therefore earn less than middle-income countries in digital investment.

In the specific case of low- and middle-income countries in Africa, after decades of implementing development policies, many African countries remain in these two income brackets, with the majority in the low-income category. Indeed, according to the World Bank's country rankings for 2024, 26 countries are classified as low-income, 22 of which are African (i.e. 84.62%); 54 countries are classified as lower-middle-income, 24 of which are African (i.e. 44.44%); 54 countries are classified as upper-middle-income, 7 of which are African (i.e. 12.96%); and 83 countries are classified as high-income, only one of which is African (Seychelles). The trend decreases from one bracket to the next. Moreover, while disparities exist between regions, the transition of African countries to high-income status is slow compared to other regions. Indeed, between 1987 and 2022, the proportion of low-income countries fell from 74% to 46% in Sub-Saharan Africa, from 26% to 3% in East Asia and the Pacific, and from 100% to 13% in South Asia (World Bank, 2024). Faced with this situation and in view of the above-mentioned literature, this article poses the central question of the effects of the digital economy on economic growth in low- and middle-income countries in Africa?

The aim of this article is to analyze the influence of the digital economy on economic growth in low- and middle-income countries in Africa. In achieving this objective, this work contributes to the economic literature in three ways: First, several comparative studies have been conducted on the effects of the digital economy on economic growth across regions (Karlsson & Liljevern, 2017; Niebel, 2018; Yousefi, 2011), but for the specific case of low- and middle-income countries in Africa, it is not yet clear whether the digital economy contributes more to economic growth in low-income countries than in middle-income countries. Secondly, this study analyzes the data and makes a comparison of the

coefficients (shares of contribution of digitization to economic growth) in order to test the hypothesis that the contribution of digitalization to economic growth depends on the level of development of the economies. Thirdly, this article has used a convergence model to see whether the digital economy contributes to the convergence of low- and middle-income countries.

The rest of the work is organized as follows: the second section presents a literature review on the digital economy and economic growth; the third section presents the methodology; the estimation results are presented in the fourth section, and the last section concludes the paper.

2. Review of the literature on the digital economy and economic growth

Theoretically, the link between the digital economy and economic growth in the economic literature revolves around two major theories: Solow's exogenous growth theory (1956, 1957) and Romer's endogenous growth theory (1986). According to exogenous growth theory, technical progress increases the productivity of factors of production and, therefore, has a positive impact on economic growth. Similarly, according to endogenous growth theory, technical progress is caused by the voluntary actions of individuals in response to market incentives (Romer, 1990). Consequently, it results from the very workings of the economy and is endogenous. Thus, technical progress is at the heart of economic growth, encouraging capital accumulation, and the combination of these two factors explains a large part of hourly productivity gains.

Empirically, several studies have shown that the digital economy is a key determinant of economic growth (Adeleye & Eboagu, 2019; Emiru & Wajebo, 2026; Gökgöz & Turan, 2025; Haftu, 2019). In the context of European Union countries, Toader et al. (2018) demonstrated that ICT has a positive effect on GDP, with a more significant impact observed in the number of mobile phone subscribers during the period from 2000 to 2017. A similar effect was found by Pradhan et al. (2018) in both the short and long term across G-20 countries. Similarly, a recent study by Gökgöz and Turan (2025) showed that ICT capital services had a positive effect on economic growth in OECD member countries during the period 2000–2018.

Similar studies have been conducted on the African continent, and the results are consistent with those of previous research. Using a sample of 40 sub-Saharan African countries over the 2006–2015 period, Haftu (2019) demonstrated that mobile phone penetration had a positive and significant impact on the region's GDP, unlike the number of internet users. Similarly, Adeleye & Eboagu (2019) found that ICT indicators such as the number of internet users and the number of fixed-line and mobile subscribers have a positive and significant economic impact on the economic growth of African countries over the period from 2005 to 2015. The results of recent studies are consistent with those previously obtained in Africa. Indeed, Emiru & Wajebo (2026) showed that over the period 1996 to 2019, digitalization had a positive and significant impact on real GDP per capita in Sub-Saharan Africa.

In addition, other authors have conducted comparative analyses of the effects of the digital economy on growth across different geographic regions (Bahrini & Qaffas, 2019; Correa & Esquivias, 2025; Myovella et al., 2020; Niebel, 2018). Over the period from 2000 to 2017, Karlsson and Liljevern (2017) demonstrated that the effect of non-ICT capital is greater than that of ICT capital on economic growth across all income brackets in a sample of 101 countries (high-income, upper-middle-income, lower-middle-income, and low-income). However, their results show that while ICT contributes to increased output in high-income countries, this is not the case in other income brackets. Similar results were obtained by Majeed and Ayub (2018) in their study. Indeed, they found that, when comparing the global and regional levels, ICTs have a larger positive and significant effect on economic growth at the global level than at the regional level. Furthermore, their results reveal that the effect of ICTs is greater in emerging and developing countries than in developed countries.

Similarly, Niebel (2018) conducted a comparable study on a sample of 59 countries (developed, emerging, and developing countries) covering the period 1995–2010. Their estimation results showed that, although digital technology contributes positively to economic growth across the different groups of countries, developing and emerging economies do not benefit more from digital technology than developed economies. As for Ghalayini et al. (2020), they focused their study on the effect of ICTs on economic growth in a panel of 89 countries divided into 7 low-income economies, 20 lower-middle-income economies, 19 upper-middle-income economies, and 43 high-income economies over the period from 1990 to 2018. Their results showed that ICTs have a positive and significant effect on economic growth in high-income countries, a weakly significant effect in lower-middle-income countries, but no significant effect in upper-middle-income and low-income countries. Similarly, Stanley et al. (2018) conducted a meta-regression analysis of 59 econometric studies that tested the Solow paradox, which posits that ICTs do not affect productivity. Their results revealed that investments in ICTs have a positive impact on economic growth, albeit with delayed effects. Indeed, they found that both developed and developing countries benefit from fixed and mobile telephone technologies, but that developed countries derive much greater benefits from information technology than developing countries.

In the African context, a number of studies have also reached similar conclusions, and the findings are consistent with those of previous research. For example, Bahrini and Qaffas (2019) used a panel of 45 countries—including 14 in the Middle East and North Africa (MENA) region and 31 in Sub-Saharan Africa (SSA)—over the 2007–2016 period to compare the impact of ICTs on economic growth in the two regions. Their results revealed that key ICT indicators, such as the number of mobile phones, internet, and broadband users, positively and significantly influence economic growth in both regions. However, their findings show that the effect of internet use and broadband adoption is greater in MENA countries than in SSA countries. As for Myovella et al. (2020), they demonstrated that mobile phone usage has a greater impact on economic growth in SSA than in OECD member countries. Conversely, broadband internet has a greater impact on economic growth in OECD countries than in SSA countries. Recently, Correa & Esquivias (2025) conducted a comparative analysis of the effects of digitalization on economic growth

between Middle Eastern countries and SSA countries over the period 2005–2021. Their results reveal that digitalization has a greater impact on economic growth in the Middle East than in SSA.

Despite the vast body of comparative research on the effects of the digital economy on economic growth, such a study is still needed for low- and middle-income countries in Africa. Indeed, from the time of African independence to the present day, the majority of African countries have remained trapped in the low- and middle-income brackets, even though research has shown that countries can leapfrog development stages thanks to digital technology (Steinmueller, 2001). Therefore, it is important to examine, within the African context, whether the digitalization of African economies helps low- and middle-income countries leapfrog development stages to catch up with high-income countries.

3. Methodological approach to the analysis

3.1. Empirical model

To study the link between the digital economy (DE) and economic growth, as well as the role of human capital in the relationship between the digital economy and economic growth, our empirical model starts from the theoretical model of Mankiw et al. (1992). These authors show that Solow's (1957) model, which takes human capital into account, better illustrates variations in per capita income between countries. This model is presented as follows:

$$\ln(Y_{i,t}) = \beta_0 + \beta_1 DE_{i,t} + \beta_2 \ln(K_{i,t}) + \beta_3 \ln(H_{i,t}) + \beta_4 \ln(L_{i,t}) + \beta_5 X_{i,t} + \epsilon_{i,t} \quad (1)$$

To take into account the effect of convergence, we follow Barro et al. (1992).

Thus, we can write the equation for the economic growth rate as follows:

$$\frac{(Y_{i,t} - Y_{i,t-1})}{Y_{i,t-1}} \approx \beta \ln(Y_{i,t-1}) + \alpha X_{i,t} + \alpha_0 + \epsilon_{i,t} \quad (2)$$

Assuming that:

$$\frac{(Y_{i,t} - Y_{i,t-1})}{Y_{i,t-1}} \approx \ln\left(\frac{Y_{i,t}}{Y_{i,t-1}}\right) \quad (3)$$

Equation (2) can then be written as follows:

$$\ln\left(\frac{Y_{i,t}}{Y_{i,t-1}}\right) = \beta \ln(Y_{i,t-1}) + \alpha X_{i,t} + \alpha_0 + \epsilon_{i,t} \quad (4)$$

There is convergence from poor to rich countries (β -convergence) if $\beta < 0$ and $0 < |\beta| < 1$

Combining (1) and (4), we obtain a growth model:

$$\ln\left(\frac{Y_{i,t}}{Y_{i,t-1}}\right) = \beta \ln(Y_{i,t-1}) + \alpha_1 DE_{i,t} + \alpha_2 \ln(K_{i,t}) + \alpha_3 \ln(H_{i,t}) + \alpha_4 \ln(L_{i,t}) + \alpha_5 X_{i,t} + \alpha_0 + \epsilon_{i,t} \quad (5)$$

Where Y is real GDP per capita; DE (digital economy), K (physical capital), H (level of human capital), L (labor capital), X is a vector of control variables such as FD (financial development), TO (trade openness) and inflation; the coefficient β measures the effect of convergence; α is a vector of coefficients associated with the different explanatory variables; the coefficient α_0 measures individual and/or time fixed effects and $\epsilon_{i,t}$ measures specification or measurement errors.

3.2. Justification for the choice of variables and expected sign

The dependent variable

The dependent variable in this study is the real GDP per capita growth rate. Indeed, in economic literature such as that of Mehmood and Azim (2013), the real GDP per capita growth rate is often used as a proxy for the economic growth of a country or nation, and we use it in this sense in this study.

The dependent variable delayed by one period

Transitory convergence is one of the main components of the neoclassical growth model. This factor depends on the initial position of the economy and indicates that, all other things being equal, poor countries would tend to grow faster than those in favorable conditions, due to lower marginal returns to factors of production. To take this effect into account, we use the initial level of real GDP per capita in the set of explanatory variables. For convergence to occur, the initial level of real GDP per capita must have a negative and significant effect on growth, according to the literature on growth models, such as that of Barro et al. (1992). The expected sign is therefore negative.

The variable of interest

The variable of interest in this study is the digital economy, represented by four digital infrastructure indicators: the number of fixed telephony subscribers per 100 inhabitants (phone), the number of mobile telephony subscribers per 100 inhabitants (cell phone), the number of Internet users as a percentage of the population (internet users), and fixed-line broadband access per 100 inhabitants (internet access). The choice of these indicators is justified by their relevance to the African context and the availability of time series. The expected sign is positive.

Independent variables

Physical capital

According to traditional growth theories, such as Solow (1956), physical capital is one of the determining factors of economic growth, as output growth depends on it. In this study, it is measured by gross fixed capital formation as a percentage of GDP, or the investment rate in each country, and the expected sign is positive.

Human capital

According to endogenous growth theories such as Romer (1990), this factor plays a direct role in economic growth, as it complements other factors such as physical capital,

technology, etc. Following Barro and Lee (2013), we approximate it by the human capital index, and the expected sign is positive.

Labor capital

According to traditional growth theories, such as Solow (1956), this is also considered a key factor in economic growth, as it constitutes a labor force that uses physical capital and technology. It is represented here by the working population in each country, and the expected sign is positive.

Control variables

Financial development

Economic literature such as Levine's (2004), shows that it is an engine of growth for countries, industries, and companies. Indeed, the more developed the financial system, the lower interest rates tend to be, which, all other things being equal, stimulates the level of investment and hence economic growth. It is represented by domestic credit granted by the financial sector in each country, and the expected sign is positive.

Open trade

Open trade has a positive impact on economic growth by increasing real GDP per capita, mainly through its effect on productivity via competition. Openness facilitates the transfer of technology and knowledge across borders, making it possible to reorganize the structure of the economy, specializing in the production of goods for which one has a comparative advantage, which, all other things being equal, increases the level of income (Jung, 2017). It is approximated here by the sum (exports relative to GDP + imports relative to GDP) in each country. We expect this effect to have a positive sign.

Inflation

It is a stabilization variable taken into account in this analysis. It allows us to take into account the lack of price stability, as the average annual percentage change in consumer prices. Indeed, high inflation erodes consumer purchasing power, which, all else being equal, leads to a reduction in aggregate demand (Bruno & Musso, 2000). The expected sign is negative.

3.3. Country categorization and data source

The empirical study covers 52 African countries (see Appendix 1) divided into two economic groups: low-income countries (21) and middle-income countries (lower (24) and upper (7)). According to the World Bank's July 2023 ranking, low-income countries are those whose per capita Gross National Income (GNI) is less than or equal to \$1135 in 2022, lower-middle-income countries are those whose GNI per capita is between \$1136 and \$4465, upper-middle-income countries are those whose GNI per capita is between \$4466 and \$13845, and high-income countries are those whose GNI per capita is greater than or equal to \$13846.

In this study, data on real GDP per capita, digital infrastructure variables (number of fixed and mobile telephone subscriptions, number of internet users and number of subscriptions to broadband access services), financial development, gross fixed capital formation, working population, inflation, trade openness ((imports + exports)/GDP) were extracted from the "world development Indicator" (WDI, 2023). Data on human capital are taken from Penn World Table 10.1.

3.4. Descriptive statistics for some variables

The table below presents some descriptive statistics for the two groups of countries over the period 2004–2022. The average real GDP per capita in the LIC is 653.9962 US dollars, with a minimum value of 262.1848 US dollars recorded by Burundi in 2022 and a maximum value of 2381.357 US dollars for Sudan in 2011. For MICs, the average is 3590.974 US dollars, with a minimum value of 646.2566 US dollars recorded by Tanzania in 2004 and a maximum value of 16747.36 US dollars for the Seychelles in 2019. As for the real GDP per capita growth rate, its average is 1.623% for the LICs and 2.073% in the MICs. These figures are still too low to speak of sustained growth in these countries.

In terms of digital economy infrastructure variables, MIC is still higher than LIC. On average, the number of fixed-line subscribers in LICs is 0.65%, compared with 5.51% for MICs. As for the number of cell phone subscribers, the average is 41.6% in LICs versus 78.5% in MICs. As for the number of Internet users, the average is 6.81% in the LICs versus 22.84% in the MICs. Finally, the percentage of fixed-line broadband Internet access is on average 0.12% in the LICs versus 2.067% in the MICs. Finally, for the digital economy, the results show an average of 28.8% for the LICs versus an average of 53.1% for the MICs. These statistics indicate that the level of diffusion of the digital economy in MICs is higher than in LICs.

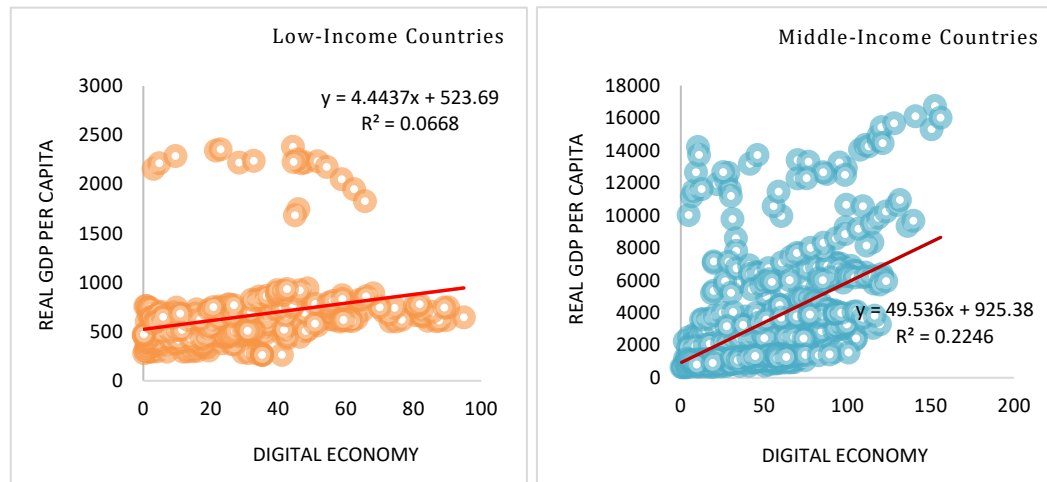
Table 1. *Results of some descriptive statistics*

Variables	Low-Income Countries			Middle-Income Countries		
	Mean	Min	Max	Mean	Min	Max
Real GDP per capita	653.996	262.184	2381.357	3590.974	646.256	16747.36
Real GDP growth	1.623	-47.591	28.676	2.0728	-62.378	121.779
Phone	0.657	0.00229	3.568	5.510	0.0114	36.884
Cell phone	41.598	0.206	133.921	78.491	1.441	206.702
Internet User	6.806	0.0310	35.154	22.842	0.464	88.130
Internet access	0.120	0.0000465	1.148	2.067	0.0001721	38.771
Digital Economy	28.796	0.1674	94.835	53.069	0.440	155.904

Source: Author based on WDI data (2023) and ITU data (2023)

Figure 1 below shows the scatterplots between the digital economy and real GDP per capita in low- and middle-income countries. The fit lines show that there is a positive relationship between the digital economy and real GDP per capita in both types of country, with middle-income countries showing the steepest slope of the fitted values. However, we can't immediately say that the digital economy has a positive effect on economic growth, because a correlation is not necessarily causation.

Figure 1. Point cloud representation between the digital economy and real GDP per capita in low- and middle-income countries

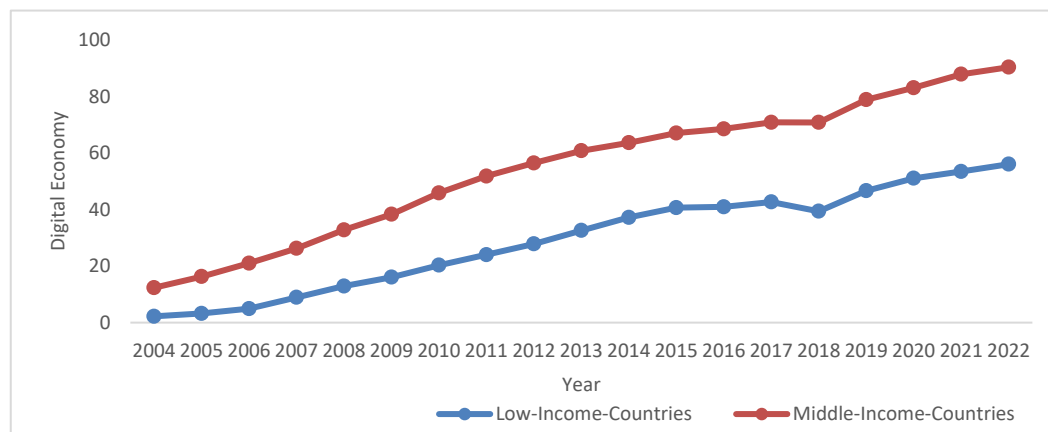


Source: author based on WDI data (2023) and ITU (2023)

3.5. Correlation and principal component analysis

The correlation analysis (Pearson correlation test) shows that the correlation coefficients between the digital infrastructure variables are significant at the 10% level (see Appendix 2 and 3). This shows that there is collinearity between the digital infrastructure variables. To avoid this collinearity, we constructed a synthetic index of the digital economy using a principal component analysis (PCA) of four digital infrastructure variables (see appendices 4, 5, 6, and 7). These variables are: the number of fixed-line telephony subscribers per 100 inhabitants, the number of mobile telephony subscribers per 100 inhabitants, the number of Internet users as a percentage of the population, and fixed-line broadband access per 100 inhabitants. Following the Kaiser (1960) rule⁽⁵⁾, the indicator is constructed according to the first component, as it provides the maximum amount of information on all the variables and represents them better. Such an index has been constructed by other authors in their work (Li & Wu, 2022; Nchake & Shuaibu, 2022).

Figure 2 below illustrates the average evolution of the digital economy over the period 2004-2022, showing an overall upward trend in both types of country. However, middle-income countries show a higher level of diffusion of the digital economy than low-income countries over the whole period.

Figure 2. Average evolution of the digital economy over the period 2004-2022

Source: author based on ITU data (2023)

3.6. Econometric estimation technique

In view of the dynamic nature of the panel and the existence of the endogeneity problem in the models, the GMM system estimator of Blundell and Bond (1998) was used. This estimator can be estimated in one or two steps. Unlike the one-step GMM, the two-step GMM takes into account the structure of the error variance-covariance matrix. But according to Monte Carlo simulations, the estimated standard errors of this estimator are biased downwards when the sample is finite (Windmeijer, 2005). To correct this problem, Windmeijer (2005) developed a finite-sample correction for the standard errors of the two-stage estimator. After this correction, he found that two-stage GMM estimators perform slightly better than one-stage GMM for coefficient estimation, with lower bias and standard errors (Windmeijer, 2005). Moreover, according to Roodman (2009), using more instruments than individuals (groups) leads to biased results, especially in the two-stage option. To avoid instrument proliferation and finite sample bias, we use Windmeijer's (2005) standard errors and the collapse option.

4. Estimation results

This section presents preliminary test results and econometric results

4.1. Preliminary tests

This subsection presents the homogeneity, multicollinearity, stationarity, and instrument validity tests.

4.1.1. Homogeneity test

In panel data studies, the test (homogeneity, heterogeneity) is very important in determining the panel structure. This test aims to see whether the data-generating process can be considered homogeneous, i.e., unique for all individuals, or whether, on the contrary, it appears totally heterogeneous. To determine the structure of the panel, we use the

sequential test procedure of Hsiao (1986) (see Appendix 8). The test results, shown in the tables in appendices 9 and 10, indicate that the panel is an individual effect panel for the different models, in both types of country. This confirms the panel structure.

4.1.2. Multicollinearity test

To test multicollinearity, we can use Pearson's correlation test, graphical correlation, and variance inflation factors (VIF). Unlike the first two tests, which perform a bivariate analysis between variables, the VIF tests the correlation between a variable (dependent variable) and a group of variables (explanatory variables). As a general rule, VIFs above 10 are cause for concern (Forthofer et al., 2007). The results reported in Appendix 11 below show VIFs that are all below 10 in all models, demonstrating that multi-collinearity is not a serious problem in these models.

4.1.3. Stationarity test

Unit root tests on non-stationary panel data emerged with the work of Levin et al. (2002). These tests check whether the variables in the model are stationary (no cointegration test) or whether, on the contrary, some are non-stationary (cointegration test is required). However, Hurlin and Mignon (2006) point out that when the time dimension is very small, these tests lead to inconsistent results. This is the case in our study ($T=19$). We therefore disregard these tests for this reason.

4.1.4. Instrument validity tests

In GMM estimations, two types of tests are associated: first- and second-order autocorrelation of errors, and Sargan and Hansen over-identification tests. The results of the different estimations in the two types of countries confirm the presence of 1st-order autocorrelation and the absence of 2nd-order autocorrelation between the variables. Clearly, the presence of first-order autocorrelation shows that the explanatory variables are indeed correlated with the error term, confirming the existence of an endogeneity problem, while the absence of second-order autocorrelation reassures us that there are enough instruments to instrument the endogenous variables and that they are not correlated with the error term. What's more, Hassen's test does not reject the hypothesis of instrument validity in the different estimates for both types of country.

4.2. Econometric results and discussion

Tables 2 and 3 below show the estimation results for low- and middle-income countries, respectively, over the period 2004–2022.

The estimation results for model 5 reported in Table 2 (column 5) show that the digital economy has a positive and significant effect on economic growth in low-income countries at the 1% threshold. For a 1% increase in the level of the digital economy, economic growth increases by 0.045% *ceteris paribus*. Likewise, the estimation results of Model 5 recorded in Table 3 (column 5) below indicate that the digital economy has a positive and significant influence on economic growth in middle-income countries at the 10% threshold. For an increase in the level of the digital economy of 1%, economic growth increases by 0.026%, all else being equal. These results could be explained by the fact that digitalization

positively transforms the structure of economies and strengthens the level of skill of the labor factor, which, all things being equal, contributes to increasing the level of overall factor productivity and therefore economic growth.

Furthermore, low-income countries have an elasticity of the digital economy greater than that of middle-income countries of 0.0191. Which means that with an equal increase in the level of the digital economy in both types of countries, it acts more favorably on the economic growth of low-income countries than that of middle-income countries. This could be explained by the fact that in low-income countries the return on capital is higher than in middle-income countries in accordance with the theory of diminishing marginal returns. Indeed, in low-income countries there are more unexploited factors and technical progress is almost absent in the different economic activities. In other words, there is more absorptive capacity to produce and use digital technology than in middle-income countries. Therefore, low-income countries could skip the different stages of development and catch up with middle-income and high-income countries thanks to a self-centered policy of diffusion of the digital economy (Steinmueller, 2001).

Table 2. Estimation results in low-income countries

	(1)	(2)	(3)	(4)	(5)
VARIABLES	lnGDP	lnGDP	lnGDP	lnGDP	lnGDP
L.InGDP per capita	-0.0692** (0.0291)	-0.0275** (0.0262)	0.00757 (0.0166)	-0.0191** (0.0195)	-0.0477*** (0.00997)
Phone	0.00942*** (0.00225)				
Investment rate	-0.00202*** (0.000489)	0.000619 (0.000381)	-0.000902 (0.000584)	0.00101** (0.000387)	0.00115*** (0.000353)
Trade openness	0.00104*** (0.000195)	0.000470*** (0.000164)	0.000619*** (0.000118)	-5.58e-05 (0.000198)	3.25e-06 (7.23e-05)
Labor	0.00197 (0.00802)	-0.000106 (0.00427)	0.0185*** (0.00453)	-0.00411 (0.00307)	-0.00501 (0.00469)
Human capital	0.00904 (0.00904)	0.0117 (0.00790)	-0.00395 (0.00595)	0.0169*** (0.00579)	0.0109*** (0.00305)
Inflation	-0.000225*** (5.53e-05)	-0.000213*** (1.47e-05)	-0.000273*** (3.13e-05)	-0.000178*** (9.86e-06)	-0.000232*** (1.60e-05)
Financial Development	-0.00188*** (0.000474)	-0.00458*** (0.00116)	-0.000534* (0.000266)	-0.00126 (0.000908)	-0.00107*** (0.000363)
Cell Phone		0.0491** (0.0227)			
Internet User			-0.00259*** (0.000619)		
Internet access				0.0922** (0.0331)	
Digital Economy					0.0452*** (0.0130)
Constant	0.361 (0.214)	0.174 (0.182)	-0.304** (0.143)	0.172 (0.146)	0.360*** (0.112)
Observations	331	342	323	262	346
Number of countries	21	21	21	21	21
Number of instruments	15	15	18	18	18
AR (1)	0.055	0.020	0.028	0.010	0.020
AR (2)	0.212	0.354	0.352	0.537	0.324
Hassen's Statistic	0.871	0.691	0.646	0.546	0.392

Note: standard errors are in parentheses ***p<0.01, **p<0.05, *p<0.1

Source: Author based on WDI data (2023), ITU data (2023) and Penn World Table 10.1

This result corroborates the leapfrog strategy developed by Steinmueller (2001) and those found by Majeed and Ayub (2018). Indeed, these authors found in their study that ICTs contribute more to economic growth in lower regions (developing and emerging countries) than in higher regions (developed countries). On the other hand, it is contrary to the results found by Niebel (2018), Bahrini and Qaffas (2019), and Karlsson and Liljevein (2017), according to which ICTs always have a more favorable effect on economic growth in developed than in developing countries.

For a robust analysis, we tested the effects of digital infrastructure variables. The results in columns 1 and 2 of Tables 2 and 3 indicate that the number of fixed telephone subscribers and the number of mobile telephone subscribers positively and significantly influence economic growth in low- and middle-income countries at the respective thresholds of 1% and 5%. For a 1% increase in the number of fixed telephone subscribers (respectively the number of mobile telephone subscribers), economic growth increases by 0.0094% and 0.0029% (respectively 0.049% and 0.018%) in countries with low and middle income. These results could be explained by the fact that landline and mobile phones help reduce transaction costs and carry out income-generating activities using mobile phones. These results corroborate those found by Adeleye and Eboagu (2019). Furthermore, we note that the landline telephone has low elasticity compared to the mobile telephone. This result could be explained by the substitution effect of the landline telephone by the mobile telephone which means that the landline telephone is used less and less to reduce transactional costs.

As for the number of Internet users, the results in column 3 of Tables 2 and 3 indicate a negative and significant effect in low-income countries at the 1% threshold and a positive and significant effect in middle-income countries at the 5% threshold. An increase in internet users by 1% reduces economic growth by 0.0026% in low-income countries and increases that of middle-income countries by 0.032%. This counterintuitive result in low-income countries could be explained by the fact that many mobile phone and computer users do not have access to the Internet due to poor network coverage and the high cost of the Internet. Furthermore, the majority of users of New Information and Communication Technologies in Africa do not master the virtues of the Internet. Consequently, the latter is not used to carry out income-generating activities.

Table 3. Estimation results in middle-income countries

	(1)	(2)	(3)	(4)	(5)
VARIABLES	lnGDP	lnGDP	lnGDP	lnGDP	lnGDP
L.InGDP per capita	-0.0642** (0.0259)	-0.0357** (0.0385)	-0.0678* (0.0333)	-0.00385** (0.0370)	-0.0738** (0.0326)
Phone	0.00294*** (0.000709)				
Investment rate	-0.00171** (0.000679)	-0.00154*** (0.000443)	-0.00170*** (0.000542)	-0.00279 (0.00164)	-0.00168* (0.000930)
Trade openness	0.00124*** (0.000422)	0.00101*** (0.000344)	0.00120** (0.000454)	0.00401*** (0.00125)	0.000978* (0.000569)
Labor	0.0254* (0.0126)	0.0301*** (0.0102)	0.0182 (0.0158)	0.102** (0.0372)	0.00850 (0.0148)
Human capital	0.0498** (0.0180)	-0.000599 (0.0416)	0.0464* (0.0232)	-0.0111 (0.0321)	0.0491** (0.0210)
Inflation	-0.000633*** (6.48e-05)	-0.000688*** (9.30e-05)	-0.000663*** (8.98e-05)	-0.000782*** (0.000206)	-0.000600*** (6.07e-05)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	lnGDP	lnGDP	lnGDP	lnGDP	lnGDP
Financial Development	-7.04e-05 (0.000253)	-0.000112 (0.000387)	0.000409 (0.000461)	-0.00107 (0.000639)	0.000451 (0.000512)
Cell phone		0.0180** (0.00690)			
Internet user			0.0322** (0.0147)		
Internet access				0.0480*** (0.0137)	
Digital economy					0.0261* (0.0147)
Constant	-0.0361 (0.332)	-0.208 (0.375)	0.102 (0.442)	-1.690** (0.789)	0.300 (0.369)
Observations	367	368	366	315	368
Number of countries	23	23	23	23	23
Number of instruments	19	19	19	16	16
AR (1)	0.016	0.019	0.018	0.009	0.019
AR (2)	0.279	0.294	0.319	0.351	0.296
Hassen's statistic	0.578	0.831	0.204	0.637	0.454

Note: standard errors are in parentheses ***p<0.01, **p<0.05, *p<0.1

Source: Author based on WDI data (2023), ITU data (2023) and Penn World Table 10.1

Finally, for access to high-speed internet on a fixed line, the results of column 4 of tables 2 and 3 indicate that it has a positive and significant effect on economic growth at the 5% threshold in countries with low income and 1% in middle-income countries. When the level of fixed-line broadband internet access increases by 1%, the effect of economic growth increases by 0.092% in low-income countries and by 0.048% in middle-income countries. This could be explained by the fact that most economic activities carried out through ICT depend on access to the internet.

Furthermore, a comparison between the elasticities of the different digital infrastructure variables shows that in low-income countries, high-speed fixed-line internet remains the variable that acts most favorably on economic growth, followed by mobile telephones and landline telephones. Compared to middle-income countries, fixed-line broadband internet still remains the variable that has the most positive impact on economic growth, followed by the number of internet, mobile, and landline users. In the same sense, by comparing the elasticities of these variables between the two types of countries, the results show that, except for the number of Internet users, the other digital infrastructure variables in low-income countries display elasticities higher than those of middle-income countries. These results are partially in line with those found by the digital economy index in both types of countries.

For the control variables, the results indicate that, except for model 3 in low-income countries, all other models indicate a negative, less than zero, and statistically significant coefficient for the initial level of real GDP per capita (in logarithms) in both types of countries. This suggests evidence of convergence of the two types of countries towards countries in a higher bracket. In low- and middle-income countries, the labor factor, trade openness, and human capital have a positive and significant impact on the economic growth of these countries. On the other hand, inflation has a negative and significant impact on economic growth in both types of countries. As for the investment rate, the estimation

results indicate a mixed effect in low-income countries. Indeed, the results of model 1 indicate a negative and significant effect on economic growth, and those of models 3 and 4 indicate a positive and significant effect on economic growth. On the other hand, in middle-income countries, its effect is negative and significant on economic growth. Furthermore, the level of financial development has a negative and significant impact on economic growth in low-income countries, but it is not significant in middle-income countries.

5. Conclusion and economic policy recommendations

Africa has experienced a rapid spread of the digital economy, particularly with the advent of the mobile phone in the 2000s. This spread has led to notable changes at the level of households, businesses, and in different economic activities. It is with this observation that this present research aims to study the effects of digitalization on economic growth in 52 African countries, divided into two groups according to their level of GNI/inhabitant: 21 low-income countries and 31 middle-income countries over the period 2004 to 2022. To measure these effects, four digital infrastructure indicators were used. This is the number of landline telephone subscribers per 100 inhabitants, the number of mobile telephone subscribers per 100 inhabitants, the number of internet users as a percentage of the population, and the internet access service, broadband on fixed line per 100 inhabitants. The measurement of these effects consisted of measuring the specific effects, then the overall effect through the digital economy index constructed from a Principal Component Analysis of these indicators. To obtain results, the two-stage system GMM estimators corrected for finite sample bias were used. The empirical results show that the digital economy positively and significantly influences economic growth in both types of countries in Africa. However, this influence is greater in LICs than in MICs due to decreasing marginal returns to factors. As for the specific effects, the results show that the number of landline subscribers, the number of mobile phone subscribers, and access to high-speed internet on landlines positively influence economic growth in low-income countries, and the number of internet users hurts economic growth. On the other hand, in middle-income countries, all digital infrastructure variables positively influence economic growth. A comparative analysis shows that, except for the number of internet users, all other digital infrastructure variables have a greater effect on the economic growth of low-income countries than that of middle-income countries. Furthermore, access to the Internet remains the variable that has the greatest impact on economic growth in both types of countries, followed by mobile telephones in low-income countries and the number of Internet users in middle-income countries.

Several economic policy implications can be drawn from our results: First, for sustained and sustainable growth, authorities and policymakers in LICs and MICs need to pursue policies that can increase the level of investment in digital infrastructure, more precisely in the field of the Internet and mobile telephones, because they are more promising in the long term than fixed telephones. Second, authorities must modernize and expand digital infrastructure across all regions and administrations for more efficient use. Indeed, digitalization of administrations makes it possible to improve their efficiency and promote

good governance. To do this, they must liberalize the market to benefit from the effects of technological transfer and foreign direct investment; they must also pursue subsidy policies and reduce taxes in order to allow the private sector to boost the digital economy sector.

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Data availability statement

The data that support the findings of the study are available from the corresponding author upon reasonable request.

Notes

- (1) African Development Bank
- (2) United Nations Conference on Trade and Development
- (3) The poverty rate is calculated as the proportion of the population living below USD 1.90 per day, expressed in purchasing power parity (PPP) for 2011.
- (4) United Nation Development Programme
- (5) In Kaiser's sense, components with an eigenvalue greater than 1 should be retained.

References

- Acemoglu, D., and Robinson, J.A. (2013). *Why Nations Fail*. Crown Publishers.
- Adeleye, N., and Eboagu, C. (2019). Evaluation of ICT development and economic growth in Africa. *Economic Research and Electronic Networking*, 20(1), 31–53. <<https://doi.org/10.1007/s11066-019-09131-6>>
- Aghion, P., and Howitt, P. (1992). A Model of Growth Through Creative Destruction. *Econometrica*, 60(2), 323. <<https://doi.org/10.2307/2951599>>
- BAD. (2021). *Perspectives économiques en Afrique 2021: De la résolution de la dette à la croissance: Une feuille de route pour l'Afrique* (édition 2021). <www.afdb.org>
- Bahrini, R., and Qaffas, A. (2019). Impact of Information and Communication Technology on Economic Growth: Evidence from Developing Countries. *Economies*, 7(1), 21. <<https://doi.org/10.3390/economies7010021>>

- Barro, R.J., and Lee, J.W. (2013). A new data set of educational attainment in the world, 1950–2010. *Journal of Development Economics*, 104, 184–198. <<https://doi.org/10.1016/j.jdeveco.2012.10.001>>
- Barro, R., Mankiw, N., Gregory, and Sala-i-Martin, X. (1992). *Capital Mobility in Neoclassical Models of Growth* (w4206). National Bureau of Economic Research. <<https://doi.org/10.3386/w4206>>
- Blundell, R., and Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, 29.
- Bruno, O., and Musso, P. (2000). Volatilité de l'inflation et croissance économique. *Revue économique*, 51(3), 693. <<https://doi.org/10.2307/3503156>>
- Calderon, C., Kambou, G., Korman, V., Kubota, M., and Cantu Canales, C. (2019b). *Une analyse des enjeux façonnant l'avenir économique de l'Afrique*. The World Bank. <<https://doi.org/10.1596/978-1-4648-1510-2>>
- Caselli, F., and Coleman, W.J. (2001). Cross-country technology diffusion: The case of computers. *Working Paper No. 8130, National Bureau of Economic Research, Cambridge, MA*.
- CNUCED. (2021). *Rapport 2021 sur le développement économique en Afrique: La contribution potentielle de la Zone de libre-change continentale africaine à une croissance inclusive*. Nations Unies.
- Correa, E., and Esquivias, M.A. (2025). The impact of digitalization, education, and institutional quality on economic growth : A comparative analysis between Sub-Saharan Africa and Middle East Countries. *Social Sciences & Humanities Open*, 11, 101423. <<https://doi.org/10.1016/j.ssaho.2025.101423>>
- Dewan, S., and Kraemer, K.L. (2000). Information Technology and Productivity: Evidence from Country-Level Data. *Center for Research on Information Technology and Organizations*, 34.
- Emiru, T.M., and Wajebo, T. (2026). The impact of digitalization on economic activity in Sub-Saharan Africa. *Journal of Economic Studies*, 53(1), 1-15. <<https://doi.org/10.1108/JES-06-2024-0383>>
- Forthofer, R.N., Lee, E.S., and Hernandez, M. (2007). Linear Regression. In *Biostatistics* (pp. 349–386). Elsevier. <<https://doi.org/10.1016/B978-0-12-369492-8.50018-2>>
- Ghalayini, L., Nasser, A., and Ishker, N. (2020). ICT Diffusion and Economic Growth: A Comparative Study Across Economies. *Journal of Economics and Business*, 3(2). <<https://doi.org/10.31014/aior.1992.03.02.237>>
- Gökgöz, F., and Turan, H. (2025). Analyzing the ICT and economic growth relation in OECD countries. *Journal of Economic Studies*, 52(6), 1060-1075. <https://doi.org/10.1108/JES-04-2024-0281>
- Gordon, R.J. (2000). Does the “New Economy” Measure up to the Great Inventions of the Past? *Journal of Economic Perspectives*, 14(4), 49–74.
- Greenan, N., and L'Horty, Y. (2000). Informatique, productivité et emploi : Beaucoup d'espoirs, peu de certitudes. *Réseaux*, 18(100), 275–288. <<https://doi.org/10.3406/reso.2000.2223>>
- Haftu, G.G. (2019). Information communications technology and economic growth in Sub-Saharan Africa: A panel data approach. *Telecommunications Policy*, 43(1), 88–99. <<https://doi.org/10.1016/j.telpol.2018.03.010>>
- Hsiao, C. (1986). *Analysis of panel data* (2. ed., 8. print). Univ. Press.

- Hurlin, C., and Mignon, V. (2006). Une Synthèse des Tests de Racine Unitaire sur Données de Panel. *Economie et Prévision, Minefi - Direction de la prévision*, 169, 253-294. halshs-00078770.
- Jung, J.W. (2017). The Impact of Trade Liberalization in Africa. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3119601>
- Karlsson, K., and Liljevern, J. (2017). *ICT Investment and the Effect on Economic Growth: A Comparative Study across Four Income Groups* [Student Thesis]. Jönköping University.
- Keller, W. (2001). International technology diffusion. *Working Paper No. 8573, National Bureau of Economic Research, MA 02138*.
- Keller, W. (2004). International Technology Diffusion. *Journal of Economic Literature*, 31.
- Levin, A., Lin, C.-F., and Chu, C.-S.J. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics*, 24.
- Levine, R. (2004). *Finance and Growth: Theory and Evidence* (w10766). National Bureau of Economic Research. <<https://doi.org/10.3386/w10766>>
- Li, Q., and Wu, Y. (2022). ICT, technological diffusion and economic growth in Chinese cities. *Empirical Economics*. <<https://doi.org/10.1007/s00181-022-02302-9>>
- Lucas, R.E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, 22(1), 3–42. <[https://doi.org/10.1016/0304-3932\(88\)90168-7](https://doi.org/10.1016/0304-3932(88)90168-7)>
- Majeed, M.T., and Ayub, T. (2018). Information and Communication Technology (ICT) and Economic Growth Nexus: A Comparative Global Analysis. *Pakistan Journal of Commerce and Social Sciences (PJCSS)*, 12 (2), 35.
- Mankiw, N.G., Romer, D., and Weil, D.N. (1992). A contribution to the empirics of economic growth. *The Quarterly Journal of Economics*, 407–437.
- Mehmood, B., and Azim, P. (2013). Does ICT Participate in Economic Convergence among Asian Countries: Evidence from Dynamic Panel Data Model. *Informatica Economica*, 17(2/2013), 7–16. <<https://doi.org/10.12948/issn14531305/17.2.2013.01>>
- Myovella, G., Karacuka, M., and Haucap, J. (2020). Digitalization and economic growth: A comparative analysis of Sub-Saharan Africa and OECD economies. *Telecommunications Policy*, 44(2), 101856. <<https://doi.org/10.1016/j.telpol.2019.101856>>
- Nchake, M.A., and Shuaibu, M. (2022). Investment in ICT infrastructure and inclusive growth in Africa. *Scientific African*, 17, e01293. <<https://doi.org/10.1016/j.sciaf.2022.e01293>>
- Niebel, T. (2018). ICT and economic growth – Comparing developing, emerging and developed countries. *World Development*, 104, 197–211. <<https://doi.org/10.1016/j.worlddev.2017.11.024>>
- PNUD. (2023). *Communiqué de Presse*.
- Pradhan, R.P., Mallik, G., and Bagchi, T.P. (2018). Information communication technology (ICT) infrastructure and economic growth: A causality evinced by cross-country panel data. *IIMB Management Review*, 30(1), 91–103. <<https://doi.org/10.1016/j.iimb.2018.01.001>>
- Romer, P.M. (1986). Increasing Returns and Long-Run Growth. *The Journal of Political Economy*, Vol. 94(No. 5. (Oct., 1986)), 1002–1037.
- Romer, P.M. (1990). Endogenous Technological Change. *The Journal of Political Economy*, Vol. 98(No. 5), 34.
- Roodman, D. (2009). How to do Xtabond2: An Introduction to Difference and System GMM in Stata. *The Stata Journal*, 9(1), 86–136.

- Solow, R.M. (1956). A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics*, 70(1), 65. <<https://doi.org/10.2307/1884513>>
- Solow, R.M. (1957). Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics*, 39(3), 312. <<https://doi.org/10.2307/1926047>>
- Stanley, T.D., Doucouliagos, H., and Steel, P. (2018). Does ICT generate economic growth? A meta-regression analysis: does ICT generate economic growth? *Journal of Economic Surveys*, 32(3), 705–726. <<https://doi.org/10.1111/joes.12211>>
- Steinmueller, W.E. (2001). ICTs and the possibilities for leapfrogging by developing countries. *International Labour Review*, 140(2), 193–210.
- Swan, T.W. (1956). Economic Growth and Capital Accumulation. *Economic Record*, 32(2), 334–361. <<https://doi.org/10.1111/j.1475-4932.1956.tb00434.x>>
- Toader, E., Firtescu, B., Roman, A., and Anton, S. (2018). Impact of Information and Communication Technology Infrastructure on Economic Growth: An Empirical Assessment for the EU Countries. *Sustainability*, 10(10), 3750. <<https://doi.org/10.3390/su10103750>>
- Windmeijer, F. (2005). A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of Econometrics*, 126(1), 25–51. <<https://doi.org/10.1016/j.jeconom.2004.02.005>>
- World Bank. (2009). *Information and Communications for Development 2009: Extending Reach and Increasing Impact*. The World Bank. <<https://doi.org/10.1596/978-0-8213-7605-8>>
- World Bank. (2012). *ICT for greater development impact*. <<http://documents.worldbank.org/curated/en/285841468337139224/ICT-for-greater-development-impact-World-Bank-Group-Strategy-for-2012-2015>>
- World Bank. (2024). *World bank country classifications by income level 2022-2023*.
- Yousefi, A. (2011). The impact of information and communication technology on economic growth: Evidence from developed and developing countries. *Economics of Innovation and New Technology*, 20(6), 581–596. <<https://doi.org/10.1080/10438599.2010.544470>>

Appendix

Appendix 1. List of countries surveyed

Low-income countries	Middle-income countries
Burkina Faso	Angola
Burundi	Algeria
Central African Republic	Benin
Chad	Cabo Verde
Congo Democratic Republic	Cameroon
Eritrea	Comoros
Ethiopia	Congo Republic
Gambia	Côte d'Ivoire
Guinea-Bissau	Djibouti
Liberia	Egypt
Madagascar	Kenya
Malawi	Lesotho
Mali	Mauritania
Mozambique	Morocco
Niger	Sao-Tomé-And-Principe
Rwanda	Senegal
Sierra Leone	Tanzania
Somalia	Tunisia
Sudan	Eswatini
South of Sudan	Ghana
Togo	Nigeria
Uganda	Zambia
	Zimbabwe
	Botswana
	Equatorial Guinea
	Gabon
	Libya
	Namibia
	South Africa
	Guinea
	Mauritius

Source: author

Appendix 2. Pearson correlation test results for MICs

	Phone	Cell phone	Internet user	Internet access
Phone	1.0000			
Cell phone	0.2589* (0.0000)	1.0000		
Internet user	0.3174* (0.0000)	0.7547* (0.0000)	1.0000	
Internet access	0.5122* (0.0000)	0.4852* (0.0000)	0.7278* (0.0000)	1.0000

Note: (*) significant correlation coefficient at the 10% threshold

Source: Author based on ITU data (2023)

Appendix 3. Pearson correlation test results for LICs

	Phone	Cell phone	Internet user	Internet access
Phone	1.0000			
Cell phone	0.0563 (0.2504)	1.0000		
Internet user	0.1249* (0.0144)	0.7288* (0.0000)	1.0000	
Internet access	0.0075 (0.9052)	0.2905* (0.0000)	0.2052* (0.0017)	1.0000

Note: (*) significant correlation coefficient at the 10% threshold

Source Author based on ITU data (2023)

Appendix 4. Results of principal components (eigenvalues) in LICs

Components	Eigenvalues	Proportions	Cumulative
Component 1	2.029	0.507	0.507
Component 2	0.993	0.248	0.755
Component 3	0.671	0.167	0.923
Component 4	0.305	0.076	1.000

Source: Author based on ITU data (2023)

Appendix 5. Results of principal components (eigenvectors) in LICs

Variables	Component 1	Component 2	Component 3	Component4
Phone	0.088	0.993	-0.066	-0.019
Cell phone	0.606	-0.067	-0.398	0.684
Internet user	0.617	-0.088	-0.291	-0.725
Internet access	0.493	0.015	0.867	0.070

Source: Author based on ITU data (2023)

Appendix 6. Results of principal components (eigenvalues) in MICs

Components	Eigenvalues	Proportions	Cumulative
Component 1	2.561	0.640	0.640
Component 2	0.848	0.212	0.852
Component 3	0.349	0.087	0.940
Component 4	0.240	0.060	1.000

Source: Author based on ITU data (2023)

Appendix 7. Results of principal components (eigenvectors) in MICs

Variables	Component 1	Component 2	Component 3	Component4
Phone	0.4510	0.6645	0.4162	0.4264
Cell phone	0.4925	-0.5038	0.6216	-0.3425
Internet user	0.5163	-0.4425	-0.4478	0.5806
Internet access	0.5362	0.3299	-0.4898	-0.6031

Source: Author based on ITU data (2023)

Appendix 8. Sequential process of the Hsiao test

It is done in three steps:

In a first step, we test the hypothesis H_0^1 of a perfectly homogeneous structure (constant and coefficient of identical explanatory variables).

If H_0^1 is rejected (p-value < at the threshold), we move on to the second step of the test which consists of testing the null hypothesis H_0^2 of homogeneity of the coefficients of the explanatory variables. If this hypothesis is rejected then we reject the panel structure.

Therefore, if this hypothesis is accepted, we retain the panel structure and we finally seek to determine in a third step whether the constants have specific individual effects.

If we reject the null hypothesis H_0^3 of homogeneity of constants, we obtain a panel model with individual effects. Otherwise (acceptance of the null hypothesis H_0^3) we obtain a completely homogeneous panel structure (pooled model).

Appendix 9. Results of the LIC homogeneity test

	F1	F2	F3	Decision
Model 1	27.103543*** (1.653e-56)	-22.993526 (1.0000)	4.4889061*** (4.477e-10)	Individual effect
Model 2	26.098774*** (1.329e-55)	-22.182095 (1.0000)	4.448683*** (5.904e-10)	Individual effect
Model 3	33.753598*** (8.404e-62)	-29.396284 (1.0000)	3.9932454*** (1.344e-08)	Individual effect
Model 4	37.037847*** (4.660e-64)	-24.255552 (1.0000)	10.370818*** (8.660e-27)	Individual effect
Model 5	27.004341*** (2.024e-56)	-22.946767 (1.0000)	4.4563246*** (5.602e-10)	Individual effect

Note: p-values are in brackets. ***, **, * respectively significant at 1%, 5%, 10%.

Source: Author based on WDI data (2023), ITU data (2023) and Penn World Table 10.1

Appendix 10. Results of the MIC homogeneity test

	F1	F2	F3	Decision
Model 1	-97.746213 (1.0000)	-73.665788 (1.0000)	4.1550474*** (1.192e-10)	Individual effect
Model 2	-212.83986 (1.0000)	-157.92746 (1.0000)	4.4371329*** (1.186e-11)	Individual effect
Model 3	-115.04683 (1.0000)	-83.633244 (1.0000)	4.7585673*** (8.568e-13)	Individual effect
Model 4	-294.5947 (1.0000)	-211.94087 (1.0000)	4.9651504*** (1.590e-13)	Individual effect
Model 5	-242.78656 (1.0000)	-177.82091 (1.0000)	4.6573592*** (1.958e-12)	Individual effect

Note: p-values are in brackets. ***, **, * respectively significant at 1%, 5%, 10%.

Source: Author based on WDI data (2023), ITU data (2023) and Penn World Table 10.1

Appendix 11. Multi-collinearity test results

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
	VIF	VIF	VIF	VIF	VIF
Phone	1.23				
Cell phone		1.34			
Internet user			1.27		

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
	<i>VIF</i>	<i>VIF</i>	<i>VIF</i>	<i>VIF</i>	<i>VIF</i>
Internet access				1.32	
Digital economy					1.33
Investment rate	1.63	1.55	1.67	2.22	1.60
Labor	1.64	1.30	1.33	1.43	1.33
Trade openness	1.45	1.42	1.42	2.01	1.43
Inflation	1.31	1.31	1.38	1.32	1.32
Financial development	1.16	1.43	1.30	1.65	1.42
Human capital	1.05	1.09	1.11	1.12	1.09
Mean	1.35	1.35	1.35	1.58	1.36

Source: Author based on WDI data (2023), ITU data (2023) and Penn World Table 10.1

Adaptive AI, behavioural pattern formation, and the development of human cognition

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Abstract. *Artificial intelligence is commonly discussed in terms of information access, automation, productivity, and decision support. While these functions are important, they may not fully capture the broader significance of adaptive AI systems. Unlike many previous informational technologies, adaptive AI systems engage in ongoing interaction that can adapt to the needs, questions, communication styles, and understanding of individual users. This creates opportunities for a more personalized and responsive form of engagement with information.*

This article explores the possibility that the importance of adaptive AI extends beyond the information it provides. Through repeated adaptive interaction, individuals may encounter and practice new approaches to reasoning, communication, information organization, perspective exploration, and problem-solving. Over time, some of these patterns may become incorporated into how individuals learn, think, communicate, and engage with new situations.

The article argues that adaptive AI systems may increasingly function as a source of pattern formation alongside the human relationships, educational experiences, professional environments, and social contexts that have historically contributed to human development. As individuals integrate patterns encountered through adaptive AI interaction with those acquired from other sources, new forms of pattern merging may emerge within the developmental process itself. Building on perspectives from developmental psychology and historical accounts of technological change, this article proposes a framework for understanding adaptive AI as a participant in processes of learning and development rather than solely as a tool for information retrieval. The article concludes that the long-term significance of adaptive AI may lie not only in what it knows, but also in its capacity to support the acquisition, refinement, and application of patterns that contribute to human development across different areas of life.

Keywords: adaptive artificial intelligence, human cognition, behavioural pattern formation, human development, social learning.

JEL Classification: D83, D91, I20, O33, Z13.

1. Introduction

Artificial intelligence is often addressed in terms of decision support, automation, productivity, and information access. A large portion of the current debate about AI's place in society has been influenced by such perspectives. However, as adaptive AI systems are integrated more into daily activities, their importance might go beyond the information or tasks they carry out.

Adaptive AI systems engage in continuous communication, in contrast to many older technologies. They can react, modify, reformulate, and interact with individuals for extended periods of time. As a result, interaction with adaptive AI differs from interaction with technologies that primarily store, retrieve, or transmit information.

This article explores an alternative perspective on the importance of adaptive AI. It investigates the possibility that repeated adaptive interaction may have wider implications for human development rather than focusing primarily on information, productivity, or automation. The primary thesis is that adaptive AI systems might become more involved in processes that have traditionally been largely influenced by social and human environments. Understanding this possibility may become increasingly important as adaptive AI systems become more deeply integrated into everyday life.

2. Human development and external sources of pattern formation

Human development has always occurred within environments that shape how individuals think, communicate, learn, interpret situations, and engage with the world around them. Families, educational systems, social groups, institutions, workplaces, cultural environments, and other sources of social influence all contribute to the patterns that individuals encounter throughout their lives. According to Bandura (1977) and Vygotsky (1978), these environments play a role in the development of habits, expectations, communication styles, reasoning techniques, and approaches to problem-solving that often persist over time.

