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Diplomacy as a non-lethal weapon: economic sanctions in the EU-US-China relationship and their effect on trade

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Abstract. *This study traces the paradigm shifts in contemporary international relations, highlighting the shift from conventional military force to the use of economic instruments as forms of political pressure, described as “non-lethal weapons”. The research focuses on the geo-economic triad formed by the European Union, the United States of America and China, aiming to show how tariff policies and trade sanctions are used to shake global power hierarchies in the absence of direct armed confrontations. The paper emphasizes the role of diplomacy not only as a mechanism that guarantees peace through negotiation, but also as a weapon of control through coercive mechanisms. Thus, economic sanctions become not just administrative punishments, but a form of modern siege that dictates the survival or marginalization of actors on the international trade scene.*

Keywords: economic diplomacy; tariff war; social costs; sanctions; cold war.

JEL Classification: F13, F14, F51, F52, F53.

Introduction

In the current international context, dominated by military conflicts that seem to be escalating at a dangerous pace, the delimitation between geopolitics and geoeconomics is becoming increasingly difficult to outline. Conventional military conflict, although not completely eliminated, is losing ground to hybrid warfare, which also manifests itself through economic warfare, using tariff controls, financial sanctions and embargo-type measures as tools. As conventional war becomes increasingly costly, in terms of political, financial and human losses, diplomacy reduces these costs, emphasizing economic measures as “non-lethal weapons” to coerce rivals. Far from being mere passive measures, the mechanisms of economic warfare represent today a powerful substitute for conventional warfare.

Radoslav B. (2024), in their article “Economic Diplomacy in the Era of Globalization”, define economic diplomacy as “the process of establishing ties with other nations, protecting national security and positively shaping the country's image abroad, also attracts foreign investment, creating a favorable business environment”. The cited definition highlights the two sides of the coin of contemporary economic diplomacy. Although attracting foreign investment and creating a favorable business environment suggests a cooperative approach, the inclusion of the objective of “protecting national security” refers to the use of military power by states to guarantee the security of states. Thus, diplomacy has not only a peaceful role, but also a coercive one, becoming a “non-lethal weapon” that guarantees increased military power of the aggressor state without it losing any financial, strategic or human resources.

The article complements the existing literature to fill the gaps regarding the systemic and structural effect of tariff wars on the global market. We also aim to determine, through a case study, how economic sanctions and tariff barriers fundamentally restructure the global balance of power and trade hierarchies within the EU-US-China triad in the absence of a conventional military conflict. Thus, we aim to demonstrate not only that diplomacy can become a weapon in unconventional wars, but also that in modern society, effective wars have shifted from the use of weapons to the use of the power of influence and the advantage of possessing economic resources.

The research focuses on the geo-economic triad formed by the European Union, the United States of America and China, aiming to show how tariff policies and trade sanctions are used to shake global power hierarchies in the absence of direct armed confrontations. While the US and EU have historically used sanctions as a tool to promote democracy and human rights, China has increasingly adopted “defensive” and counter-sanction measures, reshaping the architecture of global trade.

The research question of this study is the following: “In what way do economic sanctions and tariff barriers fundamentally restructure the global balance of power and trade hierarchies within the EU-US-China triad in the absence of a conventional military conflict?”.

To answer this question, we formulated the following two research hypotheses:

- H1: The strategic use of “weaponized interdependence” (technology and financial controls) effectively shifts global power hierarchies, replacing conventional military force as the primary tool for geopolitical dominance in the 21st century.
- H2: The weaponization of trade within the EU-US-China triad triggers a “boomerang effect”, in which controls on the export of raw materials destabilize the predictability of the supply chain, ultimately undermining the economic competitiveness of the actors applying sanctions.

The research aims not only to analyze recent economic events, but to demonstrate that, in the current context, economic diplomacy has become an indispensable tool for global governance, to the detriment of conventional military conflicts. (Alexandru. in press)

To ensure analytical clarity, it is necessary to establish the methodological limits of this research. The analysis of macroeconomic fluctuations within the EU-US-China triad requires a multi-layered framework that takes into account both direct policy interventions and indirect economic market reactions. Therefore, this study synthesizes quantitative trade indicators - such as bilateral trade, regulatory changes in foreign direct investment (FDI), and tariff deviation indices - as well as qualitative analysis of geopolitical discourse.

Literature Review

Joseph Nye, in his foundational work “Soft Power: The Means to Success in World Politics” tells us the following: “Soft power is not simply the same as influence. (...) And soft power is not necessarily better than hard power. It is not necessarily better to twist minds than to twist arms” (Nye. 2004). In the context of current research, we can consider hard power as conventional military power, and soft power as represented by tariff warfare. Thus, extrapolating, it is not desirable to start tariff wars (soft power) as an alternative to conventional ones (hard power), as these can also have devastating effects on the population, transforming conflicts between states into a burden directly felt by the average citizen.

Radoslav B. (2024), in their article “Economic Diplomacy in the Era of Globalization”, define economic diplomacy as “the process of establishing ties with other nations, protecting national security and positively shaping the country's image abroad, also attracts foreign investment, creating a favorable business environment”. The cited definition highlights the two sides of the coin of contemporary economic diplomacy. Although attracting foreign investment and creating a favorable business environment suggests a cooperative approach, the inclusion of the objective of “protecting national security” refers to the use of military power by states to guarantee the security of states. Thus, diplomacy has not only a peaceful role, but also a coercive one, becoming a “non-lethal

weapon” that guarantees increased military power of the aggressor state without it losing any financial, strategic or human resources.

Now that we have seen how Nye defines the difference between military coercive power and diplomatic coercive power, but we have also defined economic diplomacy as the main instrument for national security through Radoslav, it naturally follows to define the main concept of the research, namely tariff war.

Moving on to the field of tariff wars, Robert Gilpin (1987), defines them as “economic conflicts between two or more states, generated by the mutual imposition and escalation of customs duties on imported goods, in order to protect national industries, reduce the trade deficit or exert political and diplomatic pressure on trading partners”. This quote, through the section...” exert political and diplomatic pressure on trading partners”, validates the status of diplomacy as a non-lethal weapon, demonstrating that customs tariffs are no longer, nowadays, just fiscal policy instruments, becoming effective methods of geopolitical coercion.

Hans J Morgenthau, considered the father of “political realism,” told us as follows: “Political realism refuses to identify the moral aspirations of a particular nation with the moral laws that govern the universe. [...] All nations are tempted—and few have resisted the temptation for long—to clothe their own aspirations and actions in the moral clothes of the universe.” (Morgenthau, 1948) He also considered that: “sanctions are nothing more than manifestations of the struggle for power, camouflaged under a normative discourse” (Morgenthau, 1948). Thus, this part of the quote, “...All nations are tempted - and few have resisted the temptation for long - to clothe their own aspirations and actions in the moral clothes of the universe”; combined with the other quote “sanctions are nothing more than manifestations of the struggle for power..”, proves the hypothesis of the article, namely that economic diplomacy is not better than armed conflict, but rather an attempt to mask the thirst for power in something more tolerable, but perhaps more dangerous, than a conventional war.

To fully contextualize how trade barriers function within the EU-US-China triad, the literature must incorporate the foundational paradigm established by David Baldwin (1985) in his seminal work, “Economic Statecraft”. Baldwin conceptualizes economic sanctions and punitive trade instruments not as systemic market failures, but as deliberate techniques of foreign policy, defining them as: “the use of economic resources to influence the behavior of other states.” (Baldwin, 1985).

This theoretical framework is extremely important for the analysis carried out in this article, because it demonstrates that states use economic resources (access to markets, innovative technology resources, or embargo-type measures) not only to satisfy the needs of their own citizens, but also as instruments of political-military coercion in modern diplomatic conflicts.

Edward Luttwak (1990) in his article, “From geopolitics to geo-economics: Logic of conflict, grammar of commerce”, tells us that “everyone, it appears, now agrees that the methods of commerce are displacing military methods - with disposable capital in lieu of firepower, civilian innovation in lieu of military-technical advancement, and market penetration in lieu of garrisons and bases”. This quote validates our first hypothesis, according to which H1: “The strategic use of ‘armed interdependence’ (technology and financial controls) effectively changes the hierarchies of global power, replacing conventional military force as the main instrument for geopolitical dominance in the 21st century”, confirming that contemporary economic diplomacy becomes the weapon of modern conflicts, replacing the brute force of lethal weapons with “commercial methods”, at least as lethal from the point of view of the macroeconomic stability of states.

Methodology

The case study of this article will be entitled “Economic sanctions in the relationship between The European Union - The United States of America - China and their effect on trade”. Given the complexity of the proposed research topic, we chose to use a qualitative methodology, which will involve a comparative analysis of certain specific variables.

We chose the qualitative research method because we are discussing volatile variables, such as social impact or trade barriers, which cannot always be analyzed from an econometric point of view.

Using the case study of the EU-US-China geoeconomic triad, we aim to determine how economic sanctions and tariff barriers fundamentally restructure the global balance of power and trade hierarchies within the EU-US-China triad in the absence of conventional military conflict?

To systematically unpack this question and generate robust analytical conclusions, the research design operationalizes three distinct qualitative research instruments:

- **Analysis of Documents:** This involves the rigorous evaluation of primary texts, including national security strategies, executive orders on tariff implementations, official trade dispute filings within the World Trade Organization (WTO), and policy briefs from the European Commission, the US Department of Commerce, and the Ministry of Commerce of the People's Republic of China. This allows us to decode the strategic intent behind trade distortions.
- **Comparative Evaluation:** By analyzing the strategic maneuvers of the EU, the US, and China in parallel, this instrument identifies patterns of symmetry and asymmetry in how these actors deploy economic statecraft. It contrasts the aggressive unilateralism often seen in US-China relations with the regulatory, multilateral approach historically favored by the European Union.

- **Economic Data Synthesis:** While the core of the methodology remains qualitative and conceptual, the narrative is strictly anchored in macro-economic reality. This instrument synthesizes secondary economic data—such as aggregate bilateral trade flows, foreign direct investment (FDI) trends, and sector-specific supply chain dependencies—sourced from the World Bank, IMF, and UN Comtrade, serving as empirical evidence to validate our theoretical claims.

This study adopts a qualitative, comparative research strategy based on a structured comparative case narrative approach. The research utilizes a structured narrative framework to systematically examine and compare the selected case studies. This narrative-comparative design allows for an in-depth contextual analysis of how economic diplomacy tools function across different geopolitical environments, highlighting key patterns, strategic choices, and policy outcomes without imposing rigid Boolean formalization.

In the realm of international political economy, relying strictly on traditional statistical significance often obscures the institutional path-dependencies that trigger economic warfare. By focusing heavily on contextual depth rather than numerical variance, this comparative design approaches the EU-US-China triad not merely as three isolated economic units, but as an interdependent systemic configuration. Within this setup, each actor's economic diplomacy represents a specific combination of structural conditions—such as internal regulatory frameworks, level of market dependence, and geopolitical alignment—which collectively determine the outcome of international trade disputes.

From our perspective, the justification for focusing exclusively on the EU-US-China triad rests on its status as the structural gravity center of the modern global economy. These three nodes do not merely participate in global trade; they actively dictate its rules, norms, and legal boundaries. When the United States deploys unilateral tariff barriers under the guise of national security, or when China utilizes state-backed investment strategies and export controls on critical raw materials, the systemic shockwaves force the European Union to recalibrate its defensive toolkit, to a more defensive, geo-economic stance. Therefore, by analyzing these three distinct archetypes of economic power, our qualitative comparative assessment captures the full spectrum of modern economic statecraft. This approach transforms what could be a static description of trade friction into a dynamic, configuration-based analysis of how weaponized interdependence actually reshapes contemporary global governance.

Results and Discussions

Armed Independence: Military Force vs. Coercive Diplomacy (Testing Hypothesis 1), the empirical evaluation of the first hypothesis (H1): The strategic use of “weaponized

interdependence” (technology and financial controls) effectively shifts global power hierarchies, replacing conventional military force as the primary tool for geopolitical dominance in the 21st century.

Economic diplomacy replaces armed conflicts and military force with sanctions and embargo-type measures to gain global supremacy over spheres of influence. In order to validate the first hypothesis, it is necessary to see how the actor who controls global flows of transactions and payments can limit anyone's access to this market, destroying national economies without spending significant amounts on armaments or maintaining a military conflict.

The example we chose to support hypothesis 1 is that of the imposition of sanctions on countries in the international SWIFT system on the United States of America and the European Union, such as Iran (in 2012 and 2018) and Russia (2022).

Empirical analysis of these cases reveals a two-tiered evolutionary trajectory of financial coercion. The disconnection of Iranian financial institutions from the SWIFT network in 2012 established a significant historical precedent, demonstrating that the multilateral weaponization of global financial nodes can effectively isolate a state actor from international trade. The subsequent unilateral re-imposition of secondary sanctions by the United States in 2018 further underscored the asymmetrical power inherent in dollar-denominated clearing systems, compelling compliance from foreign corporations even as EU political positions shifted.

The issue of dollar-denominated clearing systems was again brought to the forefront following the unilateral reintroduction of secondary sanctions on the United States in 2018, and foreign corporations were effectively forced to comply, regardless of the EU's changing policy positions.

Also, on the recent international stage, starting in 2022, the political-military conflict between Russia and Ukraine is unfolding, also waged on both the conventional military and the economic front. In this context, the 2022 coordinated exclusion of major Russian banking institutions from the SWIFT network, combined with the freezing of approximately \$300 billion of the Russian Central Bank's foreign reserves, represents a critical evolutionary leap in economic warfare. By targeting the financial infrastructure rather than relying solely on traditional military interventions, the Western alliance demonstrated that controlling central nodes of global economic interdependence can inflict systemic domestic degradation comparable to conventional physical blockades, thereby conclusively validating H1.

The effectiveness of this paradigm shift lies primarily in the extreme cost-benefit asymmetry. Unlike conventional military campaigns, which inevitably require massive financial allocations and lead to catastrophic human losses, the deployment of specific

technological and financial controls allows for severe disruptions to targeted national economies. By transforming institutional nodes such as the SWIFT network into active battlefields, actors controlling these central hubs can effectively cripple the capabilities of targeted states without ever declaring a formal military conflict.

Therefore, the empirical evidence analyzed within the framework conclusively **validates Hypothesis 1 (H1)**. This trajectory of international relations clearly demonstrates that traditional indicators of geopolitical dominance - traditionally measured by territorial conquest and military power - are being systematically replaced by non-violent coercive mechanisms that destabilize the country economically and financially. Armed interdependence has thus moved from a secondary diplomatic leverage point to a primary mechanism of coercion and manifestation of dominant power.

Trade as a weapon and the boomerang effect (Testing Hypothesis 2): the empirical evaluation of the second hypothesis (H2): “The weaponization of trade within the EU-US-China triad triggers a “boomerang effect”, in which controls on the export of raw materials destabilize the predictability of the supply chain, ultimately undermining the economic competitiveness of the actors applying sanctions.”

To validate the hypothesis formulated above, we will use the qualitative analysis of two case studies as follows: the first case study will follow the control of gallium and germanium exports by China (2023–2025); the second case study will follow the CHIPS Act and the semiconductor restriction cycle in the United States of America and the third case will be about The European Union — Structural Dependency and the Transitional Cost of Weaponized Trade

Case Study 1: China's Export Controls on Gallium and Germanium (2023–2025): The first case study concerns China's decision, in July 2023, to introduce licensing requirements for the export of gallium and germanium — two materials of critical importance for semiconductor manufacturing, defense applications, and clean energy technologies. Far from constituting an isolated policy decision, this measure represented a calibrated retaliatory response to the series of export controls imposed between October 2022 and mid-2023 by the United States, the Netherlands, and Japan, which had restricted China's access to advanced semiconductor equipment. Rather than adopting an outright embargo — a move that would have carried significant diplomatic costs — Beijing required exporters to submit detailed end-use documentation to the Ministry of Commerce (MOFCOM), effectively converting its upstream market dominance into a geopolitical screening mechanism capable of selectively conditioning Western access to strategic inputs.