The transmission of patterns has historically depended on interaction. Through repeated exposure to particular ways of communicating, interpreting situations, organizing information, and responding to challenges, individuals gradually acquire patterns that become incorporated into everyday thinking and behaviour. Human development therefore involves more than the acquisition of information. It also involves the acquisition of recurring patterns that influence how information is understood, applied, and communicated (Bandura, 1977; Bronfenbrenner, 1979).

Throughout history, the environments through which patterns are transmitted have expanded. Writing allowed knowledge to persist beyond immediate human memory. Literacy increased access to ideas across time and distance. Printing technologies accelerated the spread of information throughout society. Digital technologies facilitated greater access to information, communication, and knowledge exchange. These developments altered the environments within which learning and development occurred by changing how individuals encountered information and interacted with one another (Ong, 1982).

Despite these changes, most informational technologies have remained relatively limited in their ability to adapt to the individual. Books, libraries, archives, databases, and search engines can provide access to information, but they generally do not modify their responses according to the needs, understanding, goals, or communication preferences of the person engaging with them. The interaction remains heavily reliant on the individual's ability to adapt to the information source, rather than the information source adapting to the individual.

This historical context provides a solid foundation for understanding the significance of adaptive AI systems. While previous technological developments transformed access to information, adaptive AI introduces the possibility of ongoing interaction that responds to the individual. Understanding this distinction requires examining how adaptive interaction differs from previous forms of informational engagement.

3. The emergence of adaptive interaction

Historically, most informational technologies were designed to store, organize, retrieve, or distribute data. Books, libraries, archives, encyclopaedias, databases, and search engines have expanded access to knowledge, but they generally provide the same information regardless of who is engaging with them. While these technologies have transformed the availability of information, they have remained relatively limited in their ability to adapt to the specific needs of individual users.

Human interaction has traditionally provided a unique type of engagement. Teachers, mentors, colleagues, friends, and other individuals can modify explanations, answer questions, clarify misunderstandings, provide examples, and adjust communication according to the needs of the person with whom they are interacting. The exchange is not fixed. It changes in response to feedback, confusion, curiosity, disagreement, and a growing understanding.

Adaptive AI systems introduce a similar capacity for responsiveness into interactions that occur through technology. Rather than presenting a fixed body of information, they can engage in ongoing exchanges that adjust to the individual. Explanations can be reformulated, information reorganized, alternative perspectives explored, and communication styles adjusted throughout the interaction. The interaction itself becomes dynamic rather than static.

This distinction is significant because it alters how the individual interacts with the information source. In many previous informational environments, individuals were required to adapt themselves to the structure of the information available. Adaptive AI systems introduce the possibility of the interaction becoming increasingly customized to the individual. As a result, the exchange becomes less focused on accessing information alone and more focused on the process through which information is explored, clarified, organized, and discussed.

The emergence of adaptive interaction represents a departure from earlier informational technologies not because it changes the existence of information itself, but because it

changes the nature of engagement with that information. Understanding the implications of this shift requires examining what might develop when repeated interaction becomes an increasingly common feature of everyday engagement with information.

4. Pattern internalization and merging through adaptive interaction

The emergence of adaptive AI systems creates a new type of interactive environment. Unlike previous informational technologies, adaptive AI systems do not merely store or transmit information. They engage in ongoing exchanges. They respond to questions, clarify confusion, reformulate explanations, change communication styles, present alternative perspectives, and modify responses based on the individual's needs. Rather than providing a fixed presentation of information, they constantly adapt during the interaction.

This distinction may have implications beyond information access and retrieval. Through repeated adaptive interaction, individuals may be exposed not only to information but also to recurring patterns of explanation, reasoning, communication, information organization, perspective exploration, and problem-solving. With time, some of these patterns may become internalized, influencing how individuals approach situations outside of the interaction itself (Bandura, 1977; Vygotsky, 1978). The effects of the interaction may therefore persist beyond the conversation, shaping resulting knowledge, communication, reflection, decision-making, and engagement with other people and environments (Bandura, 1977; Bronfenbrenner, 1979).

From this perspective, the importance of adaptive AI systems may not be entirely based on the information they provide. It could also lie in their capacity to participate in processes through which patterns are learned, reinforced, modified, and internalized. Through repeated adaptive interaction, AI systems may become a source of pattern internalization alongside the human relationships, institutions, and social environments that have historically shaped human development. This prospect suggests that adaptive AI may represent not only a new informational environment, but also a new source of developmental influence.

If adaptive AI systems can become a source of pattern internalization, a new possibility arises. Individuals do not simply accumulate patterns from a single source over their lifetime. Human thinking is already shaped by patterns learned from parents, teachers, instructors, other individuals, institutions, cultures, professional settings, books, and personal experiences. Development can therefore be understood as an ongoing process through which patterns from multiple sources are encountered, evaluated, modified, combined, reinforced, or discarded over time (Bandura, 1977; Bronfenbrenner, 1979; Vygotsky, 1978).

The introduction of adaptive AI systems adds a new source of pattern formation to this process. Through repeated interaction, individuals can experience recurring patterns of reasoning, explanation, communication, information organization, and problem exploration that originate from adaptive AI systems. As these patterns become internalized, they do not remain separate from existing patterns. Instead, they become part of the broader

system through which individuals interpret information, evaluate situations, communicate with others, and engage with the world.

From this point of view, the phenomenon under consideration is not the merging of humans and artificial intelligence as separate entities. Rather, it is the merging of patterns that originate from different sources and become incorporated into the same developing individual. Human-derived patterns and AI-derived patterns may gradually coexist, interact, reinforce one another, compete with one another, or produce entirely new combinations. The resulting patterns are not identical to either source. They develop from the interaction between them.

This process is not limited to AI. Human development has always involved the integration of patterns acquired from multiple sources. However, adaptive AI systems differ from previous informational technologies because they participate in ongoing interaction rather than one-directional information delivery. Through continuous adaptation, they can repeatedly introduce individuals to particular ways of reasoning, explaining, organizing information, approaching uncertainty, and exploring ideas. The influence therefore extends beyond the transmission of information and enters the domain of pattern formation.

The significance of this process may become clearer when the effects of interaction extend beyond the interaction itself. Individuals may begin to apply patterns learned through adaptive AI interaction when communicating with others, making decisions, confronting unfamiliar situations, solving problems, or interpreting new information. In such cases, the influence of the interaction is no longer confined to the conversation in which it originated. The patterns have become integrated into subsequent stages of thought and behaviour.

The concept of merging, as used in this article, refers to this process of pattern convergence through repeated adaptive interaction. It does not imply biological fusion, shared consciousness, neural integration, or the disappearance of distinctions between humans and artificial intelligence. In fact, it describes the gradual incorporation and interaction of patterns originating from different systems within the developmental processes of the individual. The focus is therefore not on the merging of entities, but on the merging of patterns that influence how individuals think, learn, communicate, and engage with the world around them.

5. Mechanisms of pattern internalization through adaptive interaction

If adaptive AI systems can become a source of pattern internalization, an important question follows: why might patterns originating from AI systems become incorporated into human thinking and behaviour in the first place? Understanding this process necessitates investigating the circumstances under which patterns are most likely to be adopted, reinforced, and maintained (Bandura, 1977; Vygotsky, 1978).

Historically, pattern internalization was dependent on both exposure and interaction. A book may contain valuable ideas, but it presents the same content to all readers, regardless of whether they understand it. Libraries provide access to large amounts of information but do not guide interpretation. Encyclopaedias and databases provide explanations, but they

cannot adjust when confusion persists. In each case, information is available, but the interaction itself is limited.

Human relationships have traditionally filled this gap. Teachers, mentors, tutors, colleagues, and other influential individuals can modify explanations, answer questions, provide examples, identify misunderstandings, and adapt communication according to the needs of the learner. Nevertheless, this process is frequently restricted by practical constraints. Individuals have different communication styles, vocabulary, prior knowledge, assumptions, learning preferences, patience, and explanatory abilities. As a result, even the most knowledgeable people may struggle to communicate effectively with certain individuals. Understanding is determined not only by the quality of the information, but also by the individual's compatibility with the source of that information (Vygotsky, 1978).

Adaptive AI systems introduce a different set of conditions. Instead of providing a fixed explanation, they can constantly reformulate information until understanding is achieved. A concept can be explained visually, conceptually, practically, technically, or through analogy. Information can be simplified, expanded, reorganized, compared, challenged, or viewed from various angles. The interaction can continue until the individual finds an explanation that aligns with their existing knowledge, communication preferences, and way of understanding the world.

This adaptability may increase the prospect of specific patterns being internalized. Individuals are not exposed only to information itself, but also to recurring ways of approaching information. Across many different conversations, they repeatedly encounter patterns of clarification, comparison, decomposition, perspective-taking, information organization, and problem exploration. Because these patterns appear in multiple contexts and are frequently presented in easily understandable formats, they may be more likely to be noticed, applied, repeated, and remembered.

The significance of adaptive interaction may therefore extend beyond informational accuracy or efficiency. By increasing compatibility between the individual and the interaction, adaptive AI systems may create conditions that facilitate pattern development and reinforcement. Over time, repeated exposure to these patterns may increase the likelihood that they will be adopted by the individual's own approaches to learning, reasoning, communication, and problem solving.

According to this viewpoint, internalization of AI-derived patterns is the result of multiple interactions. It develops from a continuous cycle of adaptation, exposure, application, reinforcement, and memory retention. The interaction becomes a mechanism through which patterns are repeatedly encountered in forms that are understandable, usable, and increasingly likely to persist beyond the interaction itself.

6. Persistence beyond the interaction

The developmental significance of pattern internalization is most evident when its effects extend beyond the interaction in which they originated. If patterns acquired through adaptive AI interaction remained confined to individual conversations, their influence

would be limited to the duration of those exchanges. The possibility discussed in this article is different. Patterns encountered through repeated adaptive interaction may continue influencing individuals after the interaction itself has ended (Bandura, 1977; Bronfenbrenner, 1979).

Persistence is a common component of human development. Individuals commonly continue to apply patterns learned from influential individuals and settings long after direct interaction has ended. A teacher's reasoning style, a mentor's problem-solving approach, or a parent's way of interpreting situations can all have an impact on behaviour years after the initial interaction. The interaction ends, but aspects of its influence remain active.

A similar process might take place after repeated interaction with adaptive AI systems. Once patterns become internalized, they do not necessarily remain tied to the context in which they were acquired. Individuals may continue using approaches to organizing information, evaluating alternatives, exploring perspectives, clarifying uncertainty, or solving problems that were repeatedly encountered during previous interactions. These patterns can be applied in situations where no AI system is present.

This process's cumulative nature is what makes it significant. The impact of adaptive interaction may not be determined by a single conversation, but rather by the gradual accumulation of effects across multiple interactions over time. Patterns that are repeatedly encountered, applied, and reinforced may become increasingly integrated into everyday thinking and behaviour. As a result, the developmental consequences of adaptive interaction may emerge gradually rather than in a single transformative event.

This perspective shifts attention away from individual exchanges and toward their lasting effects. The importance of adaptive AI systems may therefore extend beyond what occurs during interaction itself. Their influence may also be reflected in what individuals do after the interaction: how they approach new information, structure explanations, evaluate competing ideas, navigate uncertainty, and interact with others and their environments.

From this perspective, adaptive AI interaction can be understood not as a collection of isolated conversations, but as an ongoing developmental process whose effects extend beyond the moments in which interaction occurs. Although the interaction may come to an end, some of the patterns formed during it may continue to shape future thought, behaviour, and engagement with the world.

7. Developmental consequences of persistent pattern change

The significance of persistent pattern change lies not in the interaction itself, but in the possibility that patterns acquired through interaction continue influencing behaviour in contexts unrelated to the original exchange. Once internalized, such patterns can be applied to future learning experiences, professional activities, interpersonal interactions, decision-making processes, and encounters with unfamiliar situations. The developmental consequences therefore arise not from the interaction itself, but from the continued application of learned patterns across various areas of life.

This transfer may occur because individuals do not compartmentalize patterns based on where they came from (Bandura, 1977; Bronfenbrenner, 1979). Once internalized, a pattern can be used wherever it is useful. An approach to organizing information acquired in one context may later be used to understand a new topic. A method of comparing alternatives may later influence decision-making. A pattern of perspective exploration may influence interpersonal communication or the interpretation of complex situations. The original interaction may be forgotten, but the pattern remains active.

From this perspective, the developmental significance of adaptive AI interaction extends beyond information learning. What may ultimately matter is not the specific content of individual conversations, but the extent to which recurring patterns become incorporated into everyday thinking and continue influencing behaviour across various contexts. Developmental consequences emerge when patterns learned through interaction become sufficiently stable to contribute to how individuals engage with situations beyond the interaction itself.

The cumulative application of internalized patterns may gradually contribute to broader changes in how individuals learn, communicate, reason, solve problems, engage with uncertainty and not only. Such changes do not have to take place suddenly or excessively. They can appear gradually because of the repeated application of acquired patterns to new situations over time. The developmental influence of adaptive AI systems can therefore be found in the long-term accumulation and application of patterns in everyday life rather than any single interaction.

8. Implications for human development

Historically, the development of human thought and behaviour has been shaped primarily by interaction with other people and by the social environments within which individuals live (Bandura, 1977; Bronfenbrenner, 1979; Vygotsky, 1978). Families, educational institutions, social circles, professional environments, and cultural systems have traditionally been the primary channels for passing down, consolidating, and internalizing patterns across generations.

The emergence of adaptive AI systems introduces the possibility that pattern formation may increasingly occur through interaction with a new type of source. Unlike previous informational technologies, adaptive AI systems can engage in ongoing interactions that respond to the individual and adapt over time. If such systems become a regular part of everyday learning, communication, problem-solving, and information-seeking activities, their impact may extend beyond information access to the broader processes by which patterns are gained and maintained.

The significance of this possibility does not depend on the replacement of human relationships or social environments. Human development will continue to take place within families, communities, educational systems, workplaces, and larger social contexts. However, adaptive AI systems may increasingly become a part of the environments in which individuals experience new patterns, reinforce existing ones, and update previously learned ways of thinking and acting.

From this point of view, adaptive AI may be more than just a new technological tool. It might represent the introduction of a new source of developmental influence, working alongside the social environments that have historically shaped human development. The long-term significance of adaptive AI could therefore be determined not only by the information it provides, but also by the patterns it contributes to the continuous development of individuals and societies.

9. Limitations and boundaries

The argument presented in this article should not be interpreted as suggesting that all interaction with adaptive AI systems produces pattern internalization or developmental influence. The extent to which patterns are learned, retained, and applied is likely to differ between individuals, contexts, purposes of use, and patterns of involvement. Individuals may interact with the same system in very different ways, resulting in different or no patterns being internalized.

Similarly, the concept of pattern merging proposed in this article does not imply the replacement of human influence by artificial intelligence. Human development continues to take place in families, educational institutions, communities, workplaces, relationships, and larger cultural contexts. Adaptive AI systems represent an additional source through which patterns may be encountered, reinforced, modified, and internalized rather than a substitute for existing social and developmental processes.

The theory also does not assume that all patterns originating from adaptive AI systems will be adopted and retained. Individuals continue to actively participate in the processes of interpretation, evaluation, acceptance, modification, and rejection. Internalization is thus a dynamic process shaped by the individual's prior experiences, goals, values, and developmental history.

In addition, the concept of merging developed in this article should not be understood as implying biological fusion, neural integration, shared consciousness, or the disappearance of distinctions between humans and artificial intelligence. The theory focuses on the convergence and interaction of patterns through repeated adaptive interaction rather than the merger of entities, identities, or cognitive systems.

The framework presented here is intended to be used as a theoretical framework for a potential developmental process. More empirical research would be needed to investigate the extent to which AI-derived patterns are internalized, how such patterns interact with previously learned patterns, and how these processes differ across individuals and contexts.

10. Conclusions

Throughout history, informational environments have shaped how individuals learn, organize, transmit, and apply knowledge. Writing, literacy, printing technologies, and digital systems all changed the conditions under which learning and information exchange took place. However, these environments remained largely limited in their ability to constantly adapt to the needs of individual users.

The advancement of adaptive AI systems introduces a new type of interaction. Unlike previous informational technologies, adaptive AI systems can participate in ongoing exchanges that respond to the individual, modify explanations, adjust communication styles, and adapt to changing informational needs. This article contends that the importance of such systems may go beyond information access and retrieval.

The central argument established throughout this article is that adaptive AI systems may become a source of pattern internalization alongside the human relationships, institutions, and social environments that have historically shaped human development. Through repeated adaptive interaction, individuals may encounter, reinforce, and internalize recurring patterns of reasoning, communication, explanation, information organization, and problem exploration. Over time, these patterns may become integrated in everyday thought and shape behaviour beyond the interaction itself.

From this perspective, the phenomenon discussed in this article is not the merging of humans and artificial intelligence as entities. Rather, it is the merging of patterns through repeated adaptive interaction. Human-derived and AI-derived patterns may coexist, interact, reinforce, compete, and contribute to the individual's continued development. Adaptive AI's significance lies not only in the information it provides, but also in its potential participation in processes that enable patterns to be gained, maintained, modified, and applied across various aspects of life.

Adaptive AI may be more than just a new technological tool or information resource. It may represent the emergence of a new source of pattern formation operating alongside the social and developmental environments that have historically influenced human thought and behaviour. As adaptive AI systems become increasingly integrated into everyday life, understanding their role in the processes of pattern internalization and pattern merging may become increasingly important for understanding contemporary human development.

References

- Bandura, A. (1977). *Social Learning Theory*. Englewood Cliffs, NJ: Prentice-Hall.
- Bronfenbrenner, U. (1979). *The Ecology of Human Development: Experiments by Nature and Design*. Cambridge, MA: Harvard University Press.
- Georgescu, R.I., Bodislav, D.A. (2026). AI-simulated reciprocity and the narrowing of decision options within human attachment psychological architecture, *Theoretical and Applied Economics*, vol. 33, no. 1(646), 153-164.
- Ong, W.J. (1982). *Orality and Literacy: The Technologizing of the Word*. London: Methuen.
- Vygotsky, L.S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.

Tax-driven alignment between conforming and non-conforming earnings management across different accounting standards

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Abstract. *This paper discusses how corporations have been impacted by changes in tax laws that regulate how businesses report their revenues over time. Accounting for these changes can lead corporations to manipulate income (profit) by manipulating various aspects of a company's operations, including regular business practice, and, therefore, how much corporate taxes will be owed due to choices companies have made regarding which generally accepted accounting principles to follow (IFRS or GAAP). I will examine over 20 years of data on more than 20 global corporations that each file a public offering prospectus from 2015 through 2023 and tally to approximately 180 cases in total.*

Keywords: earnings management, conforming earnings management, non-conforming earnings management, effective tax rate, accounting standards, tax planning, multinational firms.

JEL Classification: H25, M41, G32, G38.

1. Introduction

The phenomenon of earnings management represents an essential behavior of firms in exercising their ability to adjust the financial results of operations in response to increasing competitive, regulatory, and taxation pressures. The process has evolved to include various techniques and strategies that can be utilized to affect the manner in which firms report income for the purpose of achieving tax compliance, access to and/or lower-cost debt and/or equity financing, and/or meeting public reporting obligations. The earnings management literature classifies earnings management techniques into two major categories: conforming earnings management (CEM) which uses accounting estimates and discretionary accounting choices permitted under accounting standards, and non-conforming earnings management (NCEM) which uses corporate operational activity that may impact taxable income and/or other real economic activity without any corresponding change to the manner in which accounting income is reported by firms (Healy & Wahlen, 1999). An understanding of the difference between these types of earnings management is important for determining how companies engage in tax management, as well as how companies utilize both types of methods together to accomplish their corporate financial objectives (Schipper, 1989).

The tax-related incentives for managers to engage in earnings management are among the strongest incentives for earnings management behavior as they are directly tied to a firm's reported net income and its cash flows. Therefore, firms will typically pursue strategies that result in lower corporate tax payments either through commercial adjustments or by using operational techniques to influence a firm's taxable income (Hanlon & Heitzman, 2010). An understanding of the relationship between a firm's corporate tax obligations, its accounting framework, and its earnings management behavior becomes more critical in a global business environment since there can be substantial differences between accounting frameworks (e.g., IFRS versus US GAAP) and tax systems between countries which make it more challenging to analyse corporate behavior and, therefore, will require analysis to consider the context in which corporate earnings management behavior is classified as non-conforming or conforming (Graham et al., 2012).

Furthermore, the differences in the accounting standards between IFRS, US GAAP, and various country-specific GAAP frameworks plays an important role in determining the opportunities available for management to engage in earnings management behaviours. Since IFRS is primarily a principles-based framework, it allows greater flexibility in terms of interpretability, as compared to US GAAP, which is primarily a rules-based accounting framework that sets out more specific guidelines for revenue recognition and measurement. These differences have an impact on the extent to which organizations engage in conforming versus non-conforming earnings management and will have an impact on the extent to which reported outcomes are comparable across different jurisdictions (Jeanjean & Stolowy, 2008). As a result, organizations will select the strategies that provide the most advantage in terms of their particular circumstances based on the accounting regime within which they operate (Ball, 2006).

The relationship between companies' earnings management (CEM) and noncompliance earnings management (NCEM) is based on information provided through the use of tax-

aligned CEM and NCEM. Multinational companies frequently combine both CEMs and NCEAs to maximize their tax advantages while remaining compliant with regulations and being transparent about their practices. This relationship is vital for international companies and multinational corporations, which operate within numerous different jurisdictions, which require adherence to different accounting and tax laws, to inform management decision-making (e.g., Frank et al. 2009). Understanding how companies leverage both CEM and NCE in an environment of different standards will help provide insights into global financial behavior (Desai 2005).

This study will analyze how twenty multinational corporations (MNCs) worldwide, that trade on stock exchanges around the globe from 2015 - 2023, will serve as a case study to provide additional understanding of corporate earnings management and taxation based upon the information developed through accounting standard differences and earnings management strategies.

In order to evaluate the impact of CEM and NCE on corporate effective tax rate (ETR) through the use of a panel data regression model. Control variables to be considered in the analysis include: firm size (SIZE), firm leverage (LEV), and firm's return on assets (ROA); as well as whether the interaction of these control variables with the CEMs and NCEs moderates the ETR as indicated through the findings of prior studies on the interaction between accounting standards and management discretion (i.e., Ball 2006).

2. Literature Review

The research regarding the relationship between earnings management and tax planning has increased significantly in the last 20 years. Most early research has focused on how aggressive tax strategies may provide agency conflict information about a firm, particularly in such situations where an organization's monitoring/govt. has limited resources (Desai & Dharmapala, 2006).

Within different institutional environments the strength and interpretation of book-tax differences varies as they depend on enforcement focus and quality of disclosure to determine whether the book-tax difference represents opportunistic behavior or structural legitimacy (Evers et al., 2015). Furthermore, there is now greater evidence linking the existence of large book-tax differences with broader consequences to a company's financial position; such as providing lower returns for each amount of earnings reported or increasing the company's exposure to financial risk (Anderson, 2025).

On the other hand, real activity manipulation is based on management's actions in managing operational decisions; for example, early reporting of sales revenue and production, which allows them to meet earnings targets (Roychowdhury, 2006).

Research on how firms determine their columnar and real earnings management approaches indicates that firms consider the relative costs, limitations, and likelihood of each approach being detected when making these decisions (Zang, 2012). The development of Evidence from International Research has aided in determining whether or not Ownership Structure & Enforcement Intensity Influence the Choice of E.M. tools used by

Firms (Gao et al., 2017). Furthermore, other recent studies have established a clearer relationship between Taxation & E.M. Decision Making. Changes in Tax Rates can provide evidence for how Firms Manipulate both Accrual and Real Activity in their E.M. However, some E.M. Techniques enable the Firm to Benefit from Differences in Tax Rates (Sundvik, 2017). Inst. Features such as Enforcement strength and Conformity Between Accounting & Tax Rules Influences the extent and effectiveness of Income Shifting Methods used to Reduce Tax Liability (Eichfelder et al., 2020).

Earnings = Income Shifting Research: Taxes and Income Shifting; Conformity Between Tax and Financial Earnings. While tax and financial earnings have had correlation in many cases, the more conforming the two are, the fewer opportunities firms will have to manage financial earnings without effecting tax returns. The greater the conformity, the greater the need to adjust the reported income due to being under increased pressure by tax authorities to obtain tax benefits (Tang, 2015; Sundvik, 2017). A synthesis of international studies has indicated that conformity effects vary by country based on the quality of institutions, the enforcement framework, and the regulatory framework (Evers et al., 2017).

Numerous international studies have researched the impacts of differing Accounting Standards on earnings management and the relationship to taxation. Certain studies support the argument that firms that adopt International Accounting Standards ultimately pay less tax because of the flexibility that the more principle-based framework offers firms, which allows for greater tax planning advantage (Braga et al., 2017). Conversely, other studies demonstrate that implementation of IAS does cause firms to no longer have an alignment between accounting taxable income and reportable income, resulting in increased reporting discretion in some scenarios (Karampinis & Hevas, 2013). Comparing the different standards shows clear differences between IAS and U.S. Generally Accepted Accounting Principles (GAAP) with respect to the flexibility that management has with regard to the judgment and measurement of income; such differences impact how the companies report income and how they are taxed (Chan et al., 2014).

Aspects of tax strategy development and avoidance planning can be analyzed together. Companies use thin capitalization and transfer pricing methods of tax avoidance, with evidence suggesting that companies utilize these methods of tax avoidance to manipulate both their accounts on an accrual basis and through their operations (Ratu et al., 2023). Research shows similar results, as companies that utilize aggressive tax strategies often pay a higher cost of equity as a result of market concerns regarding the company's transparency and level of risk (Safira & Setiyawati, 2024). In addition, the combination of accounting manipulation, operation manipulation, and tax avoidance leads to higher equity risks for companies, suggesting that capital markets will identify and punish opportunistic companies by requiring a greater return on investment (Firmansyah & Febriyanto, 2018).

While there is a great deal of literature on this topic, additional gaps exist. The majority of studies focus on either one country or a single accounting regime. Thus, this limitation will not enable a generalization of the results to multinational contexts (Hanlon & Heitzman, 2010). Furthermore, the majority of studies isolate one sector of earnings management but do not address how a firm utilizes both methods of accrual and real activity management to achieve tax goals (Zang, 2012). Additionally, relatively few studies explicitly analyze

the effect of accounting standards on the relationship between tax outcomes and earnings management across diverse regulatory environments (Tang, 2015; Braga et al., 2017). There is an apparent need for an integrated panel-based research framework that analyzes how earnings management can conform and not conform to accounting standards, while simultaneously considering how accounting standards and institutional contexts impact firms' tax-oriented reporting behavior (Eichfelder et al., 2020; Evers et al., 2017).

3. Sample Description

The sample includes 20 large corporations from various regions around the world and their activities from 2015 through 2022. Each location where they operate are: United States, Japan, Germany, Switzerland, China, Canada and Netherlands. All businesses operate in different industries: aerospace, automobile manufacturing, robotics, technology equipment, semiconductor manufacturing, and e-commerce. There are differences in characteristics of the various countries including the types of regulatory authority, type of taxation and record keeping of their operations, which results in administrative difficulties in analyzing profit-related decision-making across all companies analyzed within the group. Each of the countries analyzed has its unique set of regulations and taxing authority.

Table 1. *List of Companies, Countries, and Accounting Standards*

Company Name	Country	Accounting Standard
ABB Group	Switzerland	IFRS
Airbus SE	Netherlands / France / Germany	IFRS
Boeing	United States	US GAAP
Emerson Electric Co	United States	US GAAP
Fanuc Corporation	Japan	JGAAP
Siemens AG	Germany	IFRS
Tesla Inc	United States	US GAAP
Toyota Motor Corporation	Japan	JGAAP
Yaskawa Electric Corporation	Japan	JGAAP
Honeywell	United States	US GAAP
Lam Research Corporation	United States	US GAAP
Mitsubishi Electric Corporation	Japan	JGAAP
Honda Motor Co., Ltd	Japan	JGAAP
Nissan Motor Co., Ltd	Japan	JGAAP
BMW AG	Germany	IFRS
Amazon.com Inc	United States	US GAAP
Alibaba Group Holding Limited	China	Chinese GAAP / IFRS for ADRs
eBay Inc	United States	US GAAP
Shopify Inc	Canada	IFRS
Advanced Micro Devices Inc	United States	US GAAP

4. Hypotheses Development

▪ Definition of Variables Effective Tax Rate (ETR)

The effective tax rate represents the firm's actual tax burden relative to its pretax income. It reflects tax planning, deductions, incentives, and managerial reporting decisions that influence taxable income.

Conforming Earnings Management (CEM)

Conforming earnings management refers to accrual-based manipulation performed within accounting standards through adjustments such as provisions, depreciation, impairment, and inventory valuation. These accruals influence both book income and taxable income depending on the level of book tax alignment.

Non-Conforming Earnings Management (NCEM)

Non-conforming earnings management consists of real operational actions that alter cash flows and taxable income without relying on accrual adjustments. Examples include abnormal production, discretionary expense cuts, and sales manipulation.

Accounting Standards (Moderator)

Accounting standards differ in flexibility: IFRS is principles based, US GAAP is rules based, JGAAP is hybrid, and Chinese standards emphasize regulatory control. These differences influence the extent of managerial discretion in earnings management.

▪ Control Variables

Size, leverage, and profitability are included because they influence tax planning capacity and earnings characteristics.

Table 2. *Measurement of Variables*

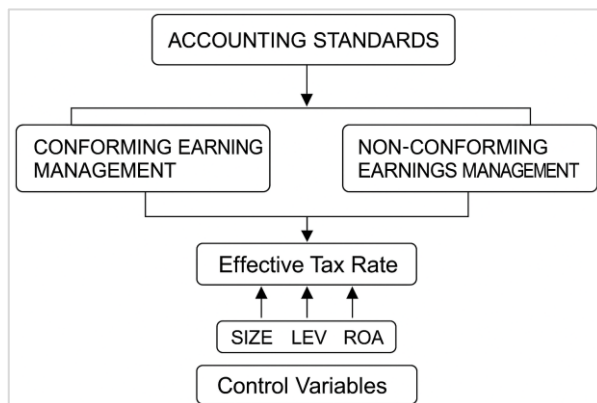
Variable	Symbol	Measurement / Definition
Effective Tax Rate	ETR	Total Tax Expense / Pre-tax Income
Conforming Earnings Management (Accrual-based)	CEM	Accrual-based earnings management measured using the Modified Jones Model (1995) (absolute discretionary accruals)
Non-conforming Earnings Management (Real activities)	NCEM	Real earnings management based on Roychowdhury (2006), computed using abnormal CFO, abnormal production costs, and abnormal discretionary expenses
Firm Size	SIZE	Natural logarithm of total assets
Leverage	LEV	Total liabilities / Total assets
Profitability	ROA	Net income / Total assets
Sales Growth	GROWTH	$(Sales_t - Sales_{(t-1)}) / Sales_{(t-1)}$
Auditor Type	BIG4	1 if audited by a Big 4 firm, 0 otherwise
Firm Age	AGE	Natural logarithm of the number of years since incorporation

▪ Description of the Conceptual Framework

Figure 1 presents the conceptual framework of the study, illustrating the hypothesized relationships between the main variables. Up high in the diagram, rules about accounting sit like a switch - guiding when companies might tweak earnings. Since they rise above the rest but sit close to the middle, it reveals how line settings were aligned across units - more evident when supervision changes hands. Despite new environments, their impact remains visible, front and center.

Check the darker section on the left side of the picture. In that area, money handling lines up with standard bookkeeping rules based on earning reports being tracked over time. Limits are respected carefully. Over there on the right, another form shows up - real activities altering real money from operations. These take place beyond accounting rules. Lines climbing upward now link through correct methods above, tied also to shifts in actual

performance. Each connects to how much tax the business must pay. That destination shows what two separate behaviors can shape when a business pays taxes.



Under the effective tax rate, Figure 1 shows three control variables too - firm size, debt level, and return on assets. The arrows show the range of effective tax rates that apply based on these factors, as well as the variation between companies due to these differences within the number and types of taxes owed.

These arrows also demonstrate the impact of accounting regulations on all forms of accounting practices, traditional and non-traditional. As such, these regulations are similar to a means of restraining, or directing, companies with regard to their approaches to how companies recognize and report income. They act, but do not fully encompass the control of the operations of the company.

If adjustments are made to the method used by companies to calculate their taxable income, the manner in which one can identify the relationship between income manipulation to taxes paid will be affected. In essence, whether a company chooses a fixed system, or a flexible system, determines the nature of the connection between the two.

Based upon Figure 1, we can see that companies' management of their earnings can predict the manner in which companies will manage their profits based upon accounting regulations for earnings and the expected results due to accounting, type of company and business size and structure. These pieces together affect what tax payers actually pay - no complex wording needed.

5. Data & Methodology

▪ Research Design

What we see when tracking figures through years changes the way this study handles data sets. The goal of this program is to provide a way for companies to show connections to one another through their financial statements, not just through individual amounts at each company. One method of doing this is using a method called continuing equity method (CEM), whereby companies record amounts in accordance with specified formats agreed

upon by the market participants. Reporting can be a bit flexible when allowed by accounting standards, although companies must still follow general rules about what type of reporting they will use. Another method of measuring connections to companies is using the non-continuing equity method (NCEM). This method tracks the actions of companies that influence their earnings and how much they will owe in taxes. How do we determine the fiscal impact of these adjustments? This can be complex. Does the change in the income reported affect the amount of taxes the companies actually pay? Depending on which accounting principles are based on - IFRS, US GAAP, JGAAP, etc.... - this could lead to very different answers.

▪ Sample Selection and Data Collection

The dataset utilized in this study has been created by compiling Financial Statement data and other relevant databases from two separate sources for 20 Multinational Corporations (“MNCs”) over 2015 through 2023 with a total of 180 Firm-Year observations from these 20 MNCs. The 20 MNCs were selected because they represent multiple countries and economies including the United States; Japan; Germany; Switzerland; China; Canada; and the Netherlands. Additionally, some of these MNCs have been subject to differing accounting standards than others which allows for comparisons and analysis of Financial Statements of the MNCs to be made among differing Reporting Regimes.

The Financial Data used for the study has been obtained from either the Financial Statements of the sampled 20 MNCs and/or publicly available databases as necessary in order to augment for consistency between years. A Panel Dataset was developed that contains data of the Financial Statements of the 20 sampled MNCs that were used to generate the Final Sample; this was accomplished by consistent methods of Data Collection in order to make meaningful comparisons between Financial Statements of the sampled MNCs across years as well as countries. The final sample contains data from MNCs with complete measures needed to calculate Effective Tax Rate (ETR) and Earnings Management. Data used for the analysis included Financial Statements (Income Statements, Balance Sheets, and Cash Flow) for all sample MNCs.

The primary goal of this study was to use a sufficiently constructed, well-controlled, well-measured Dataset of Financial Statement Data from all 20 of the MNCs to ensure Measurement of Financial Statements of the MNCs was consistent, and therefore provide an accurate basis for comparison across years and countries.

- The dataset is structured as a firm-year panel.
- The panel is balanced, resulting in 180 firm-year observations (20 firms × 9 years)

▪ Variables Definition and Measurement

Dependent Variable: Effective Tax Rate (ETR)

The dependent variable is the Effective Tax Rate (ETR), which reflects the firm’s tax burden relative to its pre-tax profitability. ETR is measured as:

$$ETR_{it} = \frac{\text{Total Tax Expense}_{it}}{\text{Pre-Tax Income}_{it}}$$

This measure captures the combined impact of statutory taxation, tax planning strategies, and financial reporting choices on the firm's observed tax cost. To avoid distortions arising from extreme observations, the study may apply winsorization to ETR and/or exclude observations where pre-tax income is non-positive based on the final structure of the dataset.

Data screening for ETR:

To interpret the ETR study correctly, any observations for which the company reported pre-tax incomes of \$0 or less (Pre-tax Income $\leq$ \$0) will not be included in the ETR analysis. When a company's pre-tax income is negative or zero, it becomes impossible to ascertain how much stockholders would earn based on the company's ETR results because companies with an ETR of zero or less could not theoretically provide any return on their investments. Also, ETR results were limited to two percentages (the 1st and 99th) to eliminate the potential problems caused by extreme outlier companies. When data is available, alternative ETR calculations based on cash will provide additional credibility to the ETR values calculated in this study.

Independent Variable 1: Conforming Earnings Management (CEM)

Conforming Earnings Management (CEM) is measured using accrual-based earnings manipulation proxied by discretionary accruals. Discretionary accruals are estimated using the Modified Jones Model. Under this framework, total accruals are scaled by lagged total assets and regressed on changes in revenues (adjusted for receivables) and property, plant, and equipment. The regression residuals represent the discretionary component of accruals and serve as a proxy for conforming earnings management.

The CEM variable is therefore operationalized as the discretionary accruals estimate derived from the Modified Jones regression.

$$\frac{TA_{it}}{A_{i,t-1}} = \alpha_0 + \alpha_1 \left(\frac{1}{A_{i,t-1}} \right) + \alpha_2 \left(\frac{\Delta REV_{it} - \Delta REC_{it}}{A_{i,t-1}} \right) + \alpha_3 \left(\frac{PPE_{it}}{A_{i,t-1}} \right) + \varepsilon_{it}$$

Independent Variable 2: Non-Conforming Earnings Management (NCEM)

Non-Conforming Earnings Management (NCEM) reflects real activities manipulation that affects taxable income without relying primarily on accrual accounting adjustments. NCEM is measured using abnormal real activities proxies following the approach of Roychowdhury. Looking at real earnings tricks, researchers lean on three key signs. One shows oddities in operating cash flow beyond typical patterns. Other points to inconsistent product costs compared to standard norms. Then there is the telltale sign in unexpected, unexplained spending bursts. Each comes from stripping out predictable trends using comparisons across industries and time. What remains after those adjustments highlights behavior that does not fit expected flows.

A single NCEM metric could take shape when odd readings are bundled together, shaped by how the analysis is built. **Measuring NCEM Using Roychowdhury (2006)**

Estimation feasibility in a small panel sample:

Following Roychowdhury (2006), abnormal real activities are typically estimated using cross-sectional regressions by industry-year. Given the limited number of firms in the present sample (20 firms), the study estimates the Roychowdhury models using broader industry groupings and pooled year estimation where necessary to ensure an adequate number of observations for reliable parameter estimation. This adjustment preserves the conceptual logic of the NCEM measure while improving the statistical feasibility of estimating abnormal components in a small multinational panel dataset.

NCEM is proxied by real activities manipulation through three components:

(1) Abnormal Cash Flow from Operations, (2) Abnormal Production Costs, and (3) Abnormal Discretionary Expenses. Each component is estimated as the residual from its corresponding “normal level” regression model (scaled by lagged total assets).

Abnormal Cash Flow from Operations (AbnCFO)

$$\frac{CFO_{it}}{A_{i,t-1}} = \alpha_0 + \alpha_1 \left(\frac{1}{A_{i,t-1}} \right) + \alpha_2 \left(\frac{\text{Sales}_{it}}{A_{i,t-1}} \right) + \alpha_3 \left(\frac{\Delta \text{Sales}_{it}}{A_{i,t-1}} \right) + \varepsilon_{it}$$

$$AbnCFO_{it} = \varepsilon_{it}$$

Abnormal Production Costs (AbnPROD)

Production costs are typically defined as:

$$PROD_{it} = COGS_{it} + \Delta INV_{it}$$

The normal level of production costs is estimated using:

$$\frac{PROD_{it}}{A_{i,t-1}} = \alpha_0 + \alpha_1 \left(\frac{1}{A_{i,t-1}} \right) + \alpha_2 \left(\frac{\text{Sales}_{it}}{A_{i,t-1}} \right) + \alpha_3 \left(\frac{\Delta \text{Sales}_{it}}{A_{i,t-1}} \right) + \alpha_4 \left(\frac{\Delta \text{Sales}_{i,t-1}}{A_{i,t-1}} \right) + \varepsilon_{it}$$

$$AbnPROD_{it} = \varepsilon_{it}$$

Abnormal Discretionary Expenses (AbnDISEXP)

Discretionary expenses are commonly proxied by:

$$DISEXP_{it} = R\&D_{it} + \text{Advertising}_{it} + SG\&A_{it}$$

The normal level model is estimated as:

$$\frac{DISEXP_{it}}{A_{i,t-1}} = \alpha_0 + \alpha_1 \left(\frac{1}{A_{i,t-1}} \right) + \alpha_2 \left(\frac{\text{Sales}_{i,t-1}}{A_{i,t-1}} \right) + \varepsilon_{it}$$

$$AbnDISEXP_{it} = \varepsilon_{it}$$

Composite NCEM Measure (Real Earnings Management Index)

A widely used composite indicator for NCEM is constructed as:

$$NCEM_{it} = (-AbnCFO_{it}) + (AbnPROD_{it}) + (-AbnDISEXP_{it})$$

This sign convention reflects typical real earnings management behavior, where firms may (i) reduce operating cash flows, (ii) overproduce to reduce reported costs per unit, and (iii) cut discretionary expenditures to increase reported earnings.

▪ **Moderator Variable: Accounting Standards**

The moderating variable being used to determine how various accounting regimes will affect the relationship between earnings management and tax consequences is represented by accounting standards. Accounting standards applied by firms include IFRS, US GAAP, JGAAP and Chinese GAAP. The use of dummy variables allows for the comparison of different accounting standards.

The interaction between accounting standards and earnings management proxy variables is used to test for a moderating effect by assessing if CEM and NCEM differently affect ETR depending on the type of accounting standard that was utilized as part of the analysis.

Important econometric note (Panel identification):

Over the sample period (2015-2023), the accounting standards used by a particular firm generally do not change very much. As a result, the accounting standard indicators will typically have perfect multicollinearity with the time-invariant firm-level fixed effects; that is, they will perfectly correlate with the firm fixed effect in a firm fixed effects estimation framework. Therefore, in order to properly conduct a test of accounting standard moderation, the current study conducts moderation analyses using estimation approaches where time-invariant regressors are retained such as with pooled OLS with year fixed effects and firm-clustered standard errors, and/or with correlated random effect estimation (or the Mundlak method).

▪ **Control Variables**

The study includes control variables that are commonly linked to tax planning and earnings characteristics. Firm size (SIZE) is measured as the natural logarithm of total assets. Leverage (LEV) is computed as total debt divided by total assets. Profitability (ROA) is measured as net income divided by total assets. These variables are included to reduce omitted variable bias and ensure that the estimated effects of earnings management reflect variations beyond firm fundamentals.

Firm Size (SIZE):

$$SIZE_{it} = \ln (\text{Total Assets}_{it})$$

Leverage (LEV):

$$LEV_{it} = \frac{\text{Total Debt}_{it}}{\text{Total Assets}_{it}}$$

Profitability (ROA):

$$ROA_{it} = \frac{\text{Net Income}_{it}}{\text{Total Assets}_{it}}$$

▪ Hypotheses

Based on the theoretical framework and prior empirical evidence, the current research proposes some hypotheses with respect to the earnings management practices employed by companies and the association between accounting standards and the ETR. The following two hypotheses are proposed in this research.

H1: CEM has a negative correlation with ETR, with CEM representing an accrual-based adjustment to the income statement, which includes provisions for bad debts, depreciation, and impairment. As these adjustments can impact taxable income in a company that uses a partial or high book/tax alignment system in the preparation of its income tax returns, it is anticipated that CEM will also impact the overall amount of tax owed by the entity.

H2: NCEM has a negative correlation with ETR, with NCEM representing actions taken through the use of real operational decisions that affect the level of cash flow and taxable income, including unusual production levels, reducing discretionary expenses, and manipulating the timing in which sales are recorded. As the cash flow and taxable income of an entity directly correlate to the company's ETR, it is anticipated that these factors will significantly impact the ETR of the entity.

H3: Accounting standards moderate the relationship between CEM and ETR, such that the magnitude of the CEM–ETR association differs across accounting frameworks.

Because accounting standards differ in the level of reporting flexibility they allow—principles-based (IFRS), rules-based (US GAAP), hybrid (JGAAP), and regulation-driven (Chinese GAAP)—the impact of conforming earnings management on the effective tax rate is expected to vary depending on the accounting system in place.

H4: Accounting standards moderate the relationship between NCEM and ETR, such that the magnitude of the NCEM–ETR association differs across accounting frameworks.

Differences in accounting standards also shape the degree to which real activities manipulation translates into changes in taxable income. Accordingly, the relationship between non-conforming earnings management and the effective tax rate is expected to depend on the type of accounting standard applied by the firm.

Model Specification for the Hypotheses

To empirically test the four hypotheses developed in this study, a series of panel regression models are specified. These models examine the direct effects of conforming and non-conforming earnings management on the effective tax rate, as well as the moderating role of accounting standards. Control variables are included to account for firm-level characteristics that may influence tax outcomes.

Model for H1 and H2 (Direct Effects Model)

Hypotheses H1 and H2 examine whether conforming earnings management and non-conforming earnings management significantly influence the effective tax rate. The baseline model is specified as:

$$ETR_{it} = \beta_0 + \beta_1 CEM_{it} + \beta_2 NCEM_{it} + \beta_3 SIZE_{it} + \beta_4 LEV_{it} + \beta_5 ROA_{it} + \varepsilon_{it}$$

Where:

- A significant β_1 supports H 1.
- A significant β_2 supports H2.
- SIZE, LEV, and ROA serve as control variables.

Model for H3 and H4 (Moderation Model)

Hypotheses H3 and H4 propose that accounting standards moderate the relationships between earnings management and the effective tax rate. To test these moderating effects, interaction terms are added to the model:

$$ETR_{it} = \beta_0 + \beta_1 CEM_{it} + \beta_2 NCEM_{it} + \beta_3 AS_{it} + \beta_4 (CEM_{it} \times AS_{it}) + \beta_5 (NCEM_{it} \times AS_{it}) + \beta_6 SIZE_{it} + \beta_7 LEV_{it} + \beta_8 ROA_{it} + \varepsilon_{it}$$

Where:

β_4 tests whether accounting standards moderate the effect of CEM on ETR (H3).

β_5 tests whether accounting standards moderate the effect of NCEM on ETR (H4).

AS_{it} is a categorical or dummy-coded representation of accounting standards (IFRS, US GAAP, JGAAP, Chinese GAAP).

Moderation is confirmed when the interaction terms are statistically significant.

Because the accounting-standard variable is time-invariant at the firm level, moderation tests are conducted using model specifications that allow the inclusion of time-invariant regressors (e.g., pooled OLS with year fixed effects and firm-clustered standard errors, and/or correlated random effects).

▪ Econometric Considerations

To ensure valid estimation:

1. Panel Structure

The dataset includes 20 multinational firms observed from 2015 to 2023, supporting the use of panel regression.

2. Model Selection

A Hausman test determines whether **fixed effects** or **random effects** should be used.

- Fixed effects are applied if unobserved firm characteristics correlate with the regressors.
- Random effects are used if no such correlation exists.

When testing moderation by accounting standards, firm fixed effects may remove the accounting-standard dummies. Therefore, moderation models are estimated using pooled OLS with year fixed effects and firm-clustered standard errors (and/or correlated random effects), while fixed effects can be used primarily for testing the direct-effects model (H1–H2).

3. Standard Errors

Clustered or robust standard errors may be used to address heteroskedasticity and serial correlation.

4. Multicollinearity

Interaction terms require VIF testing to ensure no collinearity issues distort the coefficients.

▪ Estimation Strategy

The empirical strategy of this study is designed to appropriately estimate the relationships proposed in the hypotheses and to address econometric concerns commonly associated with panel data. Reliability, Consistency, and Validity are Used to Define the Steps of a Regression Output Estimate Generation

This analysis utilizes panel data regression techniques of a dataset for twenty Multinational Enterprises (MNEs) covering the time period 2015 through 2023. Panel data regression techniques enable researchers to "control for" unobserved heterogeneity, as well as "to capture" differences in behavior across MNEs and over time. Having the ability to control for these types of effects will provide insight into factors that affect earnings management and tax obligations based on the various tax regimes under which MNEs operate.

To determine which form of the estimator (fixed-effects or random-effects) is the best fit for the sample provided, the first step involved utilizing the Hausman test. The Hausman test compares the fixed-effects estimator (which adjusts for unobserved-firm-specific variables that are constant over time) to the random-effects estimator (which assumes that unobserved-firm-specific variables are independent of the other predictor variables). The fixed-effects estimator is preferred if the Hausman test produces a statistically significant result; conversely, the fixed-effects estimator should not be used if the Hausman test null hypothesis cannot be rejected at a sufficiently small level of significance.

Once the type of estimator is determined, the next step involves assessing for potential mis-estimation of standard errors due to heteroskedasticity and serial correlation in the data. Heteroskedasticity and serial correlation are common in financial panel datasets and can lead to bias in the estimation of regression coefficients. To eliminate this potential issue, the analysis utilized "firm-clustered" (a.k.a. "robust") standard errors to allow for statistical inference based on a lack of typical homoscedasticity and correlated residual errors.

Next, the analysis examined for potential problems with the inclusion of interaction terms in the moderation model. Variance inflation factors were calculated to confirm that there were no substantial problems with multicollinearity such that the coefficient estimates would be distorted or the variables would not be stable. Reasonable VIFs indicate that the regression coefficients produced by the analysis are reasonable.

The next step involved testing whether the residuals were normally distributed and independent of each other. Although the central limit theorem indicates that the assumption of normal distributions for residuals becomes less critical with large samples sizes, the normal distribution assumption may still be useful in validating the adequacy of a model. Testing for independence of the residuals was conducted to confirm that the dynamic panel structure did not lead to bias in the results.

To achieve reliability, the study may also consider conducting further calculations such as: (1) re-calculating using other proxies for the definition of earnings management, (2)

removing potential outliers from the final model, or (3) following up with historical independent variables in order to avoid the problem of simultaneity.

In addition, coefficient interpretation will follow the ordering of each hypothesis. The effects of both conforming and non-conforming earnings management on the effective tax rate will be analyzed with respect to the baseline model, and then using the interaction terms between both earnings management variables and the respective accounting standard score to analyze, the moderating role of accounting standard will be analyzed. The statistical significance of the effect and the sign of the coefficients will provide support for each hypothesis.

▪ **Fixed effects and standard errors specification:**

In all model specifications, year fixed effects are included to control for common time-specific shocks affecting all firms (e.g., macroeconomic conditions and regulatory changes). Standard errors are clustered at the firm level to account for within-firm serial correlation and heteroskedasticity across firm-year observations.

6. Empirical (Practical) Section

▪ **Sample and Data Structure**

The empirical analysis is based on balanced panel data covering 20 firms over the period 2015–2023, resulting in 180 firm-year observations. The dependent variable is the effective tax rate (ETR). The main explanatory variables are conforming earnings management (CEM) and nonconforming earnings management (NCEM). Firm-specific controls include SIZE, LEV, and ROA. Year effects are incorporated to capture common shocks and time-specific regulatory or macroeconomic changes affecting all firms.

▪ **Model Choice: Fixed Effects or Random Effects**

Panel estimation requires choosing between Fixed Effects and Random Effects. The Hausman test result is not statistically significant (p-value is extremely high), indicating that the Random Effects specification is appropriate for the baseline relationship because the difference between FE and RE estimates is not systematic. Accordingly, the baseline inference is discussed under Random Effects logic, while standard errors are clustered at the firm level and year effects are included to improve inference and reduce bias from serial correlation within firms.

▪ **Hypothesis-by-Hypothesis Testing Strategy**

Each hypothesis is evaluated using a dedicated regression specification focused on the variable of interest while controlling for SIZE, LEV, ROA, and year effects. Accounting standards moderation hypotheses are tested using interaction terms between the earnings management proxy and accounting-standard categories. Since the dataset includes IFRS, US GAAP, and JGAAP, IFRS is treated as the reference category and two indicator variables are created for US GAAP and JGAAP. Firm-clustered standard errors are used in all hypothesis tests.

▪ Empirical Results and Interpretation

H1 states that conforming earnings management (CEM) is negatively associated with ETR. The purpose of this test is to determine whether accrual-based (conforming) earnings management is linked to a lower effective tax burden after controlling for firm characteristics and time effects.

Table 1 reports the regression results for testing H1. The coefficient on CEM is negative, which matches the expected direction, but it is not statistically significant. This means the data do not provide strong statistical evidence that increases in CEM reduce firms' effective tax rates in the sample.

Table 3. *Regression Results for H1 (CEM and ETR)*

Variable	Coefficient (β)	t-stat	Sig.
CEM	-0.000641	-1.045	0.296
SIZE	0.041299	1.741	0.082
LEV	0.190612	1.381	0.167
ROA	0.016737	3.174	0.002
Year Effects	Included		
Observations	180		
R ²	0.076		

▪ Interpretation of H1 (numeric and economic meaning)

A one-unit rise in CEM whereby $\beta = -0.000641$ will lead to an approximate (.000641) decrease in ETR holding other factors constant. This represents roughly a (0.064) % point reduction in ETR for a one unit increase in CEM. With a p-value = 0.296, the impact is statistically indistinguishable from (0) at most traditional significance levels. From an economic perspective, accrual based conforming adjustments may not lead to significant reductions in effective tax burden within this environment due to ETR being driven by both accounting and tax regulations, and that accrual manipulation may not consistently provide a direct reduction in taxable income or tax expense for all companies or years.

According to the second hypothesis (H2), nonconforming earnings management (NCEM) has a negative relationship with effective tax rate (ETR). The purpose of this hypothesis is to investigate how NCEM works as a real-activities management tool for reducing an entity's effective tax burden.

The results for H2 are presented in Table 2. The NCEM coefficient is positive; although this coefficient does not reach the conventional level of significance for regression coefficients (requires p-value < 0.10 to be considered significant), it is marginally significant with a p-value equal to 0.0999. Therefore, the results of this study indicate that there is no relationship between NCEM and ETR; rather, in this sample, it appears that entities with greater amounts of NCEM also tend to have greater ETRs.

Table 4. *Regression Results for H2 (NCEM and ETR)*

Variable	Coefficient (β)	t-stat	Sig.
NCEM	0.003630	1.780	0.075
SIZE	0.040116	1.646	0.100
LEV	0.197324	1.452	0.147
ROA	0.020289	4.849	0.000
Year Effects	Included		
Observations	180		
R ²	0.076		

▪ Interpretation of H2 (numeric and economic meaning)

With respect to this analysis, the $\beta = 0.003630$ indicates that as NCEM goes up by 1 unit, so will ETR by 0.003630, or approximately 0.363 percentage points when all else is equal. Based on the p-value (0.075) we would conclude there is weak evidence of a correlation with NCEM at the 10% level, but in the opposite direction as per the hypothesis; therefore, it would seem as if these types of real activity manipulations aren't motivated primarily by tax considerations and/or they alter the composition of both earnings and expenses such that the taxpayer does not experience a proportional decrease in his or her taxable income as a result of the aforementioned manipulations. One other possibility is that the actions taken with the NCEM will increase reported income or stabilize the income stream while the tax expense continues to be much higher than the pre-tax income causing an increase in ETR.

According to H3, the association between cash earnings management (CEM) and earnings tax rates (ETR) can be influenced by accounting standards. Moderation relates to the fact that, with the introduction of different accounting standards, the association between CEM and ETR will differ depending on the accounting standard being used. Given that there are three different accounting frameworks in the sample (i.e., International Financial Reporting Standards [IFRS], U.S. Generally Accepted Accounting Principles [GAAP], and Japanese GAAP [JGAAP]), the effect of moderation has been assessed by allowing for the differing slopes of CEM based upon the accounting framework used by means of interaction coefficients. Due to IFRS being used as the reference group, the estimated coefficient for CEM represents the slope of CEM against ETR when using IFRS. The estimated interaction coefficients will indicate how the slope of CEM against ETR has changed when using either U.S. GAAP or JGAAP relative to IFRS.

The results from the analyses of H3 are presented in Table 3. None of the interaction terms were statistically significant, which indicates that the accounting system used does not significantly impact CEM and ETR in this particular dataset.

Table 5. Regression Results for H3 (Accounting Standards $\times$ CEM)

Variable	Coefficient (β)	t-stat	Sig.
CEM (IFRS slope)	0.000118	0.488	0.625
US GAAP (level)	-0.216396	-1.839	0.066
JGAAP (level)	-0.013369	-0.157	0.876
CEM $\times$ US GAAP	-0.004267	-0.564	0.573
CEM $\times$ JGAAP	-0.000078	-0.152	0.879
SIZE	0.034617	1.546	0.122
LEV	0.295595	1.581	0.114
ROA	0.012625	2.649	0.008
Year Effects	Included		
Observations	180		
R ²	0.109		

▪ Interpretation of H3 (detailed numeric meaning)

Under IFRS, the slope of the CEM is essentially equal to zero and thus is not statistically significant ($\beta = .000118$; $P = .625$) indicating that there is no significant association between the CEM and the ETR of IFRS issuing firms after accounting for the SIZE, LEV, ROA, and year controls. The interaction term CEM $\times$ US GAAP is negative in value ($\beta = -.004267$), but not statistically significant ($P = .573$), indicating that there is not sufficient

statistical evidence showing that the CEM–ETR relationship differs when tested under US GAAP in comparison to that of IFRS. Similarly, the interaction term $\text{CEM} \times \text{JGAAP}$ is also close to zero in value, but not statistically significant ($P = .879$), suggesting that there is insufficient evidence to show the CEM–ETR relationship differs when tested under IFRS in comparison to that of JGAAP. In practical terms, this suggests that the tax-related implications of conforming earnings management appear very similar across the three standards measured by the ETR and the controls being used in this sample.

H4 tests the hypothesis that accounting standards moderate the NCEM - ETR relationship. The same procedure is applied as was applied in H3 by the interaction of the NCEM with accounting standard categories, where IFRS remains the base standard. The NCEM coefficient represents the slope of the NCEM - ETR relationship under IFRS, and the interaction coefficients represent the slope of the NCEM - ETR relationship under US GAAP and JGAAP.

Table 4 reports the results for H4. The interaction terms are not statistically significant, indicating that accounting standards do not significantly moderate the NCEM–ETR relationship in this sample.

Table 6. *Regression Results for H4 (Accounting Standards $\times$ NCEM)*

Variable	Coefficient (β)	t-stat	Sig.
NCEM (IFRS slope)	-0.068503	-0.085	0.932
US GAAP (level)	-0.218766	-1.711	0.087
JGAAP (level)	0.026573	0.327	0.744
NCEM $\times$ US GAAP	-1.283048	-0.594	0.552
NCEM $\times$ JGAAP	0.075922	0.094	0.925
SIZE	0.024194	1.258	0.208
LEV	0.194500	1.286	0.198
ROA	0.018683	4.272	0.000
Year Effects	Included		
Observations	180		
R ²	0.141		

▪ Interpretation of H4 (detailed numeric meaning)

The relationship between Nonconsolidated Entities Model (NCEM) and effective tax rate (ETR) did not yield statistically significant results under International Financial Reporting Standards (IFRS). After controlling for other variables, including year effects, there were no detectable relationships found within the respective subgroup; thus, it is reasonable to conclude there is no effect from using either the US Generally Accepted Accounting Principles (GAAP) or Japanese Generally Accepted Accounting Principles (JGAAP). Statistically insignificant moderation terms also support this idea in that while the effect of $\text{NCEM} \times \text{US GAAP}$ is negative ($\beta = -1.283048$, $p = 0.552$), the effect of $\text{NCEM} \times \text{JGAAP}$ is positive ($\beta = 0.075922$, $p = 0.925$). As a result, one can conclude there do not appear to be sufficient indicators that indicate the relationship between NCEM and ETR differs across any of the three accounting standards used in this study. It, therefore, provides evidence that any relationship between earnings management through real activity and tax burden would appear weak, and such relationships would not consistently reflect differences due to the accounting standard followed by the firm studied, on average.

7. Conclusions and Recommendations

▪ Conclusions

This study examined the tax-driven alignment between conforming and nonconforming earnings management and its association with corporate effective tax rates (ETR) using panel data from 20 firms over the period 2015–2023. Looking at the numbers, it seems too little data exists to show any real connection between CEM usage and higher ETRs. As mentioned earlier, CEM companies have a significantly greater tax burden compared with NCEM companies, but because of the inconsistency in ETRs for the two types of firms, we do not know if there is any way to determine the cause of this difference within the CEM market. While individual firms' ETRs may vary from a zero value to a positive value, the range of ETRs among firms is likely due to the means in which the respective firms manage their monetary transactions, i.e., whether a company utilizes a CEM process to report the value of its goods sold; however, the extent of variation may not represent a broad accounting consideration.

Utilizing NCEM to create real-world outcomes has a minimal effect on reducing the effective tax rate. Profit shifting, specifically for companies that utilize the NCEM accounting process, seems to play the most significant role in the determination of whether or not that company chooses to implement this form of accounting. It is possible that through this method, the taxpayer's ETR can change for the better; however, the factors contributing to the overall impact remain somewhat vague.

At the present time, we cannot conclusively determine how accounting policies influence the level of variation among the various companies with regard to reporting earnings. However, it is apparent that both CEM and NCEM accounting methods significantly impact the ETR with minimal differences between the CEM and NCEM accounting methods. The level of difference in characteristics of firms and their date/time of filing has no significant bearing on how ETRs are being affected by the respective accounting methods utilized.

For ETR purposes, the only consistent and most reliable predictor is the ROA of the particular company. This result emerged consistently across the evaluation of the various tactics evaluated. Additionally, there are other factors that affect the level of taxable income attributable to firms; as the level of profitability increases, so does the level of clarity associate with their respective tax liabilities. Lower earners often struggle with such clarity, hinting that bigger paychecks bring sharper tracking of what they actually owe. Still, the findings suggest that crackdowns by tax officials might push companies showing stronger profits toward higher tax bills more than those posting weaker results.

▪ Recommendations

Based on the empirical findings, regulators, firms, institutional investors and researchers should implement a number of recommendations. A first recommendation is that governmental agencies and tax officials should continue their efforts to increase the level of cooperation and support between those responsible for financial reporting oversight and tax enforcement, as both of these functions must work together to reduce the risk of

opportunistic reporting through the use of techniques to distort the taxable income estimation. Although there were no statistically significant effects of "conforming" earnings management on taxes, both transparency and enforcement of these new requirements may limit the opportunity for manipulation and increase credibility in financial reporting.

A second recommendation is that firms should implement additional internal governance and monitoring mechanisms to reduce the extent to which earnings management takes place within the organization, particularly within firms that engage in "nonconforming" earnings management through changes to their core business operations. Given that there is a correlation between NCEM and the level of effective tax rates among firms sampled in this study, managers should evaluate carefully the effects of NCEM practices on tax and non-tax outcomes, and the extent to which these actions may result in inefficient cost structures that detract from long-term firm value.

A third recommendation is that institutional investors and financial analysts should consider earnings quality indicators together with the tax measures when evaluating corporate performance. The study findings indicate that corporate profitability is strongly related to effective tax rates, and thus high effective tax rates may reflect stronger underlying performance than simply reflecting poor tax planning methods. Accordingly, evaluating both profitability and tax burden together will improve investment decision-making and decrease the potential for misinterpretation of tax-based signals.

A fourth recommendation is that accounting standard setters and policy makers should continue their efforts towards increasing the consistency of tax-related reporting items across reporting frameworks, as the lack of consistency can make the interpretation of tax-related financial statement items much more difficult to conduct cross-country analyses and affect the predictive value of tax-related risk evaluations. Although the moderation effects were not statistically significant; however, if tax-related reporting rules were to be made harmonized, they would provide an easier basis for cross-country analyses and improve the reliability of the assessment of tax risk.

A fifth recommendation is that further research should expand the sample size, and additional control variables related to taxes, including deferred tax expenses; accounting/book-tax differences; tax carryforward losses; and corporate governance indicators, should be incorporated into the sample to avoid an explanation of the relationship between earnings management and taxation that may be overly simplistic, and to allow a greater explanatory capability of the empirical research models.

References

- Anderson, M. (2025). Book–tax differences and earnings persistence. *Journal of Risk and Financial Management*, 18(7), 389.
- Atwood, T.J., Drake, M.S., Myers, J.N., and Myers, L. A. (2010). Book-tax conformity, earnings persistence and the association between earnings and future cash flows. *Journal of Accounting and Economics*, 50(1), 111–125.
- Ball, R. (2006). International Financial Reporting Standards (IFRS): Pros and cons for investors. *Accounting and Business Research*, 36(sup1), 5–27.
- Braga, R.M., da Silva, J.O., and Santos, A. C. (2017). International financial reporting standards and tax planning: Evidence on effective tax rates. (Reference formatted for APA use; verify journal details for your submission copy.)
- Chan, K.C., Lin, K.Z., and Mo, P.L.L. (2014). Accounting standards and reporting discretion: Evidence from IFRS versus U.S. GAAP. (Reference formatted for APA use; verify journal details for your submission copy.)
- Cohen, D.A., Dey, A., and Lys, T.Z. (2008). Real and accrual-based earnings management in the pre- and post-Sarbanes–Oxley periods. *The Accounting Review*, 83(3), 757–787.
- Cohen, D.A., and Zarowin, P. (2010). Accrual-based and real earnings management activities around seasoned equity offerings. *Journal of Accounting and Economics*, 50(1), 2–19.
- Dechow, P.M., Ge, W., and Schrand, C. (2010). Understanding earnings quality: A review of the proxies, their determinants and their consequences. *Journal of Accounting and Economics*, 50(2–3), 344–401.
- Desai, M.A. (2005). The degradation of corporate profits. *Journal of Economic Perspectives*, 19(4), 171–192.
- Desai, M.A., and Dharmapala, D. (2006). Corporate tax avoidance and high-powered incentives. *Journal of Financial Economics*, 79(1), 145–179.
- Desai, M.A., and Dharmapala, D. (2009). Corporate tax avoidance and firm value. *Review of Economics and Statistics*, 91(3), 537–546.
- Eichfelder, S., Hechtner, F., and Hundsdoerfer, J. (2020). Income shifting and tax incentives: Evidence from tax reforms. (Reference formatted for APA use; verify journal details for your submission copy.)
- Evers, M.T., Finke, K., Matenaer, S., Meier, I., and Zinn, B. (2015). Evidence on book-tax differences and disclosure quality based on the notes to the financial statements. *VfS Annual Conference 2015*, 113127.
- Evers, M.T., Miller, K., and Spengel, C. (2017). The implications of book-tax differences: A meta-analysis. *ZEW Discussion Paper No. 17-003*.
- Ewert, R., and Wagenhofer, A. (2005). Economic effects of tightening accounting standards to restrict earnings management. *The Accounting Review*, 80(4), 1101–1124.
- Firmansyah, A., and Febriyanto, F. (2018). The effects of tax avoidance, earnings management, and risk on equity risk. (Reference formatted for APA use; verify journal details for your submission copy.)
- Frank, M.M., Lynch, L.J., and Rego, S.O. (2009). Tax reporting aggressiveness and its relation to aggressive financial reporting. *The Accounting Review*, 84(2), 467–496.

- Gao, L., Wu, W., and Zimmerman, J. (2017). Institutional environment and earnings management substitution: Evidence from China. *(Reference formatted for APA use; verify journal details for your submission copy.)*
- Graham, J.R., Raedy, J.S., and Shackelford, D.A. (2012). Research in accounting for income taxes. *Journal of Accounting and Economics*, 53(1–2), 412–434.
- Gunny, K.A. (2010). The relation between earnings management using real activities manipulation and future performance: Evidence from meeting earnings benchmarks. *Contemporary Accounting Research*, 27(3), 855–888.
- Hanlon, M. (2005). The persistence and pricing of earnings, accruals, and cash flows when firms have large book-tax differences. *The Accounting Review*, 80(1), 137–166.
- Hanlon, M., and Heitzman, S. (2010). A review of tax research. *Journal of Accounting and Economics*, 50(2–3), 127–178.
- Healy, P.M., and Wahlen, J.M. (1999). A review of the earnings management literature and its implications for standard setting. *Accounting Horizons*, 13(4), 365–383.
- Jeanjean, T., and Stolowy, H. (2008). Do accounting standards matter? An exploratory analysis of earnings management before and after IFRS adoption. *Journal of Accounting and Public Policy*, 27(6), 480–494.
- Karampinis, N.I., and Hevas, D.L. (2013). The effect of IFRS adoption on tax accounting and book-tax alignment: Evidence from Greece. *(Reference formatted for APA use; verify journal details for your submission copy.)*
- La Porta, R., Lopez-de-Silanes, F., Shleifer, A., and Vishny, R.W. (1998). Law and finance. *Journal of Political Economy*, 106(6), 1113–1155.
- Leuz, C., Nanda, D., and Wysocki, P.D. (2003). Earnings management and investor protection: An international comparison. *Journal of Financial Economics*, 69(3), 505–527.
- Ratu, C., Putri, A., and Setiawan, D. (2023). Tax avoidance mechanisms and earnings management: Evidence from emerging markets. *(Reference formatted for APA use; verify journal details for your submission copy.)*
- Roychowdhury, S. (2006). Earnings management through real activities manipulation. *Journal of Accounting and Economics*, 42(3), 335–370.
- Safira, N., and Setiyawati, H. (2024). Tax planning aggressiveness and cost of equity: Evidence from emerging market firms. *(Reference formatted for APA use; verify journal details for your submission copy.)*
- Schipper, K. (1989). Commentary on earnings management. *Accounting Horizons*, 3(4), 91–102.
- Soderstrom, N.S., and Sun, K.J. (2007). IFRS adoption and accounting quality: A review. *European Accounting Review*, 16(4), 675–702.
- Sundvik, D. (2017). Tax rate changes and earnings management: Evidence from income shifting behavior. *(Reference formatted for APA use; verify journal details for your submission copy.)*
- Tang, T.Y.H. (2015). Does book-tax conformity deter opportunistic book and tax reporting? *European Accounting Review*, 24(2), 239–264.
- Zang, A.Y. (2012). Evidence on the trade-off between real activities manipulation and accrual-based earnings management. *The Accounting Review*, 87(2), 675–703.

Effect of inclusive business models on multidimensional poverty in Burkina Faso

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Abstract. *This paper analyzes the contribution of inclusive business models to multidimensional poverty. The survey data were collected in Burkina Faso in 2019 from households that were beneficiaries and nonbeneficiaries of these inclusive initiatives. The methodology is based on the approach developed by Alkire and Foster (2011) for calculating the multidimensional poverty index. Next, a semi-ordered recursive bivariate probit model was adopted to correct for endogeneity bias between participation in inclusive business models and multidimensional poverty. The results identify participation in IBMs, income, associative membership, age, and bank card ownership as the key determinants of multidimensional poverty. Specifically, participation in IBMs reduces the likelihood that a household will fall into multidimensional poverty by 31.25%, confirming their role in improving well-being. Therefore, the promotion of these models by policymakers is a strategic lever for social development.*

Keywords: inclusive business models, multidimensional poverty, pyramid base, semi-ordered recursive bivariate probit, Burkina Faso.

JEL Classification: M14, F21, C68.

1. Introduction

Multidimensional poverty remains a major structural challenge worldwide. Beyond the monetary dimension, it characterizes the inability of individuals to meet their basic essential needs (Alkire and Foster, 2011). According to a report by the United Nations Development Program and the Oxford Poverty and Human Development Initiative (UNDP and OPHI, 2025), this phenomenon affects 1.1 billion people worldwide. The scale of this scourge is particularly critical in sub-Saharan Africa, a region that, according to t, is home to 256 million people living in multiple deprived states.

Like other countries in sub-Saharan Africa, Burkina Faso faces worrying levels of poverty, despite the efforts of the government and its international partners. According to the Office for the Coordination of Humanitarian Affairs (OCHA, 2024), multidimensional poverty affected 83.3% of the population in 2023, with 66.5% experiencing severe deprivation. At the same time, approximately 7.3 million people were living below the monetary poverty line. These indicators explain the country's ranking on the Human Development Index (HDI) in 2023, with Burkina Faso ranking 186th out of 193 countries, placing it in the category of countries with low human development (UNDP, 2023).

Given the scale of this global challenge, social responsibility now falls on all stakeholders, with businesses being called upon to contribute more significantly to the collective effort. This observation places the debate on poverty, profit, and business ethics at the center of current concerns (Medina-Munoz and Medina-Munoz, 2020). In this context, inclusive business models (IBMs) have emerged as a promising lever for tackling poverty in all its forms. This approach is directly aligned with the 2030 Agenda, which emphasizes the need for partnerships and the driving role of the private sector in achieving the Sustainable Development Goals (SDGs).

Major international institutions, such as the Food and Agriculture Organization of the United Nations (FAO), the World Bank, and the African Development Bank (AfDB), have placed IBMs at the heart of their market-based development strategies (Gupta et al., 2015). IBMs aim to contribute to poverty reduction by integrating low-income communities into their value chains while maintaining the fundamental objective of generating profits (WBCSD and SNV, 2006). These entrepreneurial initiatives are both economically profitable and socially and environmentally responsible.

Inclusive businesses thus play a role in achieving development goals by including the poor in corporate supply chains as employees, producers, and business owners or by developing affordable goods and services that the poor need (UNDP, 2010; Pineda-Escobar, 2013). These inclusive enterprises have emerged as an innovative market-based means of overcoming poverty (Pineda-Escobar and Garzon-Cuervo 2016). They aim to empower marginalized populations through productive integration into the market economy (Fukuda-Parr and Hulme, 2011; German et al., 2020).

According to the literature, these models act as levers for improving living conditions through several channels: the creation of decent jobs; increased agricultural productivity; technology and knowledge transfer; and access to markets and markets (World Bank, 2018; SNV and WBCSD, 2011). Several studies (Gradl and Knobloch, 2010; FAO, 2017) have

shown that the implementation of IBMs in developing countries can help increase employment among smallholders and poor segments of the population, particularly by treating these people as employees in the supply chain.

However, few empirical studies have linked IBMs and multidimensional poverty (MP). The originality of this study lies precisely in its desire to fill this gap. Indeed, the literature has focused mainly on isolated dimensions of precariousness: income (Gebru et al., 2019; Oubda et al., 2025), food security (Wangu et al., 2020; Magnus, 2023), and consumer spending (Dia and Ahouré, 2023). Although Mdanat (2021) examined the effects on the HDI and monetary poverty, the multidimensionality that captures the simultaneity of deprivation remains largely unexplored. However, trends in monetary poverty do not systematically coincide with those in multidimensional poverty; hence, an integrated approach is needed. Alkire and Jahan (2018) highlighted that a significant proportion of the population experiencing multidimensional deprivation is not considered poor in monetary terms, and vice versa. Households may have the financial capacity to meet their basic needs, but it is also necessary to have available and accessible infrastructure in the locality where they live. Household members may even die of illness before they reach the hospital because it is too far from their home (Noglo, 2017).

By focusing on isolated indicators, previous research has potentially underestimated the overall and systemic impact of inclusive business models. This apparent disconnect between different forms of precariousness highlights the need for an integrated analysis. The overall objective of this research is to analyze the effect of inclusive business models on multidimensional poverty via survey data from Burkina Faso.

This paper makes a twofold contribution to the literature. First, it adopts a multidimensional perspective, thus going beyond the traditional monetary approach. While the latter is essential, it often fails to capture the complexity of the simultaneous deprivations experienced by vulnerable populations. Indeed, policies focused exclusively on income risk have neglected fundamental dimensions of well-being. Second, this study rigorously addresses the potential endogeneity bias inherent in the relationship between participation in IBM programs and multidimensional poverty.

The rest of the paper is structured as follows: the second section presents a review of the literature, the third section presents the methodology, the fourth section analyzes the results, and the last section discusses the economic policy implications and concludes the study.

2. Literature review

2.1. Conceptualization of inclusive business models

The World Business Council for Sustainable Development (WBCSD) launched the concept of inclusive business. This is a pro-poor business model at the base of the pyramid (BoP), which involves doing business with the poor in a way that benefits both the poor and the business.

The concept and definition of inclusive business models have been addressed differently in the literature depending on the field. Most of the concepts related to IBMs introduced in the literature involve the private sector; however, researchers have adopted different perspectives when discussing IBMs and the role of the private sector in development outcomes (UNDP, 2010; WBCSD, 2017).

Researchers argue that including people at the bottom of the social pyramid in the labor market is an approach to poverty reduction (Prahalad and Ramaswamy, 2004; London and Hart, 2011). For these researchers, inclusion aims to help the poor sustainably meet their basic economic, social, and environmental needs. As such, it is an inclusive and pro-poor development policy. Inclusive businesses aim to create opportunities and generate sustainable and decent incomes for groups that are underrepresented in the labor market.

From the perspective of development practitioners, inclusive business models make it possible to tap into the labor force of low-income individuals and the potential market they represent (customers/consumers of these companies' products). For small producers, this type of model strengthens the supply chain of companies (UNDP, 2010). Thus, the IBM is an opportunity for many people and opens doors to employment for the poor (Naguib and Jamali, 2015). There are many definitions of IBMs, with some authors focusing on environmental objectives and others on development objectives. According to Likoko and Kini (2017), definitions differ from the perspective of academics and practitioners.

According to Golja and Požega (2012), an inclusive enterprise is a long-term profitable enterprise that helps low-income societies overcome poverty and ensures long-term profitability if it is implemented effectively. It differs from a regular business in that it addresses social issues at scale through local content (supply/distribution chains and employment of marginalized groups) and the provision of essential goods and services to low-income groups.

The G20 (2016) defines inclusive business as a means of providing goods, services, and livelihoods on a commercially viable, large-scale or scalable basis to people living in poverty and integrating them into the value chain of businesses as suppliers, distributors, retailers, or customers, thereby contributing to the achievement of the Millennium Development Goals.

In short, an inclusive business is a business that seeks to contribute to poverty reduction by including communities at the BoP in its value chain without losing sight of the ultimate goal of the business, which is to generate profits (UNDP, 2008). The American economists Prahalad and Hart (2002) developed the BoP concept in the late 1990s. They developed the idea that there is wealth at the base of the income pyramid, considering that it represents an attractive potential market that is largely ignored by multinational companies.

BoPs represent people living below the poverty line or vulnerable people (women/young people, small farmers, people with disabilities, etc.).

This document shares the vision of researchers, who argue that including BoPs in the labor market is an approach to reducing poverty by helping them meet their basic needs.

2.2. Inclusive business models and multidimensional poverty

There are several ways in which inclusive business models reduce multidimensional poverty.

First, these models improve the living conditions of the poorest populations by increasing their incomes and providing them with better access to essential goods, services, or infrastructure (WBCSD and SNV, 2006). More specifically, including these populations in the value chain helps combat poverty by facilitating their access to the labor market (UNDP, 2008). This professional integration guarantees the poorest people stable and sustainable incomes, thereby promoting a steady improvement in their standard of living.

Furthermore, inclusive businesses stimulate local development through knowledge transfer, innovation, and financial investments (Lucci, 2012). Indeed, the implementation of these models often involves mentoring and technical training. This acquisition of skills increases labor productivity, which increases income and purchasing power. Similarly, access to financial services plays a pivotal role. It promotes the economic and social empowerment of individuals by enabling them to better integrate into the national economy and protect themselves against external shocks (United Nations, 2006).

Furthermore, beyond the monetary aspect, inclusive enterprises deploy business strategies that directly impact the well-being of vulnerable populations. By offering affordable goods and services, these companies enable people at the “Base of the Pyramid” to meet their basic needs (food, water, health, and housing). In this context, Bonnell and Veglio (2011) emphasize that these companies also innovate to facilitate access to energy, telecommunications, and insurance. In short, access to these essential resources helps reduce the multiple deprivations suffered by BoP populations. This dual impact on financial resources and access to basic services (health, education) is also widely supported by the work of the UNDP (2010), the WBCSD (2017), and the World Bank (2018).

The effect of IBMs on socioeconomic development is the subject of a growing body of empirical literature. Overall, Mdanat (2021), on the basis of a sample of 23 developing countries, demonstrated that these models reduce poverty and improve the Human Development Index (HDI), thereby promoting access to health, education, and a decent standard of living.

Numerous studies converge on the idea that integrating small producers into value chains significantly improves their incomes. This is the case in Ethiopia, where inclusion in the honey sector has generated a 27% increase in income (Desalgne, 2012), a finding corroborated by Gebru et al. (2019) and Worku (2019) in the malting barley industry. In Asia, Sedana and Astawa (2019) and Chia et al. (2019) noted that the integration of coffee farmers into an inclusive enterprise in Indonesia not only increases their income but also their productivity.

In addition to simple monetary income, IBMs have an effect on the overall well-being of households. In Burkina Faso, Oubda et al. (2025) confirmed this positive impact, whereas Ahouré and N'Dri (2020) highlighted an improvement in job quality in Côte d'Ivoire and Burkina Faso. These benefits also translate into increased consumer spending (on food and

overall), as observed in Kenya and Côte d'Ivoire by Dia and Ahouré (2023), or a general improvement in living standards in Uganda (Kiiza and Perderson, 2012) and Kenya (Wangu et al., 2020).

However, these models are not always successful. Wangu et al. (2021) qualify these results by showing that participation in the green bean sector in Kenya did not significantly improve household income. There are several factors behind this relative failure. The capital-intensive nature of crops limits investment by precarious producers. This underinvestment has had a negative effect on crop yields. In addition, structural failures within the sector, as well as shortcomings in the support provided by consortium partners, have exacerbated the decline in profitability.

3. Methodology

To achieve our objectives, we first adopt the methodology proposed by Alkire and Foster (2011) to calculate the multidimensional poverty index. This approach allows us to calculate multidimensional poverty indices, such as gender and place of residence, for different population groups. This approach facilitates the targeting of populations, ensuring that no one is left behind by policies aimed at reducing poverty in accordance with the recommendations of the Sustainable Development Goals (SDGs). Second, we analyze the effects of IBMs on multidimensional poverty, using the semi-ordered recursive bivariate probit model to account for potential endogeneity bias between participation in inclusive business models and multidimensional poverty.

3.1. Construction of a multidimensional poverty indicator

Measuring multidimensional poverty usually involves constructing deprivation indices that consider information provided by several deprivation indicators. We draw on the multidimensional poverty index (MPI) as a composite indicator developed by Alkire and Foster (2011). It is based on the double threshold method.

The Alkire and Foster method uses two identification thresholds: first, the different dimensions of poverty must be chosen, and the poor identified in each dimension; then, people in multidimensional poverty must be identified. In this study, four dimensions of well-being are considered in calculating the multidimensional poverty index: education, health, living conditions, and quality of employment. (See A1 in the appendix). The selection of these dimensions is based on two main criteria: first, their priority status within international development programs and the Sustainable Development Goals (SDGs); second, we take data availability into account.

To construct the MPI, we consider K primary indicators that reflect household living conditions. The idea is to summarize the information conveyed by these qualitative indicators into a single multidimensional poverty indicator denoted by C_i and written in the following general form:

$$C_i = \sum \gamma_l I_{ij} \quad (1)$$

where I_{ij} is the primary indicator, $j = (1, 2, 3, \dots, K)$ for household i , $i = (1, 2, 3, \dots, n)$; γ_i is the weight assigned to indicator I_{ij} in the calculation of the composite index C_i for household i .

The composite index C_i for household i can be rewritten in functional form as follows:

$$C_i = \frac{\sum_{k=1}^K \sum_{j=1}^{J_k} W_{jk=1}^k I_{ij_k}^k}{K} \quad (2)$$

where K is the number of primary indicators; J_k is the number of indicator modalities k ; $W_{jk=1}^k$ is the weight assigned to modality J_k ; and $I_{ij_k}^k$ is a binary variable (0/1) taking a value of 1 when household i has modality J_k (deprivation index) and 0 otherwise. The index C_i for household i is the average weight of the binary variables $I_{ij_k}^k$. Given the multitude of components and dimensions to be translated into a single deprivation indicator, the IPM requires weighting for aggregation purposes. We assume equal weighting between dimensions on the one hand and between components of the same dimension on the other hand. After this weighting, it is possible to calculate the MPI, which varies between 0 and 1. When the value of the index approaches 1, this corresponds to increased deprivation of well-being. On the basis of this deprivation index, a threshold value must be defined K above which a household is considered poor and below which it is considered nonpoor or rich. According to Alkire et al. (2016), a household is multidimensionally poor if it is deprived of at least one-third of the weighted indicators, i.e., $k = 33\%$.

The incidence of poverty measures the proportion of individuals in multidimensional poverty equal to

$H = \frac{q}{n} = \frac{1}{n} \sum_{i=1}^n q_i$, with q_i being an indicator variable when individual i is poor and q being the number of multidimensionally poor individuals.

The intensity of poverty is the average of the weighted deprivations of multidimensionally poor individuals such that $A = \sum_{i=1}^q \frac{C_i}{q}$.

Finally, the adjusted incidence, M_0 , is a combination of the incidence and intensity of multidimensional poverty such that $M_0 = H * A$. It represents the share of the population that is multidimensionally poor, adjusted by the intensity of deprivation that this population experiences. M_0 thus summarizes the incidence and intensity of multidimensional poverty.

3.2. Semi-ordered recursive bivariate probit model

In the work of Alkire and Jahan (2018), the global MPI classifies any person whose weighted deprivation score is greater than or equal to the 33% threshold as poor. This analytical framework also distinguishes between vulnerability to poverty (scores of 20% to 33%) and extreme poverty (scores above 50%).

In our econometric analysis, we adopt this breakdown: individuals with a score below 20% are defined as nonpoor, whereas those with scores between 20% and 33% are considered

vulnerable. Finally, multidimensional poverty status is assigned once the critical threshold of 33% is reached (see Figure 1, which summarizes poverty levels according to whether participants are enrolled in or excluded from the IBMs).

We thus have a multinomial ordinal indicator defined as follows:

$$MPI = \begin{cases} 1 & \text{si } MPI < 0,2 \\ 2 & \text{si } 0,2 \leq MPI < 0,33 \\ 3 & \text{si } MPI \geq 0,33 \end{cases}$$

Given that our multidimensional poverty (MP) outcome variable is ordinal and multinomial, the simple ordered probit model could have been sufficient to test this relationship. However, the variable of interest, which is participation in IBMs, could be endogenous and correlated with the outcome variable. In practice, inclusive enterprises select their participants according to specific eligibility criteria, such as income level, gender, or age. Moreover, with respect to performance and profitability, they favor BoP profiles that are likely to guarantee the best productive results. For example, with respect to integrating raw material suppliers, a company may choose to work exclusively with producers who are members of professional organizations to mitigate the risks associated with information asymmetry. These selection mechanisms, coupled with certain unobservable characteristics of individuals, simultaneously influence participation in IBMs and the level of multidimensional poverty, thus creating potential endogeneity bias.

Consequently, the use of the simple ordered probit model will lead to biased estimates. To correct for endogeneity, we follow Greene's (2012) approach and simultaneously estimate the decision to participate in IBMs and the probability of being poor via a semi-ordered recursive bivariate probit model.

Following Greene (2012), a semi-ordered recursive bivariate probit model was estimated, with the three-category multidimensional poverty variable and the binary variable participation in IBMs as joint dependent variables, the latter appearing as an ordinary predetermined variable on the right-hand side of the multidimensional poverty equation, along with the socioeconomic characteristics of households.

The observed variables of an individual's multidimensional poverty (P_i) and participation in inclusive business models (I_i) are linked to the corresponding latent variables P_i^* and I_i^* , respectively, as follows:

$$P_i = \begin{cases} 1 & \text{si } P_i^* \leq 0 \\ 2 & \text{si } 0 < P_i^* \leq \mu \\ 3 & \text{si } \mu < P_i^* \end{cases} \quad (3)$$

where 1, 2, and 3 denote the categories of nonpoor, vulnerable to poverty, and poor, respectively, and μ is a threshold parameter, and

$$I_i = \begin{cases} 0 & \text{si } I_i^* \geq 0 \\ 1 & \text{si } I_i^* < 0 \end{cases} \quad (4)$$

where 0 indicates nonparticipation in IBMs and where 1 represents participation in IBMs. The index i denotes an individual observation with $i = 1, 2, \dots, N$.

The underlying model consists of two equations linking the latent variable MP (P_i^*) and the latent variable participation in IBMs (I_i^*) to their socioeconomic characteristics, represented by the vectors x_1 and x_2 , respectively.

$$I_i^* = \beta_1 x_{1i} + \varepsilon_{1i} \quad (5)$$

$$P_i^* = \gamma I_i + \beta_2 x_{2i} + \varepsilon_{2i} \quad (6)$$

where β_1 and β_2 are column vectors of unknown parameters, γ is an unknown scalar that measures the effect of participation in IBMs on MP, and ε_{1i} and ε_{2i} are error terms assumed to follow a standard normal distribution. The total efficiency of the parameter estimate γ is obtained by estimating the maximum likelihood with complete information (Greene, 2012).

The explanatory variables of the model are assumed to satisfy the exogeneity condition such that:

$$E(x_{1i}\varepsilon_{1i}) = 0 \quad \text{and} \quad E(x_{2i}\varepsilon_{2i}) = 0$$

Given that the errors ε_{2i} in equation (3) are normally distributed with a mean of zero and a variance of one, the following probabilities apply to the single equation ordered probit model:

$$P(F_i = 1) = \varphi(-\gamma I_i - \beta_2 x_{2i})$$

$$P(F_i = 2) = [\varphi(\mu - \gamma I_i - \beta_2 x_{2i}) - \varphi(-\gamma I_i - \beta_2 x_{2i})]$$

$$P(F_i = 3) = \varphi(\mu - \gamma I_i - \beta_2 x_{2i})$$

where φ is the distribution function of the standard normal distribution. The model parameters in equations (3) and (4) are estimated via the maximum likelihood technique. However, if participation in IBMs and MP are jointly determined, estimating the ordered probit equation (equation 3) in isolation, as above, will result in a biased estimate of γ (Greene, 2012). If the correlation between ε_{1i} and ε_{2i} is zero, then, by virtue of normality, they are independently distributed. In this case, the model with equations (5) and (6) becomes recursive. The significance of the correlation is therefore essential. The possible joint determination of I_i and F_i is taken into account by allowing the errors ε_{1i} and ε_{2i} to be distributed according to a standard bivariate normal distribution with correlation, as shown below:

$$E(\varepsilon_{1i}) = E(\varepsilon_{2i}) = 0$$

$$Var(\varepsilon_{1i}) = Var(\varepsilon_{2i}) = 1$$

$$Cov(\varepsilon_{1i}, \varepsilon_{2i}) = \rho$$

The single-equation ordered probit model described in equation (6) is a special case of the two-variable semiordered probit with $\rho = 0$.

The model was estimated by imposing an exclusion restriction, although this is not strictly necessary since identification via the functional form is possible, requiring only variations in the set of exogenous variables (Wilde, 2000). For this study, we selected home ownership as the instrumental variable. This choice is inspired by the work of Dia and Ahouré (2023). This variable could therefore have a direct effect on participation in inclusive business models, but it can only affect empirical multidimensional poverty through its influence on the former.

3.3. Data source

The data for this research come from a project on the economic inclusion of young people and women through inclusive entrepreneurship in Africa (Côte d'Ivoire, Kenya, and Burkina Faso), with financial support from Canada's International Development Research Centre (IDRC). The survey was conducted from February to May 2019 in Burkina Faso and Côte d'Ivoire via a quasi-experimental protocol. The sample consisted of two stages. The treatment group consisted of lists of base-of-pyramid (BoP) populations provided by companies identified during a preliminary phase for their proven inclusive business models. The control group was established through a census of households and small businesses in the intervention areas. To ensure comparability, a matching process was carried out: for each beneficiary, two nonbeneficiaries with identical profiles (sector of activity, age, gender, and disability status) were selected. Within these strata, the final selection of individuals was made at random. The main descriptive variables are presented in the following section.

4. Results

4.1. Descriptive analysis

For the purposes of this research, any individual or household integrated into the value chain of an inclusive enterprise is considered a participant or beneficiary of an inclusive business model. In Burkina Faso, so-called base-of-pyramid (BoP) populations are involved in IBMs in the same way, generating mutual benefits for all stakeholders. However, our analysis focuses on the multidimensional benefits for BoP populations.

Synthetic indicators of multidimensional poverty

Table 1 presents a summary of the MP measures. When the deprivation threshold is set at 33%, the incidence rate (H) increases to 60.6%, indicating that more than six out of ten households experience deprivation in at least one-third of the weighted indicators. However, incidence alone does not measure the true extent of individuals' accumulated deprivation. This gap is filled by poverty intensity (A), which reflects the average number of deprivations experienced. The results reveal that households identified as poor are, on average, deprived of 59.6% of the basic needs considered. Finally, the MPI, which adjusts incidence by intensity, stands at 0.362. This value means that the population studied suffers 36.2% of the total deprivation it would experience if all households were deprived in all dimensions simultaneously.

Table 2 shows the breakdown of the MPI by dimension. The analysis reveals that job quality is the main contributing factor, accounting for 37% of the index. It is followed by the dimensions of education (22.8%) and living conditions (20.8%). Finally, the health dimension has the lowest contribution, at 19.4%.

Table 1. Summary indicators of MP

Indices	Value	Standard error
H	0.606	0.015
A	0.596	0.006
M_0	0.362	0.010

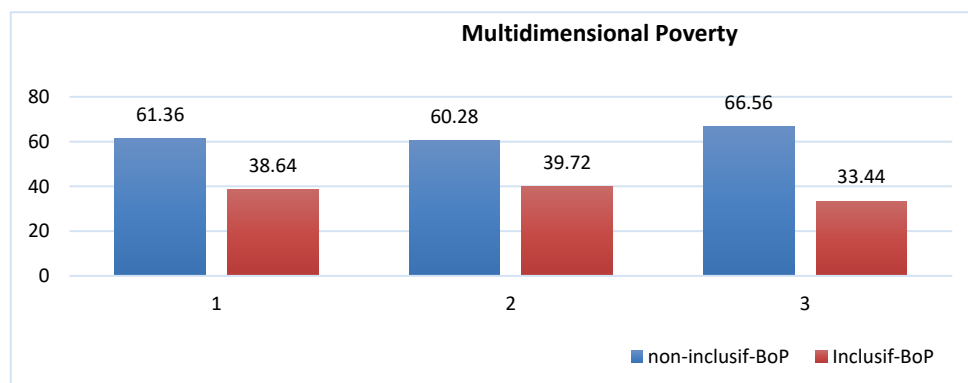
Source: Authors' estimation results on the basis of data from the 2019 LAQAD-S beneficiary survey.

Table 2. MPI by dimension

Dimensions	MPI
Education	0.228
Health	0.194
Living Conditions	0.208
Quality of work	0.370

Source: Authors' estimation results on the basis of data from the 2019 LAQAD-S beneficiary survey.

Figure 1 Share of participants and nonparticipants.



Source: Authors, based on the LAQAD-S 2019 survey,

Socioeconomic characteristics of the respondents

The dependent variable in this study is multidimensional poverty. This is an ordinal qualitative variable constructed from a composite index synthesizing household deprivation. This index has been broken down into three distinct categories, ranked according to the intensity of the deprivation identified.

Figure 1 illustrates a significant disparity between the two groups: IBM participants appear to be less exposed to multidimensional poverty than nonparticipants are. Among individuals identified as vulnerable, 39.72% are participants, whereas 60.28% are nonparticipants. This trend is even more pronounced in the category of multidimensionally

poor, where the proportion of participants (33.44%) is almost half that of nonparticipants (66.56%).

Table 3 defines the study variables and presents descriptive statistics (means and proportions). The results indicate that only 6.41% of the respondents are considered nonpoor, whereas 32.59% are vulnerable, and a large majority (61%) live in multidimensional poverty. The analysis also reveals low participation in inclusive business models (34.44%). The sample is predominantly female (64.28%), with an average age of 37. Economically, the average monthly income is 728,387.7 CFA francs. In terms of social and financial integration, 15.7% of the respondents are members of a professional association, and 29.69% have a bank card. Finally, the average level of education is six years of schooling, with approximately one-third of the sample (32.83%) living in rural areas and an average household size of seven people.

Table 3. *Description of the variables and socioeconomic characteristics of the respondents*

Variables	Definition	Means/proportions
	Dependent variables	
MP	1=nonpoor	6.41
	2= vulnerable to poverty	32.59
	3= multidimensionally poor	61.0
	Selection variable	
Participation of IBM	=1 if IBM participant, 0 otherwise	34.44
	Control variables	
Gender	=1 if female, 0 otherwise	64.28
Age	= Number of years	36.95
Income	= Monthly income in CFA francs	728,387.70
Association membership	=1 if member association, 0 otherwise	15.70
Ouagadougou	=1 if resides in Ouagadougou, 0 otherwise	55.70
Bobo-Dioulasso	=1 if resides in Bobo-Dioulasso, 0 otherwise	19.45
Household size	= number of persons in the household	7.21
Place of residence	=1 if rural, 0 otherwise	32.83
Number of business relationships	= Number of business relationships	4.11
Marital status	=1 if married, 0 otherwise	66.97
Possession of a bank card	=1 if has card, 0 otherwise	29.96
Landownership	=1 if one owns land, 0 otherwise	28.15
Observations	780	

Source: Authors' estimation results on the basis of data from the 2019 LAQAD-S beneficiary survey.

4.2. Interpretations of econometric results

The results of the semi-ordered recursive bivariate probit model estimates are shown in Table 4; the structure of the commands requires prior estimation of the two univariate models to provide starting values for the iterations. The third command then adjusts the bivariate model. The results indicate that there is a relationship between participation in IBMs and MP. The parameter ρ (which is equal to 0.731) represents the correlation between the error terms of the two equations and is significantly different from zero at 1%. This suggests that the error terms of the two equations are related. The system is therefore recursive and bivariate, and the standard ordered probit cannot be used for the purpose of this study. Table A2 shows the estimates from the semi-ordered recursive bivariate probit model (column 1) and those from the simple ordered probit model (column 2). Since the recursive bivariate model is the most robust for dealing with the endogeneity of participation, our analysis focuses exclusively on its results. The results presented in Table

A2 identify participation in IBMs, income, associative membership, age, and bank card ownership as the key determinants of multidimensional poverty. To refine the interpretation, the marginal effects derived from these estimates are summarized in Table 4 below.

The results in Table 4 reveal a negative correlation between participation in IBMs and MP. In other words, participating households are significantly less likely to experience poverty than nonparticipating households are. Specifically, participation in IBM reduces the likelihood that a household will fall into multidimensional poverty by 31.25%. This finding corroborates the work of the UNDP (2010), the WBCSD (2017), and the World Bank (2018), which argue that IBMs promote human development by acting on two levers: increasing income and improving access to basic social services (health and education). By meeting these basic needs, these models directly reduce the number of deprivations suffered by households. In addition, increased monetary resources strengthen the capacities of vulnerable populations, enabling them to meet their basic needs more effectively.

The results reveal a negative relationship between income and multidimensional poverty, suggesting that an increase in income leads to a 1.21% reduction in the probability of experiencing multidimensional poverty. An increase in income leads to improved purchasing power (*ceteris paribus*), which could help finance basic needs, namely, access to education, better nutrition, and health services.

Conversely, the results reveal that an increase in age increases the probability of falling into the MP by 2.62%. This result could reflect increased vulnerability related to the life cycle or a decline in productive capacity over time.

The results highlight a negative relationship between bank card ownership and MP. Having a bank card decreases the likelihood of experiencing multidimensional poverty by 14.64%. This finding underscores the importance of financial inclusion, which, as demonstrated in the literature (Koomson et al., 2020), is a powerful lever for poverty reduction. By facilitating access to formal financial services, bank card ownership enables households to better manage their resources and strengthen their resilience to deprivation.

The results indicate that membership in an association reduces the probability of multidimensional poverty by 5.94%. This membership offers individuals tangible benefits, such as easier access to credit and greater labor mobility. In addition to these technical aspects, community organizations constitute a robust form of social capital. By promoting mutual aid and resource sharing, they act as a powerful lever for improving households' living conditions and, by extension, reducing the incidence of multidimensional poverty.

Table 4. *Estimation of marginal effects from the semiordered bivariate probit model*

Variables	Nonpoor	Vulnerable to poverty	Multidimensionally poor
Participation of IBM	0.185** (0.096)	0.127*** (0.026)	-0.312*** (0.114)
Gender	0.006 (0.024)	0.004 (0.016)	-0.011 (0.041)
Place of residence (rural=1)	0.007 (0.042)	0.005 (0.028)	-0.012 (0.071)
Household size	-0.002 (0.002)	-0.001 (0.002)	0.004 (0.004)

Variables	Nonpoor	Vulnerable to poverty	Multidimensionally poor
Marital status (married=1)	-0.009 (0.011)	-0.005 (0.007)	0.014 (0.018)
Ouagadougou (yes=1)	-0.043 (0.040)	-0.029 (0.028)	0.073 (0.067)
Bobo-Dioulasso (yes=1)	-0.002 (0.025)	-0.001 (0.016)	0.004 (0.041)
Possession of a bank card (yes=1)	0.086*** (0.027)	0.059*** (0.022)	-0.146*** (0.042)
Association membership (yes=1)	0.035** (0.017)	0.024** (0.012)	-0.059** (0.029)
Income	0.009** (0.004)	0.010** (0.005)	-0.012** (0.006)
Age	-0.016*** (0.003)	-0.011*** (0.003)	0.026*** (0.004)
Number of business relationships	-0.000 (0.001)	-0.000 (0.000)	0.000 (0.001)
Observations	780		

Note: The asterisks (***), (**), and (*) represent the significance of the coefficients in the table at the 1%, 5%, and 10% thresholds, respectively. The numbers in parentheses represent standard deviations.

Source: Author, estimation results based on data from the 2019 LAQAD-S beneficiary survey

Conclusion and economic policy implications

This research analyzes the impact of inclusive business models (IBMs) on MP in Burkina Faso. The data were collected between February and May 2019 by the Laboratoire d'Analyse Quantitative Appliquée au Développement-Sahel (LAQAD-S) as part of a regional project involving Côte d'Ivoire and Kenya, with financial support from Canada's International Development Research Centre (IDRC). The study is based on a sample of 780 individuals from the BoP.

The Alkire and Foster approach (2011) was first used to calculate the multidimensional poverty index (MPI). Next, to measure the effect of inclusive business models on reducing multidimensional poverty, the semi-ordered recursive bivariate probit model was adopted to control for endogeneity bias because of the bidirectional relationship between multidimensional poverty and participation in inclusive business models.

Analysis of the data reveals that the multidimensional poverty index (MPI) is estimated at 36.2%. An examination of its internal structure indicates that job quality is the primary factor contributing to deprivation, ahead of the dimension related to education. The results identify participation in IBMs, income level, financial inclusion (possession of a bank card), and membership in an association as the determining factors of poverty. Specifically, participation in IBMs reduces the likelihood that a household will fall into multidimensional poverty by 31.25%, confirming their role in improving well-being.

In light of these findings, it is essential that public policies prioritize improving job quality and expanding access to basic social services, particularly in the areas of health care, drinking water supply, and electrification. In this context, inclusive business models serve as a relevant strategic lever for combating poverty in all its dimensions. Consequently, promoting the integration of vulnerable populations into IBMs is imperative to ensure the sustainable improvement of their well-being. In conclusion, policymakers would benefit

from promoting these ecosystems through the establishment of targeted programs and projects specifically dedicated to populations at the bottom of the social pyramid. This strategy is based on an incentive-based regulatory framework centered on tax breaks and investment support mechanisms.

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Authors' contributions

Conceptualization: Judith Oubda and Boukaré Maïga; Formal analysis: Judith Oubda, Eugène Dimaviya Compaoré; Data analysis: Eugène Dimaviya Compaoré; Writing - Original Draft: All authors.

Statements and declarations

Ethics approval and consent to participate

Ethical approval and consent to participate are not applicable to this study.

Consent for publication

All authors have approved the manuscript and agreed with its submission to the journal.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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The data will be made available upon request from the corresponding author.

References

- Ahouré, A.A., and N'Dri, K.D. (2020). Improving Job Quality in Cote d'Ivoire and Burkina Faso: Role of the Inclusive Business model. *Theoretical Economics Letters*, 10, 1314-1337.
- Alkire, S., and Foster, J. (2011). Counting and multidimensional poverty measurement. *J. Public Econ.* 95 (7), 476-487.
- Alkire, S., and Jahan, S. (2018). The New Global MPI 2018: Aligning with the Sustainable Development Goals. *Technical Report, OPHI Working Paper 121*. University of Oxford.
- Alkire, S., and Santos, M.E. (2010). Acute Multidimensional Poverty: A New Index for Developing Countries. *SSRN Electronic Journal*. <<https://doi.org/10.2139/ssrn.1815243>>
- Alkire, S., Jindra, C., Robles, G., and Vaz, A. (2016). Multidimensional Poverty Index 2016: Brief methodological note and results. *OPHI Briefing 42*, University of Oxford.

- Banque Africaine Développement. (2016). Stratégie du Groupe de la Banque pour l'emploi des jeunes en Afrique 2016-2025.
- Bonnell, V., and Veglio, F. (2011). Inclusive business for sustainable livelihoods. *Field Actions Science Report*, 5, 1-5.
- Business Call to Action. (2015, Mars 24). *Implementing Inclusive Business Models*. Retrieved from <https://d306pr3pise04h.cloudfront.net/docs/issues_doc%2Fhuman_rights%2FInclusiveBusinessPrimer.pdf>
- Chia, S., Tanga, C.M., Loon, J.J., and Dicke, M. (2019). Insects for sustainable animal feed: inclusive business models involving smallholder farmers. *Environmental sustainability* 23-30.
- Desalgne, P. (2012). Ethiopian Honey: Accessing International Markets with Inclusive Business and Sector Development. *SNV*.
- Dia, K., and Ahouré, A.A. (2023). Alleviating Poverty in Sub-Saharan Africa: The Role of Inclusive Business models. *Journal of African Economies*, 2023, 32, ii183–ii201 <<https://doi.org/10.1093/jae/ejac048>>
- FAO. (2017). Inclusive Business Models. Training Modules. <fao.org/3/a-i7968e.pdf> [15 February 2020].
- Fukuda-Parr, S., and Hulme, D. (2011). International norm dynamics and the “end of poverty”: Understanding the Millennium Development Goals. *Global Governance. A Review of Multilateralism and International Organizations*, 17(1), 17–36.
- G20. (2016). Inclusive Business Report. Available from: <<http://www.g20.utoronto.ca/2016/inclusive-business-report.pdf>> [28 January 2020].
- Gebru, K.M., Rammelt, C., Leung, M., Zoomers, A., and van Westen, G. (2019). Inclusive malt barley business and household food security in Lay Gayint district of northern Ethiopia. *Food Security*.
- Gebru, K., Leung, M., Rammelt, C., Zoomers, A., and van Westen, G. (2019). Vegetable Business and Smallholders' Food Security: Empirical Findings from Northern Ethiopia. *Sustainability* 11, 743.
- German, L.A., Bonanno, A.M., Foster, L.C., and Cotula, L. (2020). “Inclusive business” in agriculture: Evidence from the evolution of agricultural value chains. *World Development*, 134, 105018.
- Golja, T., and Pozega, S. (2012). Inclusive Business-What It Is all about? Managing Inclusive Companies. *International Review of Management and Marketing*, 2(1), 22–42.
- Gradl, C., and Knobloch, C. (2010). *Inclusive Business Models Guide*. Retrieved from <https://endeva.org/wp-content/uploads/2014/11/IBG_final.pdf> [11 February 2020]. Endeva.
- Greene, W. (2008). *Econometric analysis* (6th ed.). *Englewood Cliffs*.
- Greene, W. (2012). *Econometric analysis*. *New Jersey, USA: Prentice Hall PTR*.
- Gupta, J., Pouw, N.R., and Ros-Tonen, M.A. (2015). Toward an elaborated theory of inclusive development. *The European Journal of Development Research*, 27(4), 541–559.
- INSD (Institut National de la Statistique et de la Démographie). (2018). Enquête harmonisée sur les Conditions de vie des ménages de 2018: diagnostic de la pauvreté en 2018, 107. 2022.
- Kiiza, B., and Pederson, G. (2012). ICT-based market information and adoption of agricultural seed technologies: Insights from Uganda. *Telecommunications Policy*, 36, 253–259.
- Koomson, I., Villano, R., and Hadley, D. (2020). Effect of financial inclusion on poverty and vulnerability to poverty: evidence using a multidimensional measure of financial inclusion. *Soc. Indic. Res.* 149, 613–639.

- Likoko, E., and Kini, J. (2017). Inclusive business—a business approach to development. *Curr Opin Environ Sustain* 24, 84–88.
- London, T., and Hart, S. (2011). Introduction: Creating a fortune with the base of the pyramid, in T. London and S. Hart (eds), *Next generation business strategies for the base of the pyramid: New approaches for building sustainable value*. Upper Saddle River, NJ: FT Press, 19–44.
- Mangnus, E. (2023). An assessment of 'Inclusive' Business Models: Vehicles for Development, or Neo-Colonial Practices? *Journal of Agricultural and Environmental Ethics* 36:17. <doi:10.1007/s10806-023-09911-z>
- Mdanat, M. (2021). The effects of inclusive business models on development outcomes in developing countries. *International Journal of Development and Conflict*, 11, 132–152.
- Medina-Munoz, R.D., and Medina-Munoz, D.R. (2020). Corporate Social Responsibility for Poverty Alleviation: An Integrated Research Framework. *Business Ethics: A European Review* 29, 1, 3–19.
- Naguib, R., and Jamali, J. (2015). Female Entrepreneurship in the UAE: A Multi-Level Integrative Lens. *Gender in Management. An International Journal*, 30, 135–161. <https://doi.org/10.1108/GM-12-2013-0142>
- Noglo, Y. (2017). Nonmonetary poverty in Togo: a multidimensional approach. *Soc. Econ.* 75 (2), 181–211.
- OCHA. (2024, mars 13). *Burkina Faso: Aperçu des Besoins Humanitaires*. Retrieved from <https://www.unocha.org/publications/report/burkina-faso/burkina-faso-aperçu-des-besoinshumanitaires-2024-mars-2024>
- Oubda, J., Ahouré, A.A., and Zahonogo, P. (2025). Impact of inclusive business models on household welfare in Burkina Faso. *SN Business & Economics*, 5:17.
- Pineda-Escobar, M.A. (2013). A. Gonzalez-Perez (Eds.), Principles and strategies to balance ethical social and environmental concerns with corporate requirements. *Advances in Sustainability and Environmental Justice* (12): 67–91.
- Pineda-Escobar, M., and Garzon-Cuervo, F. (2016). Improving Post-2015 Development Cooperation through Donor Support for Inclusive Business. Lessons from the Great Recession: At the Crossroads of Sustainability and Recovery. *Advances in Sustainability and Environmental Justice*. (18):141–163.
- PNUD. (2023). *Rapport Annuel Burkina Faso*.
- PNUD. (2024). *Rapport sur le développement humain dans le monde en 2024*, PNUD.
- PNUD, and OPHI. (2025). *Global Multidimensional Poverty Index 2022. Unpacking deprivation bundles to reduce multidimensional poverty. Overlapping Hardships: Poverty and Climate Hazards*.
- Prahalad, C.K., and Hart, S.L. (2002). The Fortune at the Bottom of the Pyramid. *Business Strategy*, 1–14. <https://doi.org/doi/pdf/10.1162/itgg.2008.3.1.85>
- Prahalad, C.K., and Ramaswamy, V. (2004). Co-Creation Experiences: The Next Practice in Value Creation. *Journal of Interactive Marketing*, 18(3), 5–14. <https://doi.org/10.1002/dir.20015>
- Sédana, G., and Astawa, N. (2019). Establishment of inclusive Business on coffee production in Bali province: lesson from the coffee development project in Nusa Tenggara Timur province, Indonesia. *Journal Asiatique de l'agriculture et du développement rural* Volume 9, Issue 1 (2019), 111–122.
- SNV, and WBCSD. (2011). *Inclusive business: Creating value in Latin America alliance for inclusive business*. 2011, SNV, the Hague.