As U.S. technology restrictions intensified throughout 2024, China progressively escalated its countermeasures, culminating in December 2024 with an outright prohibition on the export of gallium, germanium, antimony, and superhard materials to the United

States. The economic consequences were both immediate and measurable: by 2025, European spot prices for unwrought gallium had risen by 365%, wrought germanium prices had increased by approximately 400%, and antimony prices had surged by 437%, while germanium export volumes from China fell by 60% and gallium and antimony exports were reduced to near zero. These figures are not merely indicative of price volatility — they reflect a structural disruption of supply chain predictability that cascaded across industries far beyond the immediate targets of the restriction. While the initial price shock was absorbed primarily by Western buyers, the medium-term effect was to accelerate precisely the strategic decoupling that Beijing had sought to prevent: major U.S. defense contractors redirected procurement toward non-Chinese sources.

Case Study 2: The United States — CHIPS Act and the Semiconductor Restriction Cycle: The second case study addresses the United States' use of the CHIPS and Science Act (2022) and its accompanying export control framework as instruments of trade weaponization directed against China's semiconductor industry. While officially framed as a defensive industrial policy measure aimed at securing domestic chip production capacity, these restrictions functioned in practice as a form of strategic denial — cutting off China's access to advanced microelectronics and the manufacturing equipment required to produce them. By targeting China's semiconductor access, the United States inadvertently exposed its own industrial base to a symmetric retaliatory move at the level of critical mineral inputs.

Initial assessments in Washington significantly underestimated this vulnerability. China's January 2025 decision to include core gallium extraction technologies under export control further constrained the viability of non-Chinese production by restricting access to the proprietary processing knowledge without which alternative supply chains cannot be rapidly scaled. Thus, the United States, having weaponized access to semiconductors, found itself exposed to a counter-weaponization of the upstream raw materials upon which its own fabrication capacity depends — a dynamic that illustrates the recursive logic of trade escalation within the triad.

Case Study 3: The European Union — Structural Dependency and the Transitional Cost of Weaponized Trade: The third case study concerns the European Union, which occupies a structurally distinct position within this analysis: unlike the United States or China, the EU has not been a primary actor in the weaponization cycle, but rather a collateral casualty of a bilateral escalation in which it had limited agency. Nevertheless, the EU's situation is arguably the most instructive for evaluating the systemic costs of trade weaponization, insofar as it demonstrates that the boomerang effect extends beyond the dyad of the applying and targeted actor to affect third parties embedded in the same supply chain architecture. At the time of the Critical Raw Materials Act's adoption in March 2024, the EU sourced 100% of its heavy rare earth elements from China, while its dependency on Chinese supply for rare earths broadly stood at approximately 95% — a degree of

concentration that left European industrial policy structurally exposed to any disruption in Sino-Western trade relations.

The scale of this exposure is compounded by the EU's demand trajectory for the very materials subject to active weaponization. EU demand for rare earth metals is projected to increase sixfold by 2030 and sevenfold by 2050, driven primarily by the electric vehicle transition and the expansion of wind energy capacity — sectors in which rare earths, gallium, and graphite are irreplaceable inputs. An electric vehicle requires approximately six times more critical minerals than a conventional combustion engine vehicle; an offshore wind installation requires nine times more minerals than a comparable gas plant. China's export controls over precisely these materials therefore did not merely affect current production costs — they introduced a structural uncertainty into the EU's long-term green industrial strategy that, if unresolved, risks undermining European competitiveness in the clean technology sector relative to both the United States and China.

Therefore, the empirical evidence analyzed within the framework conclusively **validates Hypothesis 2 (H2)**.

Taken together, the three case studies presented above offer consistent empirical support for the second hypothesis. Across all three actors, the weaponization of trade over critical raw materials has generated a measurable boomerang effect operating through three identifiable channels: first, price shocks that raise input costs not only for targeted actors but, through market contagion, for applying actors and third parties alike; second, an acceleration of counter-diversification efforts by targeted actors that progressively erodes the long-term leverage of the restriction; and third, a systemic deterioration of supply chain predictability that suppresses investment confidence and complicates industrial planning across the triad as a whole.

The European Union, as a non-primary actor, confronts the highest transitional cost burden in relative terms, precisely because its green industrial transition depends on the materials most subject to active weaponization.

In addition to the strictly geopolitical and macroeconomic implications analyzed in the results section, the use of trade barriers as diplomatic weapons generates a deeply asymmetric social cost. The specialized literature often tends to focus exclusively on state strategies and large trade flows, ignoring the fact that customs tariffs are not just simple political instruments, but function as indirect taxes borne directly by citizens.

The empirical data analyzed highlights a harsh economic reality. For example, during the year 2025, an average household in the United States faced an additional annual cost of approximately \$ 1,000, solely due to the introduction of new trade barriers and punitive tariffs. This amount does not represent a simple statistical correction, but a direct reduction in disposable income for the population.

The most serious impact of this phenomenon is felt at the level of vulnerable groups. Because tariffs affect the prices of consumer goods and basic components, the financial burden falls disproportionately on the shoulders of low-income people. The data show that purchasing power for basic goods has decreased by almost 2%. In an economic context already marked by volatility, such a contraction amplifies social inequalities and demonstrates the ethical limits of coercive diplomacy.

The extended discussion on the US-EU-China triad therefore forces a reassessment of the concept of economic security. When states use interdependence as a weapon to protect their strategic interests or industrial sovereignty, the real costs are not paid by governments, but are transferred entirely to end consumers, directly affecting the quality of life and social stability.

We also conducted a comparative analysis of trade indicators for 2025-2026, which highlighted the tariff rate for 2025 for each country in the triad, the rate of fluctuation of imports in relation to China, but also the primary strategy used in this non-lethal tariff war, a weapon of economic diplomacy.

Comparative Trade Metrics (2025-2026)

REGION	Effective Tariff Rate (2025)	Import volume Change (versus China)	Primary Strategy
United States of America	16,8% (Avg)	- 4,5% (Nov 2025)	Aggressive Decoupling
China	37,7% (vs USA)	+ 21% (to EU Q1 2026)	Market Diversification
European Union	8,6% (weighted)	Record High Q3 2025	De-risking & Stability

Source Data: compiled by the author based on official trade reports from the U.S. Census Bureau (2025), Eurostat International Trade Statistics (2025-2026), General Administration of Customs of the People's Republic of China (GACC, 2026), and tariff tracking data from the Peterson Institute for International Economics

The data in this table clearly highlights the tactical asymmetry within the triad. It can be seen that the United States applies an average effective tariff rate of 16.8%, reflecting an aggressive decoupling strategy that has already led to a 4.5% drop in the volume of imports from China by November 2025.

In response, China adopted a massive 37.7% tariff applied directly to American products, but compensated for this barrier by diversifying markets, achieving a historic 21% increase in exports to the European Union in the first quarter of 2026.

This massive reorientation of Chinese flows explains why the European Union recorded a record high level of imports in the third quarter of 2025 (Record High Q3 2025), a situation that forced Brussels to intervene defensively. With a more weighted tariff rate of 8.6%, the

EU is trying to maintain a balance line through the de-risking strategy, wanting to protect its industrial stability without completely breaking trade ties. Therefore, the figures demonstrate that tariffs are no longer simple taxes, but weapons for calibrating spheres of global influence.

Conclusion

The empirical and theoretical finding of this paper confirm that the nature of international conflict has fundamentally shifted. As Luttwak (1990) suggested, economic mechanisms are no longer just a complement to military force; within the EU–US–China triad, they have become the primary avenue for projecting power globally. The validation of both hypotheses indicates that this transition is deeply embedded in the current structure of international relations.

The analysis of H1 shows how central economic nodes, specifically financial infrastructure like SWIFT and dollar clearing systems, can be leveraged against actors such as Iran and Russia. These measures inflict systemic damage comparable to traditional military blockades, but at significantly lower political and financial costs. Far from being a gentle form of statecraft, weaponized interdependence allows states to project power just below the threshold of armed conflict, often masked by normative rhetoric, as Morgenthau (1948) previously noted.

At the same time, the evaluation of H2 demonstrates that economic coercion carries clear risks for those who use it. China's export restrictions on critical raw materials, such as gallium, germanium, and rare earth elements, illustrate a distinct boomerang effect. Instead of simply forcing compliance, these actions accelerate supply chain decoupling, erode long-term diplomatic leverage, and cause broader trade disruptions across the triad. The position of the European Union—often catching the fallout from US-China friction—shows that high interdependence leaves no major economy fully isolated from these spillover effects.

Based on the empirical evidence gathered from the analyzed cases, the findings strongly support (rather than definitively prove) both H1 and H2. The structured comparative narrative demonstrates patterns consistent with the initial theoretical expectations regarding the strategic deployment of economic diplomacy. However, given the qualitative nature of this study and the specific selection of cases, these conclusions should be understood as contextual insights rather than absolute generalizations. Future research could expand this design by examining disconfirming cases or counterfactual conditions to further test the boundaries of these hypotheses.

Beyond macro-level dynamics, the research highlights a critical aspect often overlooked in economic diplomacy literature: the direct social cost. Tariffs and supply restrictions directly

affect consumers through higher living costs, reduced purchasing power, and increased economic pressure on households. While economic warfare avoids the physical destruction of conventional conflict, its societal impact is real, widespread, and frequently less visible in policy debates.

In short, economic diplomacy in its current form does not necessarily offer a more peaceful alternative to traditional conflict. Rather, it represents a different channel through which power rivalries are contested. As the US, China, and the EU continue to rely on sanctions, trade barriers, and export controls, the key risk is not just economic inefficiency, but whether the global trading system itself can remain viable under sustained political pressure.

Future Research Directions

Building upon the findings of this paper, future research should further explore the long-term structural adaptation of secondary actors exposed to diplomatic coercion. While this study focused primarily on the EU–US–China triad, a critical avenue for investigation lies in how developing economies and regional blocs (such as the Mercosur) navigate weaponized interdependence. Future empirical work could quantify the extent to which these actors are diversifying supply chains, or creating alternative financial settlement mechanisms to mitigate collateral damage.

Additionally, as economic warfare increasingly intersects with emerging technologies, prospective studies should examine the strategic implications of AI supply chain restrictions, semiconductor export controls, and critical infrastructure dependencies.

Finally, future studies could also incorporate a microeconomic perspective by evaluating the firm-level responses to trade sanctions and export limits. Investigating how private enterprises alter their investment patterns, corporate compliance frameworks, and geographic footprints will provide a more comprehensive understanding of how state-level geoeconomic policies reshape market behavior in practice.

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Managing sensitive data under public control: digital borders and cybersecurity in a state-owned lottery platform — a conceptual and institutional analysis with evidence from Central and Eastern Europe

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Abstract. *State-owned lottery platforms represent a distinctive category of digital infrastructure, situated at the intersection of public governance, financial systems, and large-scale data processing. In the evolving European context characterized by strategic autonomy and digital sovereignty, these platforms increasingly operate within digital borders — a concept used here as an analytical construct designating the legal, technical, and institutional constraints that govern data flows and digital operations across territorial boundaries. This paper employs a conceptual and institutional analysis approach, drawing on European regulatory frameworks and empirical evidence from Romania's national lottery operator (CNLR), to examine how cybersecurity architectures and data governance frameworks can be designed within publicly controlled lottery systems to ensure resilience, compliance, and public trust. The paper addresses a gap in the literature by positioning state-owned lottery platforms as critical digital infrastructures whose governance has broader implications for economic convergence within the EU. The central research question asks: how do digital borders and cybersecurity governance frameworks interact with public ownership to shape digital resilience in state-owned lottery platforms, and what are the implications for economic convergence? The analysis argues that public ownership creates both constraints and strategic advantages in managing sensitive data. Furthermore, it demonstrates how disparities in cybersecurity capacity across Member States may reinforce economic divergence within the European Union, underscoring the need for coordinated policy responses.*

Keywords: digital sovereignty, cybersecurity, data governance, state-owned enterprises, lottery platforms, economic convergence, Central and Eastern Europe.

JEL Classification: L32, K24, O38, F15, L83.

1. Introduction

The digital transformation of economic and administrative systems has fundamentally altered the role of state-owned enterprises (SOEs) within the European Union. Increasingly, these entities are not merely providers of public services or market participants, but operators of complex digital ecosystems that manage sensitive data at scale. Among them, national lottery platforms occupy a particularly relevant position, as they combine financial transactions, identity verification processes, and behavioral data analytics within a highly regulated environment.

At the same time, the European Union is undergoing a broader structural shift driven by geopolitical fragmentation, technological competition, and the pursuit of strategic autonomy. In this evolving landscape, digital infrastructure is no longer perceived as neutral or purely functional, but as a domain of strategic importance. The emergence of digital borders — understood in this paper as the ensemble of legal, technical, and institutional mechanisms constraining cross-border data flows and digital operations — reflects this transformation.

Despite the growing relevance of digital governance for public sector entities, state-owned lottery platforms remain underexplored in the academic literature. Existing research on digital sovereignty (Pohle and Thiel, 2020; Bauer and Erixon, 2022) and cybersecurity governance (ENISA, 2023) tends to focus on large technology firms or general regulatory frameworks, without examining the specific institutional context of SOEs in the gambling and lottery sector. This paper addresses that gap by asking: how do digital borders and cybersecurity governance frameworks interact with public ownership to shape digital resilience in state-owned lottery platforms, and what are the implications for economic convergence?

The paper advances three interrelated arguments. First, that state-owned lottery platforms constitute critical digital infrastructures whose governance extends beyond operational concerns to encompass questions of sovereignty and public trust. Second, that public ownership generates both structural advantages and institutional constraints in the management of sensitive data, which differ materially from private-sector operators. Third, that disparities in cybersecurity capacity across EU Member States risk compounding existing economic divergences, particularly in Central and Eastern Europe (CEE).

The remainder of the paper is structured as follows. Section 2 reviews the conceptual framework of digital sovereignty and digital borders. Section 3 presents the methodology and research design. Section 4 examines cybersecurity as a pillar of economic resilience. Section 5 analyzes data governance practices, with reference to the Romanian case. Section 6 discusses cybersecurity governance and institutional capacity in publicly owned operators. Section 7 explores the implications for economic convergence. Section 8 presents a discussion and Section 9 concludes with policy implications and directions for future research.

2. Conceptual Framework: Digital Sovereignty, Digital Borders, and State-Owned Enterprises

The concept of digital sovereignty has gained increasing prominence in European policy discourse over the past decade, reflecting concerns regarding dependency on external technological providers and the vulnerability of critical infrastructures (Pohle and Thiel, 2020). It encompasses the capacity of states and supranational entities to exercise control over digital assets, including data, networks, and technological standards. Within the European Union, digital sovereignty is closely linked to the objective of strategic autonomy, which seeks to ensure resilience in an increasingly fragmented global economy (European Commission, 2021).

In this paper, digital borders is employed as an analytical concept — neither a mere metaphor nor a normative prescription — to designate the ensemble of legal provisions (e.g., data localization requirements), technical measures (e.g., network segmentation, sovereign cloud certifications), and institutional arrangements (e.g., cybersecurity certification regimes) that constrain cross-border data flows and digital operations. This framing aligns with the political economy of digitalization perspective (Flyverbom et al., 2019), which views digital governance as the outcome of competing interests among states, firms, and supranational bodies.

The analytical relevance of digital borders for state-owned enterprises is significant. SOEs operate under a dual mandate: they must comply with public interest objectives, including sovereignty-related requirements, while maintaining operational viability. This creates a distinctive governance environment that differs from private firms, which face fewer sovereignty-related constraints but are also less insulated from short-term market pressures (OECD, 2024). From an institutional economics perspective (North, 1990), the regulatory framework constitutes the rules of the game within which SOEs make governance decisions — and digital borders are increasingly part of those rules.

Lottery platforms represent a particularly illuminating case within this framework. They are subject to gambling regulations, data protection laws (GDPR), cybersecurity obligations (NIS2 Directive), and, in most EU Member States, direct state ownership or supervision. Their hybrid position — at once public institutions and market participants — makes them a productive unit of analysis for understanding how digital sovereignty intersects with institutional governance.

3. Methodology and Research Design

3.1. Research Approach and Epistemological Position

This paper adopts a qualitative, interpretive research approach grounded in an institutionalist epistemological position. Rather than seeking to generate statistically

generalizable findings, the study aims to develop analytical propositions that illuminate the governance mechanisms through which digital borders and public ownership interact to shape cybersecurity outcomes in a specific institutional domain. This approach is consistent with the objectives of conceptual and theory-building research, which seeks to generate explanatory frameworks that can subsequently be tested through larger-scale empirical work (Eisenhardt, 1989; Yin, 2018).