- UNDP. (2010). Brokering Inclusive Business Models – Private Sector Division, Partnerships Bureau.
- UNDP. (2008). Creating Value for All—Strategies for Doing Business with the Poor; United Nations Development Programme: New York, NY, USA.
- United, Nations. (2006). *In: Building Inclusive Financial Sectors for Development United Nations, New York, 182.*
- Wangu, J., Mangnus, E., and van Westen A. (2020). Limitations of Inclusive Agribusiness in Contributing to Food and Nutrition Security in a Smallholder Community. A Case of Mango Initiative in Makueni Community County, Kenya. *Sustainability* 12:5521. <<https://doi.org/10.3390/su12145521>>
- Wangu, J., Mangnus, E., van Westen, A., and Vocht, A. (2021). Inclusive Business for Smallholders' Household Food and Nutrition Security: Disconcerting Results from an Analysis of a French Bean Agri-investment in Kenya. *Journal. Development Policy Pract*, 108–127.
- WBCSD, and SNV. (2006). Inclusive business: Profitable business for successful development.
- Westen, A., Mangnus, E., Wangu, J., and Worku, S.G. (2020). Limitations of Inclusive Agribusiness in Contributing to Food. *Current opinion in environmental sustainability*.
- Wilde, J. (2000). Identification of multiple equation probit models with endogenous dummy regressors. *Economic Letters*, 69, 309–312.
- Worku, S. (2019). The Impact of an Inclusive Business Model on Local Farmers Food Security in Arsi, Ethiopia. *In Working Paper; International Development Studies; Utrecht University: Utrecht, The Netherland.*
- World Bank. (2018). IFC's Experience with Inclusive Business An assessment of IFC's role, outcomes and potential scenarios, World Bank Publications. *Available from:* <http://ieg.worldbankgroup.org/sites/default/files/Data/reports/meso_ifcinclusivebusiness.pdf> [21 December 2020].
- World Business Council for Sustainable Development (WBCSD). (2017). Inclusive Business. *Available from:* <<https://www.wbcsd.org/content/search?searchText=inclusive+business>> [5February 2020].

Appendix

Table A1. *Indicator index for multidimensional poverty*

Dimensions	Indicators	Suffering from deprivation if	Percentage of people suffering in these indicators
Education	Literacy	Household members are not literate	47.35%
	Number of years of Schooling	No family member has completed 5 years of schooling	47.17%
Health	Distance to the nearest health center	Access to health services within 30 minutes	9.15%
	Nutrition	Household meals are rarely balanced	68.70%
Living conditions	Sanitation	The household does not have adequate sanitation (according to MDG guidelines) or this sanitation is shared.	77.40%
	Electricity	The household does not have electricity	48.16%
	Cooking fuel for cooking	The household cooks with wood, manure or coal	50.94%
	Water	The household does not have safe drinking water or this water is more than a 30-minute walk away	9.24%
	Wastewater disposal	Wastewater is disposed of in the yard or on the street/in nature.	58.12%
	Working	The household owns no more than one of the following items: radio, television, telephone, bicycle, moped, or refrigerator; and also does not own a car or truck.	6.01%
Quality of work	Satisfaction with working conditions	Dissatisfaction with working conditions	78.39%
	Satisfaction with income	Dissatisfaction with income	80.90%
	Access to social protection	No access to social protection	88.97%

Source: Authors, based on Alkire and Santos (2011).

Table A2. *Determinants of MP according to the semiorordered recursive bivariate probit model*

Variables	Semiorordered recursive bivariate probit	Simple ordered probit
Participation of IBM	-1.298*** (0.352)	-0.152 (0.209)
Gender	-0.044 (0.171)	-0.022 (0.201)
Place of residence (rural=1)	-0.052 (0.294)	0.023 (0.351)
Household size	0.015* (0.009)	0.0143 (0.022)
Marital status (married=1)	0.060 (0.076)	0.046 (0.092)
Ouagadougou (yes=1)	0.304 (0.287)	0.414 (0.344)
Bobo-dioulasso (yes=1)	0.015 (0.173)	0.034 (0.207)

Variables	Semiordered recursive bivariate probit	Simple ordered probit
Possession of a bank card (yes=1)	-0.605*** (0.209)	-0.755*** (0.220)
Association membership (yes=1)	-0.246** (0.123)	-0.417** (0.212)
Income	-0.038** (0.018)	-0.046** (0.021)
Age	-0.109*** (0.025)	-0.138** * (0.024)
Number of business relationships	0.000 (0.003)	0.001 (0.004)
Disturbance correlation (ρ)	0.715*** (0.196)	
Log likelihood	-840.387	
Observations	780	

Note: The asterisks (***), (**), and (*) represent the significance of the coefficients in the table at the 1%, 5%, and 10% thresholds, respectively. The numbers in parentheses represent standard deviations.

Source: Author, estimation results on the basis of data from the 2019 LAQAD-S beneficiary survey.

Gross financial wealth or net financial strength? Household balance sheets and economic development in the European Union

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Abstract. *Household financial wealth is often treated as a visible sign of economic strength, yet its gross size offers only a partial view of how household finance relates to development. The European evidence challenges the idea that larger household financial assets are, by themselves, associated with stronger economic performance. Gross financial wealth does not provide a robust growth signal when separated from liabilities, portfolio structure and country-specific conditions. The stronger pattern emerges from net financial strengthening, where improvements in the household sector's financial position after debt is taken into account are positively associated with real economic performance. This distinction changes the interpretation of household wealth: the relevant issue is not simply how much financial wealth households hold, but whether that wealth improves the resilience and net capacity of the household balance sheet. The findings support a balance-sheet quality perspective in which financial assets become economically meaningful only when they translate into stronger net positions. Economic development is therefore connected less with the visible accumulation of gross household wealth and more with the financial strength that remains once liabilities are considered.*

Keywords: household financial wealth; net financial assets; household balance sheets; economic development; European Union.

JEL Classification: D14, E21.

Introduction

Household financial wealth has become a central variable in debates on economic development because it connects private saving, financial intermediation, portfolio allocation and macroeconomic performance. The classical finance–growth literature established that financial systems can support long-run growth by improving information, mobilising savings and allocating capital more efficiently, but this tradition mainly examined banks, markets and aggregate financial depth rather than the internal structure of household balance sheets (King & Levine, 1993; Levine, 2005; Beck et al., 2000). The European case requires a more careful distinction. A household sector with large financial assets is not necessarily stronger if asset accumulation is accompanied by rising liabilities, weak portfolio diversification or uneven access to productive financial instruments.

The relationship between finance and growth has never been purely mechanical. Financial intermediation can stimulate capital accumulation and productivity, yet its growth relevance depends on institutional quality, allocation mechanisms and the capacity of economies to transform financial resources into productive activity (Levine et al., 2000; Aghion et al., 2005; Beck & Levine, 2004). Research on finance, inequality and the poor also shows that financial development matters through distributional and access channels, not only through aggregate financial size (Beck et al., 2007). This broader perspective is particularly relevant for the European Union, where household financial positions differ widely across countries with different pension systems, credit structures, capital market participation and post-crisis adjustment paths.

Household finance offers a more suitable conceptual frame because it treats households as active financial units that save, borrow, insure, invest and manage risks under constraints that differ across income groups and institutional settings. Campbell (2006) placed household financial decisions at the centre of modern financial economics, while Guiso and Sodini (2013) described the field as a domain concerned with the way households use financial markets to organise intertemporal choices, portfolio exposure and borrowing decisions. International comparative evidence confirms that household balance sheets vary strongly across advanced economies, especially in retirement savings, risky asset holdings, mortgages and unsecured debt (Badarinza et al., 2016). Financial literacy further conditions participation in market-based assets, which means that household wealth cannot be understood only as an aggregate stock detached from knowledge, access and portfolio choice (van Rooij et al., 2011).

The macroeconomic relevance of household wealth is often discussed through consumption channels, but this connection is also heterogeneous. Financial and housing wealth can affect spending, though the magnitude and stability of wealth effects differ by asset type, liquidity and household constraints (Carroll et al., 2011; Case et al., 2005). Liquidity constraints alter saving and growth behaviour, which makes household financial structure relevant for macroeconomic adjustment rather than merely for private portfolio composition (Jappelli & Pagano, 1994). Evidence on household investment behaviour also indicates that participation, diversification and financial sophistication shape the efficiency with which households hold and manage assets (Calvet et al., 2007). A larger gross

financial position may therefore coexist with weak development relevance if it does not correspond to a stronger net position or a more resilient balance sheet.

The debt side of household balance sheets gives this distinction its macro-financial importance. Credit booms have repeatedly been linked to financial instability, and the historical evidence shows that rapid credit growth is a powerful predictor of crisis episodes (Schularick & Taylor, 2012). Asset-price expansions become especially costly when they are fuelled by leverage, since credit-financed bubbles tend to be followed by deeper recessions and slower recoveries (Jordà et al., 2015). At household level, balance-sheet shocks influence consumption more strongly among more indebted households, and increases in household debt ratios predict weaker subsequent growth and higher unemployment in cross-country evidence (Mian et al., 2013; Mian et al., 2017). These findings shift attention from asset ownership alone to the net financial position that remains after liabilities are considered.

Recent finance–growth research also questions the assumption that more finance is always growth-enhancing. Loayza and Rancière (2006) distinguish between financial development and financial fragility, while Rousseau and Wachtel (2011) show that the finance–growth association weakened in more recent data compared with earlier cross-country evidence. Non-linear approaches indicate that financial development may support growth only up to a certain threshold, beyond which additional financial depth can become less favourable or even harmful (Arcand et al., 2015; Law & Singh, 2014). Beck et al. (2014) further separate intermediation from the size of the financial system, showing that the real-sector relevance of finance depends on what finance does rather than on how large the financial sector becomes.

The novelty lies in moving the European household-finance debate from gross financial wealth towards net financial strength. Instead of treating household financial assets as a single stock variable, the analysis separates gross assets, liabilities, net financial assets, portfolio composition and annual balance-sheet changes across EU-27 countries during 2010–2024. This distinction is needed because financial sophistication, returns to wealth and household portfolio efficiency are unevenly distributed, as shown by studies on investment mistakes, financial sophistication and heterogeneous wealth returns (Calvet et al., 2009; Fagereng et al., 2020; Bach et al., 2020). The central question is not whether households hold more financial assets, but whether their financial position becomes stronger once liabilities and balance-sheet dynamics are taken into account.

The rest of the paper is organised as follows: literature review, methodology, results, discussions, and conclusions. The literature review clarifies the empirical debates on finance, household balance sheets and economic development. The methodology describes the Eurostat-based EU-27 panel, the construction of the main indicators and the econometric specification. The results section presents the evidence on financial stocks, balance-sheet changes and comparative EU patterns, while the discussions section interprets the findings against the broader finance–growth and household-finance literature. The conclusions draw the main implications of the distinction between gross financial wealth and net financial strength.

Literature review

The empirical literature on finance and development has gradually moved away from the assumption that larger financial aggregates necessarily generate stronger economic performance. Early cross-country and sectoral work linked financial depth with growth by showing that countries with more developed financial systems were better able to support sectors dependent on external finance, while later studies added concerns about causality, heterogeneity and the conditions under which finance is converted into productivity gains (De Gregorio & Guidotti, 1995; Rajan & Zingales, 1998; Luintel & Khan, 1999). This shift matters for household finance because the volume of financial assets held by households is only one part of the wider development mechanism. Financial wealth becomes economically relevant when it is associated with allocation efficiency, risk absorption and intertemporal stability rather than with balance-sheet expansion alone.

A second group of studies argues that the finance–growth relationship differs across stages of development and institutional environments. Rioja and Valev (2004) find that financial development affects the sources of growth differently across country groups, with productivity channels becoming more visible in more developed economies, while Fisman and Love (2007) reinterpret financial dependence through the ability of firms to respond to growth opportunities. Research on non-monotonic finance–growth links reaches a similar warning from another angle: additional financial depth may lose its favourable association with growth once the financial system becomes large relative to the real economy (Samargandi et al., 2015; Sahay et al., 2015). These findings weaken any direct reading of household financial assets as a simple development driver and open space for indicators that separate financial size from financial strength.

The household balance-sheet literature deepens this distinction by treating households as units whose assets and liabilities must be examined jointly. Macro-financial models of deleveraging show that debt overhang can depress demand when constrained borrowers are forced to reduce spending, while household-debt research indicates that leverage conditions monetary transmission and macroeconomic adjustment (Eggertsson & Krugman, 2012; Alpanda & Zubairy, 2019). Evidence from the Bank for International Settlements also points to a temporal asymmetry: household debt may support consumption and GDP in the short run, but higher debt ratios tend to weaken growth over longer horizons (Lombardi et al., 2017). The relevant object is therefore not the household asset stock alone, but the net position that remains once liabilities are deducted.

European evidence strengthens the case for a net-balance perspective because household financial structures differ markedly across countries. Work based on the Eurosystem Household Finance and Consumption Survey shows that euro-area households allocate wealth across real assets, deposits, risky financial assets and pension-related instruments in highly uneven ways, while financial vulnerability depends on both solvency and liquidity positions (Arrondel et al., 2016; Ampudia et al., 2016). The ECB methodological framework also confirms the value of harmonised household-level information for comparing assets, liabilities and wealth across European economies, yet country heterogeneity remains substantial even under a common statistical architecture (Household

Finance and Consumption Network, 2023). These studies support the treatment of household finance as a balance-sheet configuration rather than a single wealth aggregate.

Household portfolio research adds another layer because asset composition influences the way wealth is accumulated and transmitted. Limited stock-market participation remains a persistent empirical puzzle, and portfolio choice depends on inertia, participation costs, borrowing constraints, labour-income risk, trust and cognitive ability (Haliassos & Bertaut, 1995; Cocco et al., 2005; Guiso et al., 2008; Grinblatt et al., 2011). This literature shows that market-based household assets cannot be interpreted only through their expected returns. Participation itself is selective, and the growth relevance of household portfolios depends on who holds risky assets, how diversified those holdings are and whether households can withstand income or valuation shocks without cutting spending sharply.

The consumption channel also cautions against interpreting financial wealth as an automatic growth mechanism. Research on wealth effects finds that consumption responses differ by asset type, country setting and financial-market structure, while the marginal propensity to consume out of wealth is not uniform across economies (Slacalek, 2009). Housing and financial wealth may influence household spending, but the transmission depends on liquidity, collateral channels and the capacity to borrow against asset values. For the EU, where households differ in home ownership, pension arrangements, capital-market access and deposit preference, a gross financial asset ratio may mix several mechanisms that do not necessarily move in the same direction. The distinction between wealth level and balance-sheet improvement becomes especially relevant when annual growth is the outcome of interest.

Recent European applied research has also moved toward conditional and multi-channel explanations of macroeconomic outcomes. Studies by Hrebenciuc et al. (2025) and Cetulean et al. (2026) examine EU performance through interactions between capability, structural transformation and competitiveness, while Georgescu et al. (2025) show that digitalisation does not generate uniform environmental gains once channel configuration and energy conditions are considered. Although these contributions examine different empirical domains, they share an analytical premise that is relevant here: aggregate indicators need to be decomposed before their economic meaning becomes clear. The same logic applies to household finance, where gross assets, liabilities, net assets and annual changes may carry different relationships with development.

The gap left by the existing literature concerns the treatment of household financial wealth as a development-related balance-sheet condition in a harmonised EU-27 panel. Finance–growth studies usually focus on financial systems, credit depth or market development, while household-finance studies often rely on microdata, portfolio participation or vulnerability indicators. Fewer empirical designs connect country-level household financial assets, liabilities, net financial positions and portfolio structure to annual real GDP per capita growth across all EU member states over a recent long period. The missing distinction is not only between assets and debt, but between gross financial accumulation and net financial strengthening. This gap is addressed by testing whether economic development is associated with the size of household financial wealth or with improvements in the net financial position of the household sector.

Methodology

This study examines the relationship between household financial balance sheets and economic development in the European Union, using an econometric methodology based on country-year panel data for the EU-27 over the period 2010–2024. The data were collected from Eurostat and organised in a harmonised longitudinal structure that allows comparisons across countries and over time. The empirical processing, descriptive statistics and panel estimations were conducted in RStudio, version 2024.12.1+563. The methodological design separates gross household financial wealth from net household financial strength, since the accumulation of financial assets may coexist with higher liabilities and may not necessarily reflect a healthier household balance sheet. The main dependent variable is annual real GDP per capita growth, while complementary specifications use the logarithm of real GDP per capita and a medium-term forward growth indicator. This approach follows the broader finance-growth literature, where financial variables are treated as channels connected with allocation, investment, productivity and macroeconomic performance rather than as neutral balance-sheet aggregates (Levine, 2005).

The research question is formulated as follows:

RQ: Does household financial wealth contribute to economic development in the European Union through the size of gross financial assets or through the strengthening of net household financial positions?

Two hypotheses guide the empirical specification.

H1: Gross household financial assets are not expected to have a robust direct association with annual real GDP per capita growth once country and year fixed effects are controlled for.

H2: Improvements in net household financial assets are expected to be positively associated with real GDP per capita growth, reflecting the relevance of household balance-sheet quality for economic development.

The distinction between financial expansion and financial strength is necessary because finance can support growth when it improves allocation and resilience, but the same expansion may become less favourable when it is accompanied by debt accumulation or balance-sheet fragility (Loayza & Rancière, 2006).

The dataset is structured as a balanced conceptual panel in which i denotes the EU member state and t denotes the year. The financial variables include household gross financial assets as a percentage of GDP, household liabilities as a percentage of GDP, household net financial assets as a percentage of GDP, deposits as a share of household financial assets, equity and investment fund shares, and insurance and pension entitlements. The macroeconomic control vector includes investment as a share of GDP, inflation and unemployment, since these variables capture conditions that influence both growth and household financial behaviour.

All explanatory variables are introduced with a one-year lag in the main models, reducing the risk that contemporaneous GDP movements mechanically influence the financial indicators in the same year. The use of lagged financial and macroeconomic indicators is

consistent with empirical work that treats household financial constraints, savings behaviour and growth as temporally connected processes rather than purely contemporaneous correlations (Jappelli & Pagano, 1994).

The baseline econometric model estimates the association between lagged household gross financial assets and real GDP per capita growth through a two-way fixed-effects panel specification:

$$g_{it} = \alpha + \beta_1 FA_{i,t-1} + \gamma' X_{i,t-1} + \mu_i + \lambda_t + \varepsilon_{it}$$

where g_{it} denotes annual real GDP per capita growth, $FA_{i,t-1}$ represents lagged household gross financial assets as a percentage of GDP, $X_{i,t-1}$ is the vector of lagged macroeconomic controls, μ_i captures country fixed effects, λ_t captures year fixed effects, and ε_{it} is the idiosyncratic error term. Country fixed effects absorb persistent structural differences between EU economies, while year fixed effects account for common shocks affecting all member states in a given year. Standard errors are clustered at country level, following the standard treatment of serial correlation and grouped dependence in finance-oriented panel datasets (Petersen, 2009).

A second group of models replaces gross financial assets with net household financial assets and household liabilities, allowing the empirical design to distinguish between the size of household financial balance sheets and their net strength. The corresponding equations are written as:

$$g_{it} = \alpha + \theta_1 NFA_{i,t-1} + \gamma' X_{i,t-1} + \mu_i + \lambda_t + \varepsilon_{it}$$

$$g_{it} = \alpha + \eta_1 LIAB_{i,t-1} + \gamma' X_{i,t-1} + \mu_i + \lambda_t + \varepsilon_{it}$$

where $NFA_{i,t-1}$ denotes lagged net household financial assets and $LIAB_{i,t-1}$ denotes lagged household liabilities, both expressed relative to GDP. These specifications test whether the development relevance of household finance comes from asset accumulation alone, debt exposure, or the net position obtained after liabilities are taken into account. The distinction is economically meaningful because wealth effects and macroeconomic transmission may differ depending on whether household asset growth reflects genuine net worth gains or a balance-sheet expansion accompanied by additional obligations (Carroll et al., 2011).

The central empirical specification moves from financial stocks to financial changes, since the article focuses on whether development is more closely associated with improvements in household net financial positions than with the level of gross financial wealth. The main dynamic equation is:

$$g_{it} = \alpha + \phi_1 \Delta FA_{i,t-1} + \phi_2 \Delta NFA_{i,t-1} + \phi_3 \Delta EQFUND_{i,t-1} + \gamma' X_{i,t-1} + \mu_i + \lambda_t + \varepsilon_{it}$$

where $\Delta FA_{i,t-1}$ captures the lagged change in gross household financial assets, $\Delta NFA_{i,t-1}$ captures the lagged change in net household financial assets, and $\Delta EQFUND_{i,t-1}$ captures the lagged change in the share of equity and investment funds in household portfolios. A positive and statistically significant coefficient for $\Delta NFA_{i,t-1}$, combined with a weak or negative coefficient for $\Delta FA_{i,t-1}$, would support the interpretation that economic

development is associated more closely with household net financial strengthening than with gross asset accumulation. This balance-sheet logic is consistent with evidence showing that household leverage can amplify macroeconomic vulnerability when asset growth is accompanied by debt expansion (Mian & Sufi, 2011).

Additional specifications test whether the association between household financial assets and growth differs across institutional and macro-financial settings. The interaction model is expressed as:

$$g_{it} = \alpha + \beta_1 FA_{i,t-1} + \beta_2 (FA_{i,t-1} \times Z_{it}) + \gamma' X_{i,t-1} + \mu_i + \lambda_t + \varepsilon_{it}$$

where Z_{it} is alternatively defined as a post-COVID indicator, a high-financial-depth classification, or a Central and Eastern European country dummy. These interaction terms examine whether gross household financial assets matter differently during the post-pandemic period, in economies with deeper household financial sectors, or in newer EU member states with distinct financial structures. A medium-term robustness specification uses the average forward growth rate over three years:

$$G_{it}^{(3)} = \frac{1}{3} \sum_{s=1}^3 g_{i,t+s}$$

where $G_{it}^{(3)}$ measures the average real GDP per capita growth rate from $t + 1$ to $t + 3$. Since EU economies are exposed to common shocks and cross-country dependence, robustness checks may rely on covariance estimators suitable for panels with spatial and temporal dependence (Driscoll & Kraay, 1998).

The empirical interpretation remains conditional rather than causal. The two-way fixed-effects structure controls for unobserved country characteristics and common annual shocks, while lagged regressors reduce simultaneity concerns. The coefficients are interpreted as within-country associations between household financial balance-sheet indicators and subsequent economic performance, after accounting for investment, inflation, unemployment and unobserved fixed heterogeneity. The methodological contribution lies in separating gross financial wealth from net financial strength and in testing whether balance-sheet quality retains explanatory relevance when standard macroeconomic controls and fixed effects are included. This strategy is consistent with panel finance-growth research that evaluates whether financial variables remain associated with development once institutional, structural and time-specific components are absorbed by the model design (Beck et al., 2000).

Results

The empirical evidence separates household financial wealth into two dimensions with different growth relevance. The first concerns the accumulated size of household financial positions, captured by gross financial assets, liabilities, net financial assets and portfolio shares. The second concerns annual balance-sheet improvement, captured by changes in gross and net household financial assets. The fixed-effects estimates point to a weak

relationship between financial stocks and annual real GDP per capita growth, while the strongest statistical pattern appears when household net financial positions improve from one year to the next.

Figure 1. *Gross Household Financial Wealth versus Net Financial Strength*

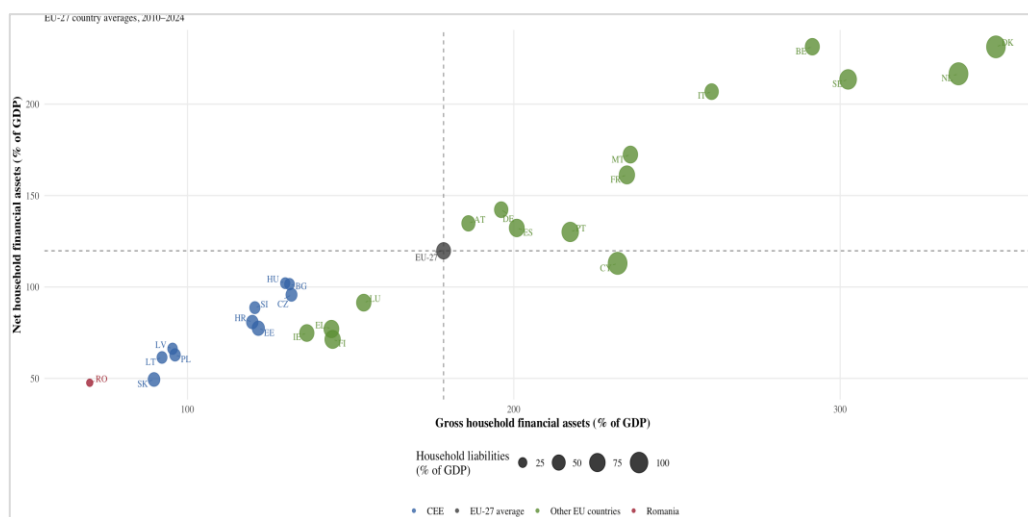


Figure 1 places EU-27 economies according to average gross household financial assets and average net household financial assets over 2010–2024, with point size reflecting household liabilities. The distance between countries is wide. Denmark is positioned close to 350% of GDP in gross household financial assets and above 230% of GDP in net financial assets, while the Netherlands and Sweden also occupy the upper-right part of the distribution, with gross positions around or above 300% of GDP and net positions above 210% of GDP. Romania remains near the lower-left area, with gross household financial assets below 80% of GDP and net financial assets close to 50% of GDP. The EU-27 average stands around 180% of GDP for gross household financial assets and about 120% of GDP for net household financial assets.

The cross-country configuration confirms that gross household financial wealth and net financial strength cannot be treated as equivalent. The vertical distance between gross and net positions reflects the relevance of household liabilities, which alter the interpretation of financial depth. Some economies appear financially large when gross assets are considered, yet their net position depends on the debt accumulated by the household sector. This separation justifies the econometric distinction between assets, liabilities and net assets, rather than reducing household finance to a single aggregate wealth measure.

Table 1 reports the baseline fixed-effects estimates for household financial stocks, portfolio structure and annual real GDP per capita growth. Lagged gross household financial assets have a coefficient of -0.0061, with a clustered standard error of 0.0160, without statistical support. Lagged net household financial assets also remain statistically weak, with a coefficient of -0.0027 and a standard error of 0.0144. Household liabilities enter with a

negative coefficient of -0.0132, but the estimate is not statistically different from zero. The first set of results gives no robust evidence that the level of household financial assets or liabilities explains annual growth after country and year fixed effects are included.

Table 1. *Baseline fixed-effects estimates for household financial stocks, portfolio structure and GDP per capita growth*

Variables	Gross assets	Net assets	Assets and liabilities	Portfolio structure
Lagged gross financial assets	-0.0061 (0.0160)	-	-0.0029 (0.0141)	-
Lagged net financial assets	-	-0.0027 (0.0144)	-	-
Lagged household liabilities	-	-	-0.0132 (0.0287)	-
Lagged deposits share	-	-	-	-0.1356 (0.1309)
Lagged equity and investment funds share	-	-	-	-0.0620 (0.0874)
Lagged insurance and pension entitlements share	-	-	-	0.0117 (0.0803)
Lagged investment	0.1214 (0.0884)	0.1264 (0.0854)	0.1081 (0.1146)	0.1269 (0.0878)
Lagged inflation	-0.3157** (0.1090)	-0.3231* (0.1164)	-0.3125** (0.1038)	-0.3445** (0.1140)
Lagged unemployment	0.1558 (0.0887)	0.1426 (0.0772)	0.1693 (0.0936)	0.1931* (0.0911)
R ²	0.6497	0.6491	0.6503	0.6570
Within R ²	0.0735	0.0720	0.0751	0.0929

Notes: The dependent variable is annual real GDP per capita growth. All specifications include country and year fixed effects. Standard errors clustered by country are reported in parentheses.

Significance levels: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; . $p < 0.10$.

Portfolio composition does not change this empirical pattern. The deposits share records a coefficient of -0.1356, the equity and investment funds share records -0.0620, and insurance and pension entitlements record 0.0117, all without statistical support. Annual growth is not robustly associated with whether household portfolios are more liquid, more market-oriented or more concentrated in long-term financial entitlements. Among the controls, inflation has the most stable coefficient, remaining negative and statistically supported across the baseline specifications, with values between -0.3125 and -0.3445 in three models. Investment is positive but statistically weak in the stock specifications, while unemployment is positive and only marginally supported.

Table 2 moves the estimation from financial stocks to annual balance-sheet changes. Lagged change in gross household financial assets is negative and highly statistically supported, with a coefficient of -0.1932 and a standard error of 0.0467. Lagged change in net household financial assets is positive and highly statistically supported, with a coefficient of 0.2238 and a standard error of 0.0509. The two estimates move in opposite directions, which gives the main result its empirical force. Growth is not stronger when household financial assets expand in gross terms alone; it is stronger when the household sector improves its net financial position.

Table 2. *Financial balance-sheet changes and GDP per capita growth*

Variables	Financial changes
Lagged change in gross financial assets	-0.1932*** (0.0467)
Lagged change in net financial assets	0.2238*** (0.0509)
Lagged change in equity and investment funds share	-0.1031 (0.0504)
Lagged investment	0.1285* (0.0517)
Lagged inflation	-0.2775** (0.0811)
Lagged unemployment	-0.0025 (0.0693)
R ²	0.6963
Within R ²	0.1281

Notes: The dependent variable is annual real GDP per capita growth. The specification includes country and year fixed effects. Standard errors clustered by country are reported in parentheses.

Significance levels: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; . $p < 0.10$.

The remaining estimates in the financial-change model preserve the same interpretation. The lagged change in the equity and investment funds share is negative and only weakly supported, at -0.1031, which leaves portfolio reallocation outside the main empirical channel. Lagged investment is positive and statistically supported at the 5% level, with a coefficient of 0.1285, while lagged inflation is negative and statistically supported at the 1% level, with a coefficient of -0.2775. Lagged unemployment becomes statistically weak, with a coefficient close to zero, at -0.0025. The model records an R^2 of 0.6963 and a within R^2 of 0.1281, above the within explanatory power of the baseline stock specifications.

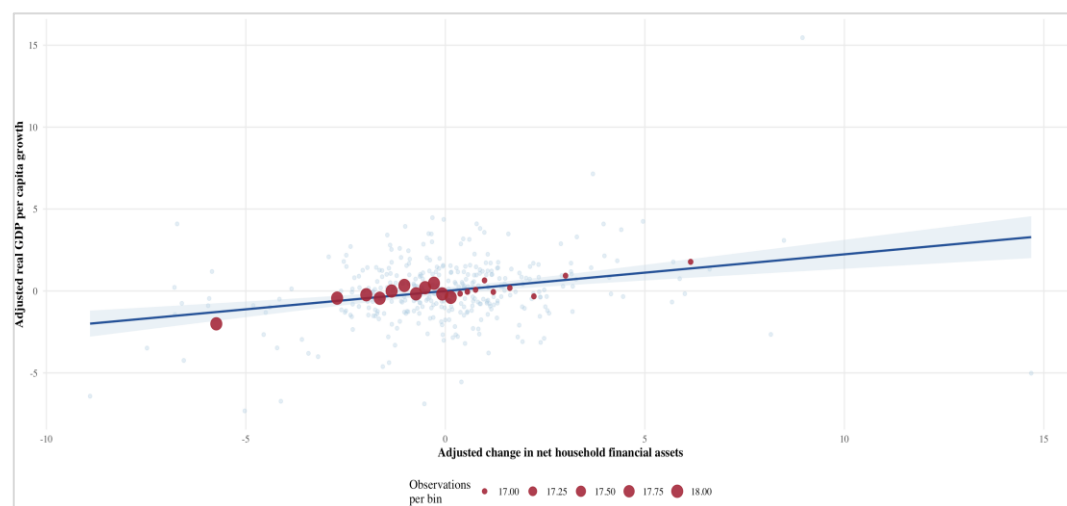
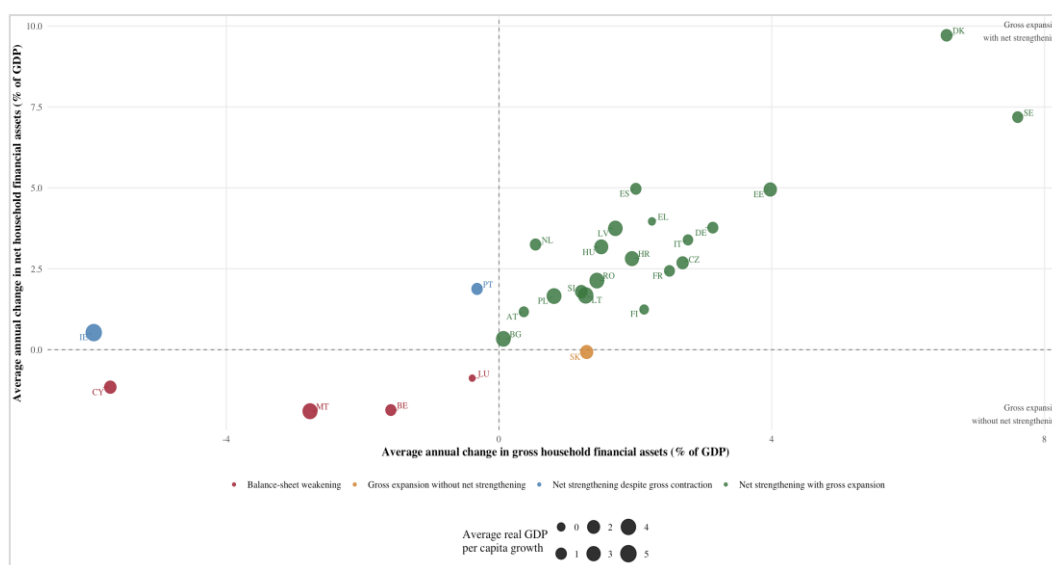
Figure 2. *Net Financial Strengthening and GDP per Capita Growth*

Figure 2 provides a fixed-effects adjusted representation of the relationship between lagged changes in net household financial assets and annual real GDP per capita growth. The fitted line has a positive slope, moving from negative adjusted growth values at lower adjusted

net-financial changes to positive adjusted growth values at higher values of the same variable. Most binned observations are concentrated around the central interval between roughly -2 and 1 on the horizontal axis, while several observations extend beyond 10. The dispersion remains visible, yet the upward slope is consistent with the positive and highly supported coefficient estimated for lagged changes in net household financial assets.

Figure 3 positions EU economies by average annual changes in gross and net household financial assets. Most countries are placed in the upper-right quadrant, where gross financial expansion is accompanied by net strengthening. Denmark records one of the strongest positions, with average annual gross financial asset growth close to 8% of GDP and net asset improvement near 10% of GDP, while Sweden also combines gross expansion above 7% of GDP with net strengthening above 7% of GDP. Romania is located in the same favourable quadrant, with positive average annual changes in both gross and net household financial assets, although from a much lower level of financial depth. Malta, Belgium, Cyprus and Luxembourg occupy weaker areas, where the average net household position deteriorates.

Figure 3. *Balance-Sheet Quality Typology of EU Economies*



The results support a sharper interpretation of household finance than a simple wealth-size argument. Gross household financial assets are clearly visible in the European descriptive landscape, but their level does not carry a robust association with annual growth in the fixed-effects models. Portfolio shares do not provide a stable alternative channel, and liabilities do not become statistically decisive in the stock specifications. The strongest signal belongs to annual improvements in net household financial assets. Economic development in the EU-27 is closer to household balance-sheet quality than to the accumulated volume of gross financial wealth, because the development relevance of household finance depends on what remains after liabilities are taken into account.

Discussions

The empirical results place household finance in a balance-sheet framework rather than a simple wealth-size framework. Gross household financial assets vary substantially across EU-27 economies, yet their level does not retain a robust association with annual real GDP per capita growth once country and year effects are controlled for. The strongest evidence appears when the estimations move from stocks to annual changes, where net household financial strengthening becomes positive and highly significant. This pattern fits the more conditional strand of finance–growth research, which treats finance as growth-relevant only when it improves allocation, resilience and productive capacity, rather than when it expands as an aggregate volume detached from real-sector transmission (Levine, 2005; Loayza & Rancière, 2006; Arcand et al., 2015).

H1 is supported by the baseline estimates, since lagged gross household financial assets do not show a statistically robust relationship with annual real GDP per capita growth. The coefficient of -0.0061 , with a clustered standard error of 0.0160 , remains statistically weak, and the same absence of support appears when net financial assets, liabilities and portfolio shares are introduced as stock variables. This result is consistent with the argument that financial depth and financial size do not automatically translate into stronger economic performance. Beck et al. (2014) distinguish between the size and function of finance, while Rousseau and Wachtel (2011) document the weakening of the finance–growth relationship in later samples. In the EU-27 setting, household financial assets in levels seem closer to historically accumulated financial depth, pension arrangements, valuation effects and institutional structures than to a direct driver of year-to-year growth.

H2 receives stronger support because lagged changes in net household financial assets are positive and highly significant in the financial-change model. The coefficient of 0.2238 , with a standard error of 0.0509 , contrasts with the negative and significant coefficient of -0.1932 estimated for lagged changes in gross financial assets. This contrast gives the main empirical finding its economic meaning. Growth is not associated with gross household asset expansion as such, but with the improvement of the net financial position after liabilities are taken into account. The result aligns with household balance-sheet research showing that debt exposure changes the macroeconomic consequences of asset accumulation, especially through consumption, deleveraging and vulnerability channels (Eggertsson & Krugman, 2012; Mian et al., 2013; Mian et al., 2017).

The weak role of portfolio composition narrows the interpretation. Deposits, equity and investment funds, and insurance and pension entitlements do not carry statistically robust associations with annual real GDP per capita growth in the baseline fixed-effects models. This does not reduce the relevance of portfolio choice for household welfare, returns or financial sophistication, but it limits the case for treating aggregate portfolio shares as direct short-run growth channels. Earlier household-finance research shows that stock-market participation, diversification and financial sophistication are unevenly distributed across households and countries, which makes aggregate portfolio indicators difficult to connect mechanically with macroeconomic outcomes (Haliassos & Bertaut, 1995; Guiso et al., 2008; Calvet et al., 2009; van Rooij et al., 2011). The EU-27 evidence is more coherent with a net-strength mechanism than with a portfolio-composition mechanism.

Several limitations condition the interpretation of the results. The estimations rely on country-level annual data, which means that household heterogeneity by income, age, education, financial literacy or asset ownership cannot be directly examined. The models also identify within-country associations rather than structural causal effects, even though lagged regressors, country fixed effects and year fixed effects reduce simultaneity and omitted heterogeneity concerns. Household financial assets and liabilities are measured as ratios to GDP, which is appropriate for macroeconomic comparability, but this scaling may also reflect changes in the denominator during periods of unusual growth, inflation or crisis adjustment. Wealth effects are known to differ by asset type, liquidity and household constraints, so aggregate annual indicators cannot fully capture the microeconomic mechanisms through which household balance sheets influence spending and resilience (Carroll et al., 2011; Case et al., 2005; Slacalek, 2009).

Conclusions

Household financial wealth in the European Union cannot be interpreted convincingly through its gross volume alone. The empirical evidence indicates that large household asset positions capture financial depth, institutional history and accumulated saving capacity, but they do not translate into a stable association with annual real GDP per capita growth. The visible size of household financial assets therefore offers an incomplete view of economic strength, especially when liabilities are left outside the interpretation.

The distinction between gross financial assets and net household financial strength gives the evidence a sharper economic meaning. Gross wealth describes the asset side of the household sector, while the net position reflects the part of that wealth that remains after debt is deducted. The strongest empirical signal appears precisely in this second dimension, where improvements in net household financial assets are positively associated with growth. The development relevance of household finance is therefore connected less with accumulation as such and more with the consolidation of the household balance sheet.

The weak role of portfolio shares further narrows the interpretation. Deposits, equity and investment funds, insurance and pension entitlements remain important for household welfare, long-term saving and risk exposure, yet they do not provide a stable growth-related channel in the fixed-effects estimates. The results point instead to a broader balance-sheet condition, in which the relation between assets and liabilities matters more than the internal composition of gross financial holdings.

The main message is that financial wealth becomes economically meaningful when it improves resilience rather than merely expanding balance-sheet size. A household sector may hold more financial assets and still remain fragile if liabilities rise in parallel or if asset growth fails to improve the net position. Across the EU-27, the more relevant development signal is not how large household financial wealth appears on the asset side, but whether households become financially stronger after debt is taken into account.

References

- Aghion, P., Howitt, P., and Mayer-Foulkes, D. (2005). The effect of financial development on convergence: Theory and evidence. *The Quarterly Journal of Economics*, 120(1), 173–222. <<https://doi.org/10.1162/0033553053327515>>
- Alpanda, S., and Zubairy, S. (2019). Household debt overhang and transmission of monetary policy. *Journal of Money, Credit and Banking*, 51(5), 1265–1307. <<https://doi.org/10.1111/jmcb.12548>>
- Ampudia, M., van Vlokhoven, H., and Źochowski, D. (2016). Financial fragility of euro area households. *Journal of Financial Stability*, 27, 250–262. <<https://doi.org/10.1016/j.jfs.2016.02.003>>
- Arcand, J.-L., Berkes, E., and Panizza, U. (2015). Too much finance? *Journal of Economic Growth*, 20(2), 105–148. <<https://doi.org/10.1007/s10887-015-9115-2>>
- Arrondel, L., Bartiloro, L., Fessler, P., Lindner, P., Mathä, T.Y., Rampazzi, C., Savignac, F., Schmidt, T., Schürz, M., and Vermeulen, P. (2016). How do households allocate their assets? Stylised facts from the Eurosystem Household Finance and Consumption Survey. *International Journal of Central Banking*, 12(2), 129–220. <<https://doi.org/10.2139/ssrn.2490969>>
- Bach, L., Calvet, L.E., and Sodini, P. (2020). Rich pickings? Risk, return, and skill in household wealth. *American Economic Review*, 110(9), 2703–2747. <<https://doi.org/10.1257/aer.20170666>>
- Badarinza, C., Campbell, J.Y., and Ramadorai, T. (2016). International comparative household finance. *Annual Review of Economics*, 8, 111–144. <<https://doi.org/10.1146/annurev-economics-080315-015425>>
- Beck, T., and Levine, R. (2004). Stock markets, banks, and growth: Panel evidence. *Journal of Banking & Finance*, 28(3), 423–442. <[https://doi.org/10.1016/S0378-4266\(02\)00408-9](https://doi.org/10.1016/S0378-4266(02)00408-9)>
- Beck, T., Degryse, H., and Kneer, C. (2014). Is more finance better? Disentangling intermediation and size effects of financial systems. *Journal of Financial Stability*, 10, 50–64. <<https://doi.org/10.1016/j.jfs.2013.03.005>>
- Beck, T., Demirgüç-Kunt, A., and Levine, R. (2007). Finance, inequality and the poor. *Journal of Economic Growth*, 12(1), 27–49. <<https://doi.org/10.1007/s10887-007-9010-6>>
- Beck, T., Levine, R., and Loayza, N. (2000). Finance and the sources of growth. *Journal of Financial Economics*, 58(1–2), 261–300. <[https://doi.org/10.1016/S0304-405X\(00\)00072-6](https://doi.org/10.1016/S0304-405X(00)00072-6)>
- Calvet, L.E., Campbell, J.Y., and Sodini, P. (2007). Down or out: Assessing the welfare costs of household investment mistakes. *Journal of Political Economy*, 115(5), 707–747. <<https://doi.org/10.1086/524204>>
- Calvet, L.E., Campbell, J.Y., and Sodini, P. (2009). Measuring the financial sophistication of households. *American Economic Review*, 99(2), 393–398. <<https://doi.org/10.1257/aer.99.2.393>>
- Campbell, J.Y. (2006). Household finance. *The Journal of Finance*, 61(4), 1553–1604. <<https://doi.org/10.1111/j.1540-6261.2006.01007.x>>

- Carroll, C.D., Otsuka, M., and Slacalek, J. (2011). How large are housing and financial wealth effects? A new approach. *Journal of Money, Credit and Banking*, 43(1), 55–79. <<https://doi.org/10.1111/j.1538-4616.2010.00365.x>>
- Case, K.E., Quigley, J.M., and Shiller, R.J. (2005). Comparing wealth effects: The stock market versus the housing market. *Topics in Macroeconomics*, 5(1), 20121001. <<https://doi.org/10.2202/1534-6013.1235>>
- Cetulean, M., Bodislav, D.A., Georgescu, R.I., Moroianu, N., Popa, R.A., and Papuc, C.M. (2026). When does digital maturity become a systemic advantage? Modelling e-commerce behaviour and competitiveness in Europe. *Systems*, 14(2), 118. <<https://doi.org/10.3390/systems14020118>>
- Cocco, J.F., Gomes, F.J., and Maenhout, P.J. (2005). Consumption and portfolio choice over the life cycle. *The Review of Financial Studies*, 18(2), 491–533. <<https://doi.org/10.1093/rfs/hhi017>>
- De Gregorio, J., and Guidotti, P.E. (1995). Financial development and economic growth. *World Development*, 23(3), 433–448. <[https://doi.org/10.1016/0305-750X\(94\)00132-I](https://doi.org/10.1016/0305-750X(94)00132-I)>
- Driscoll, J.C., and Kraay, A.C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *The Review of Economics and Statistics*, 80(4), 549–560. <<https://doi.org/10.1162/003465398557825>>
- Eggertsson, G.B., and Krugman, P. (2012). Debt, deleveraging, and the liquidity trap: A Fisher-Minsky-Koo approach. *The Quarterly Journal of Economics*, 127(3), 1469–1513. <<https://doi.org/10.1093/qje/qjs023>>
- Fagereng, A., Guiso, L., Malacrino, D., and Pistaferri, L. (2020). Heterogeneity and persistence in returns to wealth. *Econometrica*, 88(1), 115–170. <<https://doi.org/10.3982/ECTA14835>>
- Fisman, R., and Love, I. (2007). Financial dependence and growth revisited. *Journal of the European Economic Association*, 5(2–3), 470–479. <<https://doi.org/10.1162/jeea.2007.5.2-3.470>>
- Georgescu, R.I., Cetulean, M., Bodislav, D.A., and Hrebenciuc, A. (2025). Clicks, bricks, and carbon: Digitalization’s double-edged impact on supply chain emissions intensity. *Journal of Theoretical and Applied Electronic Commerce Research*, 20(4), 330. <<https://doi.org/10.3390/jtaer20040330>>
- Grinblatt, M., Keloharju, M., and Linnainmaa, J. (2011). IQ and stock market participation. *The Journal of Finance*, 66(6), 2121–2164. <<https://doi.org/10.1111/j.1540-6261.2011.01701.x>>
- Guiso, L., and Sodini, P. (2013). Household finance: An emerging field. In G. M. Constantinides, M. Harris, & R.M. Stulz (Eds.), *Handbook of the Economics of Finance* (Vol. 2B, pp. 1397–1532). Elsevier. <<https://doi.org/10.1016/B978-0-44-459406-8.00021-4>>
- Guiso, L., Sapienza, P., and Zingales, L. (2008). Trusting the stock market. *The Journal of Finance*, 63(6), 2557–2600. <<https://doi.org/10.1111/j.1540-6261.2008.01408.x>>
- Haliassos, M., and Bertaut, C.C. (1995). Why do so few hold stocks? *The Economic Journal*, 105(432), 1110–1129. <<https://doi.org/10.2307/2235407>>
- Household Finance and Consumption Network. (2023). *Household Finance and Consumption Survey: Methodological report for the 2021 wave*. European Central Bank. <<https://doi.org/10.2866/970554>>
- Hrebenciuc, A., Iacob, S.-E., Constantin, A., Cetulean, M., and Bondac, G.-T. (2025). The employment trilemma in the European Union: Linking academia, industry, and sustainability

- through dynamic panel evidence. *Sustainability*, 17(13), 6125. <<https://doi.org/10.3390/su17136125>>
- Jappelli, T., and Pagano, M. (1994). Saving, growth, and liquidity constraints. *The Quarterly Journal of Economics*, 109(1), 83–109. <<https://doi.org/10.2307/2118429>>
- Jordà, Ò., Schularick, M., and Taylor, A.M. (2015). Leveraged bubbles. *Journal of Monetary Economics*, 76, S1–S20. <<https://doi.org/10.1016/j.jmoneco.2015.08.005>>
- King, R.G., and Levine, R. (1993). Finance and growth: Schumpeter might be right. *The Quarterly Journal of Economics*, 108(3), 717–737. <<https://doi.org/10.2307/2118406>>
- Law, S.H., and Singh, N. (2014). Does too much finance harm economic growth? *Journal of Banking & Finance*, 41, 36–44. <<https://doi.org/10.1016/j.jbankfin.2013.12.020>>
- Levine, R. (2005). Finance and growth: Theory and evidence. In P. Aghion & S. N. Durlauf (Eds.), *Handbook of Economic Growth* (Vol. 1A, pp. 865–934). Elsevier. <[https://doi.org/10.1016/S1574-0684\(05\)01012-9](https://doi.org/10.1016/S1574-0684(05)01012-9)>
- Levine, R., Loayza, N., and Beck, T. (2000). Financial intermediation and growth: Causality and causes. *Journal of Monetary Economics*, 46(1), 31–77. <[https://doi.org/10.1016/S0304-3932\(00\)00017-9](https://doi.org/10.1016/S0304-3932(00)00017-9)>
- Loayza, N., and Rancière, R. (2006). Financial development, financial fragility, and growth. *Journal of Money, Credit and Banking*, 38(4), 1051–1076. <<https://doi.org/10.1353/mcb.2006.0060>>
- Lombardi, M.J., Mohanty, M.S., and Shim, I. (2017). *The real effects of household debt in the short and long run* (BIS Working Paper No. 607). Bank for International Settlements.
- Luintel, K.B., and Khan, M. (1999). A quantitative reassessment of the finance-growth nexus: Evidence from a multivariate VAR. *Journal of Development Economics*, 60(2), 381–405. <[https://doi.org/10.1016/S0304-3878\(99\)00045-0](https://doi.org/10.1016/S0304-3878(99)00045-0)>
- Mian, A., and Sufi, A. (2011). House prices, home equity-based borrowing, and the US household leverage crisis. *American Economic Review*, 101(5), 2132–2156. <<https://doi.org/10.1257/aer.101.5.2132>>
- Mian, A., Rao, K., and Sufi, A. (2013). Household balance sheets, consumption, and the economic slump. *The Quarterly Journal of Economics*, 128(4), 1687–1726. <<https://doi.org/10.1093/qje/qjt020>>
- Mian, A., Sufi, A., and Verner, E. (2017). Household debt and business cycles worldwide. *The Quarterly Journal of Economics*, 132(4), 1755–1817. <<https://doi.org/10.1093/qje/qjx017>>
- Petersen, M.A. (2009). Estimating standard errors in finance panel data sets: Comparing approaches. *The Review of Financial Studies*, 22(1), 435–480. <<https://doi.org/10.1093/rfs/hhn053>>
- Rajan, R.G., and Zingales, L. (1998). Financial dependence and growth. *American Economic Review*, 88(3), 559–586. <<https://doi.org/10.3386/w5758>>
- Rioja, F., and Valev, N. (2004). Finance and the sources of growth at various stages of economic development. *Economic Inquiry*, 42(1), 127–140. <<https://doi.org/10.1093/ei/cbh049>>
- Rousseau, P.L., and Wachtel, P. (2011). What is happening to the impact of financial deepening on economic growth? *Economic Inquiry*, 49(1), 276–288. <<https://doi.org/10.1111/j.1465-7295.2009.00197.x>>
- Sahay, R., Čihák, M., N'Diaye, P., and Barajas, A. (2015). Rethinking financial deepening: Stability and growth in emerging markets. *Revista de Economía Institucional*, 17(33), 73–107. <<https://doi.org/10.18601/01245996.v17n33.04>>

- Samargandi, N., Fidrmuc, J., and Ghosh, S. (2015). Is the relationship between financial development and economic growth monotonic? Evidence from a sample of middle-income countries. *World Development*, 68, 66–81. <<https://doi.org/10.1016/j.worlddev.2014.11.010>>
- Slacalek, J. (2009). What drives personal consumption? The role of housing and financial wealth. *The B.E. Journal of Macroeconomics*, 9(1). <<https://doi.org/10.2202/1935-1690.1555>>
- van Rooij, M., Lusardi, A., and Alessie, R. (2011). Financial literacy and stock market participation. *Journal of Financial Economics*, 101(2), 449–472. <<https://doi.org/10.1016/j.jfineco.2011.03.006>>

Government expenditures and tax policy: A comprehensive fiscal analysis for Greece from 1974 to 2018

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Abstract. *This paper examines the evolution of government expenditure, tax policy, and effective tax rates in Greece over the post-transition period 1974–2018. Using a comprehensive fiscal dataset and the Martinez-Mongay methodology for estimating effective tax rates, the study provides an integrated view of how expenditure dynamics and tax structures shaped the country's macroeconomic performance before and after key political and economic shifts. The analysis highlights the interplay between fiscal consolidation episodes, tax reforms, and expenditure pressures, while identifying structural weaknesses—particularly the heavy reliance on indirect taxation and the volatility of public investment. Empirical results show that shifts in effective tax rates significantly affected revenue composition and that expenditure rigidities constrained fiscal adjustment capacity. The findings contribute to a deeper understanding of Greece's fiscal trajectory, offering implications for sustainable tax policy design and long-term public finance management.*

Keywords: government expenditures, tax policy, effective tax rates, Martinez-Mongay methodology, fiscal consolidation, Greece, public finance, tax structure, revenue composition.

JEL Classification: E6, E62, E63.

1. Introduction

Understanding the long-run interaction between government expenditure, tax policy, and macroeconomic performance is fundamental for evaluating a country's fiscal trajectory. In the case of Greece, the post-transition period beginning in 1974 represents a particularly rich context for such an assessment. The political stabilization that followed the fall of the military regime initiated a profound reconfiguration of public administration, social policy, and economic governance. Over the next four decades, Greece underwent multiple episodes of fiscal expansion, consolidation, and structural reform, culminating in the sovereign debt crisis and subsequent adjustment programs. These developments generated significant changes both in the composition of government expenditures and in the domestic tax system. The evolution of Greece's public finances cannot be understood solely through statutory tax measures or budgetary aggregates. Effective taxation—captured through indicators that measure the actual tax burden on different economic bases—provides a more accurate assessment of how tax policy operates in practice. This paper employs the Martinez-Mongay methodology, a standard approach in European fiscal analysis, to calculate effective tax rates (ETRs) on labor, capital, and consumption over the period 1974–2018. These indicators allow us to examine how major policy reforms, administrative inefficiencies, and cyclical conditions shaped the distribution of the tax burden and the composition of public revenues.

At the same time, government expenditures expanded markedly in the post-transition era, driven initially by democratization-related spending, welfare-state development, and increased public-sector employment. Later, during the pre-crisis years, expenditure dynamics were affected by structural rigidities, electoral cycles, and the persistence of high primary deficits. The fiscal consolidation efforts of the 1990s and the stringent adjustment programs of the 2010s introduced further shifts in expenditure categories, often in ways that constrained growth-enhancing public investment. The objective of this study is to provide a comprehensive and integrated analysis of Greece's fiscal developments over the 1974–2018 period, combining expenditure patterns with a detailed assessment of the tax system's effective structure. By analyzing these two dimensions jointly, the paper contributes to the literature in three key ways.

First, it documents long-term fiscal trends using a consistent dataset covering more than four decades.

Second, it applies a harmonized ETR methodology, enabling meaningful comparisons across time and tax bases.

Third, it connects major political and economic turning points with observed changes in fiscal aggregates, thereby offering insights into the drivers of Greece's recurring fiscal imbalances.

The results of the analysis are relevant not only for the assessment of Greece's past fiscal performance but also for the design of future tax and expenditure policies that promote sustainability, economic efficiency, and social equity. The findings highlight the importance of addressing structural weaknesses—such as heavy reliance on indirect taxation, low tax base elasticity, and rigidity in current expenditures—while strengthening mechanisms that support long-term fiscal stability.

2. Fiscal Dynamics and Public Expenditure in Greece

This section provides a comprehensive overview of the evolution of government expenditures, fiscal balances, and public debt in Greece over the period 1974–2018, situating fiscal developments within their broader historical, institutional, and macroeconomic context. Following the severe economic and infrastructural destruction caused by World War II, Greece entered a prolonged phase of reconstruction in the early 1950s. Supported by the Marshall Plan (1952) and subsequent growth-oriented policies, the Greek economy embarked on a recovery path characterized by state-building, industrialization, and expanding public intervention. By the early 1970s, however, this trajectory was disrupted by the global oil crises and a sharp increase in defense expenditures. These shocks intensified existing structural weaknesses, leading to balance-of-payments deficits, rising production costs due to higher energy prices and wage pressures, declining industrial competitiveness, and accelerating inflation that eroded real incomes. Within this macroeconomic environment, government borrowing requirements expanded rapidly, exceeding 742 billion drachmas in 1978 (at constant 1995 prices), while gross fixed capital formation as a share of GDP followed a downward trend. The fiscal strain of the 1970s crisis extended beyond the private sector and deeply affected public finances. Government expenditure increased from 29% of GDP in 1970 to 33% in 1980, driven primarily by higher public consumption. Although Greece actively pursued foreign investment—often through generous tax and investment incentives—overall economic performance remained modest. A decisive shift occurred in the early 1980s with Greece's accession-oriented policy stance toward the European Economic Community (EEC), which altered the country's external economic relations and institutional framework. Despite the continued predominance of the private sector, the rapid expansion of public organizations generated significant expansionary effects. Government spending grew across a broad range of public services, including public sector wages and pensions, social security, health care, education, and infrastructure. Total government expenditure rose from 33% of GDP in 1980 to 47% in 1989, while social transfers doubled within a decade. Public consumption reached parity with private consumption, and unemployment rose persistently despite the state's role as a major employer. In the early 1990s, fiscal consolidation efforts led to reductions in public consumption, although spending on health, education, and social welfare remained largely unchanged. Nevertheless, the economy continued to run large trade deficits. The legacy of heavy borrowing during the 1980s became evident, as net interest payments doubled between 1989 and 1995 despite stabilization programs. Fiscal policy during this period was increasingly constrained by the Maastricht criteria, which required budget deficits below 3% and public debt below 60% of GDP—targets that profoundly shaped subsequent fiscal strategies. Demographic pressures further exacerbated fiscal imbalances by increasing demand for social expenditures.

Budget Deficits and Primary Balances

After a brief period of budget surpluses, Greece began to record persistent deficits from 1974 onward. Over the period 1974–2018, the overall budget deficit exhibited a clear upward trend. The deficit stood at 3% of GDP in 1975, declined temporarily to 1.7% in 1976, and then rose again to nearly 3% by 1978. A pronounced deterioration occurred

between 1979 and 1985, when the deficit increased from 2.4% to 11.6% of GDP. Although stabilization measures introduced in 1986–1987 produced a short-lived improvement, fiscal slippages resumed, with deficits reaching 14.2% and 15.9% of GDP in 1989 and 1990, respectively. During the 1990s, fiscal consolidation—driven largely by tax reforms, base broadening, and efforts to curb tax evasion—reduced the deficit from 15.9% of GDP in 1990 to 3.4% in 1999, enabling Greece's entry into the Economic and Monetary Union (EMU). However, the 2000s marked a renewed deterioration. The deficit rose from 3.7% of GDP in 2000 to 15.5% in 2009, exposing deep structural vulnerabilities. The global financial crisis of 2008–2009 sharply intensified these imbalances, culminating in Greece's request for financial assistance from the euro area and the IMF in April 2010 and the implementation of far-reaching fiscal adjustment and structural reform programs. Primary balances followed a similar pattern. Primary deficits were modest between 1975 and 1980 but expanded dramatically during the 1980s, peaking at 8.7% of GDP in 1981. Consolidation efforts in the early 1990s led to sustained primary surpluses between 1994 and 2002, reaching a maximum of 5% of GDP in 1998. Nevertheless, high interest payments prevented the elimination of overall deficits. From 2003 onward, primary deficits re-emerged, culminating in a peak of 10.5% of GDP in 2009, before declining again under adjustment programs.

Public Debt Dynamics

Public debt dynamics reflect the cumulative effects of sustained fiscal imbalances. The debt-to-GDP ratio increased from 24.6% in 1975 to 156.9% in 2012. After remaining below 30% during the late 1970s, public debt rose sharply following 1981, surpassing 100% of GDP by 1993. Stabilization efforts and strong GDP growth during the convergence period helped contain the ratio at around 100% between the mid-1990s and early 2000s. However, from 2008 onward, debt surged once more, reaching 170.3% of GDP in 2011, before declining modestly in 2012 due to debt restructuring. Importantly, periods of debt stabilization were driven more by favorable GDP growth than by sustained fiscal discipline. Persistent deficits, expansionary fiscal policies, and repeated reversals of stabilization efforts—particularly during the 1980s—contributed decisively to the accumulation of public debt.

Structure of Public Expenditure

Public expenditure in Greece increased substantially over the examined period. While government spending remained below 30% of GDP until the early 1970s, it rose sharply thereafter, reaching nearly 45% by 1990 and exceeding 50% after 2008. The most rapidly expanding components were social benefits, public sector wages, and interest payments. Social spending rose from 8.1% of GDP in 1975 to 20% in 2012, representing the largest increase among expenditure categories. Public wages and salaries increased from 8.3% to 12.5% of GDP over the same period.

In contrast, subsidies declined steadily, while capital expenditures and productive investment remained relatively limited. Greece consistently allocated a disproportionately high share of spending to defense, public administration, and interest payments—often well above the EU average—while underinvesting in growth-enhancing areas such as education, innovation, environmental protection, and infrastructure.

Assessment of Fiscal Dynamics

Overall, the persistent rise in public deficits and debt since the 1980s reflects not excessive total spending per se, but rather structural weaknesses in revenue collection, expenditure composition, and the growth model itself. High levels of tax evasion, a large shadow economy, politically driven spending cycles, and inefficient public administration undermined fiscal sustainability. Much of the accumulated debt financed unproductive expenditures rather than investments with high social and economic returns. While tax revenues increased steadily over time, expenditure growth—particularly during the 1980s and post-2008 period—outpaced revenues, leading to explosive debt dynamics and a sharp contraction in investment after the global financial crisis. The Greek case thus underscores the importance of expenditure quality, institutional capacity, and a coherent development strategy in achieving long-term fiscal sustainability. The trajectory of government expenditures in Greece over the period 1974–2018 exhibits distinct structural patterns shaped by political transitions, European integration, and macroeconomic crises. A nuanced examination reveals not only the growth in aggregate spending but also the composition and rigidity of expenditures, which have significant implications for fiscal sustainability and policy effectiveness. A closer examination of expenditure composition in Greece highlights persistent structural patterns. Current expenditures, including wages, pensions, and social transfers, consistently accounted for the largest share of total spending, representing over 65 percent in most years. This dominance of recurrent spending constrained the government's ability to pursue discretionary fiscal stimulus during economic downturns, limiting countercyclical flexibility. In contrast, public investment exhibited considerable volatility, remaining highly procyclical: it peaked during politically salient events, such as major infrastructure projects, and contracted sharply during periods of fiscal adjustment. These patterns underscore the structural rigidity of the Greek expenditure profile and the challenges it poses for effective fiscal policy and long-term growth. These features highlight the dual challenge facing Greek fiscal policy: managing high structural expenditures while maintaining investment levels necessary for long-term growth.

3. Growth and Structural Patterns

Following the restoration of democracy in 1974, Greece experienced a sustained expansion in government spending. Total expenditures, measured as a share of GDP, rose from approximately 29 percent in the mid-1970s to nearly 50 percent by the late 1980s. This growth reflected the formal establishment of the welfare state and the significant expansion of public-sector employment. Key structural drivers of this expenditure growth included compensation of employees, social transfers, and interest payments. Public-sector wages increased sharply, reflecting both quantitative expansions through hiring and qualitative improvements in salaries. Pension obligations and broader welfare programs expanded rapidly, consistent with the consolidation of post-dictatorship social policies. At the same time, rising debt accumulation gradually increased interest expenditures, adding further fiscal pressures. While aggregate spending grew steadily, public investment, measured as gross fixed capital formation, exhibited considerable volatility, indicating that discretionary infrastructure and productivity-enhancing expenditures were frequently subordinated to recurrent expenditure demands.

A periodized analysis provides a clearer view of policy patterns and fiscal responses. During Phase I, the post-dictatorship expansion (1974–1989), Greece prioritized social stabilization and political consolidation. Expenditure growth was rapid and concentrated in recurrent categories, with wages and pensions expanding faster than revenues, while public investment fluctuated according to ad hoc policy priorities. By the late 1980s, total expenditures had risen from approximately 29–32 percent of GDP in the mid-1970s to more than 48 percent of GDP. The main drivers of this growth were sharp increases in public-sector wages, the expansion of pension and social transfer programs, and the rapid growth of current expenditures associated with democratization and the formation of the welfare state. Public investment remained relatively volatile, averaging 3.5–4 percent of GDP. The accumulation of high social spending and rising debt established the conditions for later fiscal strain, and recurrent obligations began forming an increasingly rigid share of the budget, limiting the government's flexibility for countercyclical policy.

Phase II, encompassing EMU convergence and fiscal consolidation (1990–2007), was characterized by efforts to stabilize expenditures and meet the Maastricht criteria, facilitating sustainable convergence with European Union standards. Total spending stabilized at around 46–50 percent of GDP, while public investment increased temporarily in the early 2000s, driven by Olympic Games-related infrastructure projects, highlighting the sensitivity of capital expenditures to political cycles. Expenditure restraint focused largely on wage moderation and gradual pension reforms. Despite these consolidation efforts, structural rigidities persisted, particularly in social transfers, limiting true fiscal flexibility. Primary expenditures remained high relative to EU peers, although entry into the EMU in 2001 enabled lower interest expenditures due to declining borrowing costs.

Phase III, covering the sovereign debt crisis and adjustment period (2008–2018), involved unprecedented fiscal consolidation in response to the global financial crisis and subsequent sovereign debt crisis. Public wages and pensions were substantially reduced, and public investment fell sharply to historically low levels below 2 percent of GDP, raising concerns about long-term productivity growth and potential revenue capacity. Interest payments, moderated in part by ECB interventions and lower borrowing costs, continued to represent a significant budgetary component. Expenditure adjustments were heavily concentrated on politically sensitive and growth-critical categories, particularly public investment, illustrating the challenges of consolidating in the context of entrenched expenditure rigidity. During this period, expenditures peaked at over 54 percent of GDP in 2009, while EU–IMF adjustment programs imposed severe cuts: public wages were reduced by 20–40 percent, pensions were reformed and cut, and public investment fell to the lowest levels in the EU at that time.

The analysis identifies persistent growth and rigidity in government expenditure over the four-decade period, largely driven by wages, pensions, and social transfers. These structural features significantly constrained fiscal flexibility and limited the government's capacity to respond to economic shocks. On the revenue side, Greece relied heavily on indirect taxation and social security contributions, while capital taxation remained volatile and uneven. Effective tax rate evidence indicates that statutory tax reforms frequently failed to generate stable revenues, underscoring the central role of administrative efficiency and

tax compliance. The interaction between taxation and expenditure further contributed to chronic structural deficits, particularly in the pre-crisis period, as expenditure commitments consistently outpaced revenue capacity. Episodes of fiscal crisis exposed vulnerabilities in both revenue collection and expenditure management, ultimately necessitating deep consolidation measures. The sovereign debt adjustment period of 2010–2018 marked a critical turning point, characterized by substantial reductions in wages, pensions, and public investment alongside increases in VAT and excise taxes. Despite the scale of these adjustments, enduring challenges related to expenditure rigidity and limited tax bases continue to shape Greece's fiscal outlook. Overall, the Greek experience over these four decades underscores the interplay between structural expenditure rigidities, political imperatives, and the constraints they impose on fiscal flexibility. Recurrent obligations dominated the expenditure profile, often crowding out investment and limiting the government's ability to implement countercyclical or growth-supportive policies, particularly during periods of crisis. Understanding these dynamics is essential for designing fiscal frameworks that balance social objectives with long-term economic sustainability.

Controlling Expenditure Growth

Controlling expenditure growth requires addressing the structural rigidities that undermine long-term fiscal sustainability. Reforms in pension systems and public-sector employment are particularly critical, as these components account for a large and persistent share of government spending. Adjustments to indexation rules, gradual increases in retirement ages, and the introduction of performance-based employment and wage-setting frameworks can contribute to containing expenditure growth without undermining social protection or administrative capacity. At the same time, growth-enhancing public investment should be protected from cyclical spending cuts. Expenditure consolidation strategies that disproportionately reduce public investment risk weakening long-term growth prospects. Sustained investment in infrastructure, education, and innovation supports productivity growth and, in turn, strengthens the tax base and revenue-generating capacity of the economy over the medium term. Effective expenditure control also depends on clear prioritization mechanisms. The adoption of multi-year budgeting frameworks and binding expenditure ceilings can help insulate fiscal policy from short-term political pressures and ensure consistency with medium-term objectives. Emphasizing the efficiency and targeting of social spending, rather than expanding untargeted or indiscriminate allocations, improves both equity and fiscal sustainability.

Fiscal Policy Design and Sustainability

Sustainable fiscal policy design requires a balanced approach to consolidation that combines revenue enhancement with carefully targeted expenditure restraint. Excessive reliance on indirect taxation can have regressive distributional effects and dampen domestic demand, particularly during periods of weak economic activity. A more balanced adjustment strategy helps mitigate social costs while preserving macroeconomic stability. The effective use of automatic stabilizers further enhances fiscal sustainability. Tax and spending systems that respond naturally to business cycle fluctuations reduce the need for abrupt discretionary interventions, which are often politically contentious and

economically destabilizing. Progressive income taxation and countercyclical social transfers are central mechanisms through which fiscal policy can smooth economic volatility. Transparency and rule-based fiscal frameworks also play a crucial role in strengthening credibility. Medium-term fiscal frameworks, well-defined debt rules, and transparent reporting standards reduce the political bias toward short-term expansionary policies and enhance market confidence. By anchoring expectations, such frameworks contribute to lower borrowing costs and more stable fiscal outcomes.

4. Tax System Challenges, the Role of Effective Taxation and Implication for Policy Design

The consistently high ETR on labour reflects Greece's heavy reliance on social security contributions to finance its pension system. While such reliance is typical in many European countries, in Greece it has contributed to high labour costs, reduced formal employment, a large informal sector, and lower tax base elasticity. Despite repeated parametric reforms, the pension system continues to exert structural pressure, indicating a need for a more balanced financing mix. The volatility of the ETR on capital exposes institutional weaknesses in corporate taxation, including frequent tax-rate changes, unstable profit bases due to cyclical fluctuations, widespread tax planning and avoidance mechanisms, and heavy reliance on small and medium-sized enterprises with low taxable capacity. Volatility undermines investor confidence and weakens the tax system's stability, reinforcing the literature's findings that predictable and broad-based capital taxation is essential for sustainable revenue generation. Consumption taxes became the main consolidation tool during the crisis due to their administrative simplicity and revenue reliability. However, this approach carries several drawbacks such as regressivity, which disproportionately affects low-income households, negative effects on domestic demand during recession; and exposure to compliance problems, especially in sectors with high cash transactions. Nonetheless, the strong upward trend in consumption taxes suggests that indirect taxes will continue to play a major role in Greek fiscal policy unless significant reforms broaden direct tax bases.

Tax–Expenditure Mismatch, Fiscal Sustainability and Structural Turning Points

The combined analysis highlights a chronic mismatch between expenditure commitments and revenue capacity. Greece repeatedly expanded expenditures faster than revenues, particularly during politically driven expansions of the welfare state. Instead of adjusting the tax base to support these commitments, successive governments relied on: borrowing, temporary tax measures, indirect taxes, and optimistic revenue projections. This mismatch became unsustainable with the onset of the global financial crisis, when capital-market access deteriorated and the structural deficit was exposed. The crisis forced abrupt fiscal adjustment, resulting in deep recessionary effects. The sovereign debt crisis represents a watershed moment in Greek fiscal history. Unlike previous adjustments, post-2010 consolidation was externally monitored, rules-based, and comprehensive. The crisis led to reductions in wages and pensions unseen in prior decades, major increases in VAT and excise rates, restructuring of the tax administration, stronger medium-term budgetary frameworks, and improved fiscal transparency. However, the adjustment burden fell disproportionately on taxes—especially consumption taxes—and on cuts to public

investment, raising questions about the long-term growth implications of the consolidation mix. The empirical and theoretical analysis of Greece's fiscal system over 1974–2018 provides clear lessons for policymakers regarding the design of sustainable and growth-friendly fiscal frameworks. Thus, three implications emerge: Broadening the tax base is essential to reduce reliance on volatile or distortive forms of taxation. At the same time, expenditure reforms should focus on structural components—particularly pensions and public employment—rather than temporary cuts that fail to address underlying fiscal imbalances. Long-term fiscal sustainability also depends on stronger fiscal governance, achieved through improved tax enforcement, stable and predictable tax legislation⁽¹⁾, multi-year budgeting frameworks, and effective public investment management. Strengthening revenue capacity requires a systematic expansion of the tax base. Reducing dependence on indirect taxes and widening direct taxation, including personal and corporate income taxes, would enhance revenue stability. This can be achieved by closing tax exemptions, improving property taxation, and simplifying income tax brackets to make the system more transparent and efficient.

Equally important is the enhancement of tax administration⁽²⁾. Stronger enforcement mechanisms, greater digitalization, and increased auditing capacity can significantly reduce tax evasion and raise effective tax rates without increasing statutory rates. The Greek experience shows that tax reforms lacking proper administrative follow-through often fail to deliver the expected revenue gains.

Finally, stabilizing capital taxation is crucial for attracting investment and improving revenue predictability. Reducing volatility in corporate and capital taxes, while aligning tax rules with EU standards, can strengthen confidence in the tax system and support economic growth, provided that principles of fairness and equity are maintained.

5. Effective Tax Rates (ETRs): Labour, Capital, and Consumption

Effective tax rates constitute the core empirical contribution of this study⁽³⁾, offering a more accurate representation of the true tax burden than statutory rates alone. By capturing the combined effects of tax policy, compliance, and economic structure, ETRs provide critical insights into the distribution and evolution of taxation across labor, capital, and consumption.

Effective Tax Rate on Labour

The effective tax rate on labor increased markedly over the sample period, rising from approximately 23–25 percent in the 1970s to above 38 percent by the late 2000s. Throughout this period, Greece consistently ranked among the countries with the highest labor tax burdens in Southern Europe. Social security contributions accounted for more than 60 percent of total labor taxation, underscoring the central role of payroll-based financing in the fiscal system. The evolution of the labor ETR is characterized by a steady upward trend, with minor declines in the early 1990s and a sharp increase after 2010 as part of the fiscal consolidation process. High labor taxation weakens incentives for formal employment, contributes to labor-market informality, and places a disproportionate burden on wage earners.

Effective Tax Rate on Capital

Capital taxation exhibits the highest degree of volatility among the three tax bases. The effective tax rate on capital fluctuated between roughly 12 percent and 28 percent over the period under review. This instability was driven by frequent changes in corporate tax rates, shifts in investment cycles, variations in corporate profitability, and sustained erosion of the tax base through exemptions and preferential treatments. Such volatility increases uncertainty for firms and investors, discourages long-term investment decisions, and undermines the predictability of public revenues derived from capital income.

Effective Tax Rate on Consumption

The effective tax rate on consumption followed a continuous upward trajectory, increasing from around 15–18 percent in the 1970s to over 25 percent by 2018. The most pronounced increases occurred during the fiscal adjustment period between 2010 and 2015, driven by repeated VAT hikes, the broadening of the standard VAT rate, and higher excise taxes on energy, tobacco, and alcohol. The evolution of consumption taxation displays a steady long-term rise, punctuated by sharp increases during the crisis years. This pattern reflects the reliance on consumption taxes as the primary consolidation instrument, owing to their relative ease of collection and the administrative limitations affecting other tax bases.

Overall, effective tax rate trends reveal a strong and sustained increase in labor taxation with relatively low volatility, a highly volatile pattern in capital taxation, and a continuous upward trend in consumption taxation with moderate volatility. During the crisis period, labor taxation intensified mainly through higher social security contributions, capital taxation rose due to increases in corporate income tax rates, and consumption taxation experienced abrupt increases through VAT and excise measures. Together, these developments highlight the asymmetric adjustment of Greece's tax system and the structural constraints shaping fiscal policy choices over time.

6. Executive Summary and Policy Implications

This section provides an integrated analysis of Greece's fiscal evolution by jointly examining government expenditure dynamics and effective tax rates on labour, capital, and consumption. By linking spending patterns with revenue capacity, the discussion highlights the structural features of the fiscal system, the policy choices that shaped its trajectory, and the interactions between expenditure rigidity and taxation over time⁽⁴⁾.

Government expenditure expanded markedly from the post-dictatorship period to the aftermath of the sovereign debt crisis. Total spending as a share of GDP increased from approximately 29 percent in the mid-1970s to over 50 percent in the late 2000s, before contracting temporarily under the fiscal adjustment programs. During the post-dictatorship period from 1974 to 1989, expenditures grew rapidly, driven primarily by compensation of employees and the expansion of social transfers associated with the establishment of the modern welfare state and the enlargement of public-sector employment. Interest payments increased gradually as public debt accumulated, while public investment displayed considerable volatility and was frequently constrained by the rising burden of recurrent

expenditures. This phase laid the foundations for structural rigidity, reducing discretionary fiscal capacity and increasing vulnerability to future fiscal stress. During the period of Economic and Monetary Union convergence and relative fiscal stabilization between 1990 and 2007, total expenditure stabilized at around 46–50 percent of GDP. Public investment increased temporarily in the early 2000s, particularly in the context of infrastructure development for the Olympic Games, while consolidation efforts focused on wage moderation and incremental pension reforms. Nevertheless, structural rigidities persisted, especially in social transfers, and the apparent stabilization of spending masked underlying vulnerabilities. Recurrent expenditures continued to dominate the expenditure structure, limiting the scope for countercyclical fiscal policy and adjustment in response to shocks. The sovereign debt crisis and subsequent adjustment period from 2008 to 2018 marked a profound shift in fiscal policy. Expenditure reductions were concentrated on wages, pensions, and, most notably, public investment, which fell to below 2 percent of GDP. At the same time, indirect taxation, particularly value-added tax and excise duties, was increased to offset declining revenues. Despite lower borrowing costs in later years, interest payments remained a significant component of expenditure. The adjustment strategy proved highly contractionary in areas essential for long-term growth, underscoring the difficulty of achieving sustainable consolidation in the presence of entrenched expenditure rigidities. An examination of expenditure composition further reinforces these conclusions. Current expenditures, including wages, pensions, and social transfers, consistently accounted for more than 65 percent of total spending, constraining fiscal flexibility. Capital expenditures exhibited pronounced procyclicality, expanding during politically salient investment periods, such as the Olympic Games, and contracting sharply during fiscal crises. The persistence of large recurrent obligations limited the government's ability to reallocate resources or pursue discretionary stabilization policies. Effective tax rates provide a complementary perspective on Greece's revenue capacity and the distribution of the tax burden. Labour taxation increased steadily from around 23 percent in the 1970s to over 38 percent by 2010, with social security contributions accounting for more than 60 percent of the total labour tax burden. This persistent reliance on payroll-based revenue reflects structural features of the fiscal system and weakens incentives for formal employment. In combination with rigid expenditure commitments, high labour taxation exacerbates fiscal pressures by narrowing the tax base and reinforcing informality. Capital taxation displayed the greatest volatility over the period, with effective tax rates fluctuating between approximately 12 percent and 28 percent. This instability reflected frequent changes in corporate tax policy, cyclical movements in profitability, and the use of tax incentives and exemptions. Such volatility undermined investment confidence, particularly during periods of economic uncertainty, and reduced the predictability of capital-based revenues. The findings underscore the importance of stable and credible capital taxation for supporting long-term investment and revenue sustainability.

Consumption taxation followed a sustained upward trajectory, increasing from around 15–18 percent in the 1970s to over 25 percent by 2018. The sharpest increases occurred during the fiscal adjustment programs, driven by successive VAT rate hikes and higher excise taxes. Consumption taxes became the primary consolidation instrument due to their administrative simplicity and relative reliability, especially in an environment of weak tax compliance. While effective in stabilizing revenues, this strategy increased the regressivity

of the tax system and risked dampening domestic demand. The interaction between expenditure trends and effective tax rates reveals several critical fiscal dynamics. Rapid growth in recurrent expenditures exerted sustained pressure on taxation, leading to higher labour and consumption tax burdens. Persistent expenditure rigidity, combined with volatile capital taxation, contributed to chronic structural deficits, particularly in the pre-crisis period. During the sovereign debt crisis, increases in effective tax rates on labour and consumption were used to compensate for falling revenues and rigid expenditure commitments, while expenditure cuts were disproportionately concentrated on public investment and wages. Overall, the results point to clear policy implications. The dominance of recurrent expenditures limits fiscal flexibility, highlighting the need for structural reforms in pensions, public-sector wages, and expenditure efficiency. On the revenue side, heavy reliance on consumption and payroll taxes underscores the importance of diversifying the tax base, stabilizing capital taxation, and strengthening enforcement mechanisms. Protecting public investment is essential for long-term growth, as sustained cuts undermine productivity and future revenue capacity. Finally, the adoption of rule-based fiscal frameworks, including medium-term expenditure ceilings, can help mitigate political pressures, reduce procyclical behavior, and support more sustainable fiscal outcomes. The joint analysis of government expenditures and effective tax rates (ETRs) highlights persistent fiscal imbalances in Greece, arising from the interaction of structurally rigid spending and unstable revenue sources. Expansionary expenditure policies were frequently pursued despite tax systems that were incapable of generating sufficient, stable revenue, creating chronic structural deficits. Volatility in capital taxation, combined with the rigidity of recurrent spending, exacerbated these imbalances. During the pre-crisis period (2001–2009), revenue shortfalls were often masked by access to low-cost borrowing, resulting in unsustainable debt accumulation and heightened vulnerability to fiscal shocks. A central feature of Greece's fiscal trajectory is the persistent upward trend in government expenditures over the four decades studied, driven primarily by politically sensitive and institutionally rigid components such as wages, pensions, and social transfers. These expenditure categories proved largely resistant to consolidation efforts, particularly prior to the crisis, due to several factors. Social-state commitments displayed strong path dependency, while decision-making was fragmented across ministries and agencies. Electoral incentives favored short-term spending expansion, and expenditure control mechanisms were weak, especially before the establishment of the Hellenic Fiscal Council. This rigidity constrained the government's ability to implement countercyclical policies and crowded out public investment, which declined sharply during fiscal adjustment periods. The reduction in public investment during the crisis posed risks to long-term growth, given its central role in productivity and competitiveness. The findings underscore the necessity of a comprehensive approach to fiscal reform. Revenue reforms should focus on broadening the tax base, improving tax administration, and stabilizing capital taxation to reduce volatility and enhance predictability. Expenditure reforms must address structural rigidities, protect public investment, and prioritize efficiency in social spending and public-sector employment. Establishing sustainable fiscal frameworks, including balanced consolidation strategies, automatic stabilizers, and transparent, rule-based governance, is essential to support equitable, growth-friendly, and sustainable fiscal outcomes. These measures are particularly relevant not only for Greece but also for economies facing similar structural fiscal challenges. Long-term expenditure trends indicate several key policy

imperatives. Structural reforms are necessary to mitigate the constraints imposed by expenditure rigidity, particularly in pensions and wages, thereby enhancing fiscal flexibility. Protecting public investment from cyclical or politically motivated cuts is crucial for sustaining growth potential and preserving future revenue capacity. Multi-year budgeting frameworks and expenditure ceilings can reduce politically driven volatility, improve fiscal credibility, and facilitate more strategic allocation of public resources.

7. Conclusion

The comprehensive fiscal consolidation required in Greece cannot be achieved only by reducing public spending and measure to combat tax evasion, but also requires an increase in tax revenues while insisting on growth-friendly tax reforms⁽⁵⁾. An increase in tax revenues can be achieved in particular by increasing the effective taxation of the self-employed, which will lead to a reduction in the unequal distribution of the tax burden between employees and the self-employed. An increase in tax revenues is also possible through an increase in the effective taxation of consumption, which is significantly lower in Greece compared to the euro area. This can be done, as mentioned above, by increasing the tax base and taking measures to combat tax evasion. Also, a rationalization of property taxation, market-based valuation and tax base broadening also contribute further to fairer and efficient tax system. Finally, shifting the tax burden from labor to consumption or property tax can lead to an increase in growth and a reduction in public debt via the positive effect on employment, but must be seen in the context of distributional effects. Overall, it can be deduced that Greece should adopt a broad tax base, effective taxation, collection procedures and auditing techniques, and insist on rationalizing its government spending over the business cycle and establishing better proactive debt management. This would avoid not only inadequately effective policies, but also adverse effects on growth, economic recovery, and debt sustainability. However, it should be emphasized that the impact and effectiveness of the above conclusions also depend on the individual characteristics of the Greek economy, such as fiscal efficiency and administrative effectiveness. It is also clear that in recent years Greece has pursued a strategy of increasing tax revenues while rationalizing government spending. In recent years, the focus of tax reforms has been on increasing tax rates and broadening tax bases to meet the quantitative requirements of the tax packages, and less increasing public welfare and social benefits. However, these policies have been detrimental to investment, employment and growth and a new framework should be established. Moreover, theoretical studies have shown that income taxes are considered more harmful to economic growth than consumption taxes due to their progressivity, while taxation of interest income is detrimental to savings and investment. Taxation of corporate profits is also seen as harmful to economic growth, as it prevents companies from investing and increasing productivity. In the event of an increase in corporate tax rates, this tax may have a negative impact on the attractiveness for foreign investment. From the above, it is clear that the tax reform of our system is imperative in order to eliminate the weaknesses of the current system and create a new framework that is friendly to development. The Greek tax system does not seem to favor economic development and does not provide incentives for private investment and business

modernization, as it is characterized by complexity, polynomiality, and bureaucracy. The above elements, in fact, lead to fraud, shadow economy and tax evasion and, in general, to a reduction in public revenues that do not contribute to growth. Moreover, the reform and full digitalization of the tax system is an imperative and necessary condition to increase the competitiveness of the Greek economy and companies. This is because, despite several legislative changes, the tax system is still incomplete and characterized by complexity and bureaucracy. The problems of over-taxation and unfair distribution of the tax burden remain of great importance and are directly related to the phenomenon of tax evasion and fraud, as well as the reduction of revenues. In conclusion, only policies aimed at combating the shadow economy and corruption can lead to alternative sources of government revenue that will reduce the need for austerity and mitigate the economic downturn.

Notes

- (1) For an overview of legislated Greek tax changes see Asimakopoulos (2025d).
- (2) For a modern approach to transforming tax administration, see Asimakopoulos (2025a, 2025g).
- (3) For a comprehensive analysis on Greek tax policy and macroeconomic framework after the political transition, see Asimakopoulos (2025c). There is an analysis on effective tax rates.
- (4) For macroeconomic econometric evidence see Asimakopoulos (2025f). For insights on property tax see Asimakopoulos (2025e).
- (5) The evolution and the macroeconomic impact of the Greek tax system reforms from 1974 until today: findings, prospects and key recommendations, Asimakopoulos (2025h). DOI:10.12681/eadd/58639

References

- Asimakopoulos, P. (2025a). Driving tax administration excellence: An innovative balanced scorecard perspective. *SPOUDAI Journal of Economics and Business*, 75(1–2), 34–47.
- Asimakopoulos, P. (2025b). Measure what matters: A balanced scorecard for tax administrations. *Global Journal of Accounting and Economy Research*, 6(1), 63–72.
- Asimakopoulos, P. (2025c). Greek tax policy and macroeconomic framework after the political transition: A systematic approach. *Theoretical and Applied Economics*, 0(2(643), S), 261–280.
- Asimakopoulos, P. (2025d). Evolution of the Greek tax system. *Journal of Economics and Econometrics*, 68(3), 101–116.
- Asimakopoulos, P. (2025e). The impact of property tax changes in support of sustainable tax revenue in Greece. *Acta Scientiarum Polonorum. Oeconomia*, 24(1), 5–14.
- Asimakopoulos, P. (2025f). Macroeconomic impact of tax changes: The case of Greece from 1974 to 2018. *Journal of Economics and Econometrics*, 68(2), 45–68.
- Asimakopoulos, P. (2025g). Tax and macroeconomic framework: The case of Greece. *Theoretical and Applied Economics*, 32(1(642)), 237–250.
- Asimakopoulos, P. (2025h). The evolution and the macroeconomic impact of the Greek tax system reforms from 1974 until today: findings, prospects and key recommendations <DOI:10.12681/eadd/58639>

What is the nature of the relationship between inflation and economic growth? Empirical evidence for the 13 least developed African countries

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Abstract. *This study examines the relationship between inflation and economic growth in 13 least developed African countries from 1981 to 2019. Using Two-Step Least Squares (2SLS) and the Generalized Method of Moments (GMM), it identifies a nonlinear relationship between inflation and growth. The findings reveal an inflation threshold of 21.52%: below this level, inflation promotes economic growth, while above it, inflation negatively affects growth. Thus, high inflation hampers economic performance. The results also show that growth in these countries is mainly driven by gross fixed capital formation, population growth, and trade openness. In contrast, public spending and institutional development have a significant negative impact on economic growth. These findings highlight the importance for policymakers to consider the inflation threshold when designing monetary policies to ensure sustainable growth and effective inflation control.*

Keywords: inflation, economic growth, dynamic panel threshold, GMM, 2SLS.

JEL Classification: C23, O40, E31.

1. Introduction

Today, the relationship between inflation and economic growth, an important factor in promoting economic growth and sustainable development, has become one of the most widely discussed and researched topics (Nkemgha et al., 2022), (Ozyilmaz, 2022), (Rahimov, 2024) and (Erick, 2025). Price stability is a key phase in the stabilization of the macroeconomic framework and the improvement of economic growth levels (Girijasankar and Anis, 2001), the control of price increases and the achievement of economic growth are the main criteria for economic performance to which they attach importance for the least developed countries. In addition, the nature of the relationship between general consumer price increase and gross domestic product has been discussed in long-standing theoretical and empirical literature reviews (Phillips, 1958), (Cili and Alkhaliq, 2022) and (Iriagbonse-Alikor and Priscilla, 2022).

On the one hand, the linear relationship between inflation and economic growth was justified by the research studies of (Dumitrescu and Hurlin, 2012), (An & al., 2016), (Stojanovikj and Petrevski, 2021) and (Cili and Alkhaliq, 2022). This relationship is explained by several transmission channels. In this regard, we can mention the reduction in unemployment and the increase in investment (Ho and Iyke, 2020). Indeed, according to the curve of (Phillips, 1958), the increase in inflation generates the fall in the unemployment rate through the creation of new jobs. However, lower unemployment can improve the level of income and consequently increase demand. In addition, rising inflation can increase the costs of currency trials (Dumitrescu and Hurlin, 2012). This situation redirects the place of capital towards real investment and therefore economic growth.

On the other hand, the negative effect of inflation on economic growth has been shown by the studies of (Sirimaneetham and Temple, 2009), (Robert, 2013), (Faraji and Kenani, 2013), (Ruzima and Veerachamy, 2016), (Veni and Choudhury, 2007), (Shelton & al., 2021) and (Tariq, 2022). The non-linear relationship is explained mainly by the uncertainty of investment and production (Robert, 2013). That is, continued price increases make economic decision-making by public authorities ineffective (Shelton Mandeya & al., 2021). This means that the high uncertainty of inflation can turn speculative economies which should yield more than real investment or output. However, declining real investment can hamper growth processes.

Still, it does not only reduce real investment by negatively affecting the profits of producers but, it can also threaten the purchasing power of consumers by influencing their real incomes. This means that the general increase in consumer prices is eroding the purchasing power of consumers. In this case, the demand can decrease and consequently the production. In addition, inflation can undermine growth and economic development strategies by increasing the degree of uncertainty (Franses, 2018) and it can increase the income gap between individuals, groups, and regions (Çakir, 2023). So these situations can disrupt income distribution. That is, the deterioration of income distribution at the expense of fixed income groups (Şiriner and Doğru, 2005).

Moreover, price instability makes the anticipation of macroeconomic quantities irrational. That is to say, it can increase the gap between the forecast and the real in terms of

production costs and it makes economic calculation difficult. So the combination of these factors can create difficulties within companies that can reduce production. Also, inflation hampers growth through the decline in exports (Tariq, 2022). That is, the general increase in prices can increase production costs. This makes it difficult for exporting companies to compete.

In the light of the previous two sides, the contradiction between the defendants and the ignorant on the linear relationship between inflation and economic growth may explain by the different level of the inflation rate (Omay and Öznur Kan, 2010), (Su Dinh, 2015), (Ehigiamusoe & al., 2019), (Zhiyong & al., 2021), (Muhammad and Saleem, 2022), (Iriagbonse-Alikor and Priscilla, 2022) and (Buthelezi, 2023). Overall, the positive effect of inflation appears to be the case where the rate of inflation is moderate and opposite.

Indeed, according to previous research studies, we note that most of the studies have dealt with the relationship between inflation and economic growth only by testing and the sense of causality and the nature of the effect. But, they are not concerned with determining the level of inflation that guarantees economic growth.

This research study aims to analyze the nature of the relationship between inflation and economic growth and establishes the threshold for inflation, that guarantees economic growth for the 13 least developed African countries from 1981 to 2019 through a dynamic analysis of data panel based on the Least Square method in Two-step (2SLS), the generalized moment method (GMM) and the regression threshold (TR).

The interest we place in selecting the 13 least developed African countries is justified by the fact that the 13 least developed African countries are characterized by a high rate of inflation compared to other regions of the world and they suffer from lack of growth and economic development.

The outline of this paper is organized as follows: The second section describes a brief overview of the theoretical and empirical literature on the link between inflation and economic growth. The third section presents the theoretical framework and econometric model. The fourth section displays the results and discussion. The fifth section presents the political conclusion and implications.

2. Literature review

Most theoretical and empirical studies that have shown the linear relationship between inflation and economic growth, have justified this relationship by the low level of inflation (Martin, 2022). This indicates that the small price increase does reduce growth but, it can lubricate their processes. In this perspective, (Cili and Alkhaliq, 2022) determined the link between inflation and economic growth in Indonesia using static panel data from 2010 to 2014. They showed the linear relationship between inflation, investment, the demographic rate and gross domestic product. In addition, they found that the effect of private investment on growth is greater than inflation. In this case, the significant positive effect of inflation is explained by the control of consumer product prices represented by the Indonesian bank which does not reduce demand and does not deteriorate purchasing power.

Again, advanced studies agree that there is a causal relationship between the overall price increase, the gross domestic product deflator and the gross domestic product. In this regard, (Ozyilmaz, 2022) sought to determine the threshold of inflation in which it positively affects economic growth and tested the sense of causality for the countries of the European Union from 1996 to 2019. The results of the (Dumitrescu and Hurlin, 2012) test justify a two-way causal relationship between the general increase in consumer prices and gross domestic product. In addition, they noted the presence of two-way causality between the GDP deflator and economic growth. In the light of these results, we see that it is important for countries with a low level of economic growth to raise prices a little to stimulate the economy.

In addition, using co-integration and error correction (ECM) models, (Girijasankar and Anis, 2001) examined the long-term relationship between inflation and economic growth for the four South Asian countries (Bangladesh, India, Pakistan and Sri Lanka). They showed a positive and significant relationship between the general increase in consumer prices and gross domestic production and that there is a significant feedback between inflation and economic growth. This means that moderate inflation in this region is a favorable factor for economic growth. From this angle, (Girijasankar and Anis, 2001) recommended that the four South Asian countries consider the negative effects of low inflation.

On the other hand, previous reviews of theoretical and empirical literature have explained the negative effect of inflation on economic growth through higher commodity prices. This can reduce demand and therefore growth. In this regard, (Faraji and Kenani, 2013) tested the link between inflation and Tanzanian economic growth by processing historical data from 1990 to 2011. The results of the Johansen co-integration test and the regression of simple linear equations (ILS) showed the negative effect of inflation on economic growth and the absence of a long-term co-integration relationship. Indeed, the negative effect of inflation is explained by rising commodity prices and their effect on falling demand. This is the general increase in energy and agricultural prices in Tanzania. In this case, the lack of availability of products on the market can lead to higher prices for these products.

Moreover, based on the findings of previous studies, economic growth is influenced not only by inflation but also by inflation uncertainty. In this regard, Shelton Mandeya et al. (2021) examined the effects of inflation and inflation uncertainty on gross domestic product in South Africa using the Autoregressive Distributed Lag (ARDL) technique. Their analysis was conducted on quarterly data covering the period from Q1 1961 to Q4 2019. They assessed the effectiveness of inflation targeting by comparing the nature of the effect of inflation and inflation uncertainty on economic growth before and after inflation targeting. This allowed the effect of inflation targeting to be assessed while studying any changes in variable behavior. They showed that inflation has a significant negative effect on short- and long-term growth, however, inflationary uncertainty is a short-term phenomenon in South Africa with no long-term impact on gross domestic product. In addition, they found that to encourage economic growth in South Africa, the authorities must continue to implement policies and strategies that ensure price containment.

Still, the high rate of inflation does not only discourage growth but, it can hinder trade operations with the outside world. In this regard, (Tariq, 2022) focuses on the long-term effect of inflation on foreign trade and economic growth in Pakistan from 1985 to 2019

through the Autoregressive Distributed Lag (ARDL) method and the Wald test (2000). He said that inflation has a negative and significant effect on long-term growth and external trade. In addition, he noted that low inflation is advantageous for growth processes and trade incentives, while high inflation is disadvantageous to the Pakistani economy. In this case, the negative effect of inflation on trade is explained by the increase in raw material prices, which increases production costs and makes Pakistan firms uncompetitive on the external market.

Several other studies have justified the non-linear relationship between inflation and economic growth over a long period of time. From this angle, (Robert, 2013) evaluated the effect of inflation on the economic performance of a sample of 100 countries from 1960 to 1990. He indicated the presence of a significant causal relationship between inflation and economic growth and investment. The regression results showed that an increase in average inflation of 10% per year reduces the growth rate of real gross domestic product per capita from 0.2% to 0.3% and decreases the investment ratio by 0.4% to 0.6% per year. In addition, it showed that the change in monetary policy, which increases the long-term average inflation rate by 10% per year, is estimated to reduce economic growth after 30 years by 4 to 7%, more than enough to justify a strong interest rate for price stability.

Also, the study by (Nur Alam, 2023) showed the negative influence of macroeconomic instability of the economic growth of the ASACR (South Asian Association for Regional Cooperation) countries from 1991 to 2020. In this study, macroeconomic instability is measured by the rate of inflation. This type of relationship is explained by the continuous increase in consumer prices. In addition, the results of the regression of the dynamic fixed-effect panel data show the significant positive allocation of foreign direct investment, the domestic credit granted to the private sector, the exchange rate and the quality of the institutions. According to these results, he recommended that policy-makers in ASACR countries stabilize the macroeconomic state to await economic growth.

Again, in an empirical study, (Bui Hoang, 2019) studied the asymmetric effect of inflation and money supply on economic growth using a non-linear autoregressive distributed lag approach introduced by (Shin & al., 2013) for Vietnam from 1990 to 2017. It has shown that the effects of inflation on economic growth are negative and asymmetrical in the long run. In addition, he noted that the impact of money supply on growth is positive in the short and long term. As a result, the impact of rising inflation is greater than the long-term decline.

On the other hand, the negative or positive allocation of inflation to economic growth may be conditioned by the level of inflation. That is to say, the fall in the rate of inflation below a given threshold may reduce or increase economic growth and vice versa. In this regard, using a PSTR model, (Omay and Öznur Kan, 2010) examined the empirical relationship between inflation and economic growth for 6 industrial countries from 1972 to 2005. They provide evidence that there is an inflation threshold of 2.52%. In addition, they noted that the relationship between inflation and growth becomes negative when the inflation rate exceeds this threshold. They tested the robustness of this relationship through unbound regression (SUR). They found that the inflation threshold level changes slightly from 2.52% to 2.42%.

A similar study by (Su Dinh, 2015) tested the hypothesis that the relationship between inflation and economic growth is non-linear for the 5 ASEAN countries from 198 to 2011. The results of the regression of the PSTR model and the generalized moments technique (GMM) show the significant negative relationship between the general increase in consumer prices and the gross domestic product in the long term. In addition, he noted that the inflation rate must not exceed the 7.84% threshold to have the significant positive effect of inflation on the economic growth of the 5 ASEAN countries. In the light of the results obtained, he suggested that the central banks of the 5 ASEAN countries could increase the rate of economic growth by controlling the rate of inflation when it is above or near the estimated threshold. In this case, the threshold level of inflation can therefore be considered as an indicator of inflation targeting to drive monetary policy.

Moreover, previous theories have justified that the moderate inflation effect on economic growth is greater than the high. In this regard, (Iriagbonse-Alikor and Priscilla, 2022) examined the link between inflation and economic growth through the treatment of balanced panel data from Southern African countries from 1980 to 2021. They showed an inflation threshold equal to 24.7 which guarantees the positive and significant allocation of inflation on economic growth. Again, they have justified that economic growth is affected differently at low and high inflation levels. That is, economic growth is inflationary below the inflation threshold. However, the effect of inflation becomes negative only if inflation falls below the threshold. In this regard, they recommended that countries in Southern Africa reduce the rate of inflation to this level to avoid the adverse effects of general price increases on economic growth processes.

Another study was conducted by (Muhammad and Saleem, 2022). They re-evaluated the threshold effect of inflation on economic growth for 27 countries (16 developing and 11 developed economies) from 1975 to 2018. The results of the Achievable Generalized Least Squares and Fixed Effects (FGLS) methods indicate a significant negative connection between inflation and gross domestic product above the inflation threshold. They showed that inflation inhibits growth when inflation exceeds the 5.36% to 12.23% range. In addition, they found that it is important for managing authorities to consider a maximum rate between 5.4 % and 12.3 %, as an inflation interval to overcome the negative effects of high inflation.

3. Theoretical framework and econometric model

This study examines the relationship between inflation and economic growth and determines the inflation threshold that guarantees growth for the 13 least developed African countries according to UNDP (2020) from 1981 to 2019 by the Least Square Two-Step Method (2SLS) and the generalized moment method (GMM) applied to the dynamic panel data and the threshold regression technique. These countries are Niger, the Central African Republic, Chad, South Sudan, Burundi, Sierra Leone, Mali, Liberia, Mozambique, Guinea-Bissau, Eritrea, Nigeria and Togo.

This study created the entire database in the form of the 5-year average periods of the variables used to validate and ensure the consistency of the GMM estimator as follows: 1981-1984, 1985-1989, 1990-1994, 1995-1999, 2000-2004, 2005-2009, 2010-2014, 2015-

2019. In addition, averaging the data is likely to mitigate the business cycle effect. The model below, which explains the relationship between inflation and economic growth, is inspired by the work of (Khan and Senhadji, 2001) and (Kremer & al., 2013).

$$\dot{Y}_{it} = \alpha_0 + \alpha_1 Initial_{it} + \alpha_2 \pi_{it} + \beta x_{it} + \varepsilon_{it} \quad (1)$$

With:

$\dot{Y}_{it}$: the growth rate of gross domestic product per capita in t in the economy i,

$Initial_{it}$: the growth rate of gross domestic product per head in t_{-1} ,

π_{it} : the rate of inflation,

x_{it} : Other variables that could affect economic growth,

ε_{it} : error term,

i = 1,,13 and t= 1,,39

In Riding 1, the variable $Initial_{it}$ is added as an explanatory variable. This means that the level of production and the structure of an economy are not entirely independent of previous periods, and thus the output of the previous period is also reflected in subsequent periods. Table 1 presents the definition, measurement, expected sign and source of the variables:

Table 1. Definition and measurement of variables

Variables	Ratings	Measure	expected sign	Sources
Economic growth rate	GDP	Five-year average of the annual growth rate of real GDP per capita (2010 Constant \$).	-	World Bank Database (2022)
Public expenses	PE	Five-year average of the government final consumption expenditure as a share of GDP.	Positive / Negative	World Bank Database (2022)
Inflation rate	INF	Five-year average of the annual percent changes in the Consumer Price Index (CP	Negative	World Bank Database (2022)
Gross fixed capital formation	GFCF	Five-year average of the gross capital formation as a share of GDP.	Positive	World Bank Database (2022)
Population growth rate	POP	Five-year average of the annual growth rate of population.	Positive / Negative	World Bank Database (2022)
Institutional development	ID	Five-year average of the "Economic freedom" index.	Positive / Negative	Fraser Institute (2021)
Trade openness rate	TO	Five-year average of the annual growth rate of export.	positive	World Bank Database (2022)

Source: Author's

Table 2 presents the results of the descriptive variable statistics.

Table 2. Descriptive statistics

Variables	Mean	St.De.	Min.	Max.	Skewness	Kurtosis	JB	P.JB
GDP	0.51	0.14	-10.72	4.06	0.51	4.94	22.74	0.001
PE	6.47	3.91	2.89	22.61	0.02	5.02	13.64	0.042
INF	18.63	5.17	2.01	45.73	-2.83	1.09	3.54	0.100
GFCF	23.31	8.57	5.89	49.04	0.08	7.22	27.09	0.000
POP	7.39	3.64	2.05	10.11	1.98	5.58	19.31	0.011
ID	3.67	1.53	0.17	7.29	-4.17	3.61	10.14	0.079
TO	9.14	3.08	0.55	36.18	3.38	6.27	31.02	0.035

J.B: Test of Jarque-Bera, P.J.B: probability of Jarque- Berra, The null hypothesis of the Jarque-Bera test assumes the distribution of data according to a normal law. The Jarque-Bera test problem is written as H_0 : p-value < 5% vs H_1 : p-value > 5%.

Source: STATA 15

Overall, the economic growth rate has an overall average of 0.51 with a low standard deviation of 0.14. In fact, all values are between -10.72 and 4.06. On the other hand, the rate of economic growth takes a form of asymmetric distribution spread to the right as the Skewness exceeds 0. It is leptokurtic where the Kurtosis equals 4.94. In addition, this variable rejects the null assumption of normality because the p-value of 0.001 is much lower than 5%.

Moreover, from 1981 to 2019, inflation in the 13 least developed African countries recorded an overall average value of 18.63 with a very large standard deviation of 5.17. In addition, all minimum and maximum values are between 2.01 and 45.73. Based on these figures, it can be said that from 1981 to 2019, the 13 least developed African countries were characterized by a high annual average inflation rate compared to other regions of Africa and the world. In contrast, the distribution of the variable "inflation rate" is asymmetrical and weakly spread to the left where the Skewness is equal to $-2.83 < 0$ and again, it is the leptokurtic where the Kurtosis is positive $1.09 > 0$. Overall, the variable "inflation" rejects the null hypothesis of normality because the p-value equal to 0.000 much less than 5%. Table 3 shows the correlation matrix between the variables:

Table 3. *Correlation matrix*

	GDP	PE	INF	GFCF	POP	ID	TO
GDP	1						
PE	-0.39 (0.034)	1					
INF	-0.27 (0.178)	-0.02 (0.045)	1				
GFCF	0.65 (0.007)	0.89 (0.37)	-0.37 (0.071)	1			
POP	0.03 (0.371)	0.57 (0.003)	0.25 (0.051)	0.72 (0.000)	1		
ID	-0.47 (0.009)	0.01 (0.027)	0.67 (0.011)	0.15 (0.296)	0.59 (0.083)	1	
TO	0.46 (0.470)	-0.38 (0.000)	-0.44 (0.174)	0.71 (0.003)	0.09 (0.092)	0.53 (0.077)	1

Source: STATA 15

Table 3 shows that economic growth in the 13 least developed African countries is positively correlated with gross fixed capital formation, trade openness and the population rate. Gross fixed capital formation is the variable most correlated with economic growth. However, it is negatively correlated with institutional development, inflation and public spending. In addition, the inflation rate is the variable most negatively correlated with the rate of economic growth.

The inflation rate dataset shows that there is a higher inflation rate. In this regard, Ghosh and Phillips (1998) recommend adding the logarithm to the inflation rate to avoid the adverse effects of high inflation on regression outcomes. As the inflation rate data had negative values, the semi-logarithmic transformation was applied to the inflation rate variable by (Khan and Senhadji, 2001), (Drukker & al., 2005) and (Kremer & al., 2013). This transformation is done as:

$$\bar{\pi}_{it} = \begin{cases} \pi_{it} - 1 & \text{si } \pi_{it} \leq 0 \\ \ln(\pi_{it}) & \text{si } \pi_{it} > 0 \end{cases}$$

The use of lagged values of variable $\dot{Y}_{it}$ it as an explanatory variable in a fixed-effect and random-effect statistical panel data model emerges a relationship between lagged values $\dot{Y}_{it-1}, \dot{Y}_{it-2}, \dots$ and error term ε_{it} . This relationship requires an estimation of the fixed-effect model and has random effect and therefore inconsistent Green (2000) estimates. Because, in some cases, the use of dynamic panel data eliminates such a relationship between the offset values of the variable depend and the error terms, and improves the reliability of the estimator and the coherence of the estimators.