The choice of a conceptual-institutional methodology is justified by two considerations. First, the phenomenon under examination — the governance of sensitive data in state-owned lottery platforms in the context of digital sovereignty — is a relatively underexplored area of inquiry for which no established theoretical framework exists. Conceptual analysis is therefore an appropriate starting point for research in this domain (Jaakkola, 2020). Second, the complexity and context-dependence of institutional arrangements in public-sector digital governance are difficult to capture through quantitative methods alone, particularly in the absence of systematic cross-national data on cybersecurity investment and governance quality in state-owned lottery operators.

3.2. Research Design: Embedded Single-Case Study

The empirical component of the paper is structured as an embedded single-case study (Yin, 2018), with Romania's national lottery (CNLR) as the primary unit of analysis. Within this case, two embedded units of analysis are examined: (i) the data governance and cybersecurity architecture of the operator, and (ii) the institutional and regulatory environment within which it operates. This nested structure allows the analysis to move between the organizational and systemic levels, enriching the analytical framework without overstating the generalizability of findings from a single case.

The selection of CNLR as the case was theoretically motivated rather than convenience-driven. CNLR represents a paradigmatic instance of a state-owned lottery operator in a Central and Eastern European Member State: it combines full public ownership, exposure to multiple layers of EU regulation (GDPR, NIS2, national gambling supervision), significant legacy IT infrastructure, and an active digitalization program. These characteristics make it an information-rich case (Flyvbjerg, 2006) for examining the tensions and trade-offs identified in the research question. At the same time, the paper acknowledges that CNLR's institutional context reflects specificities of the Romanian administrative tradition and should not be treated as representative of all CEE operators without further comparative verification.

3.3. Data Sources and Evidence Base

Given the nature of the study as a conceptual and institutional analysis, the evidence base is constructed from three categories of sources, systematically triangulated to enhance the reliability of the analytical claims.

The first category comprises primary regulatory and policy documents, including the text of Regulation (EU) 2016/679 (GDPR), Directive (EU) 2022/2555 (NIS2), the CNLR organizational statute and publicly available annual reports, and Romania's National Cybersecurity Strategy. These documents provide the institutional and regulatory parameters within which the case operator functions.

The second category comprises comparative institutional data, including the European Commission's Digital Economy and Society Index (DESI) for Romania and comparator Member States (2020–2022 editions), ENISA's annual Threat Landscape reports (2021–2023), and the NIS Cooperation Group's peer review outputs. These sources provide the comparative benchmarking necessary to situate the Romanian case within the broader EU context and to assess the convergence implications of the argument.

The third category comprises academic literature on digital sovereignty (Pohle and Thiel, 2020; Flyverbom et al., 2019), cybersecurity economics (Bauer and van Eeten, 2009; Anderson et al., 2019), public sector governance and state capacity (Fukuyama, 2013; North, 1990), state-owned enterprise management (Bruton et al., 2015; OECD, 2024), and economic convergence (Barro and Sala-i-Martin, 1992). This literature provides the theoretical lenses through which the empirical material is interpreted.

3.4. Analytical Strategy

The analytical strategy proceeds in three stages, corresponding to the three levels of the argument. In the first stage, the paper develops and operationalizes the concept of digital borders as an analytical construct, drawing on the regulatory and institutional literature to identify its constituent dimensions (legal, technical, and organizational). This operationalization provides the vocabulary through which governance choices at CNLR are subsequently interpreted.

In the second stage, the paper applies this framework to the CNLR case, analyzing how the operator's governance choices in data management and cybersecurity architecture reflect and respond to the constraints and opportunities generated by digital borders and public ownership. The analysis proceeds by process tracing (Beach and Pedersen, 2013), identifying the mechanisms that link institutional conditions (regulatory framework, ownership structure, resource endowments) to governance outcomes (data architecture decisions, cybersecurity investment levels, compliance approaches).

In the third stage, the paper generalizes analytically from the case to the broader question of economic convergence, developing propositions about the conditions under which digital governance capacity disparities across EU Member States may reinforce or mitigate economic divergence. These propositions are explicitly framed as hypotheses for future empirical testing rather than as established findings.

3.5. Methodological Limitations

The principal limitation concerns the scope of the case. By focusing on a single operator in one Member State, the study cannot verify whether the analytical propositions developed hold across the full range of CEE lottery operators, each of which operates in a distinctive national institutional context. Cross-case comparison with operators from, for example, Bulgaria, Hungary, or Poland would substantially strengthen the generalizability of the argument. The paper treats this as an agenda for future research rather than a disqualifying weakness of the present analysis, consistent with the theory-building function of single-case research designs (Eisenhardt, 1989).

4. Cybersecurity as a Pillar of Economic Resilience

Cybersecurity has evolved from a technical concern into a fundamental component of economic stability. As digital systems become increasingly integrated into financial, administrative, and social processes, their vulnerability to cyber threats poses systemic risks. In recognition of this reality, the European Union has adopted a comprehensive regulatory framework, including the General Data Protection Regulation (GDPR, 2016), the NIS2 Directive (2022), and the Cybersecurity Act (2019).

These instruments collectively establish a governance model that emphasizes risk management, accountability, and resilience. Rather than focusing solely on incident response, they promote a proactive approach to cybersecurity, requiring organizations to identify vulnerabilities, implement preventive measures, and ensure rapid recovery capabilities. From a public economics perspective, cybersecurity can be understood as exhibiting characteristics of a public good: its benefits are non-excludable and generate positive externalities across interconnected systems (Bauer and van Eeten, 2009). Conversely, underinvestment in cybersecurity generates negative externalities, affecting not only directly involved entities but also the broader digital ecosystem.

Empirical evidence supports the link between cybersecurity investment and economic performance. Studies examining the economic cost of cyber incidents in critical infrastructure sectors consistently find significant direct costs (financial losses, operational disruption) and indirect costs (reputational damage, erosion of public trust) — the latter being particularly significant for public-sector operators (Anderson et al., 2019). The European Union Agency for Cybersecurity (ENISA) has documented increasing attack sophistication against the public sector and financial infrastructure, with state-affiliated threat actors representing a growing proportion of high-impact incidents (ENISA, 2023).

In the context of state-owned lottery platforms, cybersecurity assumes a particularly critical role. These systems are attractive targets due to the combination of financial assets and sensitive personal data they manage. Moreover, any breach or disruption carries immediate

reputational consequences, undermining public trust and potentially affecting state revenues. The concentration of regulatory obligations (GDPR, NIS2, national gambling supervision) further intensifies the governance challenge.

5. Data Governance in State-Owned Lottery Platforms: Evidence from Romania

The management of data within lottery platforms involves a complex interplay between regulatory compliance, technological capabilities, and organizational governance. These platforms process multiple categories of sensitive data, including personal identification information, financial transactions, and behavioral patterns related to gaming activities. Each of these categories is subject to specific regulatory requirements, particularly under the GDPR, which mandates purpose limitation, data minimization, and robust access controls.

To address these challenges, operators increasingly adopt data governance frameworks that combine policy and technical measures. Common approaches include data classification and tagging, role-based access control (RBAC), system segmentation, and audit logging. These measures aim to reduce the exposure of sensitive information while ensuring operational continuity.

A key tension in this context arises between data localization and the use of cloud-based solutions. Data localization requirements — reinforced by the Schrems II ruling and NIS2 obligations — demand that certain categories of sensitive data be stored within national or EU jurisdictions. At the same time, cloud computing offers scalability, cost efficiency, and access to advanced technological capabilities unavailable to many public-sector operators on premises. In practice, hybrid architecture has emerged as a dominant response, combining sovereign storage for critical or personally identifiable data with cloud-based processing for less sensitive workloads.

The Romanian national lottery (CNLR) provides a relevant illustration of these dynamics. As a state-owned operator with a mandate for both public service and revenue generation, CNLR has undertaken significant digitalization efforts, including the expansion of online platforms and mobile applications, in line with the broader modernization of Romania's public sector under EU-funded programs (PEPER project, contract no. 760045/23.05.2023). However, like many CEE operators, it faces structural challenges in integrating legacy IT systems with contemporary cybersecurity architectures. Legacy systems, often procured under earlier procurement frameworks, were not designed for modern threat environments and present substantial integration costs.

These challenges are documented in comparative assessments of EU Member State cybersecurity maturity. The European Commission's Digital Economy and Society Index (DESI) consistently identifies Romania among the Member States with lower digital

intensity and limited advanced digital skills — factors directly relevant to cybersecurity capacity. The NIS2 implementation gap between Western and CEE Member States further compounds these differences, creating asymmetries in the level of protection afforded to critical digital infrastructures across the Single Market.

A particularly salient governance dimension concerns the tension between transparency and security. State-owned operators are subject to public procurement rules and oversight mechanisms that private operators are not, which introduce delays in technology adoption and limits flexibility in vendor selection. At the same time, public accountability mechanisms can incentivize more rigorous documentation and governance practices, which represent a comparative advantage in regulatory compliance contexts.

6. Cybersecurity Governance and Institutional Capacity

The effectiveness of cybersecurity measures in state-owned lottery platforms depends not only on technological solutions but also on governance structures and institutional capacity. Drawing on the institutional economics tradition (North, 1990) and the public administration literature on state capacity (Fukuyama, 2013), this section analyzes how public ownership shapes cybersecurity governance, with particular attention to the CEE context.

Public ownership introduces specific institutional characteristics that differentiate state-owned lottery operators from private-sector counterparts. On the positive side, state-owned platforms benefit from a higher degree of public legitimacy and accountability, which may translate into stronger compliance cultures and more transparent governance processes. They are also more directly aligned with national and EU policy objectives, enabling them to prioritize long-term resilience over short-term profitability — a structural advantage in sectors where trust is a primary asset.

However, public ownership also entails institutional constraints. Bureaucratic procedures and public procurement regulations, while designed to ensure accountability, introduce significant friction in technology adoption cycles. In rapidly evolving threat environments, the inability to rapidly procure security tools or retain specialized personnel at market rates represents a structural vulnerability. This tension between accountability and agility is particularly acute in CEE Member States, where institutional capacity in cybersecurity remains uneven (ENISA, 2023).

Cross-national comparative evidence supports this characterization. The DESI index and the NIS Cooperation Group's maturity assessments consistently find that Northern and Western European Member States exhibit significantly higher cybersecurity preparedness than their CEE counterparts, reflecting differences in public investment levels, skilled labor availability, and administrative capacity. For state-owned lottery operators, this translates

into concrete operational differences: CEE operators are more likely to rely on outsourced security operations, have less developed internal security operations centers (SOCs), and face higher costs per unit of security provision.

Effective cybersecurity governance in this context requires a multi-level approach. At the organizational level, it involves developing internal capabilities — security-aware organizational cultures, continuous training programs, and structured incident response protocols. At the regulatory level, it requires alignment with NIS2 obligations and engagement with national cybersecurity authorities. At the EU level, it implies participation in information-sharing frameworks (e.g., the NIS Cooperation Group, ENISA's early warning mechanisms) and access to EU-funded capacity-building programs.

7. Implications for Economic Convergence

The relationship between digital governance and economic convergence is becoming increasingly evident in the European context. The economic convergence literature has traditionally focused on capital accumulation, technology diffusion, and labor productivity as the primary drivers of catch-up growth (Barro and Sala-i-Martin, 1992). However, the growing importance of digital infrastructure as a factor of production and a precondition for value creation introduces digital resilience as a new dimension of convergence analysis.

In the case of state-owned lottery platforms, asymmetries in digital governance capacity translate into measurable differences in operational efficiency, risk exposure, and innovation potential. Member States with more advanced digital ecosystems and stronger cybersecurity frameworks are better positioned to leverage digital technologies for revenue diversification and service innovation. Conversely, operators in lower-capacity environments face higher unit costs of security compliance, greater exposure to cyber risk, and reduced attractiveness for technology partnerships.

These differences are not merely operational: they reflect structural divergences that, if left unaddressed, may reinforce existing economic inequalities within the EU. The mechanisms linking digital governance to economic convergence operate through several channels. First, cybersecurity incidents generate direct economic costs (operational disruption, recovery expenditures, legal liability) that reduce productivity and competitiveness. Second, weak digital governance erodes public trust in digital systems, suppressing adoption rates and limiting the growth potential of digital markets. Third, differences in regulatory implementation and compliance capacity create uneven competitive conditions within the Single Market, potentially distorting resource allocation.

To mitigate these risks, coordinated policy interventions at the EU level are necessary. Mechanisms such as the harmonization of cybersecurity standards, targeted investment through structural funds and the Digital Europe Programme and dedicated technical

assistance for lower-capacity Member States could contribute to reducing the digital governance gap. The experience of the PEPER project in Romania illustrates how EU-funded research can generate locally relevant knowledge that feeds into policy design — though its scale remains limited relative to the scope of the challenge.

8. Discussion

The analysis presented in this paper highlights the complex interplay between digital sovereignty, cybersecurity governance, and institutional capacity in state-owned lottery platforms. Several findings merit broader discussion.

First, the concept of digital borders, as operationalized here, proves useful for capturing the multi-dimensional nature of digital sovereignty constraints. It encompasses not only legal data localization requirements but also technical certification regimes and institutional coordination mechanisms. However, it is important to acknowledge that digital borders are not static: they are continuously shaped by regulatory developments, technological change, and geopolitical dynamics. Future research should track how the operationalization of digital borders evolves as NIS2 implementation proceeds and as the EU's data governance framework matures (Data Governance Act, Data Act).

Second, the public ownership dimension introduces genuine analytical complexity. The literature on SOE governance (OECD, 2024; Bruton et al., 2015) documents considerable heterogeneity in SOE performance, suggesting that institutional form alone does not determine outcomes. What matters is the quality of governance structures — the clarity of mandates, the independence of oversight, the adequacy of resources — rather than ownership per se. This implies that the advantages and constraints of public ownership in cybersecurity contexts are contingent on institutional design choices, which vary substantially across Member States.

Third, the Romania case raises important questions about the generalizability of the argument. While the CNLR context is used to illustrate broader dynamics, it would be premature to treat it as representative of all CEE operators. Comparative research encompassing operators from multiple Member States — including those with different institutional histories, regulatory frameworks, and cybersecurity investment levels — would be necessary to validate the convergence implications suggested here.

Finally, a potential limitation of the current analysis concerns the reliance on publicly available sources. Organizational documents, internal security audits, or interview data with practitioners would enrich the empirical grounding of the argument. Future research should seek to combine institutional analysis with primary data collection to generate more precise causal claims.

9. Conclusions

This paper has examined how digital borders and cybersecurity governance frameworks interact with public ownership to shape digital resilience in state-owned lottery platforms, and what the implications are for economic convergence within the European Union. The analysis has advanced three principal contributions.

First, it has introduced the concept of digital borders as an operational analytical framework for studying governance constraints in state-owned digital operators, distinguishing it from its usage as a purely normative or metaphorical construct. Second, it has systematically characterized the governance implications of public ownership in cybersecurity-intensive contexts, identifying both institutional advantages (legitimacy, alignment with public interest mandates) and constraints (procurement rigidities, talent acquisition limitations). Third, it has articulated the transmission mechanisms linking digital governance disparities to economic divergence, offering a theoretical foundation for empirical research on the relationship between cybersecurity investment and economic convergence.

The policy implications are clear. Reducing disparities in cybersecurity capacity across EU Member States requires coordinated action that goes beyond regulatory harmonization to encompass investment, technical assistance, and knowledge exchange. State-owned lottery operators in CEE countries represent a particularly relevant target for such interventions, given their role as critical digital infrastructures and their structural exposure to governance capacity constraints.

Future research should pursue two primary directions. The first is empirical: cross-country comparative studies examining the relationship between cybersecurity investment levels, governance quality, and economic performance in the lottery and broader public entertainment sector. The second is theoretical: developing formal frameworks that integrate digital governance variables into existing models of economic convergence, thereby enabling more precise predictions about the conditions under which digital resilience promotes or inhibits catch-up growth.