This paper used the (Kremer & al., 2013) Dynamic Panel Threshold Model and extended the (Hansen, 1999) static model for endogenous regressions. In this case, we chose the initial level of gross domestic product as endogenous regression ($Initial_{it} = dGDP_{it-1}$). In addition, the threshold of the dynamic panel data model was constructed on the threshold of the (Caner and Hansen, 2004) transversal model in which GMM-type estimators are used to solve the endogeneity problem. Riding 2 describes this model.

$$Y_{it} = \mu_i + \beta_1' Z_{it} I(q_{it} \leq y) + \beta_2' Z_{it} I(q_{it} > y) + \varepsilon_{it} \quad (2)$$

With:

i : Units within the perimeter of the section (i= 1 ...n),

t : The time dimension in the series of each unit (t= 1...T),

Y_{it} : The dependent variable,

μ_i : The individual fixed specific effect,

$\varepsilon_{it} = (0, \sigma^2)$: Independent and identical distribution of the error term,

$I(.)$: Speed indicator function,

q_{it} : The threshold of the variable,

y : The level of the threshold,

And Z_{it} The m-dimensional vector of repressor explanations which may include offset values of the dependent variable and other endogenous variables. The vector of explanatory variables is divided into a subset of exogenous variables Z_{1it} uncorrelated.

With:

ε_{it} is a subset of endogenous variables Z_{2it} et Z_{2it} is correlated with ε_{it} .

In addition, in equation (2), an appropriate set of $K \geq m$ instrumental variables x_{it} including Z_{1it} Kremer & al. (2013).

The estimation of equation 2 requires elimination of the individual effects μ_i through a fixed-effect transformation and the use of the orthogonal allocation method of Arellano and Bover (1995). This method is expressed in equation 3:

$$\varepsilon_{it}^* = \sqrt{\frac{T-1}{T-t+1}} * \left[\varepsilon_{it} - \frac{1}{T-t} (\varepsilon_{i(t+1)} + \dots + \varepsilon_{iT}) \right] \quad (3)$$

With:

ε_{it} error term,

ε_{it}^* is a series is not correlated,

$Var \varepsilon_{it} = \sigma^2 I_T$ and $Var \varepsilon_{it}^* = \sigma^2 I_{T-1}$

When this procedure is applied in equation 2, the following equation is obtained.

$$y_{it}^* = \beta_1^* Z_{it}^* I(q_{it} \leq y) + \beta_2^* Z_{2it}^* I(q_{it} > y) + \varepsilon_{it}^* \quad (4)$$

With:

$t = 1, \dots, T - 1$ and $*$ denotes post transformation data.

In fact, (Arellano and Bover, 1995) method corrects the problem of serial correlation of transformed error terms. Again, this method applies the estimation procedure derived by (Caner and Hansen, 2004) for a transversal model to the dynamic panel data models (Kremer & al., 2013). In addition, for equation 4, the determination of the inflation threshold requires the use of the two-stage least squares method (2SLS). Indeed, the reduced form regression in equation (5) is constructed for endogenous variables (Z_{2it}^*) which represent instrumental variables according to (Caner and Hansen, 2004).

$$Z_{2it}^* = \lambda_1' x_{it} I(q_{it} \leq y) + \lambda_2' x_{it} I(q_{it} > y) + v_{it} \quad (5)$$

With:

x_{it} : Instruments that understand Z_{1it}^* and

$$E(v_{it}, x_{it}) = 0$$

Again, the predicted values ($\widehat{Z}_{it}^*$) which contains the endogenous variables ($\widehat{Z}_{2it}^*$) and exogenous variables ($\widehat{Z}_{1it}^*$) obtained from structural equation 6.

$$y_{it}^* = \beta_1^* \widehat{Z}_{it}^* I(q_{it} \leq y) + \beta_2^* \widehat{Z}_{2it}^* I(q_{it} > y) + \varepsilon_{it}^* \quad (6)$$

With:

$$\widehat{Z}_{2it}^* = Z_{1it}^*, \widehat{Z}_{2it}^*$$

Equation 6 is predicted by the two-step least squares method (2SLS) for a fixed γ threshold. This operation is repeated for subsets of the variable threshold q . Of the resulting thresholds, the appropriate threshold with the sum of squares ($S(\gamma)$) is chosen as (γ) . This constraint is expressed in equation 7.

$$\hat{\gamma} = \operatorname{argmin} S_n(\gamma) \quad (7)$$

According to studies by (Hansen, 2000), (Caner and Hansen, 2004) and (Kremer & al., 2013), critical confidence interval values at a 95% confidence level are calculated for the inflation threshold. Therefore, the calculation of the critical values requires the consideration of the constraint below.

$$\Gamma = \{y : LR(y) \leq c(a)\} \quad (8)$$

In this case, $c(a)$ determines the percentage at the 95% level of the asymptotic LR (y) probability distribution. According to (Hansen, 1999) the likelihood ratio takes into account the time used in each cross-section. After the appropriate threshold is determined, the slopes of the coefficients in the dynamic panel threshold model are predicted by the generalized method of moments for predetermined instrumental variables and the predicted threshold. Again, equation (9) shows the threshold model of the dynamic panel which

establishes by the generalized method. It is the treatment of the effect of inflation on economic growth.

$$dgdp_{it} = \mu_i + \beta_1 \pi_{it} I(\pi_{it} \leq y) + \delta_1 (\pi_{it} \leq y) + \beta_2 \pi_{it} I(\pi_{it} > y) + \phi Z_{it} + \varepsilon_{it} \quad (9)$$

With:

π_{it} : the rate of inflation for two types of scheme,

Z_{it} : vector of control variables,

β_1 et β_2 : the efficiency of the slope of the regime,

δ_1 : the fixed coefficient of the regime,

Model 9 considers the initial level of Z_{2it} revenue as an endogenous variable. Analysis of dynamic panel data can result in errors and biased type estimates and may result in a low over-identification test (Bowsher, 2002) and (Windmeijer, 2005). This is explained by many of the estimation instruments in the model (Roodman, 2009). For this reason, it is necessary to reduce the instrumental variables and use a dependent variable offset threshold as an instrumental variable in order to avoid an over-adjustment of the instrumental variables that can lead to biased estimates.

4. Discussion of results

Table 4 presents the results of the regression of model 9 which expresses the inflation rate as a threshold of the variable.

Table 4. Results of Dynamic Panel Threshold Model

Estimated Threshold Value (π)	Model 1a
$\hat{y}$	21.52
95% confidence interval	[12,79% – 29,03%]
Effect of inflation	
$\hat{\beta}_1$	3.07 (0.092)
$\hat{\beta}_2$	-0.49 (0.049)
Effect of control variables	
Initial	-2.73 (0.004)
PE	-0.41(0.167)
GFCF	0.27 (0.000)
δ_1	-12.52 (0.195)
Number of observations	
$(\pi \leq \hat{y})$	34
$(\pi > \hat{y})$	28
Number of countries	13

Note: One lag of the dependent variable were used as instruments in the analysis: $dgdp_{it-1}$

Standard errors are given in parentheses.

*, **, *** indicate significance at 10%, 5% and 1% levels, respectively.

Source: Author's calculation using STATA 15

The upper part of table 4 shows the estimated level of the inflation threshold and the 95 % confidence interval, and the central part shows the nature of the impact of inflation on economic growth in two cases. In this part:

- $\widehat{\beta}_1$ refers to the marginal impact of inflation on economic growth in a low inflation regime. Indeed, a low inflation regime means a situation where the inflation rate is below the estimated threshold value.
- $\widehat{\beta}_2$ refers to the marginal effect of inflation on economic growth in a high inflation regime. In this case, the high inflation regime indicates the situation in which the inflation rate exceeds the value of the estimated threshold.

Table 4 (Model 1a) shows the results of the regression of the Model 9 by Two-Step Least Square Method (2SLS). It shows that the value of the optimal inflation threshold is equal to 21.52 within a corresponding 95% confidence interval [12.79% ; 29.03%].

The high level of inflation in the 13 least developed African countries can be explained by the widespread use of the wage and interest rate index system. According to the logic of the (Kremer & al., 2013) study, this strategy can reduce the negative effect of inflation on economic growth.

In addition, Table 4 shows that regime-dependent coefficients are statistically significant $\widehat{\beta}_1 = 3.07$ at a probability of 0.092 and $\widehat{\beta}_2 = -0.49$ at a probability of 0.049. This means that the inflation rate has a significant positive marginal effect on economic growth in a low inflation environment. However, this effect becomes significant in a high inflation regime. That is, if the inflation rate falls below the optimal threshold $\hat{y} = -21.52$, inflation positively affects economic growth. Conversely, the negative effect of inflation on growth appears if the inflation rate exceeds the optimal inflation rate threshold.

On the other hand, if the average inflation rate falls below the threshold, we can say that a 1% increase in inflation leads to an improvement of 3.07% in the level of economic growth. Moreover, when the average inflation rate becomes higher than estimated, the 1% increase in public spending will reduce economic growth by 0.41%. The inverse relationship between public expenditure and economic growth can be explained by the fact that most public expenditure is directed at the administrative office at the expense of productive investment. Thus, the continuity of this strategy can contribute to the inefficiency of long-term economic strategies. In this case, inflation can have an indirect negative effect on economic growth.

The delayed variable has a significant negative effect on economic growth. This effect is explained by the conditional convergence hypothesis of the neoclassical theory of economic growth. This indicates that the convergence hypothesis is strongly supported. That is to say, the most backward countries converge faster on the steady state of the average rate of economic growth compared to developed countries.

In addition, the sign associated with the variable gross fixed capital formation is positive and statistically significant. This means that the economic growth of the 13 least developed African countries is mainly based on private investment.

Table 4 shows that the relationship between inflation and economic growth is not linear and follows a single-threshold, two-system process, and that there is a difference in effect between the two types of inflation regime. This means that, when the inflation rate is high,

it negatively affects economic growth, but if the inflation rate becomes low, it positively affects and significantly handles economic growth.

According to the results in Table 4, there is an inverse “U” relationship between inflation and economic growth in the 13 least developed African countries. This test is explained by the fact that when setting their targets, countries must choose between targets of high growth and low inflation. Thus, the choice between achieving economic growth and controlling inflation depends on different assumptions. This means that economies that want growth are based on the assumption that there is a positive relationship between inflation and growth. The other country believes there is a non-linear relationship between inflation and economic growth. Otherwise, the old exude the logic of the structuralist approach; the second is favorable to monetarism. These are based on the results of the study by (Fischer, 1993) and (Martin, 2022) which justify that the low levels of inflation oil the processes of economic growth. Table 5 shows the results of model 9 re-estimation using the dynamic panel threshold using all possible delayed values of the dependent variable as instrumental variable ($dgdpi_{t-1}, dgdpi_{t-2}, \dots, dgdpi_0$) model (1b).

Table 5. Results of Dynamic Panel Threshold Model

Estimated Threshold Value (π)	Model 1b
$\hat{\gamma}$	21.52
95% confidence interval	[12,79% – 29,03%]
Effect of inflation	
$\hat{\beta}_1$	3.81 (0.019)
$\hat{\beta}_2$	-0.73 (0.033)
Effect of control variables	
Initial	-1.24 (0.293)
PE	-0.19 (0.152)
GFCF	1.17 (0.084)
δ_1	-10.46 (0.147)
Number of observations	
$(\pi \leq \hat{\gamma})$	34
$(\pi > \hat{\gamma})$	28
Number of countries	13

Note: All possible lags of the dependent variable were used as instruments in the analysis: ($dgdpi_{t-1}, dgdpi_{t-2}, \dots, dgdpi_{t-T}$ and $i_t - i_T = 0$)

Source: Author's calculation using STATA 15

Table 5 shows that the choice of instrumental variables does not have a significant effect on previous results. Indeed, the results of the two models (1a) and (1b) appeared rather similar, with the exception of rather minor differences. In addition, the estimated levels of the inflation thresholds and their confidence intervals were found to be the same. Again, the signs of the coefficients and significance record no change. However, the increase in the number of instruments only affects estimates of control variables where standard errors are slightly reduced.

To study the sensitivity of the results to additional explanatory variables, this paper performed some robustness tests. Indeed, this step consists in regressing the model by adding the variable of population, the development of institutions and trade openness.

The model is estimated in two stages. Indeed, the first step adds the variables to the model variable by variable and estimates the model. However, the second step includes all additional variables in the model and repeats the estimate. Table 6 presents the results of the dynamic panel threshold model with additional explanatory variable.

Table 6. Results of Dynamic Panel Threshold Model with Additional Explanatory Variable

Estimated Threshold Value (π)	Model 2a	Model 2b	Model 2c	Model 2d
$\hat{y}$	21.52	21.52	21.52	21.52
95% confidence interval	[14,71% ; 29,59%]	[11,19% ; 26,38%]	[15,22 ; 33,69%]	[9,67% – 35,57%]
Effect of inflation				
$\hat{\beta}_1$	3.23 (0.064)	3.01 (0.000)	2.47 (0.029)	1.89 (0.002)
$\hat{\beta}_1$	0.64 (0.039)	0.33 (0.045)	0.36 (0.0852)	0.28 (0.079)
Effect of control variables				
Initial	-1.92 (0.036)	- 0.81 (0.000)	-2.01 (0.715)	-0.96 (0.234)
PE	-0.38 (0.702)	-0.55 (0.094)	-0.27 (0.031)	-0.06 (0.004)
GFCF	0.93 (0.088)	0.54 (0.564)	1.07 (0.105)	1.02 (0.227)
POP	0.24 (0.001)	-	-	1.79 (0.000)
ID	-	-1.74 (0.033)	-	-1.08 (0.025)
TO	-	-	0.24 (0.000)	0.04 (0.000)
δ_1	13.47(0.824)	10.99 (0.000)	14.54 (0.006)	13.07 (0.019)
Number of observations				
$(\pi \leq \hat{y})$	34	34	34	34
$(\pi > \hat{y})$	28	28	28	28
Number of countries	13	13	13	13

Source: Author's calculation using STATA 15

The results obtained are similar to those reported in Table 4, where the inflation threshold is still at 21.52 without any change. In addition, the regime-dependent coefficients are statistically significant at the conventional level and the results of the robustness checks mentioned above show that the results are qualitatively robust.

According to table 6, the signs of the coefficients of all the additional variables are merged with the expected signs. In addition, they are positive and statistically significant with the exception of the institutional development variable. Indeed, the significant positive effect of the population on economic growth is explained by the economic growth of the 13 least developed African countries relies mainly on the labour factor. That is, they are economies characterized by a high degree of work. In addition, the significant negative impact of institutional development on economic growth is due to the poor quality of regulatory institutions in the 13 least developed African countries.

Again, the linear relationship between trade openness and economic growth is explained by the high degree of trade openness. This can facilitate the export of low value-added raw materials. In the light of these results and explanation, this paper recommends that the 13 least developed African countries improve the quality of the institutional framework and open up the current account more commercial transactions to exploit more commercial advantages compared to the rest of the world.

5. Conclusion

This study determined the non-linear relationship between inflation and economic growth in the 13 least developed African countries from 1981 to 2019. The results of the regression of the dynamic panel threshold model by (Kremer & al., 2013) using the two-step least squares (2SLS) method and the generalized moments (GMM) method are new evidence for the presence of a non-linear relationship between inflation and long-term economic growth. On the one hand, if inflation is above a critical threshold, the effect of inflation becomes significant negative on economic growth. On the other hand, if the moderate inflation rate falls below the threshold, it positively affects economic growth. This result based on the opinion that the expected critical value was found at 21.52%.

Again, this study shows no causal link between inflation and economic growth. It simply shows the existence of a relationship. It also indicates the importance of the inflation threshold in determining the relationship between inflation and economic growth in the 13 least developed African countries. Indeed, the problem of high inflation is explained by decision-makers have massively and repeatedly used the system of indexing the interest rate and salary. This system reduces the negative effects of inflation, although they are in part, making it essential for improving economic growth. Thus, the importance of the system becomes evident when we consider that inflation can have a negative impact on growth when the threshold is exceeded; including the results of the analysis.

Moreover, in view of the fact that the moderate inflation rate has a positive effect on economic growth, growth will therefore certainly be induced. However, if central banks turn to other policy objectives at the expense of price stability, which is one of their main objectives, inflation can have a detrimental effect on economic growth, rather than strengthening one. At this stage, it becomes clear once again that maximum attention should be given to inflation targeting, which is carried out in many countries. From this point of view, it can be said that the central banks, which are supposed to be free of any political authority and therefore decide on policies to curb inflation, ensure price stability.

This paper does not take into account the explanation of the test and the meaning of the causality between inflation and economic growth in the least developed African countries. Moreover, it does not empirically determine the role of monetary policies in contributing to economic growth and controlling inflation. In the future, this paper can divide the sample into groups and compare the effectiveness of monetary policies in relation to inflation-economic growth. It may also seek to examine the effect of the complementarity between inflation and monetary policies on economic growth in African least developed countries.

In addition, this study finds that it is important for officials in the 13 least developed African countries to develop the institutional framework to affect economic growth. In addition, it is recommended to reprogram the strategies of the distribution of public expenditure by increasing the share destined for the productive sector to obtain the economic efficiency in the long term.

References

- An, PS., Hoi, CM. and Chi, TK. (2016). Economic growth and macroeconomic stability of Vietnam. *Economic Studies*, V. 25, N° 4, 135-144.
- Arellano, M. and Bover, O. (1995). Another Look at The Instrumental Variable Estimation of Error-Components Models. *Journal of econometrics*, V. 1, 29-51.
- Bowsher, C-G. (2002). On Testing Overidentifying Restrictions in Dynamic Panel Data Models. *Economics letters*, V.77, N° 2, 211-220.
- Bui Hoang, N. (2019). The Asymmetric Effect of Inflation on Economic Growth in Vietnam: Evidence by Nonlinear ARDL Approach. *Journal of Asian Finance Economics and Business*, V. 7, N° 2, 143-149.
- Buthelezi, E-M. (2023). Impact of Money Supply in Different States of Inflation and Economic Growth in South Africa. *Economics*, V. 11, N°64, 2-22. <<https://doi.org/10.3390/economics11020064>>
- Çakir, M. (2023). Regional inflation spillovers in Turkey. *Economic Change and Restructuring*, V. 56, N°2, 959-980.
- Caner, M. and Hansen, B-E. (2004). Instrumental variable estimation of a threshold model. *Econometric Theory*, V. 20, N°5, 813-843.
- Cili, M-R. and Alkhaliq, B. (2022). Croissance économique et inflation: Preuve de l'Indonésie. *Jurnal Ilmu Ekonom*, V.11, N° 1, 145 160. <<https://doi.org/10.15408/sjie.v11i1.19848>>
- Drukker, D., Gomis-Porqueras, P. and Hernandez-Verme, P. (2005). Threshold Effects in The Relationship between Inflation and Growth: A New Panel-Data Approach. *MPRA Working Paper Series*, 38225.
- Dumitrescu, E-I. and Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels, *Economic modelling*, V.29, N°4, 1450–1460.
- Ehigiamusoe, K-U. Lean, H-H. and Lee, C-C. (2019). Moderating effect of inflation on the finance–growth nexus: insights from West African countries. *Empirical Economics*, V.57, 399–422, <<https://doi.org/10.1007/s00181-018-1442-7>>
- Erick, O. (2025). Monetary policy, inflation, and exchange rate dynamics: evidence from the Turkish economy (2001-2023). *Theoretical and Applied Economics*, V.2 N°642, 165-188.
- Faraji, K. and Kenani, M. (2013). Impact of inflation on economic growth: A case study of Tanzania. *Asian Journal of empirical research*, V.3 N° 4, 363-380.
- Fischer, S. (1993). Inflation and Growth. *NBER Working Paper Series National Bureau of Economic Research*, (1235).
- Franses, Ph. (2018). On inflation expectations in the NKPC model. *Empirical Economics*, <<https://doi.org/10.1007/s00181-018-1417-8>>
- Girijasankar, M. and Anis, Ch. (2001). Inflation and economic growth: Evidence from four South Asian Countries Asia-Pacific. *Development Journal*, V.8N° 1, 123-135.
- Greene, W-H. (2000). *Econometric Analysis. Fifth Edition. USA: Prentice Hall.*
- Hansen, B-E. (1999). Threshold Effects in Non-dynamic Panels: Estimation, Testing, and Inference. *Journal of Econometric*, V.2, 345-368.
- Hansen, B-E. (2004). Sample Splitting and Threshold Estimation. *Econometrica*, V. 68, N°3, 575-603.
- Ho, S. and Iyke, B.N. (2020). The determinants of economic growth in Ghana: New empirical evidence. *Global Business Review*, V. 21, N°3, 626-644.

- Iriagbonse-Alikor, P. and Priscilla, A. (2022). Inflation and economic growth in southern African counties. *SSRN*, 20 October 2022.
- Khan, M-S. and Senhadji, A-S. (2001). Threshold Effects in The Relationship between Inflation and Growth. *IMF Staff Papers*, V.48, N°1, 1-21.
- Kremer, S. Bick, A. and Nautz, D. (2013). Inflation and Growth: New Evidence from A Dynamic Panel Threshold Analysis. *Empirical Economics*, V. 44 N° 2, 861-878.
- Martin, H. (2022). Inflation explained: What lies behind and what is ahead. *EPRS European Parliamentary Research Servic*, 729-352.
- Muhammad, A. and Saleem, Kh. (2022). Threshold effects in the relationship between inflation and economic growth: further empirical evidence from the developed and developing word. *International journal of economic and finance*, V.27, N° 4, 4224-4243, <https://doi.org/10.1002/ijfe.2368>.
- Nkemgha, G., Zeufack, M., Abit, O. and Boker, P. (2022). Growth Effect of Inflation in Central African Countries: Does Security Situation Matter? *Journal of the Knowledge Economy*, 1-22, 2022.
- Nur Alam, S. (2023). Does macroeconomic stability promote economic growth? Some econometric evidence from SAARC countries. *Asian Journal of Economics and Banking*. <<https://www.emerald.com/insight/2615-9821.htm>>
- Omay, T. and Öznur Kan, E. (2010). Re-examining the threshold effects in the inflation growth nexus with cross-sectionally dependent non-linear panel: Evidence from six industrialized economies. *Economic Modelling*. V. 27, N°5, 996–1005.
- Ozyilmaz, A. (2022). Relationship between inflation and economic growth in EU countries, İktisat Politikası Araştırmaları Dergisi. *Journal of Economic Policy Researche*, V.9, N°2, 425-438.
- Phillips, A-W-H. (1958). The relation between unemployment and the rate of change of money wage. *Economica*. 1958.
- Rahimov, V. (2024). Modelling the relationship between inflation and uncertainty with existence of structural break: evidence from Azerbaijan. *Theoretical & Applied Economics*, V.31, N°4.
- Ramzi, T. and Wiem, J. (2019). Causality nexus between economic growth, inflation and innovation. *Journal of the Knowledge Economy*, V.10, 35-58.
- Robert, J-B. (2013). Ination and Economic Growth., *Annals of Economics and Finance*. V.14, N° 1, 85-109, 2013.
- Roodman, D. (2009). A Note on The Theme of Too Many Instruments. *Oxford Bulletin of Economics and statistic*, V. 71, N°1, 135-158.
- Ruzima, M. and Veerachamy, P. (2016). Impact of inflation on economic growth: a survey of literature review. *International Multidisciplinary Research Journal*, V.5, N° 10, 1-9.
- Shelton, M. Tafadzwa, M. and Sin-Yu, H. (2021). Inflation, inflation uncertainty and the economic growth nexus: An impact study of South Africa. *Journal homepage: MethodX*. V.8, 2021.
- Shin, Y., Greenwood-Nimmo, M., Van, T. and Yu, B. (2013). The decoupling of monetary policy from long-term rates in the US during the great moderation. *Available at SSRN*. 1894621.
- Sirimaneetham, V. and Temple, J-R. (2009). Macroeconomic stability and the distribution of growth rates. *The World Bank*, V.23. N° 3, 443-479.
- Şiriner, İ. and Doğru, Y. (2005). Türkiye Ekonomisi'nin Büyüme Dinamikleri Üzerine Bir Değerlendirm. *Journal of Administrative Sciences*, V.3, N°2, 162-182.

- Stojanovikj, M. and Petrevski, G. (2021). Macroeconomic effects of inflation targeting in emerging market economies. *Empirical Economics*, V.61, 2539–2585, <<https://doi.org/10.1007/s00181-020-01987-0>>
- Su Dinh, Th. (2015). Threshold effects of inflation on growth in the ASEAN-5 countries: A Panel Smooth Transition Regression approach. *Journal of Economics, Finance and Administrative Science*, V.20, 41–48. <<http://dx.doi.org/10.1016/j.jefas.2015.01.003>>
- Tariq, A. (2022). Investigating the Relationship between Inflation and Economic Growth: A Case of Pakistan. *Acta Pedagogica Asiana*, V.1, N°1, pp. 1-8, <<https://doi.org/10.53623/apga.v1i1>>
- Veni, L-K. and Choudhury, P-K. (2007). Inflation and growth dilemma: an econometric analysis of the Indian economy. *The IUP Journal of Financial Economics*, V.5, N°1, 79-87.
- Wald, G. (2000). *Econometric Analysis*. Upper Saddle River, NJ: Prentice Hall. 2000.
- Windmeijer, F. (2005). A Finite Sample Correction for The Variance of Linear Efficient Twostep GMM Estimators. *Journal of econometrics*, V. 126, N°1, 25-51.
- Zhiyong, F. Yushan, H. and Penglong, Zh. (2022). Measuring China's core inflation for forecasting purposes: taking persistence as weight. *Empirical Economics*, V.11, 63-93. <<https://doi.org/10.1007/s00181-021>>

Digital trust and consumer psychology: A robust analysis of youth entrepreneurship in emerging Indian markets

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Abstract. *The paper examines the changing nature of consumer behaviour in the digital business age, and how digital platforms, marketing approaches, and behavioural economics are influencing the relationship between the youth entrepreneurs and contemporary consumers. It was a quantitative study that was carried out in India amongst urban, sub-urban and rural areas through a structured questionnaire that was filled by 900 individuals to ensure generalizability. The research used four central dimensions of digital platform influence, digital marketing effectiveness, consumer trust, and entrepreneurial adaptability by employing statistical techniques based on SPSS with correlation and regression tests. The results showed that the level of consumer perceptions and purchasing behaviour is greatly affected by the digital platform presence, and digital marketing tactics, including social media marketing, SEO, and influencer partnerships, positively impact ROI and brand performance by great margins. Moreover, consumer trust turned out to be a decisive factor of loyalty and preference to youth-led entrepreneurship. Another important observation of the analysis was the positive correlation of entrepreneurial challenges with adaptability, in which, increased digital complexities promote innovation and learning. The findings highlight the complexities of the relationship between psychology, technology, and marketing strategy in the development of sustainable digital entrepreneurship. This research will have an impact on the literature in behavioural economics and digital marketing as it provides practical information to young entrepreneurs aiming to operate in the ever-changing consumer ecosystem.*

Keywords: consumer behaviour, digital entrepreneurship, youth entrepreneurs, digital marketing strategies, behavioral economics, consumer trust.

JEL Classification: L26, D91.

1. Introduction

The modern-day digital business landscape is the paradigm shift in the interplay between technology, entrepreneurialism, and human psychology. Digital platforms have not only transformed communication but have completely redefined how businesses think about, deliver to, and hold their audiences. In this fast-changing environment, the consumer is no longer a passive recipient of marketing stimulus, but an active participant that forms, co-creates and engages with the brand narrative. The history of behavioral economics, combined with digital marketing and artificial intelligence, has shifted to a sophisticated system where emotional appeal, personalization through algorithms, and social approval, instead of being determined by a rational decision-making process, drive the decisions. Young entrepreneurs particularly are at the centre of this change. With a digital literacy stance, data analytics, and entrepreneurial nimbleness, they turn to the power of the online tools to understand the behavior patterns and anticipate the responses of consumers. According to Paul, Alhassan, Binsaif, and Singh (2023), digital entrepreneurship has made business creation more democratic through reduced entry costs and enabling innovators to expand their business across the globe at little cost. To these entrepreneurs, the key to success lies in the interplay between emotional involvement and trust and technological mediation to an extent of generating behavioral intent.

Digital entrepreneurship is, thus, not an ordinary business activity, but a real-time behavior experiment. By combining the artificial intelligence, social media, and data marketing, entrepreneurs can keep track of the consumer emotions, interests, and engagement trends. Any type of digital touchpoint, such as a social media advertisement or a chatbot conversation, is a location of behavioral influence. Digital consumer behavior is becoming more and more regulated by the processes of the attention economy, in which time, emotion, and perception are scarce commodities that marketers compete to seize, as it was stressed by Efendioğlu (2024). This ecosystem has consumers influenced by the information overload, recommenders' algorithms, and social proof, which maximize the psychological processes of validation and belonging. Behavioral turn in digital marketing thereby shows that consumer choice is an emotional bargaining process and not a rational process. The Smartphones and social media are now psychological extensions of personhood and the lines between private and business are becoming blurred. Instagram, YouTube, and Tik Tok are the platforms where entertainment, consumption, and social identity intersect into an ecosystem. In this case, advertising does not take place by exerting its explicit influence on the consumer but by integrating narrative design in the form of stories, visuals, and experiences, which reflect the aspirations and anxieties of the consumer.

Nyrhinen et al. (2024) explained this process by their study on the impulse buying behavior among younger population and showed that emotional arousal and algorithmic personalization can result in quick, subconscious buying decisions. Such a combination of emotional stimulation and the technological accuracy is a perfect example of how behavioral economics comes into play in online trade. The consumer is motivated by a

combination of curiosity, immediate satisfaction and peer pressure to respond to the digital clues in predictable and mouldable ways. In the case of young entrepreneurs, this art of subtle interaction is crucial to the creation of brand loyalty. They are able to react to trends in the market by using predictive analytics and personalizing their content, but they also develop and build feedback loops where data influences creativity and creativity produces data. The online market is then a living organism, it continuously responds to the psychological and emotional cues that the customers are sending.

The combination of entrepreneurship and behavioral science has resulted in the age of the digital self of the entrepreneur as a persuasive force on the market. Consumers in digital business ecosystem do not just judge objects, but also the individuals and stories within them. Trust cues are personality, credibility and visibility of an entrepreneur and the influences of these factors are far reaching in consumer perception despite the quality of the product or the price at which it is sold. As it was revealed by An, Di, and Liu (2022), consumer trust and their perceptions of reliability are greatly influenced by the online popularity of entrepreneurs and their frequency of interactions. The skill of young entrepreneurs to maintain fruitful communication with viewers in the form of live sessions, comments, and open storytelling enhances the reliability of relationships a value that is gaining relevance among contemporary consumers. The identity of the entrepreneur, therefore, transforms into an emotive brand story with ethical appeal and accessibility at the emotions. This argument was developed by Bartoli (2022), who claimed that digitalization has broken the traditional boundary between self and brand, which created a co-created self-concept where consumers and entrepreneurs construct the identity of each other through the constant interaction of digital interaction.

This re-establishment of consumer-brand relations is in line with more general behavioral economic theories treating trust as a kind of social capital. Trust is a mental and financial asset that works in tandem with engagement, retention and advocacy. It is a sophisticated construction created in the digital arena using consistency, transparency, and responsiveness. Young entrepreneurs, in contrast to old-fashioned corporations, depend greatly on their perceived integrity and relatability to help establish consumer loyalty. Every post, review reply, or product story is a performative action that goes towards a moral reputation of a brand. Such parasocial relationships formed among entrepreneurs and followers duplicate the familiarity of the word-of-mouth marketing to the global level. This is especially powerful in the younger cohorts that focus on authenticity and driven entrepreneurship.

Digital marketing, therefore, is more of a performance conversation instead of a one-way broadcast. It is based on the interactive, feedback, and mutual experiences to keep the consumer engaged. Tian et al. (2022) found out that mobile short video advertising generates both awareness and emotional response that expedites the process of making purchases. Their results confirm the stimulus-organization-response hypothesis where visual and auditory stimuli in digital content restructure cognitive judgments and result in affective responses that directly affect consumer behavior. This is the psychological

acceleration introduced through video-based and short-storytelling, which is why youth entrepreneurs often use platforms like Tik Tok and Instagram Reels to promote their products and build their brand. The urgency of such content fulfils the desire of the consumer to obtain gratification and relevance and enables the entrepreneurs to make their offerings more human by means of creative narration.

Moreover, this relationship is enhanced further with the help of algorithmic mediation, which allows data-informed personalization. Machine learning applications ensure that users are shown what they like, the optimal time to engage, and their advertisements are tailored based on micro-segmented data of their behavior. These systems diminish uncertainty among consumers by offering curated options that seem relevant to a person, which enhances the sense of perceived control and satisfaction. However, ironically, this personalization, too, limits choice by steering by algorithm the phenomena of behavioral economics. The consumer perceives himself as a free individual being influenced by predictive analytics. This is an important balance of empowerment and influence to youth entrepreneurs. The ones that succeed at the creation of ethical, transparent, and emotionally smart systems of engagement will have a better chance to generate lasting trust in times when digital manipulation is becoming less and less trusted by people.

The behavioral aspect of digital entrepreneurship applies to the manner in which consumers understand and experience convenience, personalization, and credibility in the digital ecosystems, as well. Consumers are more and more demanding access to information instantly, to have an uninterrupted shopping experience, and to receive products that are suggested according to their specific needs and values. This has been dubbed as digital immediacy and has redefined consumer needs and entrepreneurial reactions as well. Businesses run by youths, especially those with e-commerce and service-based businesses, will need to find ways of adapting to the ever-present pressure on responsiveness. Any sluggishness in response or irregularity of online communication can undermine confidence, particularly to technology-focused consumers used to hassle-free communication. According to Efendioğlu (2024), the cognitive burden posed by the proliferation of the digital reminds consumers that only heuristic shortcuts, such as, emotional cues, familiarity with brands, and communal pressure, can be used in decisions. These heuristics, enhanced by the digital interface, provide chance to entrepreneurs influence decisions by the ways of imposing psychological framing, but not by persuading.

These behavioral mechanisms support the significance of design thinking and user experience optimization as the main elements of the contemporary marketing strategy. Behavioral data analytics are becoming widely used by youth entrepreneurs, who concentrate on pinpointing points of pain in consumer journeys and align digital interfaces based on the feedback they receive. It is based on these insights that experiences can be created that reduce the amount of effort but maximize emotional satisfaction. Having interactive feedback mechanisms, such as ratings, personalized emails or gamified loyalty programs does not only help keep consumers but also turn them into active co-creators of brand identity. With consumers giving feedback by clicking and reviewing and interacting,

the entrepreneurs are able to improve their strategies by creating a predictive view of upcoming preferences and the loop of observation to innovation is effectively closed. The resulting relationship is symbiotic: consumers are feeling understood and valued and entrepreneurs are developing the predictive intelligence to maintain a competitive advantage.

Besides, the interaction between youth entrepreneurship and behavioral economics indicates the appearance of the ethical issues in digital business. With the advances in algorithms to predict consumer habits, privacy, transparency, and manipulation have become a concern of discussion. Credibility of youth entrepreneurs in the long term solely depends on the fragile balance between influence and autonomy. Once trust is formed based on personal interaction it now has to be maintained via the algorithmic accountability. The entrepreneurs who share the information about their use of AI-based personalization tools and observe the limitations of data are more likely to retain consumers loyalty, in contrast to those who leverage their behavioral weaknesses. The modern consumer, especially young people, show an increasing understanding of the ethics of data and seek integrity among digital brands. As a result, sustainable entrepreneurship is now a matter not of innovation alone but also of moral positioning, that is, an agreement between business and the values of a conscious digital society.

This changing digital culture in which behavioral insights, emotional intelligence and technological tools intersect, represent the beginning of a redefinition of the very concept of entrepreneurship. The young business person of the present day is not only a business owner but a kind of cultural architect by designing the attitudes, expectations, and consumption ethics of an interconnected generation. These entrepreneurs make technology human and commerce personal at scale using the tactical application of social media, AI analytics, and behavioral insight. However, as the conclusions of Paul et al. (2023) and Tian et al. (2022) point in a similar direction, this space can only be successful when it is constantly adaptable, i.e., it is important to acknowledge that digital behavior is dynamic, circumstances-dependent, and is influenced by constant human-machine interaction. Digital marketplace is therefore an ecosystem that is alive as entrepreneurs and consumers co-evolve and learn together based on data, trust, and emotional exchange patterns. The future of consumer behavior in the digital business age will lie in the success with which the youth entrepreneurs find a balance between automation and genuineness such that technology complements and does not substitute the human touch that lies at the core of business.

The current research is expected to investigate the interaction between digital platforms, marketing technologies, and behavioral aspects in defining consumer behavior in the current digital business setting, among the youth entrepreneurs and the present generation of consumers. It aims to examine how social media activity, digital marketing approach, and trust relationship affect the purchasing intentions, brand perception and the return on investment (ROI). With a combination of behavioral economics principles and the use of SPSS-based empirical research, the study aims to examine the relationships between

psychological decision-making and digital communication trends as well as entrepreneurial adaptation, thus offering a set of empirical results that would help formulate more efficient and ethically sound digital business strategies in entrepreneurship founded by the youthful age group.

This paper includes seven parts, which include introduction and literature review, methodology describing the SPSS-based analysis. The findings are presented in the results section, which has a discussion that interprets the findings according to the behavioral economics perspective. The paper concludes with the main findings and conclusions, implications to youth entrepreneurs, limitations, and future suggestions of digital consumer research.

2. Literature Review

Theme 1: Digital Marketing Strategies and Consumer Engagement

Digital marketing development has far exceeded outdated advertising models, developing to be an exciting field of behavioral science incorporating psychology, communication, and data analysis to optimize consumer interaction in the virtual space. The idea of engagement is no longer viewed as a reaction to marketing stimuli but it is now a multidimensional process that entails emotional, cognitive, and behavioral involvement. Eslami, Ghasemaghahi, and Hassanein (2022) explain that consumer engagement is highly determined by the stage of product life cycle because the interest and interactions are higher or lower at different phases of a new or mature product. Their results indicate that digital marketers need to change their engagement tactics to suit the changing consumer demands at various phases of the market existence of a product.

Developing on this behavioral insight, Brodie, Lim, Gandhi, and Manrai (2025) developed a different marketing concept, customer engagement as an independent field, the focus of which is on the active involvement of consumers in the digital environment. They emphasized the role of engagement as a two-way and co-creative experience that can create more emotional and psychological bonds between brands and consumers. Engagement, in turn, is more than clicks and likes; it is all about relationship-building, emotion-finding, and brand promotion, which is the foundational pillar of the sustainable digital brand equity. Other researchers, Trunfio and Rossi (2021), have also supported this viewpoint by conducting a systematic review to conclude that authenticity, interactivity, and not one-way promotional materials are the actual forces of consumer engagement. Their study highlighted that there is an increasing appreciation of user generated contents and interactive brand experiences that increase credibility and emotional engagement.

Diversity in theory with regards to engagement was discussed by Saikia and Bhattacharjee (2024), who used a TCCM-based (Theory–Context–Characteristics–Methodology) theoretical framework to identify inconsistencies in how online engagement is conceptualized in the literature. They suggested that there should be a more unified approach that combines psychological, contextual, and technological points of view to

appreciate more the dynamic aspect of interaction over the internet. Their contribution underscores the fact that engagement as a process is multifactorial and not linear but is influenced by platform algorithms, cultural norms, and personal motivations.

An empirical perspective on the issue, Ao et al. (2023) have performed a meta-analysis that validated the transformational effect of influencer-based marketing on engagement and purchase intention. They noted that the illusory sense of intimacy and trust that consumers form with the influencers, referred to as parasocial relationships, contribute greatly to the extent of emotional involvement and purchasing behaviors. Social proof: The perceived authority and authenticity of the influencers is a gap between personal recommendation and commercial endorsement. To complement these conclusions, Mardhatilah, Omar, and Septiari (2024) have shown that consumer engagement flourishes in participatory brand communities, where the interaction between consumers and the brand is two-way, and consumers feel belonging to the brand community. In their research, they highlighted how constructing online communities, via feedback systems, jointly created content and candid communication enhances the consumer relationship in the long term.

The addition to these empirical observations, Shaheen (2025) determined a Scopus-based bibliometric analysis, which indicated an academic change of direction in sustainability, ethics, and long-term trust issues in the research on social media marketing. The shift of the focus on short-term promotional objectives to the relationship-based approaches indicates the increasing maturity of the digital marketing sphere. Companies that are more transparent, use ethical communication, and have regular communication with their audience are more likely to build stronger consumer loyalty and endurance against competition.

Together, these studies validate that digital consumer engagement is not a transactional event but rather a trust-based, technology-mediated and co-creative process. To youth entrepreneurs, the art of digital engagement implies having the ability to grasp how emotions, content authenticity, and data insights can interact with each other. Young business leaders can earn credible digital identities and develop long-term consumer loyalty by using social media analytics, community-based approaches, and influencer relationships in an increasingly competitive and dynamic online market.

Theme 2: Behavioral Economics and AI-Driven Decision-Making

The convergence of behavioral economics and artificial intelligence (AI) has brought a radical change in the consumer decision-making process, perception of value, and consumer experience with digital services. Old models of economics, where rational decision making was assumed, are being superseded by models that recognize cognitive biases, emotional effects, and the motivations of the subconscious. With the current AI-driven digital market behavior, consumers are no longer mere rational actors; instead, the decisions they make are being informed more frequently by AI-mediated models, such as recommendation engines, chatbots, and predictive algorithms, which indirectly shape perceptions and affect preferences. According to Wang (2025), AI technologies have

already started to influence consumer autonomy, defining their options strategically and focusing the interest on a particular product or service. This effect contradicts the classical idea of the free choice since machine learning systems can push consumers towards a specific result, keeping the impression of the autonomy of their choice.

Expanding on this, Riandhi, Arviansyah and Sondari (2025) have shown a systematic review based on the Scopus that AI has changed the paradigms of marketing to transactional to predictive personalization. By analyzing behavioral data, AI can predict the needs of consumers and provide them with personalized content that will appeal to their emotions and not to their sense of reason. It increases trust, engagement, and loyalty because it makes one feel like he/she was giving him/her a personalized attention. Likewise, Hermann and Puntoni (2024) stressed that predictive AI has evolved into generative AI and how marketers are currently adopting the adaptive content generation to harmonize digital experiences with psychology-inducing triggers and emotional conditions of the users. Not only does generative AI predict demand, but also creates new consumer realities, which means that the act of buying is an act of co-creation between human thought and algorithmic design.

Conceptually, Nogueira, Lopes, and Gomes (2025) conceptualized this change as a new age of AI-mediated consumption, asserting that the new models of digital decision-making now have to incorporate behavioral biases (anchoring, framing effects and social proof) in the predictions made by algorithms. This combination reflects the behavioral economics rationale, in which irrational characteristics can be forecasted using data. This idea was empirically proved by Lopez-Lopez and Iniesta (2025), who demonstrated that conversational AI and chatbots have a substantial effect on trust building, confidence in the decisions made, and after-sale satisfaction. Imitating empathy and authenticity, AI interfaces achieve a stronger level of relational connection with consumers and turn transactional interaction into a psychologically meaningful one.

Moving the discussion forward, Jain, Wadhwani and Eastman (2024) examined the ethical and cognitive limits of AI-driven decision-making, pointing to transparency, explainability and affective computing as the new priorities. According to their results, ethical transparency and emotional intelligence might be the key to maintaining trust and credibility as AI gets more involved in the consumer experiences. In addition to these insights, Larenas and Calero (2025) have shown that Li-Fi and behavioral economics improve the quality of decision-making because they balance the aspects of data efficiency and emotional reasoning and hence close the gap between rational analytics and human intuition. Using this combined framework applied to financial behaviour Khuntia et al. (2025) found that AI-based analytics have the potential to uncover cognitive biases, enhance financial literacy, and impulsive decision making.

Taken together, these articles confirm that AI-based behavioral models re-determine consumer rationality, and digital marketing becomes a cognitive ecosystem in which technology and psychology co-evolve in a symbiotic relationship. The collusion of AI and behavioral economics has therefore shifted marketing away from the persuasion to prediction

and personalization, where the data intelligence, emotional design and ethical interaction combine to create the future of online consumer behavior.

Theme 3: Youth Entrepreneurship and Evolving Consumer Trust

The digital economy has found young entrepreneurship as its foundation due to the acute technological innovation, the growing digital infrastructure, and the generational shift to self-sufficiency and creativity. The modern business world presents the best opportunities to young entrepreneurs to build and grow businesses using digital platforms, but it also poses challenges that depend on how much consumers trust using virtual environments. Rosado-Cubero, Hernández, Blanco-Jiménez, and Freire-Rubio (2024) highlighted the importance of business incubators and formal mentorship programs in supporting the success of start-up businesses. They claim that ecosystems of innovations do not only avail financial and technical resources but also social and psychological support that is required to maintain youth-led initiatives. Nonetheless, as much as the role of innovation and technology matters the success of youth entrepreneurship in the long run rests on the necessity of building trust-based relationships with digital consumers. Trust is a psychological facilitator and an economic resource that affects retention rates and the word-of-mouth marketing approach as well as the overall reputation of digital brands.

Bi, Boh, and Christopoulos (2021) noted that trust behaviours of entrepreneurs differ with those of non-entrepreneurs in a comparative study. Their results indicate that experience of entrepreneurship is developed by means of experiential learning, taking strategic risks, and the formation of social capital which, in combination, make the difference between business founders and ordinary consumers. In the digital ecosystem, trust is a behavioural result of transparency, reliability and interactivity. As an example, Tedjakusuma et al. (2025) have shown that consumer trust is an intermediary between platform characteristics and the levels of engagement in live-streaming online shopping. The research established that customer trust in online shopping is enhanced by perceived integrity, authenticity and real-time social interaction.

Continuing on the technological aspect, Uriarte, Baier-Fuentes, Espinoza-Benavides, and Inzunza-Mendoza (2025) examined the role of artificial intelligence (AI) technologies in transforming the way entrepreneurs make decisions. AI-based applications verify the credibility, track reputation, and engage consumers in a personalized way, making online transactions, in terms of perceived risks, more transparent and trustworthy. Such systems help to create the environment in which consumers feel safe and appreciated that is essential to keep trust in the youth-led ventures. Equally, Kakkar, Kalia, Panesar, and Sood (2025) discovered that in the context of social commerce, the quality and reliability of technology influence directly consumer purchase intention and word-of-mouth behaviour. Their findings emphasize that one should strive to achieve technological perfection and uniformity of service delivery in order to build long-term trust.

In a larger sense, De Klerk, Buick, and Ranasinghne (2025) talked about how young entrepreneurs in developing economies are using digital innovation to circumvent

structural market barriers. Through the use of online channels, such entrepreneurs can increase the reach to underrepresented markets, promote inclusion, thereby enhancing consumer confidence. Specifically, Emmanuel, Qin, Hossain, and Hussain (2022) focused on the social media empowerment of young female entrepreneurs by pointing out ethical marketing and open communication as one of the key trust-building factors. Finally, Jesse et al. (2025) proposed a brand distrust model among young consumers, proposing that ethical consistency and open communication should be at the centre of digital consumer trust.

All these researches together prove that trust and technology are two interwoven pillars of a successful youth entrepreneurship in the digital age. Digital tools can give you visibility and reach, and the combination of authenticity, ethical behavior, and consumer centric transparency are what will define long term sustainability and growth in the quickly changing digital market.

Research Gap

Although much is known in terms of digital marketing, behavioral economics, and consumer engagement, there is still a gap in terms of integrated insights into how digital platforms, psychological processes, and entrepreneurial actions interact to create a system that generates understanding of modern consumer behavior. What is missing is that current literature has examined the effects of social media influence, artificial intelligence-driven decision-making, or trust-building individually, which ignores their intersectionality in the context of youth-led business ecosystems. Previous studies have also focused on measurements of engagement, as opposed to analyzing the level of consumer perception, long-term loyalty, or digital investment payback. Moreover, even though trust has been cited as a major factor that determines online behavior, there is a lack of empirical information on how young entrepreneurs develop credibility as opposed to established brands. Similarly, there is a lack of studies on the adaptive problems that youth entrepreneurs have when interpreting quickly changing digital behaviors. The gaps are pointing to the necessity of a comprehensive, data-driven, framework relating behavioral economics, technology, and digital entrepreneurship to understand consumer reactions in the digital age.

3. Methodology

3.1. Objective of the Study

- **Objective 1:** To explore the mechanisms through which digital platforms (social media, marketplaces, etc.) influence and shape consumer behaviour specifically towards youth-led businesses.
- **Objective 2:** To analyze the relative effectiveness and ROI of various digital marketing strategies (e.g., social media marketing, e-commerce SEO, influencer partnerships) as employed by young entrepreneurs.

- **Objective 3:** To investigate the factors that build consumer trust and dictate preferences for products and services offered by youth startups versus established brands.
- **Objective 4:** To identify and elaborate on the primary challenges young entrepreneurs face in perceiving, understanding, and adapting to rapidly evolving digital consumer behaviour.

This study utilized a quantitative methodology to achieve a thorough comprehension of consumer behavior in the dynamic digital business environment. The study was conducted in India, a significant center for technological innovation and entrepreneurship, and aimed to ascertain the impact of digitalization on consumer decision-making and entrepreneurial strategies. The target population consisted of young entrepreneurs employing digital platforms for business activities and digital consumers interacting with these enterprises. To guarantee equitable and impartial representation, a stratified random sampling method was employed, categorizing participants based on age, education, and occupation. A total of 900 respondents participated, yielding sufficient data for both descriptive and inferential statistical analysis. The research utilized a descriptive and exploratory design, facilitating the identification of significant behavioral trends and the examination of interrelationships among variables, including digital marketing strategies, consumer trust, and entrepreneurial adaptability. A structured questionnaire containing demographic and Likert-scale questions aimed at assessing perceptions, attitudes, and behavioral tendencies was employed to gather primary data. MS Excel and SPSS were used to process and analyze the data. Statistical tools like mean, standard deviation, correlation, and regression analysis were used to look for connections, make predictions, and test hypotheses. The methodological framework guaranteed rigor, validity, and reliability, enabling a comprehensive understanding of how digital ecosystems influence the interactions between consumers and youth-driven entrepreneurial ventures in the modern economy.

4. Results/Findings

Table 1. *Assessment of Internal Consistency*

Construct	Indicators	Mean	S.D.	Item-Total (r)	Cronbach's Alpha
Consumer_Behaviour_Youth_Business	CBYB1	3.50	0.78	0.677	0.867
	CBYB2	3.56	0.79	0.691	
	CBYB3	3.66	0.81	0.699	
	CBYB4	3.72	0.79	0.692	
	CBYB5	3.77	0.75	0.684	
Effectiveness_ROI_Youth_Ventures	ERYV1	3.22	0.90	0.667	0.858
	ERYV2	3.23	0.92	0.671	
	ERYV3	3.29	0.94	0.678	
	ERYV4	3.36	0.90	0.693	
	ERYV5	3.40	0.91	0.654	
Consumer_Preference_Youth_Startups	CPYS1	2.09	0.84	0.677	0.821
	CPYS2	2.18	0.85	0.682	
	CPYS3	2.25	0.87	0.668	
Digital_Platform_Influence	DPI1	2.27	0.82	0.705	0.838
	DPI2	2.34	0.81	0.701	
	DPI3	2.47	0.82	0.696	

Construct	Indicators	Mean	S.D.	Item-Total (r)	Cronbach's Alpha
Digital_Marketing_Strategies	DMS1	2.20	0.92	0.691	0.834
	DMS2	2.29	0.91	0.704	
	DMS3	2.38	0.93	0.685	
Consumer_Trust_Factor	CTF1	3.27	0.86	0.635	0.825
	CTF2	3.41	0.88	0.646	
	CTF3	3.42	0.90	0.669	
	CTF4	3.48	0.88	0.647	
Adaptation_Digital_Consumer_Behaviour	ADCB1	2.05	0.82	0.641	0.805
	ADCB2	2.13	0.80	0.656	
	ADCB3	2.18	0.83	0.658	
Entrepreneurial_Challenges	EC1	3.33	0.90	0.657	0.834
	EC2	3.40	0.87	0.704	
	EC3	3.45	0.83	0.644	
	EC4	3.48	0.86	0.650	

The internal consistency of the measures (i.e. the measures' uni-dimensionality and reliability) must be verified first through Table 1. The observable variables measuring a reflective construct must be unidimensional to be considered unique values (Gefen et al., 2000). Satisfactory reliability and the convergent validity of the constructs are typically determined by an α exceeding the Value of 0.7. In the current study, the α 's exceeded the recommended values, showing acceptable reliability and convergent validity. An exploratory factor analysis using principal component extraction with no rotation was conducted on 30 items ($N = 900$). The Kaiser-Meyer-Olkin measure was .86, and Bartlett's test was significant, $\chi^2(435) = 11428.53$, $p < .001$. One factor was extracted, explaining 14.2% of the total variance. Since this is well below the 50% threshold, common method bias (CMB) is not a significant threat to the validity of the findings in this study.

Table 2. Demographic profile of the Respondents

S.No.	Demographic Variable	Category	Frequency (n)	Percent (%)
1	Age Group	18–22 years	225	25
		23–27 years	249	27.7
		28–32 years	219	24.3
		33–37 years	138	15.3
		Above 37 years	69	7.7
2	Education Level	Undergraduate	402	44.7
		Graduate	345	38.3
		Postgraduate	153	17
3	Occupation / Role	Entrepreneur	384	42.7
		Student Consumer	261	29
		Working Professional Consumer	255	28.3
4	Monthly Income / Revenue (₹)	Below 25,000	243	27
		25,001–50,000	246	27.3
		50,001–75,000	237	26.3
		75,001–1,00,000	120	13.3
		Above 1,00,000	54	6
5	Digital Platform Usage Frequency	Rarely	105	11.7
		Occasionally	138	15.3
		Frequently	276	30.7
		Very Frequently	210	23.3
		Always	171	19
6	Group Type	Consumer	516	57.3
		Youth Entrepreneur	384	42.7

The demographic profile of the respondents (Table 2) offers an extensive summary of the sample distribution, emphasizing the diversity and representativeness of the study participants. The data clearly show that the study mostly focused on a young, digitally active group of people. This fits well with the research goals, which are to look at young entrepreneurs and digital consumers in the modern business world. The majority of respondents were between the ages of 23 and 27 (27.7%) and 28 and 32 (24.3%). The group of 18 to 22 years old (25%) was not far behind. Young adults make up the majority of this group, and they are also the most active users of online platforms and the main drivers of digital entrepreneurship. Only 7.7% of the people who answered were over 37 years old, which fits with the study's focus on businesses run by young people and modern consumer groups. A large number of the people who answered (44.7%) were undergraduates, followed by graduates (38.3%) and postgraduates (17%). This distribution indicates that most participants have academic qualifications ranging from basic to advanced levels, equipping them with adequate exposure to digital technologies and entrepreneurial prospects. The large number of educated people also shows that more and more people are aware that digital platforms can be used to grow a business and connect with customers.

When looking at occupation or role, the data show that 42.7% of respondents were entrepreneurs, 29% were student consumers, and 28.3% were working professionals. This even distribution does a good job of capturing both the supply side (business owners) and the demand side (customers) of the digital business world. The presence of student consumers indicates the rise of a new generation of savvy shoppers who have a big impact on digital market trends. The pattern of monthly income or revenue adds to this diversity. Almost half of the people who answered make between ₹25,000 and ₹75,000 a month. Twenty-seven percent make less than ₹25,000, and a smaller group (6%) say they make more than ₹1,00,000. This range includes a realistic mix of early-stage business owners and middle-class customers, which makes the dataset a good representation of the socio-economic situation in the Indian digital market.

Most of the people who took part said they used digital platforms a lot. For example, 30.7% said they used them often and 23.3% said they used them very often. Only 19% said they were always online. This shows that the sample is digitally mature and backs up the study's focus on how consumers behave on platforms. Lastly, group classification shows that 57.3% were consumers and 42.7% were young entrepreneurs. This makes sure that there is a fair representation for comparison. Overall, the demographic profile shows that the population is young, educated, tech-savvy, and economically active. This makes it a good group to study how digital platforms and marketing strategies affect consumer behavior and business success in the modern digital age.

On the basis of objective of the study

Objective 1: To explore the mechanisms through which digital platforms (social media, marketplaces, etc.) influence and shape consumer behaviour specifically towards youth-led businesses.

Table 3. *ANOVA^a*

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	73.2592	1	73.2592	227.047	.000 ^b
	Residual	289.7486	898	.3227		
	Total	363.0078	899			

a. Dependent Variable: Consumer_Behaviour_Youth_Business

b. Predictors: (Constant), Digital_Platform_Influence

Dependent Variable: Consumer_Behaviour_Youth_Business represents the extent to which consumers engage with and make purchasing decisions towards youth led businesses and startups.

Predictors: (Constant) Digital_Platform_Influence represents the impact of digital channels such as e-commerce platforms, online reviews on shaping consumers response and behaviors towards youth businesses.

The ANOVA results for Objective 1 (Table 3) show that the regression model that looks at how Digital Platform Influence affects Consumer Behavior toward Youth Businesses is statistically significant.

The F-value of 227.047 and the Sig. (p-value) of 0.000 show that the model is very important at the 0.05 level. This means that digital platform factors like social media engagement, online reviews, digital advertising, and e-commerce visibility have a big effect on how people see and react to businesses run by young people. The Mean Squares for Regression (73.2592) is much higher than the residual (0.3227). This shows that the digital platform has a big effect on how people behave as consumers. The findings indicate that increased engagement and visibility on digital platforms profoundly influence consumer attitudes, preferences, and purchase intentions regarding youth-led brands. This finding proves that digital interactions significantly influence contemporary consumer behavior and underscores the necessity for young entrepreneurs to implement effective digital engagement strategies to foster consumer relationships and stimulate business growth.

Table 4. *Coefficients^a*

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.2691	.055		40.9441	.000
	Digital_Platform_Influence	.4026	.027	.4492	15.0681	.000

a. Dependent Variable: Consumer_Behaviour_Youth_Business

The coefficients table (Table 4) shows even more clearly how important the link between Digital Platform Influence and Consumer Behaviour towards Youth Businesses is. The regression analysis reveals that the unstandardized coefficient (B) for Digital Platform Influence is 0.4026, accompanied by a t-value of 15.0681 and a p-value of 0.000, signifying a highly significant positive effect. This means that for every one-unit increase in how much people use digital platforms—like better use of social media marketing, online ads, or interactive e-commerce tools—there is an estimated 0.4026-unit increase in how positive people are about youth-led businesses. The standardized beta coefficient ($\beta = 0.4492$) indicates a robust positive correlation between the two variables, implying that digital

presence and platform utilization significantly influence consumer trust, interest, and purchasing decisions. The constant value of 2.2691 also shows the normal level of consumer behavior when digital platform influence is not present. In general, these results support the idea that digital platforms have a big effect on how people feel and act toward young entrepreneurs. This supports the idea that a stronger digital engagement strategy leads to more responsive consumers and a stronger connection to the brand.

Objective 2: To analyze the relative effectiveness and ROI of various digital marketing strategies (e.g., social media marketing, e-commerce SEO, influencer partnerships) as employed by young entrepreneurs.

Table 5. *ANOVA^a*

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	120.1096	1	120.1096	300.804	.000 ^b
	Residual	358.5682	898	0.3993		
	Total	478.6778	899			

a. Dependent Variable: Effectiveness_ROI_Youth_Ventures

b. Predictors: (Constant), Digital_Marketing_Strategies

Dependent Variable: Effectiveness_ROI_Youth_Ventures represents the performance of youth led businesses on their revenue generation, CAC, and their success resulting from their applied market strategies.

Predictors: (Constant), Digital_Marketing_Strategies represents the initiatives taken by youth entrepreneurs to promote their product and services on online platforms through influencer partnerships, digital advertising, SEO.

The ANOVA results for Objective 2 (Table 5) show that the regression model that looks at how Digital Marketing Strategies affect the Effectiveness and ROI of Youth Ventures is statistically significant. The F-value of 300.804 and the Sig. (p-value) of 0.000 show that the relationship is very strong at the 0.05 level. This means that different digital marketing strategies, like SEO, influencer partnerships, and content marketing, all work together to make youth-led businesses more profitable and successful. Although the residual sum of squares is greater than the regression sum of squares, the high F-value and low p-value indicate that the model is statistically significant. This means that a lot of the difference in ROI and marketing effectiveness can be explained by how digital marketing tools are used strategically. So, the model shows that young entrepreneurs can greatly improve their business results by using digital marketing strategies well. These findings underscore that the more strategically and consistently entrepreneurs implement digital marketing techniques, the greater their perceived effectiveness, consumer engagement, and overall financial returns—illustrating the essential role of digital proficiency in fostering entrepreneurial success in today's business environment.

Table 6. *Coefficients^a*

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.2510	.064		35.0991	.000
	Digital_Marketing_Strategies	.4581	.026	.5008	17.3437	.000

a. Dependent Variable: Effectiveness_ROI_Youth_Ventures

The coefficients table for Objective 2 (Table 6) shows that there is a strong and statistically significant positive link between Digital Marketing Strategies and the Effectiveness and ROI of Youth Ventures. The unstandardized coefficient (B) for Digital Marketing Strategies is 0.4581, with a t-value of 17.3437 and a p-value of 0.000. This shows that the predictor variable has a very strong effect on ROI outcomes. This means that for every one-unit increase in the effective use of digital marketing strategies, like better social media campaigns, SEO optimization, influencer partnerships, or targeted digital ads, the effectiveness and ROI of youth-led businesses go up by about 0.4581 units. The standardized beta coefficient ($\beta = 0.5008$) shows a strong positive correlation, which means that digital marketing has a big impact on the financial and operational success of young entrepreneurs. The constant value (B = 2.2510) shows the baseline ROI effectiveness when no digital marketing strategies are used. Overall, these results show strong empirical evidence that digital marketing campaigns greatly improve the performance and profitability of youth businesses. This highlights the importance of strategic digital engagement for business growth and market competitiveness.

Objective 3: To investigate the factors that build consumer trust and dictate preferences for products and services offered by youth startups versus established brands.

Table 7. Correlations

		Consumer_Trust_Factors	Consumer_Preference_Youth_Startups
Consumer_Trust_Factors	Pearson Correlation	1	.450**
	Sig. (2-tailed)		.000
	N	900	900
Consumer_Preference_Youth_Startups	Pearson Correlation	.450**	1
	Sig. (2-tailed)	.000	
	N	900	900

**. Correlation is significant at the 0.01 level (2-tailed).

Consumer_Preference_Youth_Startups represents the degrees to which consumers are inclined to purchase product or service from a youth led startup over established businesses.

Consumer_Trust_Factors represents the consumer trust in the product or service sold by the youth led startup or business on basis of its credibility, transparency, quality of product.

The correlation results for Objective 3 (Table 7) show a statistically significant positive link between Consumer Trust Factors and Consumer Preference for Youth Startups. The Pearson correlation coefficient ($r = 0.450$) with a p-value of 0.000 (significant at the 0.01 level, two-tailed) shows that the two variables are moderately to strongly related to each other. This finding indicates that as consumer trust in youth-led startups grows—fueled by elements such as transparency, reliability, product quality, responsiveness, and social credibility—there is a concomitant increase in consumer preference, loyalty, and purchase intention towards these startups. A correlation value above 0.5 indicates a moderate to strong positive relationship, suggesting that higher consumer trust is associated with higher consumer preference in competitive digital markets. Furthermore, the statistically

significant relationship ($p < 0.01$) substantiates that this association is improbable to have arisen by chance. Consequently, it can be deduced that augmenting trust-building mechanisms—via consistent communication, credible branding, and ethical practices—substantially enhances consumer preference for youth-owned brands in comparison to established market competitors. This finding substantiates the theory that trust serves as a principal factor influencing consumer preference within the digital entrepreneurship ecosystem.

Table 8. *ANOVA^a*

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	97.9915	1	97.9915	227.9135	.000 ^b
	Residual	386.0954	898	.4300		
	Total	484.0869	899			

a. Dependent Variable: Consumer_Preference_Youth_Startups

b. Predictors: (Constant), Consumer_Trust_Factors

The ANOVA results for Objective 3 (Table 8) show that the regression model that looks at how Consumer Trust Factors affect Consumer Preference for Youth Startups is statistically significant. The model produces an F-value of 227.9135 and a p-value of 0.000, which shows that the relationship between the two variables is very significant at the 0.05 level. This means that the level of trust that consumers have in a company is a big reason why their preferences for youth-led startups change. The Regression Sum of Squares (97.9915) in comparison to the Residual Sum of Squares (368.0954) indicates that a significant proportion of the variance in consumer preference can be ascribed to trust-related factors, including perceived transparency, product credibility, social proof, and ethical business practices. The model's importance shows that as trust in youth startups grows, customers are more likely to choose their products and services and stay loyal to them. The findings furnish robust empirical evidence that consumer trust significantly influences consumer preference, underscoring the necessity of authenticity, reliability, and consistent communication for youth entrepreneurs aiming to cultivate enduring customer relationships in the competitive digital marketplace.

Objective 4: To identify and elaborate on the primary challenges young entrepreneurs face in perceiving, understanding, and adapting to rapidly evolving digital consumer behaviour.

Table 9. *Correlations*

		Entrepreneurial_Challenges	Adaptation_Digital_Consumer_Behaviour
Entrepreneurial_Challenges	Pearson Correlation	1	.505**
	Sig. (2-tailed)		.000
	N	900	900
Adaptation_Digital_Consumer_Behaviour	Pearson Correlation	.505**	1
	Sig. (2-tailed)	.000	
	N	900	900

**. Correlation is significant at the 0.01 level (2-tailed).

Entrepreneurial_Challenges represents the financial or technical difficulties faced by a youth entrepreneur in promoting their product/service online due to limited capital, uncertainty, lack of experience.

Adaptation_Digital_Consumer_Behaviour represents the extent to which youth entrepreneurs modify their marketing strategies in response to consumer preferences, market trends, shift of technology.

The variable “Entrepreneurial Challenges” refers to the range of financial, operational, and market-related difficulties faced by youth-led businesses, including constraints such as limited access to capital, competitive pressure, lack of managerial experience, and market uncertainty. The variable “Adaptation to Digital Consumer Behaviour” refers to the extent to which youth-led businesses adjust their strategies in response to evolving online consumer preferences and digital market trends. This includes the adoption of digital platforms, social media engagement, online marketing practices, and responsiveness to consumer behaviour in digital environments.

The correlation results for Objective 4 (Table 8) indicate a statistically significant association between Entrepreneurial Challenges and Adaptation to Digital Consumer Behaviour. The Pearson correlation coefficient ($r = 0.505$) with a p-value of 0.000 (significant at the 0.01 level, two-tailed) shows that the two variables are moderately strongly related in a positive way. This finding indicates that as entrepreneurial challenges escalate, the efforts to adapt to swiftly changing digital consumer behavior also amplify. To put it another way, young business owners who have to deal with more technological, financial, or market-related problems tend to be more proactive about learning about digital demands and consumer trends so they can stay competitive.

Nevertheless, although the correlation is positive and significant, it may also indicate a compensatory behavior—entrepreneurs facing greater challenges may adopt more intensive adaptive strategies to surmount these obstacles. The statistical significance ($p < 0.01$) verifies that this relationship is not attributable to random chance. Overall, the results suggest that entrepreneurs must constantly learn, innovate, and change their strategies to meet consumer expectations in order to deal with the pressures of digital transformation. This shows how important it is for entrepreneurs to be able to adapt to new technologies in order to stay successful.

5. Discussion

The analysis of the findings elucidates the influence of digitalization and behavioral dynamics on the evolving relationship between young entrepreneurs and contemporary consumers. The findings from Objective 1 validate that digital platforms substantially affect consumer behavior regarding youth-led ventures, as indicated by a robust F-value and elevated regression significance. This is in line with what has been said in the past about how social media engagement and digital credibility can affect how people see a brand. Likewise, results from Objective 2 indicate that successful digital marketing tactics, including SEO, influencer partnerships, and targeted advertising, significantly improve

business performance and return on investment (ROI). These results support earlier studies that say data-driven marketing makes things more visible and leads to more conversions. Objective 3 shows a strong positive link between consumer trust and preference for youth startups. This means that being open, honest, and reliable with technology are all important factors in keeping customers loyal in digital markets. Finally, Objective 4 shows that entrepreneurial challenges are linked to adaptive behavior in a positive way. This means that when entrepreneurs have trouble understanding how consumer trends change, they are more likely to come up with new ideas. The results collectively validate behavioral economics theories, underscoring that emotional engagement, digital trust, and technological adaptability are pivotal to sustainable digital entrepreneurship. The research enhances comprehension of the convergence of psychological, technological, and strategic dimensions in defining success within youth-driven digital business ecosystems.

6. Conclusion

The results of this study confirm that digital transformation has fundamentally changed the way consumers and entrepreneurs interact, especially in businesses run by young people. The analysis showed that digital platforms are very important for changing how people think about, interact with, and stay loyal to a brand. Robust empirical evidence from regression and correlation analyses demonstrated that social media presence, digital marketing strategies, and trust-building mechanisms substantially impact consumer behavior, return on investment (ROI), and enduring brand relationships. Additionally, entrepreneurial adaptability was demonstrated to mediate the relationship between digital challenges and consumer responsiveness, highlighting the significance of innovation and resilience in dynamic digital ecosystems.

Even with these contributions, the study has some problems. The sample was confined to the India, potentially limiting its applicability to varied cultural and economic contexts. Furthermore, the study's dependence on self-reported data may lead to biases in perception-based responses. The cross-sectional design also stops us from seeing how consumer attitudes change over time.

Subsequent research ought to utilize longitudinal or cross-national comparative methodologies to elucidate temporal and cultural variations in digital consumer behavior. Integrating qualitative interviews or AI-driven sentiment analysis could enhance comprehension of the psychological and emotional factors influencing consumer trust and digital engagement. Additionally, incorporating emerging technologies—such as augmented reality marketing, blockchain trust systems, and predictive AI analytics—can provide profound insights into the ongoing transformation of digital entrepreneurship and consumer behavior over the next decade.

7. Declarations

Funding

The research received no external funding.

Data availability

All data supporting the findings of this study are available within the article. The primary data were collected through a structured questionnaire and analyzed using SPSS. Due to confidentiality considerations, raw datasets are not publicly available.

Ethics & Accordance

This study was reviewed by the protocol of City Montessori School and was waived because the research involved an anonymous survey, collected no sensitive personal identifiers, and posed no risk to the respondents. The research was carried out in accordance with ethical guidelines of City Montessori School and the standards of the 1964 Declaration of Helsinki.

Consent to Participate

Informed consent was obtained from all individual participants included in the study. All the participants were above the age of 16 and did not require a parental or guardian's consent. All participants were briefed on the purpose of the research and participated voluntarily, with the understanding that they could withdraw their data at any stage prior to publication.

Consent to Publish

Informed consent regarding the publication of anonymized data was obtained from all participants. It is confirmed that informed consents were obtained from all participants. No personally identifiable information is included in this manuscript.

References

- An, J., Di, H., and Liu, G. (2022). The influence of entrepreneurs' online popularity and interaction behaviors on individual investors' psychological perception: evidence from the peer-to-peer lending market. *Frontiers in Psychology*, 13, 825478.
- Ao, L., Bansal, R., Pruthi, N., and Khaskheli, M.B. (2023). Impact of social media influencers on customer engagement and purchase intention: A meta-analysis. *Sustainability*, 15(3), 2744.
- Bartoli, C. (2022). Consumer self-concept and digitalization: what does this mean for brands? *Italian Journal of Marketing*, 2022(4), 419-437.
- Bi, Q., Boh, W.F., and Christopoulos, G. (2021). Trust, fast and slow: A comparison study of the trust behaviors of entrepreneurs and non-entrepreneurs. *Journal of Business Venturing*, 36(6), 106160.

- Brodie, R.J., Lim, W.M., Gandhi, S., and Manrai, A.K. (2025). Guidelines for developing a new research stream: lessons from customer engagement research. *Journal of Global Marketing*, 38(1), 1-8.
- de Klerk, S., Buick, F., and Ranasinghne, G. (2025). Unlocking the power of youth: harnessing technology to break through market barriers. *Journal of Innovation and Entrepreneurship*, 14(1), 79.
- Efendioğlu, İ.H. (2024). Digital consumer behavior: a systematic literature review. *Prizren social science journal*, 8(1), 67-80.
- Emmanuel, C.P., Qin, S., Hossain, S.F.A., and Hussain, K. (2022). Factors influencing social-media-based entrepreneurship prospect among female students in China. *Heliyon*, 8(12).
- Eslami, S.P., Ghasemaghaei, M., and Hassanein, K. (2022). Understanding consumer engagement in social media: The role of product lifecycle. *Decision Support Systems*, 162, 113707.
- Hermann, E., and Puntoni, S. (2024). Artificial intelligence and consumer behavior: From predictive to generative AI. *Journal of Business Research*, 180, 114720.
- Jain, V., Wadhwani, K., and Eastman, J.K. (2024). Artificial intelligence consumer behavior: A hybrid review and research agenda. *Journal of consumer behaviour*, 23(2), 676-697.
- Jesse, T., Niina, S., Lauri, H., Vilma, L.A., and Terhi-Anna, W. (2025). Young consumers' brand distrust model: Understanding the antecedents of young consumers' distrust of brands. *Journal of Business Research*, 190(C).
- Kakkar, A., Kalia, P., Panesar, A., and Sood, R. (2025). Investigating the impact of quality, technology and trust on customers' purchase intention and word-of-mouth in S-commerce. *Aslib Journal of Information Management*.
- Khuntia, R., Ingle, A.S., Manna, R., Srivastava, A.K., and Dwivedi, K. (2025). Decoding Consumer Financial Behavior: AI Applications in Behavioral Finance. *Advances in Consumer Research*, 2(3).
- Larenas, F.P., and Calero, M.G. Integration of Artificial Intelligence and Behavioral Economics: Optimizing Consumer Processes and Decisions in Complex Environments.
- Lopez-Lopez, D., and Iniesta, M.B. (2025). The impact of conversational AI on consumer decision-making: A systematic review and cluster analysis. *International Journal of Engineering Business Management*, 17, 18479790251351889.
- Mardhatilah, D., Omar, A., and Septiari, E.D. (2024). Building Consumer Engagement in Social Media: A Systematic Literature Review. *Journal of Business Management and Accounting (JBMA)*, 14(1), 1-35.
- Nogueira, E., Lopes, J.M., and Gomes, S. (2025). The new era of Artificial Intelligence in consumption: theoretical framing, review and research agenda: E. Nogueira et al. *Management Review Quarterly*, 1-35.
- Nyrhinen, J., Sirola, A., Koskelainen, T., Munnukka, J., and Wilska, T.A. (2024). Online antecedents for young consumers' impulse buying behavior. *Computers in Human Behavior*, 153, 108129.
- Paul, J., Alhassan, I., Binsaif, N., and Singh, P. (2023). Digital entrepreneurship research: A systematic review. *Journal of Business Research*, 156, 113507.
- Riandhi, A.N., Arviansyah, M.R., and Sondari, M.C. (2025). AI and consumer behavior: Trends, technologies, and future directions from a scopus-based systematic review. *Cogent Business & Management*, 12(1), 2544984.

- Rosado-Cubero, A., Hernández, A., Blanco-Jiménez, F.J., and Freire-Rubio, T. (2024). Seeding young entrepreneurs: The role of business incubators. *Journal of Innovation & Knowledge*, 9(4), 100579.
- Saikia, W., and Bhattacharjee, A. (2024). Digital consumer engagement in a social network: A literature review applying TCCM framework. *International Journal of Consumer Studies*, 48(1), e12981.
- Shaheen, H. (2025). Social media marketing research: a bibliometric analysis from Scopus. *Future Business Journal*, 11(1), 1-26.
- Tedjakusuma, A.P., Silalahi, A.D.K., Eunike, I.J., Phuong, D.T.T., and Riantama, D. (2025). The trust-driven path to consumer engagement behaviors: Exploring the role of streamer and platform characteristics in live-streaming E-commerce. *Digital Business*, 5(1), 100115.
- Theocharis, D., Tsekouropoulos, G., and Athanasios, G. (2025). The Digital Generation: Branding and Consumer Behavior in Tech Adoption. *Rural and Regional Development*, 3(3), 10009.
- Tian, K., Xuan, W., Hao, L., Wei, W., Li, D., and Zhu, L. (2022). Exploring youth consumer behavior in the context of mobile short video advertising using an extended stimulus–organization–response model. *Frontiers in Psychology*, 13, 933542.
- Trunfio, M., and Rossi, S. (2021). Conceptualising and measuring social media engagement: A systematic literature review. *Italian Journal of Marketing*, 2021(3), 267-292.
- Uriarte, S., Baier-Fuentes, H., Espinoza-Benavides, J., and Inzunza-Mendoza, W. (2025). Artificial intelligence technologies and entrepreneurship: a hybrid literature review. *Review of Managerial Science*, 1-49.
- Wang, Z. (2025). The Influence of AI on Consumer Behavior: Shaping Choices and Preferences in the Digital Marketplace. *Systems and Soft Computing*, 200397.
- Gefen, D., Straub, D., and Boudreau, M.-C. (2000). Structural Equation Modeling and Regression: Guidelines for Research Practice. *Communications of the Association for Information Systems*, 4.

Can monetary policy drive inclusive social development in Africa? Instrumental variables quantile regression approach

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Abstract. *This paper examines whether, beyond its conventional aims of price stability, monetary policy is a determinant of inclusive social development in Africa. The analysis is based on a panel of African countries covering the period 2010–2022. The empirical strategy employs three complementary econometric models: a fixed-effects model to capture country-specific variations, a two-stage least squares (2SLS) regression to address endogeneity, and an instrumental-variable quantile regression (IV-QR) to study the heterogeneity impact according to levels of inclusive development. The empirical results provide robust evidence that monetary policy has positive and causal effects on inclusive human development in Africa. Bank liquidity, monetary depth, and real interest rate stability significantly improve the inequality-adjusted human development index (IHDI). Instrumental variable quantile regressions reveal remarkably stable coefficients across the conditional distribution of inclusive development, indicating the absence of strong heterogeneity across countries. Furthermore, alternative estimations show that monetary policy reduces social and income inequalities while enhancing human development. These findings suggest that monetary policy operates as a macrostructural lever for inclusive development rather than a purely distributive instrument. These findings call for monetary authorities to strengthen macroeconomic stability, enhance liquidity management, and foster financial deepening as strategic tools to promote inclusive human development in African economies.*

Keywords: monetary policy, inclusive development, social inequalities, IV-QR.

JEL Classification: E52, O15, D63, C26, C31.

Introduction

African countries face the challenge of developing economic policies that can stimulate development while also ensuring that inequalities are taken into account in this socioeconomic progress. Among these, monetary policy is one of the important policy orientations for achieving inclusive development. It 'is a critical tool in the hands of central banks, aims to control the money supply and interest rates to ensure price stability and foster economic growth' (Abou et al., 2024). It involves measures taken by the central bank, such as setting interest rates and controlling the money supply'.

Monetary policy, although geared toward traditional macroeconomic objectives such as growth, price stability and reducing unemployment (Iddrisu et al., 2022), should also be designed as a strategic instrument for achieving inclusive human development. This adjusts average human development achievements by taking into account social and economic disparities (Foster et al., 2005). It therefore contributes to improving living conditions by reducing educational, health and economic inequalities in the context of socioeconomic progress.

However, it has been shown that monetary policy affects the rich and the poor at different levels, taking into account the average effect of macroeconomic changes (Kang et al., 2013). However, one of the main criteria for assessing a country's level of inclusive human development (Foster et al., 2005) is the inequality-adjusted human development index (IHDI). However, this approach appears to be ineffective because of the relatively large gap between the IHDI and HDI levels of African countries. For example, for our sample, the average IHDI for the period 2010–2022 is 0.356, whereas the HDI is 0.541. This means that there is significant inequality between individuals in terms of access to education, health and income levels, resulting in a loss of human development due to inequalities equivalent to an average of 0.185. Furthermore, Africa is considered one of the most unequal regions in the world (Odusola, 2017; Xu et al., 2021). In this context, monetary policy, while traditionally aimed at price stability and economic growth, must now be redefined as a strategic lever to promote human development that integrates inequalities and takes into account socioeconomic losses. Given the importance of monetary policy as a driver of inclusive development, this paper asks the following: To what extent can monetary policy decisions contribute to promoting inclusive human development?

The literature emphasizes the dynamic nature of monetary policy and its essential role in stabilizing economies and external sustainability (Iddrisu et al., 2025; Fielding, 2004). However, it does not explore the indirect impact of monetary policy on human development while taking into account socioeconomic losses. This aspect could help to explore the specific role of monetary policy in the long term in inclusive well-being. Indeed, monetary policy, while traditionally aimed at price stability and economic growth, must now be redefined as a strategic lever for promoting inclusive human development. An approach aimed at stimulating not only growth but also ensuring that its fruits benefit the entire population, especially the most marginalized. Hence, the purpose of this paper is to analyze the transmission effects of monetary policy on inclusive human development in Africa.

Our study sheds new light on the contribution of monetary policy to inclusive human development in Africa and contributes to the literature at both the theoretical and empirical levels. First, unlike previous studies that emphasize the role of monetary factors in macroeconomic stabilization, our research goes further by taking into account the social aspects of progress while integrating the various disparities that lead to more inclusive human development. Empirically, we account for the endogeneity of inclusive development by using instrumental variable regressions and examining the effect across different intervals via quantile regression, which resolves potential issues of unobserved heterogeneity within our sample. We also study the specific effects of the main monetary policy indicators and synthesize them to obtain an overall effect that, taken together, significantly influences inclusive human development. Furthermore, we appreciate the differentiated effect of monetary policy on each dimension of inclusive human development, taking into account social inequalities, income inequality, and human development; these various analyses have thus far been conducted only separately in the literature. The joint analysis of these phenomena, which focuses on African countries that not only have a low level of human development globally but also a low level of inclusivity, constitutes a substantial contribution to the literature.

Following the introduction, the literature review is analyzed in the first section, followed by the methodological approach in the second section, and the third section presents and discusses the results before concluding this paper.

1. Literature review

Fiscal and monetary policy instruments are traditionally used either individually or in combination to achieve the same overall objective, which is to promote inclusive growth (Batool and Bhatti, 2021; Ahiadorme, 2022). However, Morosoli et al. (2024) find that monetary policy, characterized by low inflation, plays a more decisive role than fiscal policy in promoting inclusive development. Iddrisu et al. (2022), on the other hand, believe that effective monetary policy may not improve human development, even if its main objectives are achieved. According to them, policymakers should therefore ensure that the effectiveness of monetary policy is not limited to price stability but also considers the moderation of banking costs to promote human development.

Furthermore, a monetary policy aimed at stabilizing aggregate demand is likely to improve the living conditions of the poorest in the long term and, as a result, ensure inclusive human development (Romer and Romer, 1998). This extension of the objectives of a well-targeted monetary policy would be more effective in promoting development than simply stimulating economic growth, as advocated in traditional theory. It would therefore affect inflation and unemployment rates, which in turn influence household purchasing power, affect access to health and education, facilitate access to credit for disadvantaged groups, and thus promote broader economic participation and, consequently, a reduction in inequalities or an improvement in inclusive human development (Chowdhury, 2019; Pérez-

Moreno et al., 2025). These authors argue that socially inclusive and environmentally sustainable economic growth is a central public policy priority for most governments around the world, and they recommend orienting monetary policy toward more inclusive development, particularly human development that integrates marginalized groups.

The government therefore uses monetary policy instruments through the central bank to bring about socioeconomic change, which helps reduce social inequalities and considers marginalized groups in the assessment of human development. With regard to these instruments, some authors believe that the M2 and M3 money supply, interest rates, inflation rates and yield curves do not directly measure the effectiveness of monetary policy (Romer and Romer, 1998; Fielding, 2004; Uhlig, 2005; Galbraith et al., 2007; Nwoko et al., 2016). However, other authors consider reserve requirements, interest rates and the money supply to be instruments that can be used to activate transmission channels from the financial sector to the real sector, stabilize policies, promote financial inclusion, reduce social inequalities and support equitable growth (Modigliani et al., 1970; Amidu, 2006; Chiu et al., 2018; Ciccarelli et al., 2015). However, the empirical link between monetary policy and inclusive development has not been clearly demonstrated in some studies (Olanmi & Olagunju, 2020; Ahiadorme, 2022; Ekomane, 2021; Romer and Romer, 1999).

Srithilat et al. (2017) analyze the impact of monetary policy on inclusive development via time series data covering the period 1989--2016 in Laos. Using unit root tests, Johansen cointegration and an error correction model, the authors highlight an inverse relationship between money supply, interest rates and inflation (used as indicators of monetary policy) and GDP per capita, a component of human development. However, monetary policy, as measured by the M3 money supply, significantly influences inclusive growth (Khabo and Harmse, 2005). Their study focused on South Africa for the period 1960--1997, applying the OLS method and the augmented Dickey–Fuller test.

Olanmi and Olagunju (2020) determined the impact of monetary policy on inclusive growth in Nigeria via a multivariate regression model. By exploring the collected data, with the CPI as a proxy for inclusive growth and the exchange rate, interest rate and money supply as indicators of monetary policy, they find a positive and significant relationship between the money supply and inclusive growth. Indeed, a 1% increase in money supply increases individual well-being by 12%. In contrast, the exchange rate and interest rate have a negative and insignificant impact on per capita income. This implies the appropriate implementation of monetary policy measures (particularly money supply) to induce changes in the economy by improving citizens' well-being. Similarly, Ahiadorme (2022) assesses the role of monetary policy in inclusive growth by exploring a sample of 144 countries covering the period 2000--2018. The author uses the dynamic GMM approach and proves that, in the short and long term, a monetary policy aimed at low inflation and stable economic growth is likely to permanently improve the inclusiveness of growth and the living conditions of the poor.

In addition to empirical investigations into the effect of monetary policy on inclusive economic growth, which is a factor in inclusive development, other studies have examined other components of inclusive development. Romer and Romer (1999), for example, analyze the short- and long-term effects of monetary policy on poverty and inequality. They use a simple regression on US time series data for short-term effects and cross-country panel data for long-term effects. Their study revealed that the results of short-term analysis contrast with those of long-term analysis. The decrease in interest rates resulting from expansionary monetary policy reduces poverty in the short term without having any obvious impact on income distribution. However, in the long term, expansionary monetary policy reduces the incomes of the poor and exacerbates inequality.

Unlike Romer and Romer (1999), Kang et al. (2013) overcome econometric problems and maintain the consistency of short- and long-term data to better understand the heterogeneous effects of monetary policy on the welfare of individual economic agents, poverty and income inequality. They use the interest rate as the key variable of monetary policy, as do central banks.

Furthermore, Ekomane (2021) identified the transmission channels through which monetary policy affects social welfare, as captured by the HDI, in Cameroon from 1990–2015. Using a conventional structural autoregressive methodology, he shows that the HDI responds significantly to monetary policy impulses with a two-year lag through the income-consumption channel and the credit-consumption channel. For Fielding (2004), changes in monetary policy instruments, particularly interest rates, have a greater impact on poor households than on rich households in the case of the WAEMU. Iddrisu et al. (2022) also examine the effect of monetary policy effectiveness on human development in Africa. The authors use both microbanking data from the BankScope database maintained by Fitch/IBCA/Bureau Van Dijk and macronational data with annual series covering a sample of 320 banks in 29 African countries over the period 2002–2013. They use fixed effects, random effects and instrumental variable regression methods, with an instrument on the basis that the effectiveness of monetary policy depends on the independence of the central bank. Their results suggest that effective monetary policy translates into high interest rates on bank loans and deposits, which tends to promote human development. However, the estimated net effects show that effective monetary policy does not, on balance, improve human development.

Morosoli et al. (2024) identify the economic policies and factors that promote inclusive development. They use the multidimensional inclusiveness index proposed by Dörffel and Schuhmann (2022) in a panel OLS regression framework with fixed effects (FE), as well as the generalized method of moments (GMM) estimates, which is based on a sample of 178 countries over the period 1980–2018. Their results reveal a robust association between monetary policy, as captured by inflation, financial development and trade openness, in both the short and long term. Low inflation and stable economic growth, i.e., the achievement of monetary policy objectives, are likely to bring about lasting improvements

in the inclusiveness of growth and the living conditions of the poorest, and thus in inclusive human development (Ahiadorme, 2022).

We note that the literature on monetary policy and human development shows mixed results, with a majority of studies agreeing that poorly targeted monetary policy may not improve the distribution of growth benefits. However, other research shows that monetary policies focused on inclusiveness can reduce inequalities and improve inclusive development. To date, this literature has focused on specific monetary policy variables related to inclusive growth, as well as on a few aspects contributing to well-being, such as poverty, inequality and human development. The instruments used do not always effectively assess the effectiveness of monetary policy. The empirical link between monetary and real variables requires the use of robust methods to correct for econometric inference problems. The scope of application remains limited in Africa, even though the challenge of the contribution of monetary policy to inclusive development is crucial, as fiscal policy alone cannot promote a high and inclusive level of human development. Furthermore, the quantile regression with instrumental variables methodology allows us to test the hypothesis that the effects of monetary policy vary according to levels of inclusive development, which is something that certain studies have not explored. In these respects, this paper makes a solid contribution, both theoretically and empirically, to the literature.

2. Methodology and Data

2.1. Econometric method

Empirical analysis of the effects of monetary policy on inclusive development can be carried out via the pooled OLS method. However, applying this method to panel data masks certain econometric problems related to the inability to correct for biases due to endogeneity and heterogeneity. Indeed, monetary policy, which influences bank reserves, the money supply and interest rates, can affect the IHDI by changing health and education conditions through its effect on economic growth. Furthermore, inclusive human development (reflected in inclusive economic growth and the consideration of inequalities in education and health) could, in turn, influence monetary policy decisions. However, the effects of financial variables are rarely homogeneous (Koenker, 2005, 2017; Chernozhukov & Hansen, 2006).

Furthermore, despite the variables included in our model, the probability of omitting other factors that could explain inclusive human development remains significant. Furthermore, as monetary policy is measured by bank liquidity, money supply and lending rates, as well as by a composite index of these three indicators that captures demand, supply and cost aspects, measurement errors are highly likely to occur. Thus, the monetary policy variable is potentially endogenous. It is therefore appropriate to use regression methods that address endogeneity.

For the regression technique, three estimators are used to test the effect of monetary policy on inclusive development. We use fixed effects (FEs) to control for unobserved

heterogeneity that is invariant over time, then 2SLS with internal and external instruments, which allows us to control for endogeneity, and finally quantile regression with instrumental variables (IVQRs), which allows us to capture heterogeneous effects along the conditional distribution of the IHDI while treating endogeneity. To control for endogeneity, we use internal instruments, namely, two-period lagged values of monetary policy variables. We then use external instruments corresponding to regional averages of monetary policy, referring to the technique developed by Mundlak (1978). These instruments ensure that the observed relationships are causal and not spurious. Finally, we combine quantile regression with instrumental variables introduced by Chernozhukov and Hansen (2005) to account for country heterogeneity in the model.

The smoothed instrumental variable quantile regression developed by Kaplan (2022) and Kaplan and Sun (2017), which is used in this paper, allows us to obtain relatively homogeneous subgroups and improves computational efficiency and statistical accuracy through smoothing. This method is robust to distribution assumptions and outliers, providing reliable and insensitive estimates (Hao and Naiman, 2007; Kudryavtsev, 2009). It also allows for the treatment of models with multiple endogenous variables and effectively manages issues of simultaneity and reverse causality (Oudanou et al., 2024; Ouedraogo, 2025). It is therefore better suited to testing the hypothesis of our study, which is that the effects of monetary policy may vary considerably depending on the different levels of inclusive development in Africa. We therefore use the basic quantile model of Chernozhukov and Hansen (2006), simplified as follows:

$$Y_{it} = Z_{1,it}\beta_1(\alpha) + Z_{2,it}\beta_2(\alpha) + W'_{it}\gamma(\alpha) + \varepsilon_{it}(\alpha) \quad (1)$$

where

Y_{it} denotes the dependent variable for unit i at time t ;

$Z_{1,it}$ and $Z_{2,it}$ are two potentially endogenous regressors;

W'_{it} is a vector of exogenous control variables;

$\beta_1(\alpha)$ and $\beta_2(\alpha)$ measure the causal marginal effects of X specific to the conditional quantile of Y .

$\varepsilon_{it}(\alpha)$ is an unobserved error term

On the basis of equation (1) and the literature, we specify our econometric model used in the instrumental variable quantile regression in equation (2):

$$\begin{aligned} IHDI_{it} = & \beta_0 + \beta_1 BANKLIQRES_{it} + \beta_2 BROADMOGDP_{it} + \beta_3 REALINTRAT_{it} \\ & + \beta_4 HUCAP_{it} + \beta_5 GOVINVEST_{it} + \beta_6 CC_{it} + \beta_7 CPI_{it} + \beta_8 TNRR_{it} \\ & + \delta_i + \gamma_t + \varepsilon_{it} \end{aligned} \quad (2)$$

where δ represents the unobserved effect specific to each country; γ denotes the time fixed effect; and ε signifies the error term.

However, we specify an alternative regression by combining our three indicators capturing monetary policy into a composite index as follows:

$$IHDI_{it} = \beta_0 + \beta_1 POMO_{it} + \beta_2 HUCAP_{it} + \beta_3 GOVINVEST_{it} + \beta_4 CC_{it} + \beta_5 CPI_{it} + \beta_6 TNRR_{it} + \delta_i + \gamma_t + \varepsilon_{it} \quad (3)$$

The new monetary policy variable is designed as a composite index, constructed via z score standardization of the three variables that make up monetary policy, followed by unweighted linear aggregation, in accordance with the methodological recommendations of Nardo et al. (2005), to test the robustness of our results.

2.2. Data and variables

As part of this study, we draw on data from various secondary sources. It is based on a panel of 43 African countries covering the period from 2010--2022. The choice of sample is dictated by data availability. The variable relating to inclusive development is measured by the inequality-adjusted human development index (IHDI) to consider distributional inequalities in the dimensions of the HDI. According to Kovacevic (2010) and Alkire and Foster (2010), this indicator reflects the distribution of human development gains within the population and between the different dimensions, integrating inequalities into the quantification of human development. It is adequate for measuring inclusive development (Hicks, 1997; Foster et al., 2005; Casadio Tarabusi & Guarini, 2016). The IHDI also takes into account the extent of inequalities in each dimension of the HDI by updating their average value.

In this paper, inclusive development is explained by our independent variable of interest, which is monetary policy. According to the literature, the effect of monetary policy on inclusive development depends on how it is measured. Indeed, financial dynamics in terms of depth, activity, and size improve inclusive human development, whereas the inability of banks to transform mobilized deposits into credit for financial access negatively affects inclusive human development (Asongu & Nting, 2022; Asongu and Nwachukwu, 2015). Therefore, to measure the monetary policy variable in this paper, we use three indicators: a stock indicator, namely, bank liquidity; a supply indicator, which is the M2 money supply; and a credit cost indicator, measured by the real interest rate.

According to the literature, inclusive development is supposedly influenced by human capital, public investment, corruption control, the inflation rate, and natural resource rents. The definitions, sources, and descriptive statistics for all the variables are presented in Table (1).

Table 1. *Descriptive Statistics*

Variables	Obs	Mean	Std. Dev.	Min	Max	Definitions	Source
ihdi	559	.356	.099	.184	.633	Inequality-adjusted Human Development Index	United Nations Development Programme (UNDP, 2024)
bankliqres	559	21.6	16.494	2.259	94.82	Bank liquid reserves to bank assets ratio (%)	International Financial Statistics (International Monetary Fund, 2024)

Variables	Obs	Mean	Std. Dev.	Min	Max	Definitions	Source
broadmogdp	559	38.725	24.391	.023	110.54	Broad money (% of GDP)	International Financial Statistics (International Monetary Fund, 2024)
realintrat	416	7.602	9.654	-15.69	52.437	Real interest rate (%)	International Financial Statistics (International Monetary Fund, 2024)
hucap	468	1.94	.482	1.166	2.908	Human Capital Index	Penn World Table 10.02
govinvest	559	5.765	3.264	0	10	Government investment	World Development Indicators (World Bank, 2024)
cc	559	-.617	.602	-1.6	1.016	Control of Corruption: Estimate	Worldwide Governance Indicators (World Bank, 2024)
cpi	541	6.34	6.481	-4.295	36.907	Consumer price index (2010 = 100)	World Development Indicators (World Bank, 2024)
tnrr	516	10.007	8.684	.002	43.94	Total natural resources rents (% of GDP)	World Development Indicators (World Bank, 2024)

Source: authors

To diagnose any potential multicollinearity issues upstream, we created the correlation matrix shown in Table 2 in the appendix. This reveals a lack of strong correlation between the regressors in our empirical model, as the coefficients do not exceed the critical threshold established by Kennedy (2008). For the author, the absolute value of the correlation coefficient between two regressors should not exceed 0.8. Graph 1 shows the relationship between monetary policy and inclusive development using the average level for countries. This finding indicates that an accumulation of liquidity, in the absence of an effective mechanism for transmitting credit at low cost to the real economy, can limit its impact and mitigate its distributive effects favorable to inclusive development. However, monetary policy appears to be more relevant to inclusive development when assessed multidimensionally rather than through isolated indicators.

3. Results

3.1. Baseline results

The results of the joint FE, DMC and instrumental variable quantile regression models, which examine the heterogeneity of monetary policy effects according to the level of human development adjusted for inequality, are presented in Table 2. The IVQR coefficients are virtually constant between the 10% and 90% quantiles, indicating a lack of heterogeneity in terms of inclusive development among African countries.

Improved bank liquidity is associated with more inclusive human development. This can be explained by the fact that excess bank liquidity facilitates access to credit for financing social spending (education and health), regardless of human development levels. The stability of the coefficient across all quantiles indicates a structural and generalized effect. Indeed, improving the African banking system's ability to provide liquid resources benefits

countries with low IHDI levels as well as those with medium or high IHDI levels. These results are consistent with the literature, which shows that financial stability indirectly promotes well-being (Casadio Tarabusi & Guarini, 2016).

Similarly, an increase in the money supply relative to GDP improves the IHDI, reflecting the role of monetary depth in stimulating inclusive economic activity. In this sense, monetary depth would promote investment by resolving liquidity constraints, which would stimulate inclusive socioeconomic activities. Furthermore, when the amount of money held by economic agents increases, it improves their transactions in the social sector, thereby contributing to strengthening inclusive human development. These results are consistent with those of Kang et al. (2013), who find that monetary policy, when it promotes bank liquidity, can reduce inequalities and promote more inclusive human development.

Control of the real interest rate is associated with an improvement in the IHDI, reflecting a decline in economic uncertainty. This can be explained by the fact that an improvement in the interest rate is predictive of greater monetary credibility, controlled inflation and more efficient capital allocation, macroeconomic conditions that indirectly promote inclusive human development. These results disagree with those of Ekomane (2021), who shows that the money supply and interest rates reduce GDP per capita, as well as with those of Khabo and Harmse (2005), who argue that the M3 money supply promotes inclusive growth.

Monetary policy, as measured by bank liquidity, monetary depth and real interest rate stability, has a positive and consistent effect on inclusive development. These monetary transmission mechanisms are more institutional than distributive, operating at the macroeconomic level rather than among specific groups, in a structural manner and independent of the level of inclusive development. As a result, monetary policy, through its real and financial transmission mechanisms, is not limited to macroeconomic stability but also influences the dimension of inclusive development. This extension of the role of monetary policy is thus an additional determinant of inclusive development.

Table 2. Estimation results with internal instruments

Variables	Dependent Variable: Inclusive social Development						
	FE	2SLS	Quantile instrumental variable regression				
			10%	25%	50%	75%	90%
Bank liquid reserves	0.000241*** (6.89e-05)	0.000665** (0.000269)	0.000665*** (0.000227)	0.000665*** (0.000227)	0.000665*** (0.000227)	0.000665*** (0.000227)	0.000661*** (0.000226)
Broad money	0.000556*** (0.000143)	0.00244*** (0.000155)	0.00244*** (0.000108)	0.00244*** (0.000108)	0.00244*** (0.000108)	0.00244*** (0.000108)	0.00244*** (0.000108)
Real interest rate	0.000281* (0.000167)	0.000834*** (0.000193)	0.000834*** (0.000183)	0.000834*** (0.000183)	0.000834*** (0.000183)	0.000834*** (0.000183)	0.000834*** (0.000183)
Human Capital Index	0.101*** (0.00889)	0.107*** (0.00774)	0.107*** (0.00711)	0.107*** (0.00711)	0.107*** (0.00711)	0.107*** (0.00711)	0.107*** (0.00746)
Government investment	-0.00106*** (0.000385)	-0.00249*** (0.000691)	-0.00249*** (0.000677)	-0.00249*** (0.000674)	-0.00249*** (0.000674)	-0.00249*** (0.000674)	-0.00249*** (0.000684)
Control of Corruption	0.00560 (0.00497)	0.0120*** (0.00415)	0.0120*** (0.00346)	0.0120*** (0.00346)	0.0120*** (0.00346)	0.0120*** (0.00346)	0.0121*** (0.00342)
Consumer price index	-4.31e-05 (0.000201)	0.000260 (0.000492)	0.000260 (0.000373)	0.000260 (0.000373)	0.000260 (0.000373)	0.000260 (0.000373)	0.000266 (0.000369)
Total natural resources rents	-0.000477** (0.000230)	0.00151** (0.000659)	0.00151*** (0.000442)	0.00151*** (0.000442)	0.00151*** (0.000442)	0.00151*** (0.000442)	0.00154*** (0.000491)

Dependent Variable: Inclusive social Development							
Variables	FE	2SLS	Quantile instrumental variable regression				
			10%	25%	50%	75%	90%
Constant	0.149*** (0.0173)	0.0485*** (0.0140)	-0.351*** (0.0119)	-0.201*** (0.0119)	0.0485*** (0.0119)	0.299*** (0.0119)	0.448*** (0.0119)
Observations	336	278	278	278	278	278	278
R-squared	0.476	0.851					
Number of countries	29						
Under identification test (Kleibergen–Paap rk LM statistic)		32.663***					
Hansen J statistic (overidentification test of all instruments)		16.389***					

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

We have incorporated external instruments into the model. These are constructed from regional averages of monetary policy variables. The results presented in Table 3 confirm those obtained using only internal instruments in Table 2. This convergence of estimates reinforces the robustness and credibility of our empirical results.

Table 3. Estimation results with internal and external instruments

Dependent Variable: Inclusive social Development						
Variables	2SLS	Regression quantile à variable instrumental				
		10%	25%	50%	75%	90%
Bank liquid reserves	0.000635** (0.000265)	0.000635*** (0.000232)	0.000635*** (0.000232)	0.000635*** (0.000232)	0.000635*** (0.000232)	0.000632*** (0.000235)
Broad money	0.00245*** (0.000154)	0.00245*** (0.000111)	0.00245*** (0.000111)	0.00245*** (0.000111)	0.00245*** (0.000111)	0.00245*** (0.000111)
Real interest rate	0.000868*** (0.000188)	0.000868*** (0.000181)	0.000868*** (0.000181)	0.000868*** (0.000181)	0.000868*** (0.000181)	0.000867*** (0.000180)
Human Capital Index	0.107*** (0.00767)	0.107*** (0.00704)	0.107*** (0.00704)	0.107*** (0.00704)	0.107*** (0.00704)	0.107*** (0.00735)
Government investment	-0.00251*** (0.000690)	-0.00251*** (0.000676)	-0.00251*** (0.000674)	-0.00251*** (0.000674)	-0.00251*** (0.000674)	-0.00250*** (0.000683)
Control of Corruption	0.0118*** (0.00415)	0.0118*** (0.00347)	0.0118*** (0.00347)	0.0118*** (0.00347)	0.0118*** (0.00347)	0.0119*** (0.00344)
Consumer price index	0.000286 (0.000490)	0.000286 (0.000381)	0.000286 (0.000380)	0.000286 (0.000380)	0.000286 (0.000380)	0.000292 (0.000372)
Total natural resources rents	0.00153** (0.000657)	0.00153*** (0.000437)	0.00153*** (0.000437)	0.00153*** (0.000437)	0.00153*** (0.000437)	0.00156*** (0.000482)
Constant	0.0478*** (0.0139)	-0.352*** (0.0114)	-0.202*** (0.0114)	0.0478*** (0.0114)	0.298*** (0.0114)	0.447*** (0.0114)
Observations	278	278	278	278	278	278
R-squared	0.851					
Underidentification test (Kleibergen–Paap rk LM statistic):	63.702***					
Hansen J statistic (overidentification test of all instruments):	40.177***					

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The results of measuring monetary policy via a composite index constructed from our three basic indicators specified in equation (3) are presented in Table 4. These remain stable, robust, and statistically significant, which is consistent with those obtained from the disaggregated measures of the variables used to assess monetary policy.

Table 4. Estimation results when measuring monetary policy via a composite index and regressing with internal and external instruments

Dependent Variable: Inclusive social Development							
Variables	FE	2SLS	Quantile instrumental variable regression				
			10%	25%	50%	75%	90%
Monetary policy	0.00298*** (0.000574)	0.0174*** (0.00164)	0.0173*** (0.00158)	0.0174*** (0.00152)	0.0174*** (0.00152)	0.0174*** (0.00152)	0.0174*** (0.00154)
Human Capital Index	0.105*** (0.00867)	0.118*** (0.00857)	0.118*** (0.00736)	0.118*** (0.00714)	0.118*** (0.00714)	0.118*** (0.00714)	0.118*** (0.00675)
Government investment	-0.000919** (0.000379)	-0.00281*** (0.000822)	-0.00281*** (0.000776)	-0.00281*** (0.000796)	-0.00281*** (0.000796)	-0.00281*** (0.000796)	-0.00281*** (0.000817)
Control of Corruption	0.00472 (0.00487)	0.0313*** (0.00505)	0.0313*** (0.00350)	0.0313*** (0.00349)	0.0313*** (0.00349)	0.0313*** (0.00349)	0.0313*** (0.00369)
Consumer price index	-7.13e-05 (0.000192)	-0.000915 (0.000556)	-0.000924 (0.000595)	-0.000915* (0.000555)	-0.000915* (0.000555)	-0.000915* (0.000555)	-0.000925 (0.000568)
Total natural resources rents	-0.000551** (0.000220)	0.00195*** (0.000698)	0.00193*** (0.000619)	0.00195*** (0.000595)	0.00195*** (0.000595)	0.00195*** (0.000595)	0.00202*** (0.000619)
Constant	0.157*** (0.0173)	0.0803*** (0.0153)	-0.319*** (0.0128)	-0.170*** (0.0123)	0.0803*** (0.0123)	0.330*** (0.0123)	0.479*** (0.0128)
Observations	336	278	278	278	278	278	278
R-squared	0.469	0.793					
Number of countries	29						
Under identification test (Kleibergen–Paap rk LM statistic)		81.834***					
Hansen J statistic (overidentification test of all instruments):		11.917***					

Robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

We tested the sensitivity of our results by incorporating additional control variables into our base model specified in equation (2). The results are presented in Table 5 and confirm those of the base model. According to Elistia and Syahzuni (2018) and Sarkodie and Adams (2020), individual wealth captured by “GDP per capita growth (annual %)” and access to electricity (% of population) are key determinants of inclusive development. We therefore add these values to our baseline model.

Table 5. Estimation results with the addition of control variables and regression with internal and external instruments

Dependent Variable: Inclusive social Development							
Variables	FE	2SLS	Quantile instrumental variable regression				
			10%	25%	50%	75%	90%
Bank liquid reserves	0.000249*** (5.53e-05)	0.000366 (0.000234)	0.000366* (0.000206)	0.000366* (0.000206)	0.000366* (0.000206)	0.000366* (0.000206)	0.000359* (0.000208)
Broad money	0.000337*** (0.000116)	0.00183*** (0.000171)	0.00183*** (0.000154)	0.00183*** (0.000154)	0.00183*** (0.000154)	0.00183*** (0.000154)	0.00183*** (0.000151)
Real interest rate	0.000364*** (0.000135)	0.00122*** (0.000206)	0.00122*** (0.000210)	0.00122*** (0.000210)	0.00122*** (0.000210)	0.00122*** (0.000210)	0.00122*** (0.000209)

Dependent Variable: Inclusive social Development							
Variables	FE	2SLS	Quantile instrumental variable regression				
			10%	25%	50%	75%	90%
Human Capital Index	0.0483*** (0.00822)	0.0937*** (0.00706)	0.0937*** (0.00571)	0.0937*** (0.00571)	0.0937*** (0.00571)	0.0937*** (0.00571)	0.0941*** (0.00599)
Government investment	-0.000559* (0.000313)	-0.00192*** (0.000606)	-0.00192*** (0.000660)	-0.00192*** (0.000660)	-0.00192*** (0.000660)	-0.00192*** (0.000660)	-0.00191*** (0.000661)
Control of Corruption	0.00555 (0.00399)	0.0125*** (0.00360)	0.0125*** (0.00344)	0.0125*** (0.00344)	0.0125*** (0.00344)	0.0125*** (0.00344)	0.0126*** (0.00336)
Consumer price index	-6.82e-05 (0.000162)	0.000584 (0.000417)	0.000584* (0.000314)	0.000584* (0.000314)	0.000584* (0.000314)	0.000584* (0.000314)	0.000597** (0.000303)
Total natural resources rents	-0.000412** (0.000186)	0.00186*** (0.000626)	0.00186*** (0.000499)	0.00186*** (0.000499)	0.00186*** (0.000499)	0.00186*** (0.000499)	0.00192*** (0.000515)
GDP per capita growth	-8.88e-05 (0.000161)	-1.38e-05 (0.000519)	-1.38e-05 (0.000495)	-1.38e-05 (0.000495)	-1.38e-05 (0.000495)	-1.38e-05 (0.000495)	5.96e-06 (0.000481)
Access to electricity	0.00122*** (9.60e-05)	0.000851*** (0.000138)	0.000851*** (0.000146)	0.000851*** (0.000146)	0.000851*** (0.000146)	0.000851*** (0.000146)	0.000852*** (0.000146)
Constant	0.198*** (0.0145)	0.0515*** (0.0135)	-0.349*** (0.0115)	-0.199*** (0.0115)	0.0515*** (0.0115)	0.301*** (0.0115)	0.450*** (0.0115)
Observations	336	278	278	278	278	278	278
R-squared	0.665	0.870					
Number of countries	29						
Under identification test (Kleibergen–Paap rk LM statistic):		52.240***					
Hansen J statistic (overidentification test of all instruments)		43.978***					

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

3.2. Results from alternative estimations

Tables A2, A3, and A4, presented in the appendix, summarize the estimates derived from monetary policy regressions on social inequality, income inequality, and human development, respectively. These results allow us to assess the differentiated effect of monetary policy on each dimension of inclusive development.

The estimates indicate that monetary policy contributes to reducing social and income inequality, thereby strengthening inclusive development, understood as a development process that takes these disparities into account. Furthermore, monetary policy has a positive effect on human development while reducing social and economic inequalities, thereby promoting more inclusive human development in African countries. These results reinforce the theoretical conception of inclusive development formulated by Alkire and Foster (2010).