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Comparative analysis of fiscal sustainability in Romania and Hungary. Empirical evidence for the period 2015–2024

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Abstract. *This article examines public debt sustainability and sovereign fiscal risk dynamics in Romania and Hungary over the period 2015–2024, offering a comparative perspective on two emerging economies within the European space. Using a comparative time-series analysis based on data extracted from Eurostat and IMF databases, the study analyzes the evolution of the budget deficit, government financing costs, and the interest rate-growth differential as key determinants of fiscal vulnerability. The results reveal distinct risk profiles between the two countries, despite a similar regional macroeconomic context. In particular, the $(r-g)$ differential turned persistently positive in the post-2022 period, reaching approximately +5.6 percentage points in Romania and +7.8 percentage points in Hungary by 2024, signaling a deterioration in automatic debt dynamics for both economies. The research confirms that fiscal discipline and institutional credibility appear to be associated with lower sovereign financing costs. From this perspective, policymakers should prioritize fiscal consolidation and institutional reform as essential mechanisms for ensuring long-term debt sustainability.*

Keywords: public debt, fiscal sustainability, sovereign risk, budget deficit, comparative analysis.

JEL Classification: H63, H62, E62, E43.

Introduction

In recent decades, the international community has recognized fiscal sustainability as a fundamental pillar in ensuring macroeconomic stability and the smooth functioning of monetary unions. Fiscal sustainability is the essential condition that enables countries to respond effectively to external shocks and finance the public goods necessary for development, being broadly defined as a government's ability to manage its financial obligations without compromising long-term stability or requiring sudden and destabilizing adjustments.

Fiscal sustainability refers to the ability of governments to maintain public finances under control over time, without generating excessive debt or fiscal imbalances. It depends on several interrelated factors, including the level of public debt, the budget balance, borrowing costs, and the credibility of fiscal institutions. Recent crises, the 2008 global financial crisis, the COVID-19 pandemic, and the energy shock triggered by the war in Ukraine, have put increasing pressure on public finances across Europe, leading to higher deficits and rising debt levels. The literature emphasizes that debt sustainability cannot be assessed using simple thresholds. Blanchard (2019), in the article "Public Debt and Low Interest Rates", shows that the relationship between interest rates and economic growth is essential, while Reinhart and Rogoff (2010), in the article "Growth in a Time of Debt", highlight that high levels of public debt can negatively affect economic growth, especially in emerging economies.

More recent studies focus on the role of fiscal fundamentals and financing conditions. Afonso, Alves, and Monteiro (2024), in the article "Sovereign risk dynamics in the EU: The time varying relevance of fiscal and external (im)balances", show that stronger fiscal positions and institutional credibility reduce sovereign risk, while Armendariz et al. (2024), in the article "Taming Public Debt in Europe: Outlook, Challenges, and Policy Response", point out that the post-pandemic period has increased the risk of debt non-stabilization across European economies. At the same time, the tightening of monetary policy after 2022 has led to higher borrowing costs, creating additional pressure on countries with weaker fiscal positions, as emphasized in the S&P Global Ratings (2024) report "EU Sovereign Debt 2024: High Cost of Debt Weighs on Interest Expenditure". In this context, the Debt Sustainability Analysis (DSA) framework developed by the European Commission and the IMF has become a key tool for understanding debt dynamics and assessing fiscal risks.

This article examines the relationship between fiscal sustainability, public debt dynamics, and the cost of sovereign financing in Romania and Hungary during the period 2015–2024 and is relevant to the economic literature for several reasons. Firstly, the paper provides an updated empirical analysis covering a period marked by major external shocks, capturing how these shocks affected the two economies differently, depending on their specific fiscal vulnerabilities.

Secondly, the study contributes to the literature through a comparative analysis of two emerging economies in Central and Eastern Europe that exhibit markedly different fiscal

trajectories, despite sharing a similar regional context. While Romania recorded the largest budget deficit in the EU in 2024, Hungary maintained a structurally higher debt level but achieved a more consistent fiscal adjustment during the 2015–2019 sub-period. This divergence suggests that fiscal vulnerability in emerging economies cannot be captured by a single indicator, and that economic growth capacity, institutional credibility, and openness to European markets are equally relevant in explaining differences in sovereign risk perception.

Thirdly, the research provides relevant evidence for policymakers in emerging European economies. The comparison between Romania and Hungary suggests that fiscal consolidation alone is not sufficient to ensure long-term debt sustainability, economic growth capacity, openness to European markets, and institutional credibility play an equally important role. These findings indicate that emerging economies should prioritize not only deficit reduction, but also structural alignment with European frameworks as a precondition for sustainable debt management.

The next sections of this article are structured as follows. Section 1 presents a review of the literature and the theoretical foundations of fiscal sustainability and sovereign risk. Section 2 describes the data and methodology used in the comparative analysis. Section 3 details the results obtained and their interpretation in terms of fiscal indicators and the cost of financing. The final section summarizes the conclusions and proposes public policy recommendations.

1. Literature review and hypotheses development

1.1. Fiscal sustainability and the role of economic growth

Fiscal sustainability has become a key concern in macroeconomic research, especially after successive crises that have put increasing pressure on public finance across Europe. A central question in this literature is under what conditions public debt can be sustained without leading to a fiscal crisis. One of the most influential empirical contributions is provided by Reinhart and Rogoff (2010), who show that economies with high levels of public debt tend to experience lower growth rates, particularly in the case of emerging economies with limited access to international capital markets. Their findings suggest that debt accumulation is not neutral, as high levels of indebtedness can weaken the very growth dynamics needed to maintain debt sustainability. This view is also supported by earlier work such as Barro (1990), which highlights how excessive public debt can crowd out productive investment, and by Checherita-Westphal and Rother (2012), who find a non-linear relationship between public debt and growth in European countries, with negative effects becoming more pronounced at higher debt levels. It should be noted, however, that the findings of Reinhart and Rogoff (2010) have been subject to academic debate. Herndon, Ash, and Pollin (2014) challenged their conclusions by identifying data errors and methodological inconsistencies, suggesting that the negative relationship between high

debt and growth is weaker and less robust than originally claimed. While this critique does not invalidate the broader argument that high debt levels are associated with macroeconomic vulnerabilities, it does underscore the importance of interpreting such thresholds with caution.

In the context of the present study, these arguments are particularly relevant for Hungary, whose public debt-to-GDP ratio has consistently exceeded the 60% Maastricht threshold over the period 2015–2024, raising questions about the potential impact of debt on long-term growth. Blanchard (2019) revisits this debate from a different perspective, arguing that when the interest rate on government debt is lower than the economic growth rate, higher levels of debt can be sustained without necessarily increasing tax burdens. In such cases, economic growth helps reduce the debt-to-GDP ratio over time. This insight is especially relevant for Romania during the 2015–2019 period, when strong economic growth, peaking at 7.1% in 2017, helped offset the impact of rising budget deficits on debt dynamics.

Building on the theoretical framework proposed by Blanchard (2019), together with the empirical evidence provided by Reinhart and Rogoff (2010) and subsequent studies, we formulate the following hypothesis:

H1: Romania's higher real GDP growth rate during 2015–2024 partially offsets the negative effects of its persistently large budget deficit on public debt dynamics.

1.2. Sovereign risk, financing costs, and fiscal discipline

A second strand of the literature examines the relationship between fiscal fundamentals and the cost at which governments borrow from financial markets. Laubach (2009) provides early empirical evidence showing that higher budget deficits and rising public debt are associated with increases in government bond yields. This relationship has been widely confirmed in the European context, including in studies such as Ardagna, Caselli, and Lane (2007), which highlight the role of fiscal imbalances in driving sovereign spreads within the euro area.

More recent contributions extend this analysis by emphasizing the role of institutional credibility. Afonso, Alves, and Monteiro (2024), using a panel of 27 European economies, show that improvements in fiscal sustainability led to a significant reduction in sovereign risk, as measured by Credit Default Swap (CDS) spreads. Importantly, their results indicate that this relationship becomes stronger during periods of rising indebtedness, suggesting that markets become more sensitive to fiscal discipline when debt trajectories deteriorate. Their findings also underline that countries with more credible fiscal frameworks benefit from lower risk premium, regardless of the current level of public debt. The S&P Global Ratings (2024) report on European sovereign debt confirms these dynamics in the post-pandemic context. Since mid-2022, the tightening of monetary policy by the European

Central Bank has led to a sharp increase in government bond yields, reversing the previous decade of low financing costs. This change has disproportionately affected countries with weaker fiscal positions and lower credit ratings.

In this context, Romania and Hungary, both being subject to the Excessive Deficit Procedure, face a particularly challenging environment, characterized by the combination of persistent fiscal imbalances and rising borrowing costs. Drawing on the empirical evidence linking fiscal deficits to higher sovereign financing costs (Laubach, 2009; Afonso, Alves, and Monteiro, 2024; S&P Global Ratings, 2024), we formulate the following hypothesis:

H2: Countries with higher and more persistent budget deficits face higher sovereign financing costs, as reflected in government bond yields and spreads relative to Germany.

1.3. Post-pandemic debt dynamics and the $(r-g)$ differential in emerging Europe

The post-pandemic period has significantly changed the fiscal sustainability outlook for European economies. Armendariz et al. (2024) show that public debt increased sharply in 2020, while the subsequent recovery has been uneven across countries. In emerging Europe, persistent deficits, the energy shock, and the tightening of monetary policy after 2022 have created a challenging environment, with rising financing costs and slowing growth. Within this context, the interest rate–growth differential ($r-g$) becomes a central indicator of debt sustainability. According to the Debt Sustainability Analysis (DSA) framework developed by the European Commission and the IMF, when the interest rate exceeds economic growth, public debt tends to increase automatically in the absence of a primary surplus. As highlighted in the literature (Domar, 1944; Blanchard, 2019), this mechanism is fundamental for understanding debt dynamics.

Recent evidence suggests that this dynamic has worsened in the post-pandemic period, with a higher risk of debt non-stabilization across European economies (Armendariz et al., 2024). In the case of Romania and Hungary, the post-2022 environment represents a clear structural break from the more favorable conditions observed during 2015–2019, as rising bond yields and slowing growth have led to a persistently positive ($r-g$) differential. Building on these arguments, we formulate the following hypothesis:

H3: The interest rate–growth differential ($r-g$) turned persistently positive for both Romania and Hungary in the post-pandemic period, signaling an unfavorable shift in automatic debt dynamics for both economies.

1.4. Differences in fiscal vulnerability in Central and Eastern Europe

While much of the European literature tends to treat fiscal vulnerability as a single dimension, usually measured through the debt-to-GDP ratio, more recent research suggests that this approach may be too simplified. In particular, studies such as Armendariz et al.

(2024) show that emerging European economies display different types of fiscal risk that cannot be captured by a single indicator. According to Armendariz et al. (2024), some countries are mainly exposed to stock risks, which are related to high levels of accumulated public debt, while others face flow risks, driven by persistent and increasing budget deficits. This distinction is important because it shows that fiscal vulnerability depends not only on how much debt a country has, but also on how that debt evolves over time. Romania and Hungary provide a clear example of this divergence. Hungary has maintained a relatively high debt-to-GDP ratio, consistently above the Maastricht threshold, which points to a structural vulnerability related to debt levels. In contrast, Romania has a lower level of public debt but recorded the highest budget deficit in the European Union in 2024, at around 7% of GDP, suggesting a different type of risk linked to fiscal imbalances.

Based on these arguments, which consistently point to the existence of different vulnerability profiles across emerging European economies, we formulate the following hypothesis:

H4: Romania and Hungary exhibit fundamentally different fiscal vulnerability profiles, despite sharing a similar regional macroeconomic context.

Despite the extensive literature on fiscal sustainability and sovereign risk, several important gaps remain. First, most studies focus on broad cross-country analyses, with limited attention given to direct comparisons between specific emerging European economies such as Romania and Hungary. Second, a large part of the existing research is based on the low-interest rate environment that characterized the pre-pandemic period, while less attention has been given to the recent context of monetary tightening and rising financing costs after 2022. This raises the question of whether conclusions drawn in the low-interest-rate environment remain valid under current conditions. Third, although the interest rate–growth differential ($r-g$) is widely used in theoretical frameworks, its empirical application to recent developments in Central and Eastern Europe remains relatively limited.

This study addresses these gaps by providing a comparative and updated analysis of fiscal sustainability in Romania and Hungary over the period 2015–2024, with a particular focus on the role of the ($r-g$) differential and the heterogeneity of fiscal vulnerabilities.

2. Research methodology

2.1. Sample Description

The research is based on the analysis of two European Union member states, Romania and Hungary, selected for their similar regional context but divergent fiscal trajectories over the period 2015–2024. Annual statistical data were extracted from Eurostat and the International Monetary Fund databases to ensure the relevance and currentness of the conclusions.

2.2. Variable Definition

For the comparative analysis, data were collected for the following indicators:

Variable	Indicator description	Data source
Debt/GDP	General government gross debt as % of GDP	Eurostat, gov_10dd_edpt1
Deficit/GDP	Government budget balance as % of GDP	Eurostat, gov_10a_main
GDP growth	Real GDP growth rate (% year-on-year)	Eurostat, nama_10_gdp
Interest rate	Government bond yield, 10-year maturity (%)	Eurostat, irt_lt_mcby_m
(r-g) differential	Interest rate minus real GDP growth rate (pp)	Own calculation based on Eurostat data

2.3. Analytical Framework

To ensure the rigor of this comparative analysis, it is essential to detail the methodology of the key indicators, as they serve as the pillars for validating the research hypotheses. Given the descriptive nature of the study, hypotheses are evaluated based on the consistency, direction, and magnitude of observed relationships between variables across the analyzed period, rather than through formal statistical testing.

Public debt and budget deficit: The main fiscal indicators used in this study are public debt and budget balance, both expressed as a percentage of GDP and sourced from Eurostat. These indicators are selected because they capture both the stock of government debt and the annual fiscal position, allowing for a clear assessment of fiscal sustainability. In addition, they provide a direct benchmark through the Maastricht criteria (60% of GDP for debt and 3% for deficit), making it possible to evaluate whether Romania and Hungary follow a stable fiscal path. Within the analysis, these indicators are used to compare the evolution of fiscal discipline and to identify potential risks related to increasing debt levels and persistent budget imbalances.

Real GDP growth rate: This indicator measures the annual percentage change in real output, adjusted for inflation, and is used to capture each country's economic performance, independent of the effects of price levels. In the context of this study, real GDP growth plays a dual role: it reflects each economy's ability to generate resources for debt service and serves as the denominator in the spread between the interest rate and the growth rate, an essential element for assessing debt sustainability.

Government bond yield — 10-year maturity: This indicator is included in the analysis because it reflects the cost at which governments borrow in financial markets and serves as a key indicator of sovereign risk. It is particularly relevant to this study, as it allows for an assessment of financing conditions and their impact on the sustainability of public debt. By comparing bond yields in Romania and Hungary, the analysis captures differences in investor confidence and highlights how changes in interest rates influence pressure on public finances during the 2015–2024 period.

Interest rate-growth differential (r-g): This indicator is calculated as the difference between the 10-year government bond yield and the real GDP growth rate and constitutes

the central variable in the Debt Sustainability Analysis methodology developed by the European Commission and the International Monetary Fund. When r exceeds g , public debt tends to increase automatically in the absence of a primary surplus, generating a self-reinforcing debt dynamic. In this study, the indicator is used to compare the debt dynamics in Romania and Hungary and to assess whether current economic conditions support or hinder public debt sustainability over the period chosen. Formally, the debt dynamic equation is expressed as:

$$\Delta(D/Y) = (r - g) / (1 + g) \times D(t-1) - PB$$

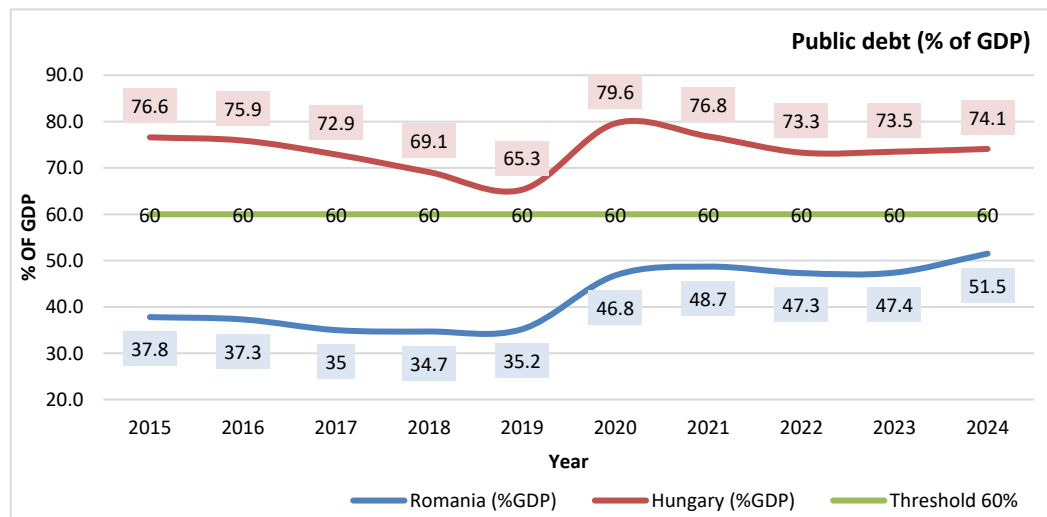
where D/Y represents the debt-to-GDP ratio, r is the nominal interest rate, g is the real GDP growth rate, and PB is the primary balance as a percentage of GDP. When $r > g$, public debt tends to increase automatically in the absence of a primary surplus. This framework follows the approach employed by Blanchard (2019) and Armendariz et al. (2024).

3. Results and discussions

3.1. Trends in public debt and the budget deficit

A comparative analysis of fiscal indicators reveals clear differences between the two economies in terms of vulnerability. Romania has a significantly lower level of public debt than Hungary throughout the 2015–2024 period, remaining below the 60% of GDP threshold set by the Maastricht Treaty, while Hungary consistently exceeds this threshold, with a debt level of 74.1% of GDP in 2024. This difference reflects the different fiscal structures between the two countries.

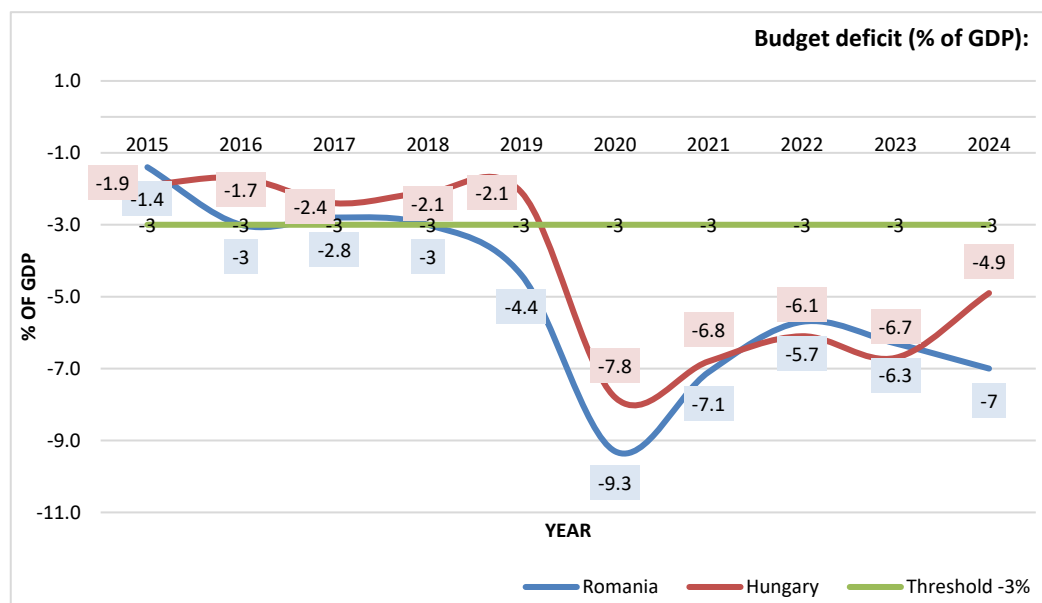
Figure 1. Public debt (% of GDP): Romania vs. Hungary, 2015–2024



Source: Author's calculations based on Eurostat data

However, the picture reverses when it comes to the budget deficit. Romania is experiencing persistent and rapidly rising budget deficits, reaching approximately 7% of GDP in 2024, being the highest deficit in the European Union, compared to approximately 4.9% in Hungary. Both countries exceed the 3% of GDP threshold imposed by the Stability and Growth Pact and are subject to the Excessive Deficit Procedure, but the magnitude of Romania's fiscal imbalance is significantly greater.

Figure 2. Budget deficit (% of GDP): Romania vs. Hungary, 2015–2024

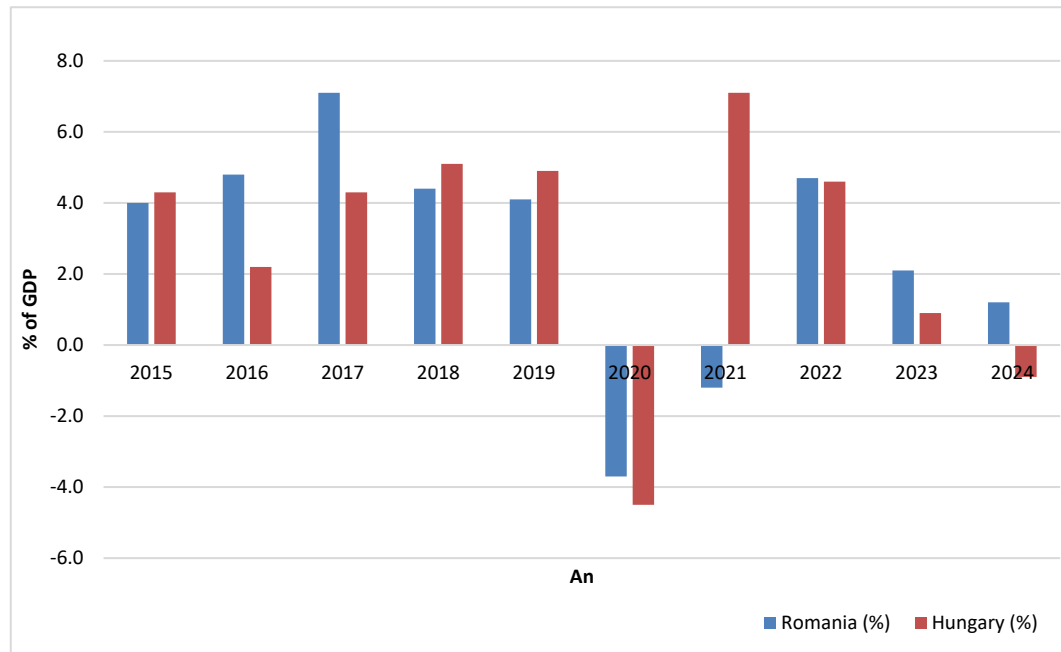


Source: Author's calculations based on Eurostat data

These results confirm Hypothesis H4: the two economies exhibit distinct fiscal vulnerability profiles: Romania faces a risk primarily driven by high and rising budget deficits, which negatively affect debt dynamics, while Hungary faces a risk associated with the high level of accumulated public debt, reflecting a structural vulnerability.

3.2. Economic Growth Potential and GDP Trends (H1 Validation)

Beyond fiscal indicators, the study examined each economy's ability to generate real economic growth, as this is the factor that determines the extent to which Romania's budget deficit is sustainable in the medium term. The results indicate that Romania recorded a higher rate of real economic growth than Hungary in most years of the period analyzed. In the 2015–2019 subperiod, both economies grew robustly, with Romania peaking at 7.1% in 2017. The pandemic shock of 2020 affected both countries similarly, with contractions of approximately 3.7% for Romania and 4.5% for Hungary. However, the divergence becomes more evident in the post-pandemic period. While Romania returned to a positive trajectory, Hungary recorded negative growth of -0.9% in 2024.

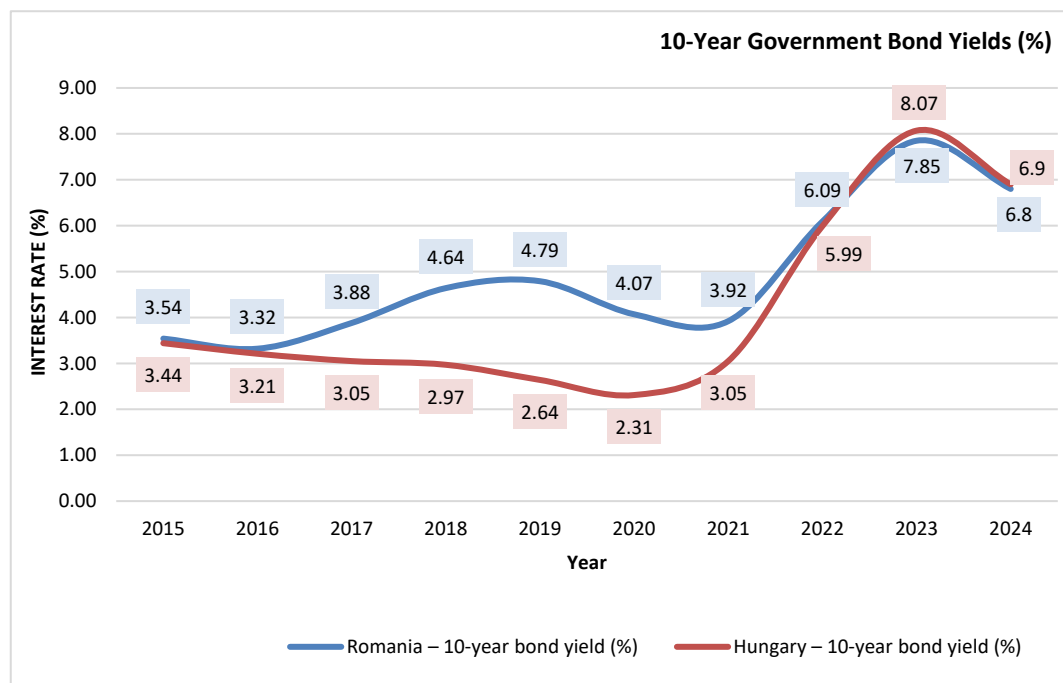
Figure 3. *Real economic growth rate (%): Romania vs. Hungary, 2015–2024*

Source: Author's calculations based on Eurostat data

These results confirm Hypothesis H1: Romania's higher economic growth potential partially offsets the negative effects of the persistent budget deficit on public debt dynamics. In particular, stronger economic growth increases the size of the economy, which reduces the relative weight of public debt when expressed as a percentage of GDP. This means that even if the government continues to run deficits and accumulate debt in absolute terms, the debt-to-GDP ratio can remain stable or increase at a slower pace. As a result, Romania is able to maintain a lower debt-to-GDP ratio compared to Hungary, where economic growth has been less effective in compensating for fiscal imbalances, despite the presence of larger and more persistent deficits in Romania.

3.3. The Cost of Public Debt Financing (H2 Validation)

An analysis of 10-year government bond yields shows a similar trend for Romania and Hungary during the 2015–2019 period, when financing costs were relatively low, driven by the European Central Bank's accommodative monetary policy. The situation changes after 2022, when, amid high inflation and the energy crisis, monetary policy becomes more restrictive, and interest rates rise significantly in both countries. They reach high levels in 2023 (approximately 7.85% in Romania and 8.07% in Hungary), after which they slightly decline in 2024.

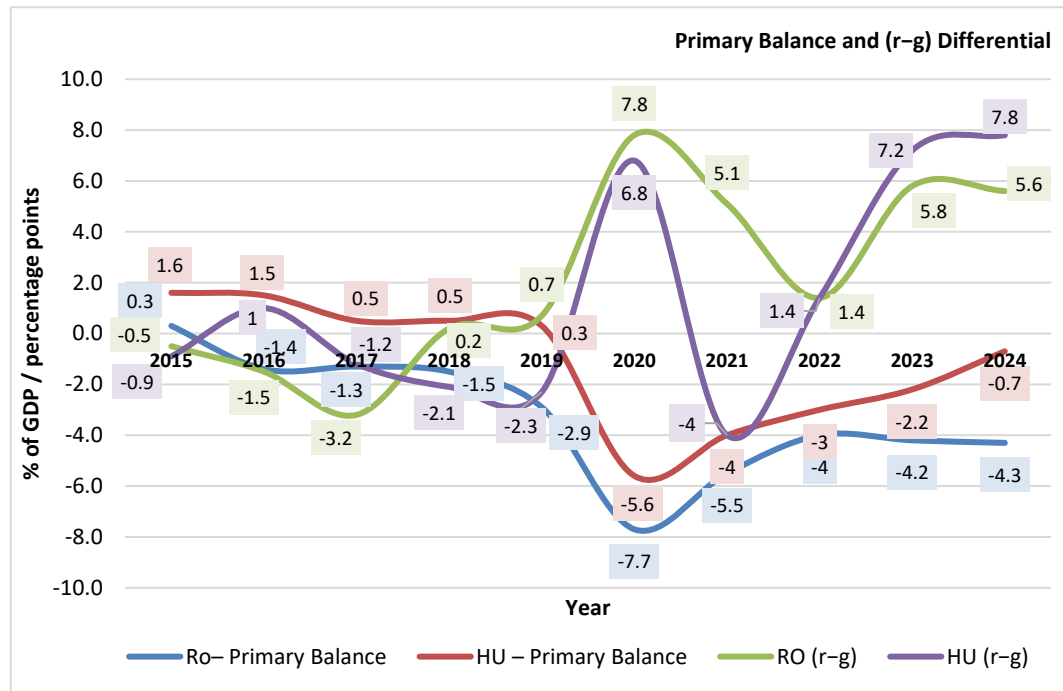
Figure 4. 10-Year Government Bond Yield (%): Romania vs. Hungary, 2015–2024

Source: Author's calculations based on Eurostat data

The increase in government bond yields after 2022 reflects a deterioration in financing conditions for both countries, driven by tighter monetary policy and higher inflation. This trend is more pronounced in Romania, where higher and more persistent budget deficits contribute to increased perceived risk by investors. These results partially support Hypothesis H2, as they show that countries with weaker fiscal positions tend to face higher borrowing costs. However, the relationship is not entirely direct, as interest rates are also influenced by external factors such as the European Central Bank's monetary policy and global economic conditions. To complement the descriptive analysis, a simple correlation between the budget deficit and government bond yields indicates a positive relationship, suggesting that higher fiscal imbalances are associated with increased financing costs.

3.4. Debt Sustainability Analysis — the (r–g) Gap

The key indicator of the sustainability analysis, meaning the gap between the interest rate and the economic growth rate ($r-g$), shows a clear deterioration in conditions for both economies following the pandemic. Between 2015 and 2019, this differential was generally negative or close to zero in both countries, indicating a favorable situation: the economy was growing faster than the cost of debt. After 2020, and especially after 2022, the situation changes. The spread turns positive and increases significantly, reaching approximately 5.6 percentage points in Romania and 7.8 percentage points in Hungary by 2024.

Figure 5. *The (r–g) differential: Romania vs. Hungary, 2015–2024*

Source: Author's calculations based on Eurostat data

This chart shows the difference between the interest rate and the economic growth rate, known as $(r-g)$, for Romania and Hungary during the period 2015–2024. The indicator is essential because it shows whether public debt tends to increase or stabilize. If the interest rate is higher than economic growth (i.e., $r > g$), then debt increases “automatically,” even without new borrowing, because the cost of debt is higher than the rate at which the economy is growing. To offset this effect, the government should have a primary surplus. In our case, both countries have deficits, which amplifies the pressure on the debt.

It is observed that after the pandemic period, the differential becomes positive and remains high for both countries, indicating a deterioration in debt sustainability conditions. These results confirm Hypothesis H3, as they show that in the recent period, public debt has been influenced by unfavorable dynamics driven by high financing costs and insufficient economic growth.

Conclusions and limitations

The present study examined the dynamics of fiscal sustainability in Romania and Hungary over the period 2015–2024, by focusing on the role of economic growth, financing costs, and the interest rate–growth differential. The results show that different types of fiscal

imbalances, high budget deficits in the case of Romania and high public debt in the case of Hungary, lead to distinct risk profiles. At the same time, the paper brings updated evidence for the post-2022 period, a period that is marked by rising interest rates and increasing pressure on public finances.