Conclusion

This study examined the impact of distributive monetary policy on inclusive development in Africa over the period 2010–2022, employing complementary econometric approaches, including fixed-effects models, two-stage least squares, and instrumental variable quantile regression. The overall findings provide evidence of a positive, statistically significant, and robust effect of monetary policy on inclusive human development.

The results indicate that monetary policy operates primarily as a structural macroeconomic lever. Its influence is transmitted through systemic mechanisms particularly bank liquidity management, money supply dynamics, and real interest rate movements that contribute to improving overall socioeconomic conditions. However, the absence of differentiated effects across initial levels of inclusive development suggests that monetary policy does not automatically correct structural asymmetries between countries. While it strengthens the general macroeconomic environment, it does not, in itself, function as a targeted redistributive instrument.

The analysis of transmission channels shows that increased bank liquidity consistently supports inclusive development by enhancing financial intermediation and facilitating access to credit. Similarly, financial deepening—captured by the expansion of the money supply relative to GDP appears especially beneficial for economies with lower levels of human development, where financing constraints remain more acute. Moreover, the stabilization of real interest rates helps reduce macroeconomic uncertainty, improves the predictability of investment decisions, and promotes a more efficient allocation of resources toward social and productive sectors.

These findings call for a reassessment of the strategic orientation of monetary policy in the African context. Beyond price stability, monetary authorities would benefit from explicitly incorporating economic and social inclusion objectives into the design and implementation of their policy instruments, particularly with regard to liquidity management, credit regulation, and financial development. Nevertheless, the redistributive capacity of monetary policy remains limited in the absence of coherent coordination with fiscal policy. Stronger policy coordination therefore appears essential to amplify the effects on inequality reduction and sustainable improvements in welfare.

Finally, this study faces certain limitations, notably, the limited availability of data on inclusive development and the absence of explicit modeling of monetary–fiscal policy interactions. Future research could further investigate institutional complementarities and assess the extent to which optimal coordination of macroeconomic policy instruments may strengthen inclusive development trajectories in Africa.

Author contributions

All the authors contributed to the design and development of the study. The methodology and analysis of the results were written by the first author. The introduction and literature review were written by the second author. All the authors have read and approved the final manuscript. All authors accept responsibility for all aspects of their work.

Conflict of interest statement

The authors present no conflicts of interest.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declaration of funding

No funding was received.

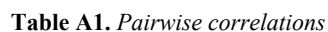
References

- Abor, J.Y., Agoba, A.M., Mumuni, Z., and Yawson, A. (2022). Monetary policy, central banks' independence, and financial development in Africa. In *The economics of banking and finance in Africa: Developments in Africa's financial systems* (pp. 227-267). Cham: Springer International Publishing.
- Ahiadorme, J.W. (2022). Monetary policy in search of macroeconomic stability and inclusive growth. *Research in Economics*, 76(4), 308-324.
- Alkire, S., and Foster, J. (2010). Designing the inequality-adjusted human development index (HDI). Oxford Poverty & Human Development Initiative (OPHI).
- Amidu, M. (2006). The link between monetary policy and banks' lending behavior: the Ghanaian case. *Banks & bank systems*, (1, № 4), 38-48.
- Asli Demirgüç-Kunt, and Ross Levine. 2009. Finance and Inequality: Theory and Evidence. *Annual Review Financial Economics*. 1:287-318.
- Asongu, S. and Nting, R. (2022). The Role of Finance in Inclusive Human Development in Africa Revisited. *Journal of Economic and Administrative Sciences*. 38 (2), 345–370.
- Asongu, S. and Nwachukwu, J.C. (2015). Finance and Inclusive Human Development: Evidence from Africa; AGDI Working Paper.
- Batool, Z., and Bhatti, A.A. (2021). Efficacy of Macroeconomic Policies to Achieve Inclusive Growth: Evidence from Developing Countries. *Forman Journal of Economic Studies*, 17(2).
- Beck, T., Levine, R., and Loayza, N. (2000). Finance and the Sources of Growth. *Journal of financial economics*, 58(1-2), 261-300.
- Casadio Tarabusi, E. and Guarini, G. (2016). Level Dependence of the Adjustment for Unbalance and Inequality for the Human Development Index. *Social Indicators Research*. 126, 527–553
- Chernozhukov, V., and Hansen, C. (2006). Instrumental quantile regression inference for structural and treatment effect models. *Journal of Econometrics*, 132(2), 491-525.
- Chiu, J., Dong, M., and Shao, E. (2018). On the welfare effects of credit arrangements. *International Economic Review*, 59(3), 1621-1651.
- Chowdhury, A. (2019). Monetary policy for inclusive and sustainable development. *Macroeconomic Policies in Countries of the Global South*, 173-209.
- Ciccarelli, M., Maddaloni, A., and Peydró, J.L. (2015). Trusting the bankers: A new look at the credit channel of monetary policy. *Review of Economic Dynamics*, 18(4), 979-1002.

- Ekomané, J.L. (2021). How is monetary policy transmitted to the human development index? *Journal of Economics and Political Economy*, 8(4), 261-275.
- Elistia, E., and Syahzuni, B.A. (2018). The correlation of the human development index (HDI) with economic growth (GDP per capita) in 10 ASEAN member countries. *Jhss (journal of humanities and social studies)*, 2(2), 40-46.
- Fielding, D. (2004). How does monetary policy affect the poor? Evidence from the West African Economic and Monetary Union. *Journal of African Economies*, 13(4), 563-593.
- Foster, J.E., Lopez-Calva, L.F., and Szekely, M. (2005). Measuring the Distribution of Human Development: Methodology and an Application to Mexico. *Journal of Human Development*, 6 (1), 5–25.
- Galbraith, J.K., Giovannoni, O., and Russo, A. J. (2007). The Fed's real reaction function: monetary policy, inflation, unemployment, inequality and presidential politics (No. 511). Working Paper.
- Hicks, D.A. (1997) The Inequality-Adjusted Human Development Index: A Constructive Proposal. *World development*, 25 (8), 1283–1298.
- Iddrisu, A.G., Andani, A., and Abor, J. Y. (2022). Effective monetary policy, banks' pricing behavior and human development in Africa. *International Journal of Banking, Accounting and Finance*, 13(1), 61-87.
- Iddrisu, K., Abor, J.Y., Issah, O., and Gyebi, F.O. (2025). Monetary Policy and Inclusive Growth in the Era of Economic Uncertainty: Navigating Challenges and Opportunities. In: Yakubu, I.N. (eds) *Strategic Approaches to Banking Business and Sustainable Development Goals*. Sustainable Development Goals Series. Springer, Cham. <https://doi.org/10.1007/978-3-031-80744-2_16>
- Kang, S.J., Chung, Y.W., and Sohn, S.H. (2013). The effects of monetary policy on individual welfares. *Korea and the World Economy*, 14(1), 1-29.
- Kennedy, P. (2008). *A guide to econometrics*. John Wiley & Sons.
- Koenker, R. (2005). *Quantile regression* (Vol. 38). Cambridge university press.
- Kovacevic, M. (2010). Measurement of inequality in Human Development—A review. *Measurement*, 35, 1-65.
- Modigliani, F., Rasche, R., and Cooper, J.P. (1970). Central bank policy, the money supply, and the short-term rate of interest. *Journal of Money, Credit and Banking*, 2(2), 166-218.
- Morosoli, C., Draper, P., Freytag, A., and Schuhmann, S. (2024). Drivers of Inclusive Development: An Empirical Investigation. *The European Journal of Development Research*, 36(4), 987-1015.
- Mundlak, Y. (1978). On the pooling of time series and cross section data. *Econometrica: journal of the Econometric Society*, 69-85.
- Nardo, M., Saisana, M., Saltelli, A., and Tarantola, S. (2005). Tools for composite indicators building. European Commission, *Ispira*, 15(1), 19-20.
- Nwoko, N.M., Ihemeje, J.C., and Anumadu, E. (2016). The impact of monetary policy on the economic growth of Nigeria. *African Research Review*, 10(3), 192-206.
- Odusola, A. (2017). Fiscal space, poverty and inequality in Africa. *African Development Review*, 29(S1), 1-14.
- Olakanmi, O.A., and Olagunju, O. (2020). Monetary policy and inclusive growth in Nigeria. *International Journal of Development and Economic Sustainability*, 8(2), 1-9.

- Pérez-Moreno, S., Martín-Fuentes, N., and Albert, J. F. (2021). Rethinking monetary policy in the framework of inclusive and sustainable growth. In *Economic policies for sustainability and resilience* (pp. 319-364). Cham: Springer International Publishing.
- Roger Koenker. 2017. Quantile Regression: 40 Years On. *Annual Review Economics*. 9:155-176. <<https://doi.org/10.1146/annurev-economics-063016-103651>>
- Romer, C. and Romer, D. (1999). Monetary policy and the well-being of the poor. *Federal Reserve Bank of Kansas City, QI*, 21-49. [Retrieved from].
- Romer, C.D., and Romer, D.H. (1998). Monetary policy and the well-being of the poor.
- Rumbogo, T., McCann, P., Hermes, N., and Venhorst, V. (2021). Financial inclusion and inclusive development in Indonesia. In *Challenges of governance: Development and regional integration in Southeast Asia and ASEAN* (pp. 161-181). Cham: Springer International Publishing.
- Sarkodie, S.A., and Adams, S. (2020). Electricity access, human development index, governance and income inequality in Sub-Saharan Africa. *Energy Reports*, 6, 455-466
- Srithilat, K., Sun, G., and Thavisay, M. (2017). The impact of monetary policy on economic development: Evidence from Lao PDR. *Global Journal of Human-Social Science*, 17(2), 9-15.
- Uhlig, H. (2005). What are the effects of monetary policy on output? Results from an agnostic identification procedure. *Journal of Monetary Economics*, 52(2), 381-419.
- Wong, J. (2019). Financial Development and Inclusion. In *Paving the Way to Sustained Growth and Prosperity in Central America, Panama, and the Dominican Republic*. International Monetary Fund.
- Xu, C., Han, M., Dossou, T.A.M., and Bekun, F.V. (2021). Trade openness, FDI, and income inequality: Evidence from sub-Saharan Africa. *African Development Review*, 33(1), 193-203.

Graph 1. Monetary Policy and Inclusive Development



Variables	(ihdi)	(bankliqres)	(broadmogdp)	(realintrat)	(hucap)	(govinvest)	(cc)	(cpi)	(tnrr)
ihdi	1.000								
bankliqres	0.040	1.000							
broadmogdp	0.668***	-0.173***	1.000						
realintrat	-0.162***	0.046	-0.205***	1.000					
hucap	0.776***	0.043	0.351***	-0.184***	1.000				
govinvest	0.124***	-0.002	0.056	0.102**	0.140***	1.000			
cc	0.444***	-0.234***	0.468***	-0.103**	0.317***	-0.037	1.000		
cpi	-0.034	0.418***	-0.178***	-0.056	-0.027	0.092**	-0.183***	1.000	
tnrr	-0.098**	0.274***	-0.260***	-0.102**	-0.140***	0.074*	-0.382***	0.088**	1.000

*** p<0.01, ** p<0.05, * p<0.1

Table A2. *Regression of monetary policy on social inequality*

Variables	FE	2SLS	Dependent Variable: social inequality				
			Quantile instrumental variable regression	social inequality	social inequality	social inequality	social inequality
			10%	25%	50%	75%	90%
monetary policy	-0.132** (0.0617)	-0.962*** (0.115)	-1.421*** (0.157)	-1.283*** (0.162)	-1.078*** (0.202)	-0.878*** (0.191)	-0.761*** (0.109)
Human Capital Index	-6.168*** (0.931)	-5.338*** (0.612)	-2.371*** (0.780)	-3.821** (1.514)	-4.101*** (0.884)	-4.574*** (0.846)	-6.414*** (0.367)
Government investment	0.173*** (0.0407)	0.372*** (0.0616)	0.404*** (0.109)	0.506*** (0.0843)	0.374*** (0.0688)	0.255** (0.125)	0.417*** (0.121)
Control of Corruption	-0.0453 (0.523)	0.142 (0.348)	0.701 (0.461)	0.948 (0.589)	0.341 (0.590)	0.363 (0.878)	0.0790 (0.750)
Consumer price index	0.0123 (0.0206)	0.0917** (0.0370)	0.195*** (0.0355)	0.125** (0.0559)	0.0598 (0.0534)	-0.0731 (0.0607)	0.0120 (0.0790)
Total natural resources rents	0.0588** (0.0236)	-0.00885 (0.0451)	0.00606 (0.114)	0.0383 (0.0672)	0.0568 (0.0646)	0.118 (0.0777)	0.0169 (0.0513)
Constant	44.81*** (1.852)	45.77*** (1.238)	36.20*** (1.426)	40.61*** (2.588)	43.62*** (1.278)	47.30*** (2.573)	52.01*** (1.195)
Observations	336	278	278	278	278	278	278
R-squared	0.251	0.552					
Number of countries	29						

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A3. *Regression of monetary policy on income inequality*

Variables	FE	2SLS	Dependent Variable: income inequality				
			Quantile instrumental variable regression	social inequality	social inequality	social inequality	social inequality
			10%	25%	50%	75%	90%
Monetary policy	0.0291 (0.154)	-2.025*** (0.361)	-1.979*** (0.355)	-2.871*** (0.594)	-1.700 (1.415)	-0.829 (0.638)	-0.936* (0.551)
Human Capital Index	0.197 (0.291)	3.788** (1.852)	0.543 (2.851)	7.265* (3.987)	5.125 (3.291)	8.680*** (2.388)	4.311*** (1.137)
Government investment	0.371*** (0.100)	0.604*** (0.232)	0.179 (0.403)	0.699** (0.297)	0.694* (0.384)	0.106 (0.483)	0.0818 (0.198)
Control of Corruption	1.836 (1.287)	5.117*** (1.109)	9.748*** (2.964)	5.472*** (1.816)	4.134*** (1.348)	3.798 (2.477)	8.022*** (0.864)
Consumer price index	0.108** (0.0506)	0.161 (0.131)	-0.142 (0.112)	0.0330 (0.264)	0.257* (0.146)	0.382 (0.240)	0.140 (0.207)
Total natural resources rents	0.0772 (0.0581)	0.0691 (0.142)	-0.436** (0.208)	-0.0737 (0.275)	0.0624 (0.230)	0.189 (0.165)	0.490*** (0.171)
Constant	39.95*** (4.568)	41.92*** (3.425)	44.97*** (3.978)	33.38*** (6.891)	36.85*** (6.222)	34.95*** (7.310)	50.85*** (2.021)
Observations	335	278	278	278	278	278	278
R-squared	0.069	0.203					
Number of countries	29						

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A4. *Regression of monetary policy on human development*

Variables	Dependent Variable: human development						
	FE	2SLS	Quantile instrumental variable regression				
			10%	25%	50%	75%	90%
Monetary policy	0.0109*** (0.00227)	0.0560*** (0.00514)	0.0558*** (0.00477)	0.0560*** (0.00486)	0.0560*** (0.00486)	0.0560*** (0.00486)	0.0556*** (0.00478)
Human Capital	0.134*** (0.00907)	0.141*** (0.00786)	0.142*** (0.00714)	0.141*** (0.00717)	0.141*** (0.00717)	0.141*** (0.00717)	0.142*** (0.00725)
Government investment	0.000675* (0.000396)	-0.000383 (0.000893)	-0.000478 (0.000964)	-0.000383 (0.000913)	-0.000383 (0.000913)	-0.000383 (0.000913)	-0.000396 (0.000915)
Control of Corruption	0.00916* (0.00510)	0.0469*** (0.00559)	0.0468*** (0.00564)	0.0469*** (0.00549)	0.0469*** (0.00549)	0.0469*** (0.00549)	0.0470*** (0.00606)
Consumer price index	0.000469** (0.000201)	-7.81e-05 (0.000645)	-0.000278 (0.000741)	-7.81e-05 (0.000707)	-7.81e-05 (0.000707)	-7.81e-05 (0.000707)	-6.80e-05 (0.000724)
Total natural resources rents	-0.000862*** (0.000230)	0.00245*** (0.000710)	0.00241*** (0.000674)	0.00245*** (0.000627)	0.00245*** (0.000627)	0.00245*** (0.000627)	0.00256*** (0.000651)
Constant	0.292*** (0.0184)	0.281*** (0.0175)	-0.119*** (0.0161)	0.0308* (0.0157)	0.281*** (0.0157)	0.531*** (0.0157)	0.678*** (0.0179)
Observations	336	278	278	278	278	278	278
R-squared	0.545	0.831					
Number of countries	29						

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Framework: Sample

Algeria, Angola, Botswana, Burundi, Burkina Faso, Cabo Verde, Central African Republic, Chad, Comoros, Congo Dem. Rep., Congo Rep., Côte d'Ivoire, Djibouti, Egypt, Eswatini, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe.

Analysing the relationship between tourist flows and socio-economic development. A comparative case study: Romania vs. PIGS countries

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Abstract. *The share of tourism in GDP is below 3% in Romania, while the PIGS countries are recognized for the significant impact of tourists influx on socio-economic development. Following the analysis carried out at national level, I found a stronger relationship between the dynamics of the tourist flows and that of GDP per capita / employed population in PIGS countries, compared to Romania, where the linkage is weaker. At regional level, significant divergences were found, especially in terms of the percentage change in the employed population, both between PIGS and Romania NUTS 2 regions, and between the regions of Romania.*

Keywords: tourist flows, economic development, tourism, Romania, PIGS.

JEL Classification: F64, L83, O11, Z32.

1. Introduction

Tourism is one of the most important and dynamic industries with a strong impact on the economy, society, and the environment. The development of this sector has reshaped the economies of some countries, requiring a reassessment of the relationship between tourism and sustainability. The process of developing public policies has been oriented worldwide towards maintaining a balance between the potential negative effects of tourism and the economic and social advantages that it generates.

The study aims to provide an assessment of the relationship between tourist flows and socio-economic development in Romania and PIGS countries (Portugal, Italy, Greece and Spain). Tourism often acts as a driver of social change and economic growth, while tourist flows generate significant changes in the destination areas, influencing infrastructure, local culture, and employment opportunities. Thus, tourism stimulates the local economy through the capital increase channel. At the same time, this sector supports creating new jobs, thus contributing to the reduction of unemployment, but also to the development of infrastructure at the national level (transport, hotels / restaurants / catering, supermarkets) and locally, in this case having as a benchmark the locals who offer traditional products for sale. In the same vein, tourists' spending stimulates other economic sectors (such as transport, trade, agriculture), contributing to the strengthening of the national currency through external revenue, which enhances regional economic performance.

The social and cultural impact occurs through cultural exchange, the reevaluation of traditions, the development of urban areas and the capitalisation of the tourism potential of less advantaged areas. Sustainable development is another relevant concept, emphasizing the connection between environmental protection and the economic performance of tourism. The study is also relevant for domestic citizens, helping them to better understand how the diversity of tourist flows can increase the number of foreign tourists to Romania, while also encouraging communities to support the preservation of sites and attractions with tourism potential.

The main objective of the paper is to identify the degree to which factors such as the dynamics of the number of tourist overnight stays, GDP/capita, the employed population, and the population at risk of poverty rate interact at the level of Romania, compared to the PIGS countries.

2. Literature review

According to Hughes and Scheyvens (2016), tourism's capacity to influence sustainable development has risen to the top of the Sustainable Development Goals of the 2030 Agenda, with the tourism sector contributing to global development and promoting sustainability. Goals such as economic growth, ocean conservation, consumption and production provide a narrow perspective on the complex relationship between tourism and sustainable development (Saarinen, 2020). The concept of sustainable development, as presented in the Our Common Future report, suggests a type of development that "meets

the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). Sustainable tourism has evolved over time, initially focusing exclusively on environmental issues, to now integrating the social and economic dimensions of development (Torres-Delgado and López Palomeque, 2012). At the same time, tourism studies reveal significant gaps regarding the feasibility of implementing and maintaining an authentic sustainable tourism trajectory (Marsiglio, 2015; Sharpley, 2020).

The economic literature has extensively analysed the role of international tourism in the process of national economic development (Ghali, 1976; Sinclair, 1998; Lanza and Pigliaru, 1994; Hazari and Sgro, 1995). The so-called Tourism-Led Growth (TLG) hypothesis has been investigated in numerous comparative empirical studies at the international level (Lee and Chang, 2008; Sequeira and Maças Nunes, 2008; Figini and Vici, 2010), as well as in time series analyses conducted for individual countries in Latin America, Asia and Europe.

The efficiency of tourism as a factor of stimulating economic growth has proven to be particularly pronounced in the case of small economies specialised in tourism, such as many island states (Brau et al., 2007).

As for European countries, the contribution of tourism to economic dynamics has been highlighted by Balaguer and Cantavella - Jordà (2002) and Capó Parrilla et al. (2007) for Spain, by Dritsakis (2004) for Greece, and by Proença and Soukiazis (2005) for Portugal. These mechanisms include significant foreign exchange inflows, the stimulation of intersectoral linkages, increased public investment in infrastructure, and multiplier effects on employment.

For destination countries, tourism represents an important source of income, contributing both to the standard of living in certain regions, and to employment opportunities, new investments and infrastructure development (Haralambopoulos and Pizam, 1996; Dwyer et al., 2004; Galani-Moutafi, 2004; Oh, 2005; Kim et al., 2006; Lee and Chang, 2008; Po and Huang, 2008; Polyzos, 2011; Schubert et al., 2011). In addition, tourism also strengthens the balance of payments, while supporting regional economic growth (Lee and Chang, 2008; Meade, 1951; Song et al. 2012; Oh, 2005; Kim et al., 2006; Polyzos, 2011; Panahi et al., 2014; Po and Huang, 2008; Schubert et al., 2011).

Regarding poverty reduction through tourism, empirical studies conducted across different countries reached mixed results, with evidence varying in most cases. Balaguer and Cantavella-Jordà (2002) carried out such a study for Spain, showing that tourism can promote economic growth on the long-term, enabling people to escape poverty as a consequence of per capita income increase. Meanwhile, another study conducted for South Africa by Saayman et al. (2012) suggested that tourism can contribute to poverty reduction only if disadvantaged population could benefit from tourism spending in the region.

Tourism is particularly sensitive to external shocks, from volatile geopolitical events that reshape travel flows to the escalation of climate risks that disrupt operations and change consumer preferences (Gössling and Scott, 2024).

Inflation in this sector is reflected in increasing operational costs and the broader consequences of economic interdependence, as well as vulnerabilities to climate and geopolitical factors. At the same time, the challenges arising from the economic, geopolitical and climate sectors are significant for tourism, even as the sector returns to pre-pandemic levels (World Tourism Organization, 2024). Due to climate disruptions, tourism infrastructure costs have increased, according to Scott et al. (2019) and Tanriserver et al. (2024), these events having the capacity to disrupt supply chains, intensify resource shortages, while contributing to inflationary pressures in the tourism sector.

3. Methodology

This research analyses a series of statistical data published by Eurostat for the period 2007-2024 related to tourist flows (percentage change in the number of overnight stays), economic development (percentage change in GDP/capita) and social development (population at risk of poverty rate), the percentage change in the employed population being reflected in both types of development. The year 2007 marks Romania's accession to the European Union (January 1, 2007), but also the starting point of the global economic crisis (December 2007), followed in 2009 by the spread of the crisis at European level. The outbreak of the COVID-19 pandemic in 2020 and the escalation of the geopolitical tensions in 2022 represented additional challenges that strongly impacted the economy during the examined period.

Regarding the analysis, the graphical method has been used to assess the main trends in Member States from the perspective of tourist flows and their influence on socio-economic development. At the same time, in order to capture the statistical association between the indicators, the Pearson statistical correlation has been used.

The present research focuses on the comparison between Romania and the PIGS countries in order to assess Romania's positioning relative to the most popular mass tourism destinations. The PIGS countries faced severe economic challenges during the EA sovereign debt crisis (2009-2014) which began in Greece, recording high debts and excessive deficits that revealed significant economic vulnerabilities and high default risks.

The analysis includes a national component, where comparisons were made at the national level, and a regional one, for which comparisons between the analysed NUTS 2 regions have been carried out. However, Portugal was not included in the regional analysis, as the territorial reorganization affected the availability of data for some regions and indicators.

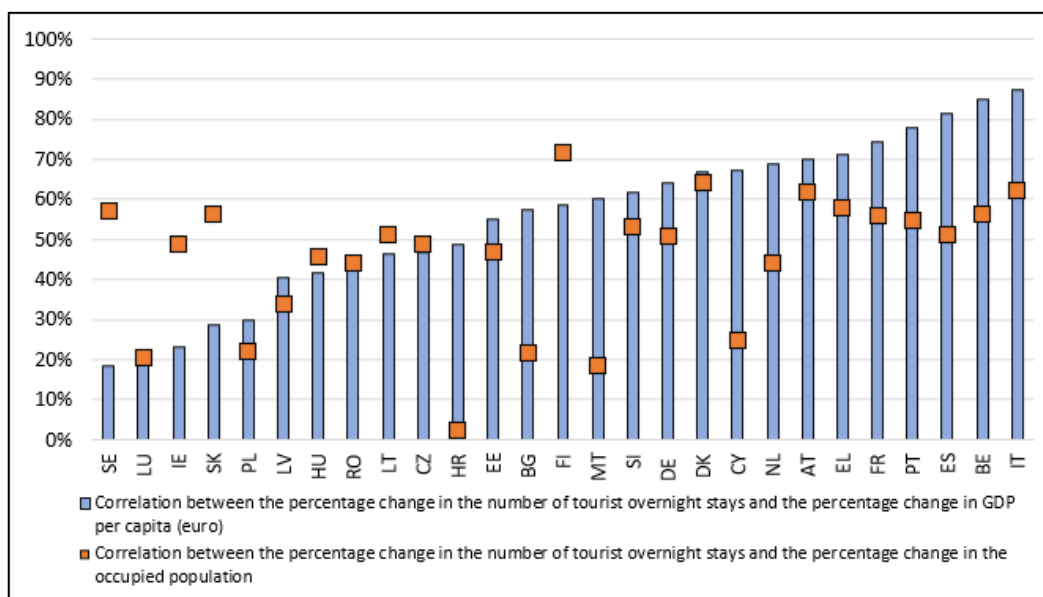
4. Results and interpretations

In this section, several data series on tourist flows and their influence on representative socio-economic indicators were analysed and interpreted.

The main socio-economic indicator analysed is GDP (Gross Domestic Product) per capita (expressed in euros). The correlation between this indicator and the tourist flow, expressed by the number of tourist overnight stays in the partner country (*Figure 1*), is positive for all countries, highlighting the fact that tourism development has positive effects on economic development. The PIGS countries record some of the highest values (Greece - 71%, Portugal - 78%, Spain - 81%, Italy - 87%), with the high correlation underlining the importance of tourism for their economies. On the other hand, in the case of Romania, the correlation is more modest (42%), suggesting a weaker relationship between the two indicators.

Investments in tourism create new jobs both through the development of infrastructure and the maintenance of accommodation capacities. The results also show positive correlations between the tourist flows and the percentage change in the employed population at EU level (*Figure*) in all Member States cases. The PIGS countries record moderate values (above 50%), while Romania shows a correlation of 42%, lower than the ones specific to this country-group. In this respect, the data obtained highlight a stronger relationship between tourist flows and socio-economic development in the PIGS countries compared to Romania.

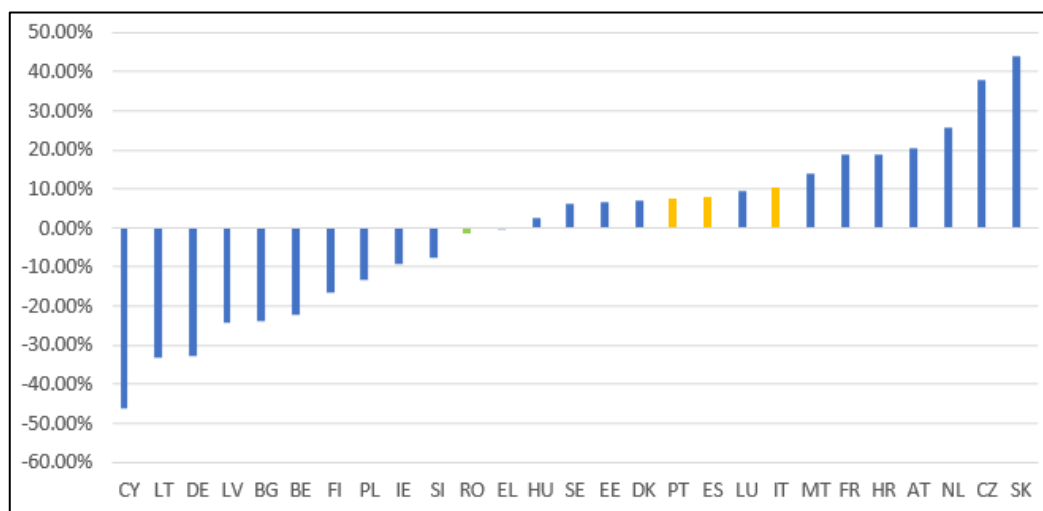
Figure 1. Correlation between the percentage change in the number of tourist overnight stays and the percentage change in GDP per capita (euro) / percentage change in the employed population



Source: own processing in Microsoft Office Excel, based on Eurostat data

Another effect explored in the literature is the impact of tourist flows on poverty rate. According to *Figure 2*, more than half of the countries show a positive correlation (maximum 44% - Slovakia) between tourist flows and poverty rate, while the PIGS countries record weak correlations (maximum 10% - Italy, minimum 0% - Greece).

Figure 2. Correlation between the percentage change in the number of tourist overnight stays and the people at risk of poverty rate

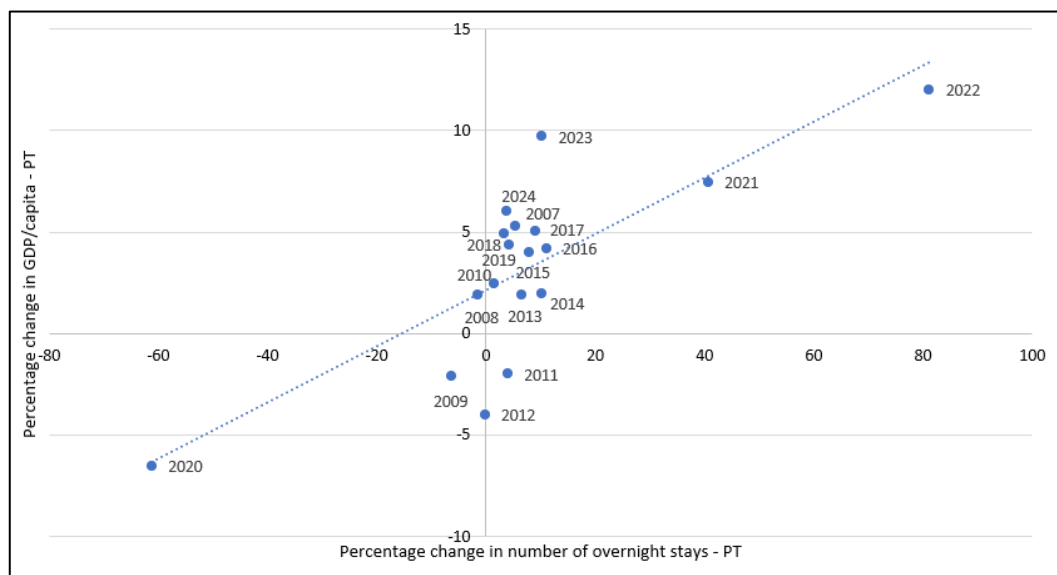


Source: own processing in Microsoft Office Excel, based on Eurostat data

On the other hand, Romania shows a negative correlation, close to 0%, which highlights the absence of a significant short-term impact of tourism on poverty. The poverty rate is influenced by factors such as the increase in the standard of living, unemployment, migration, education, health status and demography, all of these factors manifesting differently in the analysed countries. Tourism generates effects over time on poverty both in terms of size and duration of the impact, depending on the national specifications. It is also worth mentioning that poverty has an autoregressive influence, which makes poverty alleviation process particularly complex and long-term.

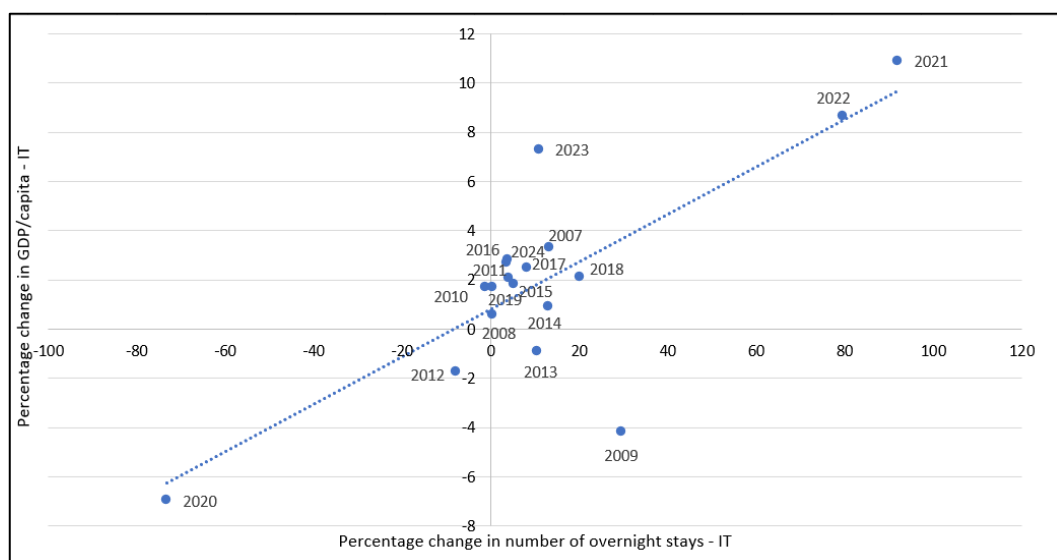
By comparatively analysing the percentage change in GDP per capita and the percentage change in the number of overnight stays for each country in the PIGS group, it was observed that, during the 2007-2024 period, the two indicators followed a similar path. The 2007-2019 interval was characterised by limited variations in both indicators, the percentage change in GDP per capita presenting more significant differences, while the tourist flows remained relatively constant. The economic crisis that affected the period 2009-2014 generated negative percentage changes in GDP, while the COVID-19 crisis produced similar effects in 2020. The period 2020-2022 was marked by significant reductions in tourism due to the impact of the pandemic and the geopolitical tensions. In particular, the trend indicates that increases in one indicator are generally accompanied by increases in the other, a relationship confirmed by the high correlation values previously calculated.

Portugal (*Figure 3*) and Italy (*Figure 4*) follow the general trend, with the negative changes in GDP and tourist flows recorded during the crisis years (2009) and the pandemic period (2020) being recovered in the immediately following years.

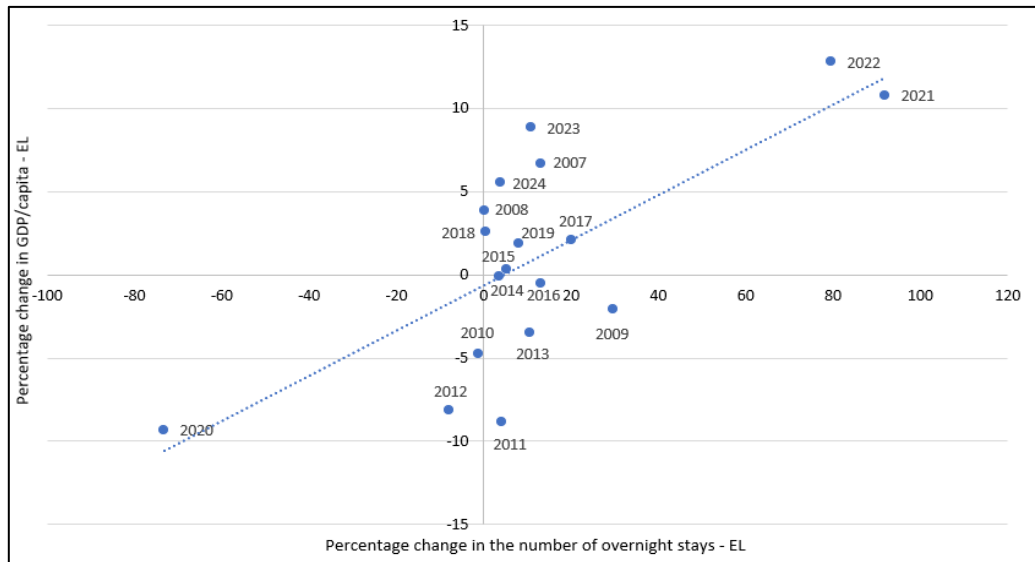
Figure 3. *Percentage change in GDP per capita vs. percentage change in overnight stays for Portugal*

Source: own processing in Microsoft Office Excel, based on Eurostat data

Greece (*Figure 5*) and Spain (*Figure 6*) experienced a more difficult period between 2009 and 2016, when the global crisis overlapped with the economic shock affecting the euro area. Nevertheless, the relationship between the analysed indicators remained strong and positive. However, to regain competitiveness, these countries reduced their generous social benefits, while stimulating youth employment.

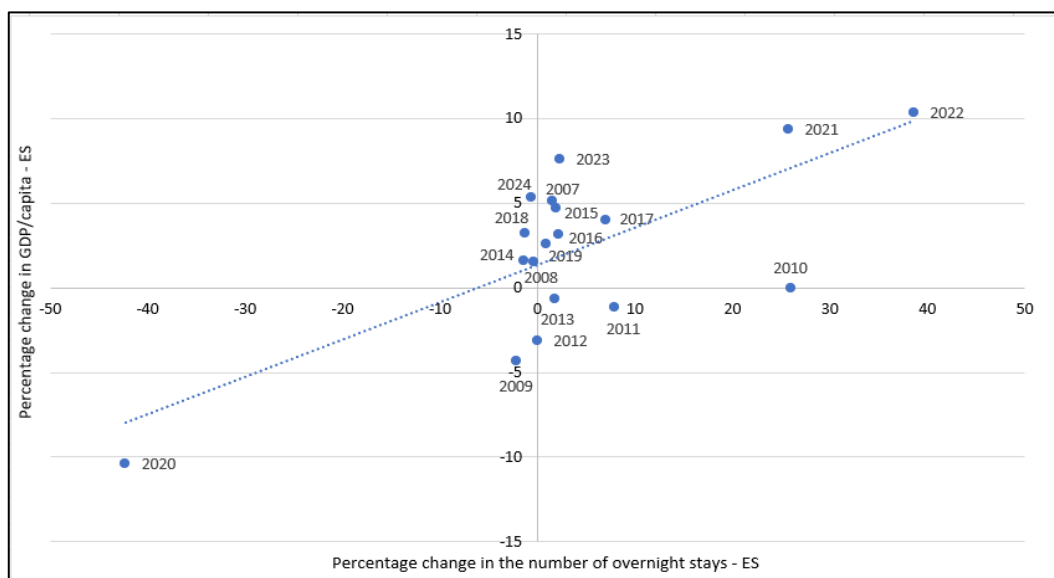
Figure 4. *Percentage change in GDP per capita vs. percentage change in number of overnight stays for Italy*

Source: own processing in Microsoft Office Excel, based on Eurostat data

Figure 5. *Percentage change in GDP per capita vs. percentage change in overnight stays for Greece*

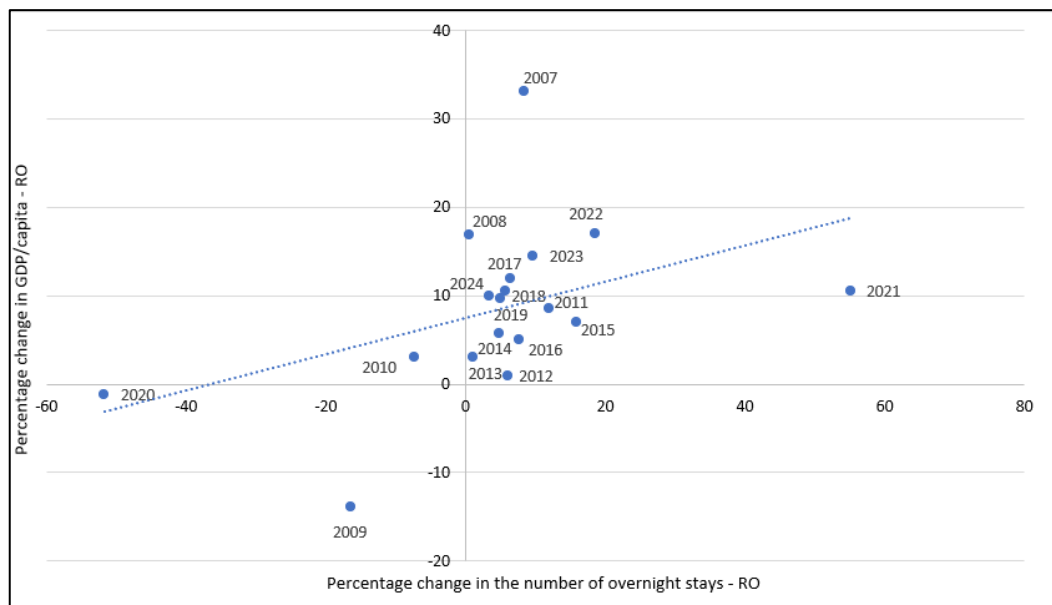
Source: own processing in Microsoft Office Excel, based on Eurostat data

In Romania (*Figure 7*), the trend of the analysed indicators is lower even though economic growth was positive throughout the period, except for 2009 and 2020. The data show that the slope of the graph is slightly more inclined to the right, which is also reflected in the lower correlation between the percentage change in the number of overnight stays and that of GDP per capita compared to that obtained in the case of PIGS countries.

Figure 6. *Percentage change in GDP per capita vs. percentage change in number of overnight stays for Spain*

Source: own processing in Microsoft Office Excel, based on Eurostat data

Figure 7. Percentage change in GDP per capita vs. percentage change in number of overnight stays for Romania



Source: own processing in Microsoft Office Excel, based on Eurostat data

The detailed analysis at the level of the regions of the PIGS countries and Romania reveals a positive correlation between GDP per capita growth and the increase in the number of overnight stays in all cases. The regions of the PIGS countries present correlations above 70% between GDP per capita growth and the increase in the number of overnight stays, while in Romania, correlation coefficients above 70% are found only in the Bucharest-Ilfov region (73%) and the West region (71%), areas with the highest economic development in Romania, while the lowest correlation coefficient has been found in the North-East region (22%).

A different situation can be observed in the case of the correlation between the percentage change in the number of overnight stays and the percentage change in the employed population (*Annex 1*). In the PIGS countries, most of the correlation coefficients are positive (excepting Ciudad de Melilla in Spain which presents a negative correlation of 47% and Peloponnisos in Greece which records a negative correlation of 16%), the highest value being reported for the Valle d'Aosta region in Italy (88%). By contrast, in Romania, the correlations are predominantly negative (the lowest being recorded in the North-East region, -57%), with the exception of the Bucharest-Ilfov region (+26%). These results highlight the fact that, although tourism contributes to economic development in Romania, its impact on job creation at regional level remains limited, the only positive relationship being identified for the Bucharest-Ilfov region, where business tourism is more promoted.

Annex 2 presents a relevant indicator for tourism activity, namely the occupancy rate of accommodation units in 2024. It can be observed that the average for European countries

is approximately 60%, while among the PIGS countries, only Portugal (62.46%) and Spain (69.59%) exceed this threshold. Italy (58.3%) and Greece (50.4%) exceed only half of the accommodation capacity, while Romania has the lowest occupancy rate of accommodation units (28.12%), its tourism potential not being appropriately exploited.

5. Conclusions

This paper revealed a close relationship between tourism and socio-economic development in EU countries, highlighting the countries belonging to the southern European submodel through stronger correlation coefficients than those calculated for Romania, against the background of the high share of the tourism sector in GDP in the PIGS countries.

According to the results, in PIGS countries, the increase in tourist flows generates a dynamic of the economy that also leads to an increase in the employment rate. In all four analysed countries, tourism is very developed, with a long tradition, the tourism potential having a high degree of capitalisation. In these conditions, it is worth noting that there is a continuous trend of development of mass tourism, especially international tourism, which has a major contribution to GDP growth. This is noticeable both at the national and regional levels.

In southern European countries, the increase in the number of overnight stays is synchronised to a lesser extent with the employment rate, since, in many cases, the increase in the influx of tourists can be managed without a significant increase in the number of workers in this sector, the results of tourism being reflected in GDP, both through the production and expenditure methods.

In Romania, the percentage change in GDP per capita is lower (as the country has not yet adopted the euro and is currently facing a difficult period from an economic point of view) and is influenced by the percentage change in tourist flows to approximately the same extent as the dynamics of the employment rate. It is worth noting that in Romania, tourism is poorly promoted compared to the other countries analysed, and the deficient infrastructure affects the exploitation of the tourism potential.

Maintaining and developing tourist flows requires the creation and maintenance of infrastructure and accommodation capacities, which also involves the creation of new jobs. In the PIGS countries, it can be observed that the percentage change in the number of overnight stays is positively associated with percentage change in the employed population, while, in Romania, positive correlations are observed only in highly developed urban areas (Bucharest, Cluj, Iași), where both the accommodation capacity and the occupancy rate of accommodation units are higher.

The assessment shows that the effects of tourism on the poverty rate are not immediate, but, over time, depending on the national specificities and the intensity of tourism, this sector contributes to reducing poverty, developing opportunities for rural and disadvantaged areas. Involvement in tourism can increase respect for the environment and

local culture, encouraging education and professional training of communities. However, if tourism is not properly managed through sustainable policies, several negative effects can result, such as cultural degradation, urban congestion, price increases and increased economic dependence on tourists.

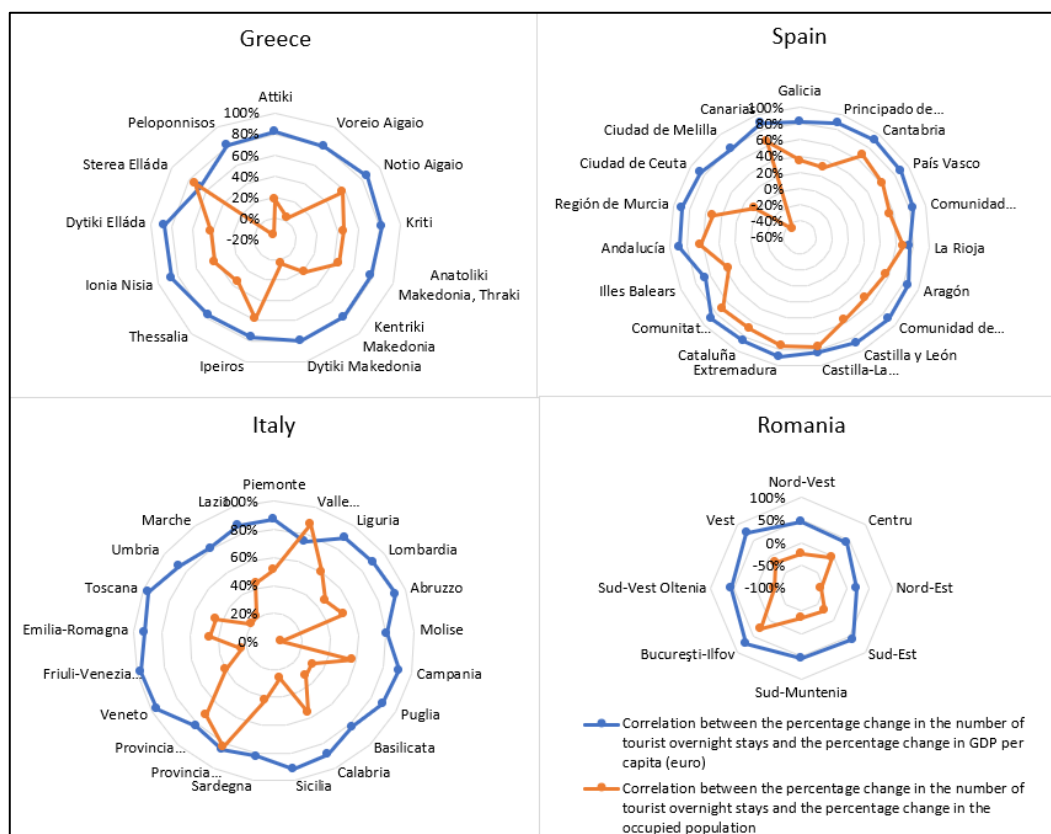
Another challenge is the impact of tourism on the environment. In countries such as Spain and Italy, citizens have taken a stand against the tourism congestion in cities (which causes the degradation of monuments, a decrease in the quality of life, pollution, etc.) and have called for a reduction in the tourist flows. In order to respond to all the challenges generated by the tourism sector, there is a need to develop and promote strategies and policies that take into account economic, social and environmental sustainability with the aim of achieving the medium and long-term objectives of harmonious development while respecting the principles of sustainable development.

This paper is subject to certain limitations regarding the number of indicators used and the typology of tourism analysed. However, the research could be further expanded by developing panel econometric models and conducting in-depth comparative analyses based on the results obtained.

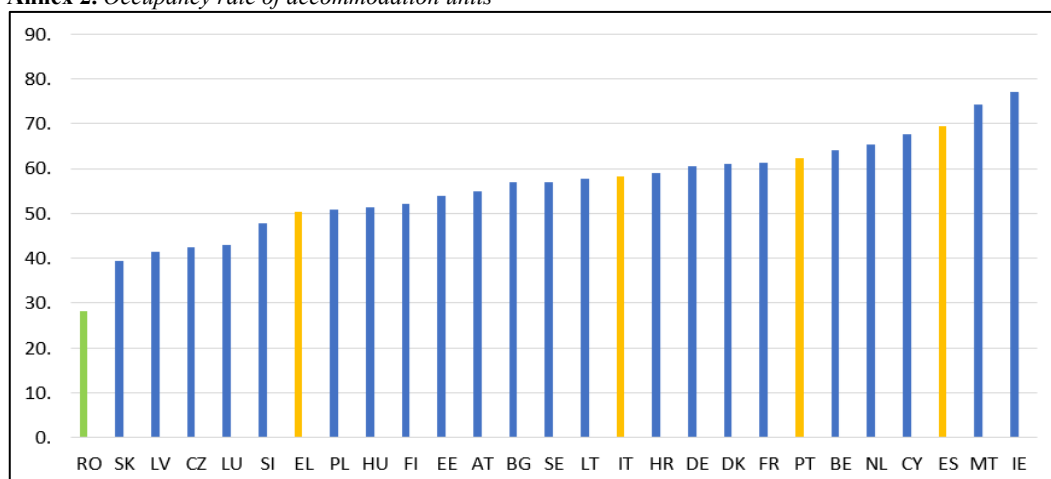
References

- Aliyeva, S., Chen, X., Yang, D., Samarkhanov, K., Mazbayev, O., Skenuly, A., Issanova, G. and Kozhokulov, S. (2019). The Socioeconomic Impact of Tourism in East Kazakhstan Region: Assessment Approach. *Sustainability*, 11(17), 4805.
- Balaguer, J. and Cantavella-Jorda, M. (2002). Tourism as a long-run economic growth factor: the Spanish case. *Applied economics*, 34(7), 877-884.
- Brau, R., Lanza, A. and Pigliaru, F. (2007). How fast are small tourism countries growing? Evidence from the data for 1980-2003. *Tourism Economics*, 13(4), 603-613.
- Dritsakis, N. (2004). Tourism as a long-run economic growth factor: an empirical investigation for Greece using causality analysis. *Tourism economics*, 10(3), 305-316.
- Elgin, C. and Elveren, A.Y. (2024). Unpacking the economic impact of tourism: A multidimensional approach to sustainable development. *Journal of Cleaner Production*, 478, 143947.
- Eurostat. (2026). Eurostat database, available at: <<https://ec.europa.eu/eurostat/data/database>>
- Figini, P. and Vici, L. (2010). Tourism and growth in a cross section of countries. *Tourism Economics*, 16(4), 789-805.
- Ghali, M.A. (1976). Tourism and economic growth: An empirical study. *Economic Development and Cultural Change*, 24(3), 527-538.
- Hazari, B.R. and Sgro, P. (1995). Tourism and growth in a dynamic model of trade. *The Journal of International Trade & Economic Development*, 4(2), 234-252.
- Huges, E. and Scheyvens, R. (2020). Corporate social responsibility in tourism post-2015: a Development First approach, in *Tourism and Sustainable Development Goals*, Routledge.

- Kalantzi, O., Tsiotas, D. and Polyzos, S. (2017). The contribution of tourism in national economies: evidence of Greece. *Journal of Business and Social Sciences*, 5(10), 41-64.
- Lee, C.C. and Chang, C.P. (2008). Tourism development and economic growth: A closer look at panels. *Tourism management*, 29(1), 180-192.
- Marsiglio, S. (2015). Economic growth and environment: tourism as a trigger for green growth. *Tourism Economics*, 21(1), 183-204.
- Paci, R. and Marrocu, E. (2014). Tourism and regional growth in Europe. *Papers in Regional Science*, 93(1), 25-51.
- Palaios, P., Sarker, P.K. and Leventis, F. (2025). Inflation in Tourism Sector: New Evidence from Climate and Geopolitical Spillover Effects. *International Journal of Tourism Research*, 27(5), e70116.
- Parrilla, J.C., Font, A.R., and Nadal, J.R. (2007). Tourism and long-term growth a Spanish perspective. *Annals of tourism research*, 34(3), 709-726.
- Pascariu, G.C. and Țigănașu, R. (2014). Turismul și dezvoltarea regională sustenabilă în România și Franța: o abordare din perspectiva noii geografii economice. *Amfiteatru Economic*, 16(8), 870-880.
- Popescu, D. Săseanu, A., Bulin, D., Grazia, C. (2014). Econometric models in Romanian tourism under the impact of sustainable development. *Amfiteatru Economic*, 16(8), 1063-1075.
- Pigliaru, F., and Lanza, A. (1994). The tourism sector in the open economy. *International Review of Economics*, 41, 15-28.
- Saarinén, J. (2020). *Tourism and sustainable development goals: research on sustainable tourism geographies*, Routledge.
- Sequeira, T.N. and Maças Nunes, P. (2008). Does tourism influence economic growth? A dynamic panel data approach. *Applied economics*, 40(18), 2431-2441.
- Sharpley, R. (2020). Tourism, sustainable development and the theoretical divide: 20 years on. *Journal of Sustainable Tourism*, 28(11), 1932-1946.
- Sinclair, M.T. (1998). Tourism and economic development: A survey. *The Journal of Development Studies*, 34(5), 1-51.
- Soukiazis, E. and Proença, S. (2008). Tourism as an alternative source of regional growth in Portugal: a panel data analysis at NUTS II and III levels. *Portuguese Economic Journal*, 7(1), 43-61.
- Torres-Delgado, A. and Palomeque, F.L. (2012). The growth and spread of the concept of sustainable tourism: The contribution of institutional initiatives to tourism policy. *Tourism Management Perspectives*, 4.
- Tung, L.T. and Cuong, L.K., (2020). Impact of Tourism on Poverty Reduction: Evidence from an Emerging Tourism Market. *Montenegrin Journal of Economics*, 16(3), 45-55.
- World Commission on Environment and Development (WCED). (1987). *Our common future* world commission on environment and development.

Annex 1. Correlation between tourist flows and the dynamics of GDP per capita / employed population at regional level

Source: own processing in Microsoft Office Excel, based on Eurostat data

Annex 2. Occupancy rate of accommodation units

Source: own processing in Microsoft Office Excel, based on Eurostat data