The comparison between Romania and Hungary shows that a country with lower public debt can still face significant fiscal fragility if budget deficits remain persistently high, while a country with higher debt may preserve relative stability if fiscal adjustment is more credible. This conclusion is in line with Armendariz et al. (2024), who argue that European economies face heterogeneous debt risks, and with Blanchard (2019), who shows that debt sustainability depends crucially on the relation between interest rates and growth, not just on the debt stock itself.

Another relevant research outcome emphasizes that economic growth can temporarily soften fiscal pressures, but it cannot substitute for fiscal discipline in the long run. Romania's stronger growth performance helped limit the deterioration of the debt ratio despite larger deficits, but the paper's results also suggest that this mechanism becomes less effective when growth slows and interest rates remain high. This interpretation is closely connected to Blanchard (2019), who emphasizes that favorable debt dynamics depend on growth remaining above financing costs, and to Reinhart and Rogoff (2010) and Checherita-Westphal and Rother (2012), whose findings suggest that excessive debt or persistent fiscal imbalances may eventually weigh on growth itself.

A third conclusion is that the post-2022 period marks a structural shift in the fiscal environment of both countries, meaning that conclusions based on the low-interest-rate decade can no longer be applied without caution. The results show that after 2022 both Romania and Hungary entered a period of positive and elevated $(r-g)$, which mechanically worsens debt dynamics. This supports the broader message of IMF (2024) and Armendariz et al. (2024) that tighter financial conditions have changed the sustainability outlook across Europe. In this sense, the paper does more than describe a country comparison; it also illustrates a wider European transition from a permissive borrowing environment to a more restrictive one.

A fourth conclusion is that financial markets appear to penalize not only the level of debt, but also the credibility of the fiscal trajectory. Romania's higher deficits seem to have contributed to stronger financing pressure, even though Hungary has a higher debt stock. This suggests that investors are sensitive to the expected direction of fiscal policy, not merely to the current debt ratio. This conclusion is consistent with Laubach (2009), who finds that deficits and debt affect interest rates, and with Afonso, Alves, and Monteiro (2024), who show that sovereign risk falls when fiscal positions improve and institutional credibility is stronger.

One last concluding remark is that Romania and Hungary illustrate two different channels through which fiscal vulnerability can materialize in emerging economies: Romania through a flow imbalance, and Hungary through a stock imbalance. This distinction is important because it implies different policy priorities. Romania's case points to the urgency of deficit control, while Hungary's case highlights the importance of reducing the legacy burden of accumulated debt. This broader interpretation aligns well with Armendariz et al. (2024), who distinguish among different forms of fiscal exposure in Europe, and it strengthens the paper's claim that fiscal vulnerability is multidimensional.

However, several limitations should be considered. First, the analysis focuses on only two countries, which limits the extent to which the results can be generalized to other emerging European economies. Second, the approach is mainly descriptive and based on a limited number of macroeconomic indicators, without using econometric methods or additional measures of sovereign risk. Third, the relatively short time span covered (2015–2024) and the limited number of annual observations reduce the statistical robustness of the findings and should be acknowledged as a constraint on their generalizability. As noted by Armendariz et al. (2024), empirical conclusions drawn from short panels in emerging economies are particularly sensitive to the specific period analyzed, which in this case includes structural breaks such as the pandemic shock and the post-2022 monetary tightening. Fourth, the absence of additional control variables—such as inflation dynamics, exchange rate volatility, or credit rating changes—means that some of the variation in sovereign financing costs may reflect factors not fully captured by the indicators used. Future research could expand the analysis by including more countries, applying econometric techniques such as panel regression or time-series correlation analysis, and incorporating a broader set of sovereign risk indicators, including CDS spreads, to better understand the relationships between fiscal variables and financing costs.

Overall, the results suggest that fiscal sustainability is not determined by a single factor, but by the interaction between economic growth, fiscal discipline, and financing conditions. The comparison between Romania and Hungary shows that both high public debt and persistent budget deficits can create vulnerabilities, especially in a context of higher interest rates. This underlines the need for a more balanced and forward-looking approach to fiscal policy.

Policy recommendations

Based on the empirical findings of the study, the following policy recommendations can be formulated for Romania and Hungary. Each recommendation addresses the specific fiscal vulnerabilities identified in the analysis.

For Romania, the main focus of policy makers should be:

Strengthen fiscal consolidation: Gradually reduce the budget deficit through better tax collection, spending discipline, and medium-term fiscal planning. This would help lower borrowing costs and improve fiscal credibility.

Improve fiscal governance and institutional credibility: Reinforce fiscal rules, increase budget transparency, and strengthen independent fiscal oversight to stabilize investor confidence and sovereign risk perception.

For Hungary, the main focus of policy makers should be:

Gradually reduce the public debt ratio: Maintain primary surpluses during periods of economic growth and avoid procyclical fiscal expansion to lower structural debt vulnerability, in line with the insights of Olivier Blanchard.

Support long-term economic growth: Promote productivity-enhancing investment and deeper integration with European markets to improve growth capacity and reduce debt pressures, consistent with the research of Carmen Reinhart and Kenneth Rogoff.

This policy recommendation is broadly valid from an economic perspective. European countries should place greater emphasis on pro-market policies that enhance long-term growth potential, such as productivity-enhancing investment, reduced regulatory and fiscal burdens, and improved business environments. Higher and more stable economic growth can strengthen debt sustainability by increasing the denominator of the debt-to-GDP ratio and narrowing the interest rate–growth differential. In this sense, the paper confirms that under tighter post-pandemic financial conditions, fiscal sustainability requires not only deficit control, but also credible institutions and sufficient growth capacity to prevent adverse debt dynamics.

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The dominant role of trust and security over data privacy in digital services: a comparative study of telemedicine users and non-users

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Abstract. *This study examines how perceived privacy, perceived security, and trust shape behavioral intention to use telemedicine services among users and non-users. Perceived privacy refers to concerns regarding control and confidentiality of personal health data, while perceived security deals with technical protection against unauthorized access or misuse. Using PLS-SEM, the study tests a trust-mediated adoption model across two experiential stages of adoption. The measurement model met accepted reliability and validity criteria, with composite reliability above 0.70 and AVE above 0.50. Results show that trust is the strongest predictor of behavioral intention, while perceived security affects adoption both directly and indirectly through trust. Perceived privacy plays a more limited, context-dependent role, mainly through trust among non-users. The findings show that privacy and security are distinct antecedents of trust and offer practical guidance for strengthening telemedicine adoption through visible security safeguards, transparent data-use communication, and privacy control for potential users.*

Keywords: telemedicine adoption, trust, perceived security, data privacy, behavioral intention, PLS-SEM..

JEL Classification: I11, O33, D91, M31.

1. Introduction

Over the past decade, digital transformation has reshaped public and private services by moving beyond automation toward data-driven systems, digital platforms, and citizen-centred approaches. In healthcare, this transformation is particularly important because digital technologies do not only improve administrative efficiency, but also impact the interaction between patients, physicians, and health information systems. Telemedicine represents one of the most visible examples of this transformation, as it enables remote consultations, monitoring, and communication between patients and healthcare professionals. Its relevance of telemedicine has increased due to its potential to improve access to care, particularly in rural or underserved areas, while reducing costs and waiting times for both patients and providers (Anawade, et al., 2024).

Despite these advantages, telemedicine adoption remains challenged by limited internet access, lack of adequate devices, low digital literacy, and concerns regarding cybersecurity and personal data protection (Huawei, 2024; Crossan, et al., 2026). Therefore, telemedicine should be viewed not only as an innovation in healthcare delivery, but also as a critical example of high-risk digital service adoption, as its use depends on citizens' willingness to disclose sensitive medical and personal data through digital platforms. Its success depends not merely on availability, but on citizens' acceptance and continued use.

Traditional technology acceptance models, particularly Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT), identify perceived usefulness, perceived ease of use, performance expectancy, and facilitating conditions as central predictors of behavioral intentions (Davis, 1989; Venkatesh, et al., 2003). In digital health contexts, however, adoption also depends on psychological and risk-related factors such as trust, perceived risk, privacy concerns, and security perceptions (Catapan, et al., 2025). This extension is particularly important because healthcare technologies involve uncertainty, vulnerability, and information asymmetry. Individuals may avoid using telemedicine even when they perceive it as useful if they do not trust the service. Trust, in turn, is shaped by perceptions of system security and data privacy and may mediate the effects of usefulness, risk, and privacy on behavioral intention (Adjekum, et al., 2018; Dhagarra, et al., 2020; Zhu, et al., 2023).

Despite the growing literature regarding traditional technology adoption models, three limitations remain. First, many studies integrate trust into TAM or UTAUT extensions, but they often treat trust primarily as an additional predictor of behavioral intention rather than examining its mediating role in the relationship between risk-related perceptions and adoption intention. Second, privacy and security are frequently discussed together although they may reflect different psychological mechanisms: privacy concerns relate to control over personal data, while perceived security concerns the technical and institutional safeguards that protect data from unauthorized access or misuse (Dinev, et al., 2013; Wijaya, et al., 2026). Third, previous research often analyses general samples of potential or current users without explicitly distinguishing between users and non-users (Holtz, et al., 2022). This distinction is theoretically important because users evaluate telemedicine based on direct experience, whereas non-users form adoption intentions through anticipatory beliefs, perceived uncertainty, and expectations about risk.

Addressing these limitations, the present study contributes to technology acceptance research by examining how perceived privacy, perceived security, and trust shape behavioral intention to adopt telemedicine. More specifically, it tests whether trust mediates the effects of perceived privacy and security on behavioral intention, and whether these mechanisms differ between telemedicine users and non-users. By comparing these two groups, the study moves beyond a general adoption model and investigates whether trust formation is structurally different across experiential stages of adoption.

2. Literature Review

2.1. Telemedicine adoption and its determinants

In simple terms, telemedicine refers to the remote delivery of healthcare services through audio calls, video consultations, or dedicated digital platforms (Serper & Volk, 2018). The literature generally distinguishes four main components of telemedicine: real-time consultations, asynchronous transmission of clinical data, remote patient monitoring, and mHealth applications used for communication, self-management, and data collection (Wells, et al., 2022; Ezeamii, et al., 2024). In practice, these components are often combined within integrated care services, particularly for chronic disease management. For example, patients with chronic diseases may simultaneously benefit from online consultations, remote monitoring, and mobile applications that support disease self-management and preventive health behaviours (Alakeel, et al., 2025).

Research consistently shows that telemedicine improves access to healthcare and is especially effective in managing chronic conditions such as diabetes, where it contributes to better glycaemic control and higher patient engagement (Ezeamii, et al., 2024). These benefits are particularly relevant given the major economic burden chronic diseases place on healthcare systems and national economies (Hacker, 2024). Studies also report reductions in hospitalizations and length of stay, alongside improvements in patient satisfaction and quality of life, especially among vulnerable populations and individuals living in remote or underserved areas (Alakeel, et al., 2025; Borges do Nascimento, et al., 2025).

Although telemedicine consistently demonstrates clinical and economic benefits, the literature highlights several barriers that limit its large-scale implementation. These include inadequate infrastructure and limited access to technology, digital literacy gaps, and regulatory challenges. Moreover, telemedicine cannot fully replace face-to-face care, as certain medical conditions still require in-person consultations, reinforcing the need for hybrid care models (Tabacelan, et al., 2024; Ezeamii, et al., 2024).

In this context, its success depends not only on availability but also on actual adoption by patients and providers. Real health and efficiency gains occur only when telemedicine is actively used, yet evidence shows that adoption is not automatic (Kruse & Heinemann, 2022). To explain this process, research commonly relies on the Technology Acceptance Model and the Unified Theory of Acceptance and Use of Technology. TAM (Davis, 1989) explains adoption through perceived usefulness and ease of use, which shape intention and

actual use. UTAUT (Venkatesh, et al., 2003) extends this framework by incorporating performance expectancy, effort expectancy, social influence, and facilitating conditions. In healthcare, both models are widely applied to understand and predict telemedicine adoption behavior (Rouidi, et al., 2022). In the present study, TAM is used as the broader theoretical background for understanding behavioral intention, but the focus is narrowed to trust, perceived privacy, and perceived security because telemedicine adoption involves sensitive health data and therefore stronger risk-related evaluations than many other digital services.

2.2. Trust in digital health adoption

In technology adoption research, trust is defined as the expectation that another party – whether a person, organization, or system – will act competently and in the user’s best interest, particularly under conditions of uncertainty or vulnerability. However, trust is a multidimensional construct, encompassing interpersonal trust in healthcare professionals, technological trust in system performance and accuracy, and institutional or data-related trust concerning privacy and security of information (Adjekum, et al., 2018). Evidence consistently shows that higher trust in digital health solutions is associated with stronger adoption intentions, continued use, and higher perceived usefulness. However, prior studies differ in how they position trust: some treat it as a direct antecedent of behavioral intention (Hong, et al., 2019; Dhagarra, et al., 2020) while others examine it as a mediator between perceived risk, privacy or security, and intention (Zhang, 2024). This inconsistency justifies examining trust as a mediating construct in the present study. Taking all of the above into account, the following hypotheses are proposed:

H1. Trust has a positive influence on behavioral intention to use telemedicine.

H2. Trust mediates the relationship between perceived privacy and behavioral intention to use telemedicine.

H3. Trust mediated the relationship between perceived security and behavioral intention to use telemedicine.

2.3. Perceived privacy and perceived security as distinct risk-related constructs

While prior research has identified multiple antecedents of trust, including performance expectancy, ease of use, and social influence within models such as UTAUT and TAM (Lee & Ok, 2026), the present study adopts a more focused approach by emphasizing perceived security and perceived privacy. This choice is grounded in the specific characteristics of telemedicine, where concerns related to sensitive health data and potential risks play a central role in shaping users’ perceptions (Catapan, et al., 2025). In this context, security and privacy are not secondary considerations but central drivers of trust, as they directly address users’ primary concerns. Consequently, adoption decisions are shaped less by usability alone and more by whether the system is perceived as secure, reliable, and protective of personal information (Houser, et al., 2023).

Although perceived security and perceived privacy are closely related, they should not be treated as interchangeable constructs. Perceived security refers to users’ subjective assessment of the degree to which a digital system is safe from unauthorized access and data misuse. Perceived privacy concerns relate to users’ beliefs about the risks of

inappropriate disclosure or misuse of personal data (Dinev, et al., 2013; Zhang, 2024). Thus, privacy concerns are primarily linked to informational control and disclosure, whereas security perceptions are linked to technical protection and system reliability. In this study, both constructs are treated as distinct risk-related antecedents of trust.

Regarding privacy, its role in technology adoption is not always straightforward. The privacy paradox literature suggests that individuals may express concern about personal data protection while still adopting digital services when perceived benefits, convenience, trust, or necessity outweigh perceived risk (Youn, et al., 2023; Ashrafi, et al., 2025). This aspect is particularly relevant in telemedicine, where users may value access to care while remaining concerned about the disclosure of sensitive medical data. Therefore, perceived privacy concerns may influence behavioral intention directly, but it may also influence it indirectly through trust, as supported by previous studies (Dhagarra, et al., 2020; Schomakers, et al., 2021). Based on these considerations, the following hypotheses are proposed:

H4. Perceived privacy has a positive influence on behavioral intention to use telemedicine.

H5. Perceived privacy has a positive influence on trust in telemedicine services.

Similar to privacy, security perceptions influence adoption both directly – by reducing perceived risk – and indirectly, by strengthening users' trust in the service. In a peer-to-peer lending study, perceived security emerged as the most influential determinant of adoption intention ($\beta = 0.337$), with trust also partially mediating the effect (Wijaya, et al., 2026). The dual pathway of security – directly on behavioral intention and indirectly via trust – is a recurrent finding in the literature (Shrestha, et al., 2021). Thus, the following hypotheses are formulated:

H6. Perceived security has a positive influence on behavioral intention to use telemedicine.

H7. Perceived security has a positive influence on trust in telemedicine services.

2.4. Users and non-users: experiential differences in trust formation

Levels of trust, as well as perceptions of security and data protection, may differ between users and non-users of telemedicine because the two groups evaluate digital health services from different experiential positions. For users, trust is grounded in direct interaction with the telemedicine system, whereas for non-users, trust is formed in a more anticipatory manner, based on expectations, perceived uncertainty, concerns and assumptions about system security. This distinction is important because the same antecedents may not influence behavioral intention in the same way across both groups. However, prior literature rarely distinguishes clearly between these two groups, potentially leading to an incomplete understanding of telemedicine acceptance (Holtz, et al., 2022; Haque, et al., 2023).

By investigating how privacy and security perceptions shape trust and subsequently influence behavioral intention, the study provides a deeper understanding of the mechanisms underlying telemedicine adoption. Moreover, by distinguish between users and non-users of telemedicine services, the research examines whether trust operates

differently as a mediating mechanism for individuals with direct telemedicine experience compared to those whose evaluations are based mainly on expectations and perceived risk. This comparative perspective allows the study to move beyond a general adoption model and to assess whether adoption mechanisms differ between experience-based and anticipation-based evaluations of digital health services.

3. Methodology

The data used in this study were collected as part of a broader research project on telemedicine adoption. The study used convenience and snowball sampling to reach individuals with different levels of familiarity with telemedicine, due to the lack of a complete sampling frame. However, this approach may have introduced self-selection bias and limits the generalizability of the findings. Before participating, respondents were informed that their responses would remain anonymous and would be used strictly for research purposes. Participation was voluntary, and all respondents completed an informed consent form prior to starting the survey.

Respondents were classified as telemedicine users if they reported having used telemedicine services in the past 12 months. Respondents who reported no previous use of telemedicine were classified as non-users. This distinction was used to compare experience-based evaluations among users with anticipation-based evaluation among non-users. The study items were adapted from a previous study conducted by Zhang (2024) with wording adjusted for telemedicine context. The constructs measured were behavioral intention, trust, perceived privacy and perceived security. All constructs' items were measured on a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Both groups answered the same constructs, with minor wording adjustments: items were phrased prospectively for non-users and retrospectively for users. This approach minimized the likelihood of purely hypothetical evaluations among non-users. Group classification was based on a screening question regarding prior telemedicine use. No formal pilot test was conducted before data collection. However, the questionnaire items were adapted from validated scales, and item reliability and validity were assessed during the measurement model evaluation. The MICOM procedure confirmed configural invariance and compositional invariance for all constructs. Therefore, partial measurement invariance was established, allowing meaningful comparison of path coefficients between users and non-users.

To examine the relationships among the constructs included in the conceptual model, Partial Least Squares Structural Equation Modelling (PLS-SEM) was employed. PLS-SEM was selected because the study focuses on prediction-oriented relationship among latent constructs and assesses direct and indirect effects, while also offering robustness when working with moderate sample sizes. The analysis was conducted separately for users and non-users using SmartPLS 4. Statistical significance was assessed through bootstrapping with 5000 resamples, using one-tailed tests and a significance threshold of $p < 0.05$.

4. Results

The analysis of the sample reveals notable differences between users and non-users of telemedicine services. In terms of age, non-users are more strongly concentrated in the youngest category (18-24 years old), accounting for 54.8% of this group, compared to 35.9% among users. Older adults are notably underrepresented in both groups – only 4.4% of users and 7.1% of non-users. This age structure should be considered when interpreting the findings, as younger respondents may have higher digital familiarity but may also have less frequent interaction with healthcare services than older adults. In terms of gender composition, our sample is heavily female-dominated. Women make up 79.6% of users and 72.8% of non-users. Male participation is slightly lower among users at 20.4% versus 27.2% among non-users. This imbalance may influence the results, particularly if women are more likely to participate in health-related surveys or to express stronger interest in healthcare access and digital health services (Dluhos-Sebesto, et al., 2021).

Regarding education, participants from both groups tend to be highly educated. University graduates form the largest group in both users (67.4%) and non-users (51.7%), which may be associated with higher digital literacy and greater ability to evaluate privacy, security, and trust-related aspects of telemedicine. Among users, 64.1% are urban residents versus 35.9% rural, a ratio mirrored almost exactly in non-users. The near-identical rural/urban residence distribution across both groups suggest that place of residence is unlikely to be a significant differentiating factor between users and non-users in this sample. Overall, users tend to have higher monthly incomes than non-users, with 24.3% of them earning above 6500 RON. Conversely, the lowest income category (below 2500 RON) is substantially more represented among non-users (37%) than users (19.3%). This income difference may indicate that economic resources influence telemedicine adoption, either through access to digital services, internet connectivity, or ability to pay for private digital health services. Therefore, while the sample is appropriate for exploratory analysis of telemedicine adoption mechanisms, the findings should not be interpreted as fully representative of the general population. A detailed description of the sample' descriptive statistics is presented in Table 1.

Table 1. *Descriptive statistics*

Variable	Category	Users (n = 181)	Non-users (n = 375)
Age	18–24 years	65 (35.9%)	207 (54.8%)
	25–34 years	62 (34.3%)	83 (22.0%)
	35–44 years	26 (14.4%)	30 (7.9%)
	45–54 years	20 (11.0%)	28 (7.4%)
	Over 54 years	8 (4.4%)	27 (7.1%)
Gender	Male	37 (20.4%)	102 (27.2%)
	Female	144 (79.6%)	273 (72.8%)
Education	Primary / Lower secondary	0 (0.0%)	5 (1.3%)
	High school	34 (18.8%)	110 (29.3%)
	University	122 (67.4%)	194 (51.7%)
	Postgraduate	35 (19.3%)	66 (17.6%)
Residence	Rural	65 (35.9%)	134 (35.7%)
	Urban	116 (64.1%)	241 (64.3%)
Monthly Income (RON)	Below 2500	35 (19.3%)	139 (37.0%)
	2500–3500	28 (15.5%)	47 (12.5%)
	3501–4500	24 (13.3%)	45 (12.0%)
	4501–5500	20 (11.0%)	55 (14.7%)
	5501–6500	30 (16.6%)	42 (11.2%)
	Above 6500	44 (24.3%)	47 (12.5%)

4.1. The Measurement (Outer) Model

Table 2 summarizes the reliability and convergent validity results for the measurement model among telemedicine users and non-users. The composite reliability values range from 0.858 to 0.954 across both groups, exceeding the minimum threshold of 0.70 (Nunnally & Bernstein, 1994). Similarly, Cronbach's alpha values are high for both non-users (0.856 to 0.942) and for users (0.872 to 0.946), indicating strong internal consistency of the construct (Cortina, 1993).

In addition, convergent validity was assessed using the average variance extracted (AVE). All AVE values are above the commonly accepted threshold of 0.50, indicating adequate convergent validity (Fornell & Larcker, 1981). The similarity of these indicators' values across the two groups further suggests that the measurement model performs consistently and equivalently for both telemedicine users and non-users.

Table 2. *Measurement reliability*

Variable	Composite Reliability (CR)		Cronbach's alpha		Average Variance Extracted (AVE)	
	Non-users	Users	Non-users	Users	Non-users	Users
Perceived Privacy (PP)	0.952	0.937	0.916	0.914	0.779	0.794
Perceived Security (PS)	0.944	0.954	0.942	0.946	0.853	0.860
Behavioral Intention (BI)	0.858	0.889	0.856	0.876	0.776	0.802
Trust (T)	0.890	0.899	0.882	0.872	0.810	0.796

Table 3 presents correlations among latent constructs and the square roots of AVE. In both groups, the Fornell-Larcker criterion is met, with AVE square roots exceeding inter-construct correlations, which are all below the 0.80 threshold (Kennedy, 2008), confirming discriminant validity at the construct level. Table 4 reports indicator loadings and cross-loadings, showing that all items load higher on their intended constructs than on others, confirming adequate discriminant validity at the item level (Hair, et al., 2021). Both tables can be found in Appendix.

The findings collectively confirm that all four constructs are empirically distinct and that the measurement model is strong. The near-identical metric properties across groups also satisfy a condition for meaningful multi-group analysis.

4.2. The Inner Model

Table 5 presents the estimated path coefficients of the research model for both groups. The structural model demonstrates moderate to substantial predictive power for behavioral intention, explaining 56.7% of variance among non-users and 47.3% among users. This indicates that the model accounts for a larger share of adoption intention among non-users. Trust is moderately explained by perceived privacy and perceived security, with R² values of 32.3% for non-users and 33.3% for users. These values compare favourably with similar studies in the literature (Wijaya, et al., 2026).

The similar explanatory power for trust across the two groups suggests that the antecedents included in the model contribute comparably to trust formation, even though their individual path effects differ between users and non-users.

Table 5. Path coefficients, with p-values in parentheses, for both users and non-users

	Non-users					Users				
Estimated Coef- ficients	Direct Effects		Indirect Effects	Total Effects		Direct Effects		Indirect Effects	Total Effects	
Model	BI	T	BI	BI	T	BI	T	BI	BI	T
BI	-	-	-	-	-	-	-	-	-	-
T	0.675*** (p < 0.001)	-	-	0.675*** (p < 0.001)	-	0.644*** (p < 0.001)	-	-	0.644*** (p < 0.001)	-
PP	-0.026 (p = 0.313)	-0.142** (p < 0.005)	-0.095** (p < 0.005)	-0.121 (p = 0.037)	-0.142** (p < 0.005)	0.027 (p = 0.335)	-0.087 (p = 0.083)	-0.056 (p = 0.092)	-0.029 (p = 0.345)	-0.087 (p = 0.083)
PS	0.133* (p = 0.011)	0.603*** (p < 0.001)	0.406*** (p < 0.001)	0.539*** (p < 0.001)	0.603*** (p < 0.001)	0.065 (p = 0.191)	0.599*** (p < 0.001)	0.386*** (p < 0.001)	0.451*** (p < 0.001)	0.599*** (p < 0.001)
R ² / Adjusted R ²	56.7%/ 56.4%	32.2%/ 31.9%	-	-	-	47.3%/ 46.4%	33.3%/ 32.6%	-	-	-

*** p-value < 0.001; ** p-value < 0.01; * p-value < 0.05

4.2.1. Direct and Indirect Effects on Behavioral Intention

Trust has a positive and the strongest effect on behavioral intention being the most consistent predictor in the entire model. For non-users, $\beta = 0.675$ ($p < 0.001$), and for users, $\beta = 0.644$ ($p < 0.001$). Therefore, H1 is supported for both users and non-users. This is an important finding for digital adoption, reflecting the idea that trust may be one of the primary gateways to intention to use telemedicine, regardless of whether someone is already a user or not.

The mediation analysis was assessed using the specific indirect effects obtained through bootstrapping. For users, the indirect effect of perceived privacy on behavioral intention through trust was not statistically significant ($\beta = -0.056$, $p = 0.092$), indicating that trust does not mediate this relationship in the user group. For non-users, the indirect effect of perceived privacy on behavioral intention mediated by trust was statistically significant, but negative ($\beta = -0.095$, $p < 0.005$). Therefore, H2 is not supported for users and is only partially supported for non-users, as the effect is significant, but in the opposite direction.

Regarding the mediation of trust between perceived security and behavioral intention, the relationship is positive and significant for both users ($\beta = 0.386$, $p < 0.001$) and non-users ($\beta = 0.406$, $p < 0.001$), confirming that trust mediates this relationship in both groups. Hence, H3 is supported.

Regarding the direct effects on behavioral intention, perceived privacy does not exert a statistically significant influence in either group. Among non-users, perceived privacy has a negative but non-significant effect on behavioral intention ($\beta = -0.026$, $p = 0.313$), while among users, the effect is also non-significant ($\beta = 0.027$, $p = 0.335$). These results suggest that perceived privacy do not directly explain behavioral intention once trust is included in the model. Thus, H4 is not supported for either group.

On the other hand, perceived security has a positive and significant influence on behavioral intention for non-users ($\beta = 0.133$, $p < 0.001$), but its effect is not statistically significant for users ($\beta = 0.065$, $p = 0.191$). This suggests that perceived security directly contributes to adoption intention only in the non-users group, whereas among users its role is primarily captured through trust. Therefore, H6 is supported only for non-users.

4.2.2. Direct Effects on Trust

For non-users, perceived privacy has a negative and significant effect on trust ($\beta = -0.142$, $p < 0.005$), whereas the effect is not significant among users ($\beta = -0.087$, $p = 0.083$). Hence, H5 is statistically significant for non-users, but not supported in the expected positive direction. The finding that relationship between perceived privacy and trust is negative rather than positive may suggest that, among individuals without prior telemedicine experience, privacy-related perceptions may function as a source of uncertainty rather than as a trust-building factor. In contrast, among users, that non-significant effect indicates that privacy concerns may become less salient once individuals have direct experience with telemedicine services.

Regarding perceived security, the results show a positive and statistically significant influence on trust in both groups: non-users ($\beta = 0.603$, $p < 0.001$) and users ($\beta = 0.599$, $p < 0.001$). Thus, H7 is supported for both users and non-users.

The effect sizes (Table 6) provide additional insight into the relevance of these relationships. Following Cohen's (1992) benchmarks, trust has a large effect on behavioral intention among both non-users ($f^2 = 0.713$) and users ($f^2 = 0.525$), while perceived security also show a large effect on trust in both groups ($f^2 = 0.468$ and $f^2 = 0.484$, respectively). In contrast, perceived privacy has only a small effect on trust among non-users ($f^2 = 0.026$) and no meaningful effect among users ($f^2 = 0.010$). Overall, the model's explanatory power is driven mainly by trust and perceived security, while perceived privacy plays a limited role.

Table 6. *Effect sizes (f^2) of the constructs*

	Non-users		Users	
	BI	T	BI	T
T	0.713	-	0.525	-
PP	0.001	0.026	0.001	0.010
PS	0.024	0.468	0.005	0.484

5. Discussion

5.1. Theoretical Implications

This study focuses on understanding the role of perceived privacy, perceived security and trust on behavioral intention of patients to use telemedicine services. Trust emerges as a critical predictor of behavioral intention and the near-identical magnitude across groups underscores trust as a universal gateway to digital adoption, consistent with prior findings in online shopping, digital lending, and other digital service contexts (Gefen, et al., 2003; Wu, et al., 2011; Wijaya, et al., 2026). The strong influence of trust on behavioral intention also supports prior extensions of TAM and UTAUT that position trust as a mechanism for

reducing uncertainty in high-risk digital environments (Schomakers, et al., 2021; Asif & Sarwar, 2025). Users who perceive a digital service as trustworthy implicitly interpret this as a signal that their interests will be protected, reducing the psychological cost of adoption. Therefore, the study supports the argument that trust should be integrated more explicitly into TAM and UTAUT-based models of digital health adoption.

The findings also reveal an important distinction between perceived privacy and perceived security. Perceived privacy alone does not directly drive or suppress behavioral intentions. Moreover, its effect on trust is significant only among non-users and operates in the negative direction. The idea that privacy operates through trust to indirectly influence behavioral intention is also supported in the study of Luo, et al. (2023). At the same time, a previous study has reported a statistically negative effect on behavioral intention (Dhagarra, et al., 2020). This suggests that for someone without prior telemedicine experience, privacy-related perceptions may activate concerns about data disclosure, confidentiality, or control over personal health information. Rather than functioning as a direct adoption driver, privacy appears to shape behavioral intention indirectly by influencing trust. These findings are consistent with the broader privacy paradox literature (Ashrafi, et al., 2025).

By contrast, perceived security has a strong positive impact on trust in both groups and also influence behavioral intention indirectly through trust. Among non-users, perceived security also has a significant direct effect on behavioral intention. This suggests that security plays both an immediate and trust-mediated role in telemedicine adoption, particularly in the adoption stage. Prior research has also support these results (Zhang, 2024; Gupta, et al., 2025). Theoretically, this may indicate a hierarchical risk evaluation process in digital health contexts: individuals first evaluate whether the system appears technically secure, and this perception then supports the development of trust.

The stronger influence of perceived security compared to perceived privacy on behavioral intention, both directly and indirectly through trust, suggests that individuals may prioritize the overall safety and reliability of telemedicine systems over concerns related to personal data disclosure. Although users remain aware of potential privacy risks, their willingness to adopt digital health technologies appears to increase when they perceive the system as sufficiently secure and trustworthy. A similar finding is suggested by Zhang (2024).

5.2. Practical Implications

Since trust plays a central role in behavioral intention across both groups, strengthening trust through transparency and user control over personal data is essential. Providing patients with clear information regarding data collection and usage practices, as well as enabling them to manage their consent, can enhance confidence in digital health services.

At the same time, the results suggest that adoption strategies should differ between users and non-users. For non-users, privacy-related communication and transparency mechanisms may be particularly important during the pre-adoption stage, as privacy assurances appear to function as trust-building signal before initial adoption occurs. This implies that privacy communication is a pre-adoption marketing tool, not a general engagement lever, and should be concentrated in awareness and consideration campaigns

targeting non-users. In contrast, for existing users, continued engagement may depend more strongly on system reliability, consistent performance, and visible security protections. Therefore, strong security and privacy protections, supported by strict standards and regulatory frameworks, play a crucial role in reducing user reluctance and fostering the adoption of telemedicine technologies (Jawad, 2024).

6. Limitations and Future Research

Several limitations should be acknowledged. First, the study relies on self-reported data collected through a single questionnaire, which may introduce common method bias. In addition, the sample is predominantly female and highly educated, with underrepresentation of male, older adults and lower educational levels, likely reflecting online recruitment bias and limiting generalizability. Second, the study was conducted in Romania, and the findings should therefore be interpreted within this national and cultural context. Trust in healthcare institutions, digital health maturity, and privacy perceptions may vary across countries, limiting the generalizability of the results. Third, future research should move beyond cross-sectional survey designs by using longitudinal panel studies to examine how trust changes after telemedicine use, or experimental design to test how privacy and security communication affects trust formation among potential users.

7. Conclusion

This study confirms a trust-mediated adoption model in which perceived security and perceived privacy shape behavioral intention primarily through their effect on trust. Trust emerges as a dominant driver of telemedicine adoption intention, while security influences adoption through both direct and trust-mediated pathways. The study's original contribution lies in showing that privacy and security do not play equivalent roles: security is a consistent antecedent of trust across both users and non-users, whereas privacy has a more limited and context-dependent role, especially in the non-users group. By distinguishing between users and non-users, the study shows that telemedicine adoption mechanisms differ across experiential stages. Together, these findings suggest that healthcare digital service providers should treat trust as a strategic mechanism built through robust security and transparent privacy practices in order to reduce hesitation among potential adopters.

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Appendix

Table 3. Correlations among latent constructs with square roots of AVE for both users and non-users

	Non-users				Users			
	PP	PS	BI	T	PP	PS	BI	T
PP	0.882	-0.357	-0.071	-0.073	0.891	-0.317	-0.114	-0.103
PS	-0.357	0.924	0.496	0.552	-0.317	0.928	0.442	0.571
BI	-0.071	0.496	0.881	0.746	-0.114	0.442	0.896	0.684
T	-0.073	0.552	0.746	0.900	-0.103	0.571	0.684	0.892

Table 4. Combined loadings and cross-loadings for both users and non-users

	Non-users				Users			
	PP	PS	BI	T	PP	PS	BI	T
PP1	0.748	-0.217	0.019	-0.022	0.847	-0.266	-0.111	-0.106
PP2	0.926	-0.296	-0.071	-0.086	0.884	-0.275	-0.090	-0.042
PP3	0.923	-0.339	-0.076	-0.054	0.922	-0.282	-0.094	-0.078
PP4	0.920	-0.367	-0.048	-0.059	0.910	-0.303	-0.106	-0.118
PS1	-0.309	0.923	0.472	0.528	-0.279	0.931	0.417	0.570
PS2	-0.351	0.940	0.468	0.510	-0.261	0.952	0.445	0.571
PS3	-0.364	0.939	0.463	0.520	-0.330	0.925	0.423	0.520
PS4	-0.291	0.891	0.428	0.479	-0.317	0.902	0.342	0.442
BI1	-0.114	0.487	0.852	0.637	-0.041	0.375	0.842	0.546
BI2	-0.077	0.399	0.888	0.639	-0.124	0.394	0.910	0.608
BI3	-0.002	0.425	0.903	0.694	-0.133	0.417	0.933	0.676
T1	-0.055	0.488	0.701	0.924	-0.100	0.517	0.641	0.927
T2	-0.038	0.459	0.598	0.850	0.017	0.427	0.460	0.816
T3	-0.101	0.540	0.709	0.925	-0.164	0.570	0.699	0.928

Comparative assessment of development in G20 countries using Human Development Index, Social Progress Index, and Taxonomic Measures

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Abstract. *This study ranks G20 countries using the Human Development Index (HDI), the Social Progress Index (SPI), and taxonomic measures. It also examines the relationship between the Human Development Index (HDI) and SPI across their respective dimensions. Using secondary data, the analysis applies Hellwig's method along with descriptive tools such as tables, graphs, and scatter plots. Results show that Australia records the highest HDI (0.951), while India ranks lowest (0.633). Australia leads in expected years of schooling, Japan in life expectancy, Germany in mean years of schooling, and the United States in GNI per capita. Canada achieves the highest SPI score (88.48), whereas India ranks last (58.80). Hellwig's synthetic measure places China first in 2021, while South Africa ranks lowest. Overall, the findings reveal substantial development disparities within the G20, a positive correlation between HDI and SPI, and notable growth in HDI and SPI in China and India.*

Keywords: Human Development Index HDI, Social Progress Index SPI, Taxonomic measures, Comparative Analysis, and G20.

JEL Classification: O15, R11, Q01.

1. Introduction

As each country is unique, categorizing and ranking them is common practice. Numerous studies (Malul, Hadad and Ben-Yair, 2009; Stiglitz and Sen, 2009; Eckehard, 2011; Radojicic et al., 2012; Pérez-Ortiz et al., 2014; Khayyat and ; Lee, 2016) rank and measure countries based on a variety of factors, including economic, environmental, political, social, and/or any other indicators. However, much of this literature remains fragmented and lacks a unified analytical framework for integrating these dimensions. (Andaish and Vansiya, 2025) Examined the various degrees of sustainable development within the SAARC region utilizing the Taxonomic approach. A country's rank can indicate and gauge its level of economic development. International organizations like the World Bank, UNDP, IMF, and OECD all have systems for classifying and ranking countries based on their unique sets of parameters. "Development" has traditionally been interpreted in solely economic terms: a country that was experiencing economic growth was regarded as developing (Myint, 1958). This GDP-centric approach, however, has been widely criticized for its inability to capture distributional aspects, human well-being, and sustainability. Later works by authors (Haq, 1973; Streeten, 1981; 1994; Sen, 1984; 1993; 1999; Griffin and Knight, 1989; Varshney, 1998; Anand and Sen, 2000; n.d.) were instrumental in establishing a new concept of development in which economic growth was considered a necessary condition but one that needed to clarify the level of development of a country.

An alternative approach to the traditional, singular concentration on economic growth is human development. Human development began in 1990 as an alternative development that served as a critique of conventional development (Pieterse, 2010). In 1990, a new post-development discourse emerged, highlighting the interconnectedness of human development and social progress, leading to it being recognized as a development decade. In 1990, when the United Nations Development Programme (UNDP) released its first human development report, the conversation around progress shifted from being predominantly economic to being primarily focused on human development. Since then, the idea of development has placed a greater emphasis on human potential and well-being. The goal of human development is to improve human rights, freedom of expression, choice, dignity, entitlement, skills, knowledge, wisdom, art, experiences, and ideas, as well as self-esteem, confidence, longevity, productivity, sufficient resources for a decent standard of living, and self-realization (Malakar & Sapkota, 2021). The purpose of human development, or the human development approach, is to enhance the

richness of human life rather than only the economy in which people live. It is a strategy that is concentrated on people, their potential, and their options. Human Development is basically an approach to enhancing human well-being (Sen, 1985). Human development shows how human capability and opportunity are balanced (UNDP, 1990)

The Social Progress Index (SPI) is an alternative measurement to HDI that can be used to assess well-being. It was introduced by Michael Green and his team in 2010 and has been in use since 2013. The SPI provides clear and reliable social outcome data to inspire action (Scott et al., 2021). Social progress refers to the ability of a society to meet the fundamental needs of its people, provide a solid foundation for individuals and groups to enhance and maintain the quality of their lives, and create a framework that enables everyone to reach their full potential (Fehder & Stern, 2013). The three major components of social progress are basic human needs, foundation of well-being, and opportunity. Each component has four sub-components.(Scott et al., 2021). The Social Progress Index is an accurate measure of a country's performance across various social and environmental indicators that are essential for nations at all stages of economic development. It helps in evaluating a nation's performance in comparison to its economic peers and overall performance (Green et al., 2022).

(Malakar and Sapkota, 2021) They analyzed the HDI of Nepal and other SAARC member countries. In relation to Bharat (India)'s human development, (Narayana, 2006) examined the problems with evaluating educational accomplishment and creating multiple educational goals and targets. According to (Poudel, 2014), the HDI is a key metric used to assess a country's overall performance. (Reddy, 2016) claims that the HDI calculation is utilized each year to determine the value of the human resources that are available everywhere. (Robert M, 1991) Did a fantastic job evaluating the competitiveness of each state. He emphasized that success is not something that nations inherit; rather, it is something that is created. Differences in country values, cultures, economic systems, institutions, and historical context affect success in the competitive fight. (Petrovskaya, Kozyr and Nasybullina, 2018) used an analysis of the G20's competitiveness in human development to show that there are many areas where G20 nations are similar even though there are significant differences in the G20 HDI and its indicator outcomes. (Vansiya and Sharma, 2021) analyzed the HDI and its indicators for BRICS countries. (Andaish and Rasuli, 2022) investigated the HDI and its three aspects for Afghanistan and its neighbouring countries.

The existing literature on development measurement reveals several important gaps. Most studies rely on single composite indices such as the Human Development Index or the Social Progress Index, which capture only partial dimensions of development. While HDI focuses on basic human capabilities such as health, education, and income, SPI emphasizes broader social and environmental outcomes but does not explicitly incorporate economic performance. Moreover, prior research remains largely fragmented and descriptive, often limited to regional analyses (e.g., SAARC or BRICS) without providing a comprehensive global comparison. In particular, taxonomic approaches such as Hellwig's method have been underutilized in large-scale comparative studies, and there is a lack of systematic evaluation of how rankings differ across alternative methodologies. Consequently, the absence of an integrated and methodologically rigorous framework that combines and compares these approaches constitutes a significant research gap.

To address this gap, the present study develops a multidimensional theoretical framework that integrates economic, human, and social perspectives of development. Grounded in the capability approach of Amartya Sen, the framework combines HDI and SPI with a taxonomic aggregation technique based on Hellwig's method to construct a composite development index. This approach enables the transformation of diverse indicators into a unified measure by assessing each country's distance from an ideal benchmark. The framework assumes that while HDI and SPI are complementary, their results may differ due to methodological variations, and thus a comparative analysis can reveal deeper insights into development disparities. By synthesizing multiple dimensions and methodologies, the study provides a more comprehensive, robust, and comparable assessment of development across countries.

The study aims to (i) construct a composite development index using Hellwig's method, (ii) compare country rankings obtained from HDI, SPI, and the taxonomic measure, and (iii) examine the relationship between HDI and SPI across G20 countries. It is hypothesized that significant differences exist between rankings derived from traditional indices (HDI, SPI) and those obtained using taxonomic methods, reflecting the multidimensional complexity of development. By integrating multidimensional indices with a rigorous taxonomic approach, this study contributes to the literature by providing a more comprehensive and methodologically robust framework for cross-country development assessment.

2. Materials and Method

In the current investigation the researchers, based on a quantitative comparative framework for cross-country analysis, along with the human development methodology and social progress methodology, utilized Hellwig's method, one of the oldest taxonomic measures, which is based on standardisation. This method, introduced by Hellwig (1968) in the field of economics, is selected over alternative techniques such as Principal Component Analysis (PCA), TOPSIS, and Data Envelopment Analysis (DEA) due to its ability to construct a synthetic development measure based on distance from an ideal solution while maintaining interpretability and comparability across countries. The study is based on secondary data obtained from the United Nations Development Programme (UNDP), the Social Progress Imperative database, and the World Bank database. The analysis focuses on the year 2021, which is selected as the reference year due to the availability of complete and comparable post-pandemic data across countries. The choice of this year ensures consistency and minimizes missing observations across indicators.

This method consists of several stages:

Stage one: Determination of the set of partial indicators based on the following criteria:

- Substantive relationship to economic and sustainable development
- International comparability
- Data availability
- Data source credibility

The selection of indicators in the study is further justified both empirically, based on data completeness and cross-country variability, and theoretically, based on the existence of development economics literature.

Stage two: Determining the nature of the indicators based on their impact on economic development.

Indicators are classified as stimulants variables positively associated with overall development, and their sub-components, such as income, health and education, and destimulants variables negatively associated with overall development and their sub-components. Destimulants are transformed into stimulants using an appropriate transformation.

Stage three: Standardization of indicators

$$Z_{ij} = \frac{X_{ij} - X_j}{S_j}$$

Where:

Z_{ij} = to the normalized value of the indicators j for county i

X_{ij} = value of the variables

X_j = mean of the indicator j

S_j = standard deviation of the indicator j

Standardization ensures comparability by removing scale effects and transforming all indicators into dimensionless variables.

Stage four: Calculation of the Hellwig synthetic measure and ranking of the countries.

Pattern coordinates:

$$Z_{0j} = \text{Max}_i \{Z_{ij}\}$$

Distance of objects from the pattern:

$$dio = \sqrt{\frac{1}{n} \sum_{i=1}^m (Z_{ij} - Z_{0j})^2}$$

The values of the synthetic variable were determined:

$$S_i = 1 - \frac{dio}{do}$$

$$do = \text{mean } dio + 2 \text{ SD } dio$$

The synthetic measure S_i takes values in the range (0,1), where higher values indicate a higher level of development and closer proximity to the ideal pattern. This enables a linear ordering (ranking) of countries. The rationale for constructing the synthetic measure is to aggregate multidimensional development indicators into a single composite index while preserving the relative distance of each country from the optimal benchmark.

To support interpretation, the study also employs descriptive statistics, tabular analysis, graphical visualization, trend analysis, and scatter plots. These techniques facilitate the identification of patterns, disparities, and relationships among variables.

3. Result and Discussion

The G-20 is a group of 20 countries along with the European Union, comprising of 19 nations such as Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, and the European Union. The G20 was formed after the Asian financial crisis with the primary aim of facilitating dialogue and consensus-building among G20 members, invited countries' international organizations, and affinity groups to promote public policies and discuss global challenges. The goal is to find ways to address these challenges that affect humanity at a global level.

3.1. Human Development Index performance of G20 countries

Researchers in this section attempted to analyze the HDI performance of G20 countries.

Table 1. *G20 Human Development Index and its Components*

HDI rank	Country		SDG3	SDG4.3	SDG4.4	SDG8.5		
		Human Development Index (HDI)	Life expectancy at birth	Expected years of schooling	Mean years of schooling	Gross national income (GNI) per capita (2017 PPP \$)	GNI per capita rank minus HDI rank	HDI rank
		Value	(years)	(years)	(years)			
		2021	2021	2021	2021	2021	2021	2020
5	Australia	0.951	84.5	21.1	12.7	49,238	18	5
9	Germany	0.942	80.6	17.0	14.1	54,534	6	7
15	Canada	0.936	82.7	16.4	13.8	46,808	9	15
18	United Kingdom	0.929	80.7	17.3	13.4	45,225	9	17
19	Japan	0.925	84.8	15.2	13.4	42,274	12	19
19	Korea (Republic of)	0.925	83.7	16.5	12.5	44,501	9	20
21	United States	0.921	77.2	16.3	13.7	64,765	-14	21
28	France	0.903	82.5	15.8	11.6	45,937	-2	28
30	Italy	0.895	82.9	16.2	10.7	42,840	0	32
35	Saudi Arabia	0.875	76.9	16.1	11.3	46,112	-10	38
47	Argentina	0.842	75.4	17.9	11.1	20,925	17	47
48	Turkey	0.838	76.0	18.3	8.6	31,033	-3	48
52	Russian Federation	0.822	69.4	15.8	12.8	27,166	-1	49
79	China	0.768	78.2	14.2	7.6	17,504	-8	82
86	Mexico	0.758	70.2	14.9	9.2	17,896	-16	88
87	Brazil	0.754	72.8	15.6	8.1	14,370	-5	86
109	South Africa	0.713	62.3	13.6	11.4	12,948	-17	102
114	Indonesia	0.705	67.6	13.7	8.6	11,466	-11	116
132	India	0.633	67.2	11.9	6.7	6,590	-6	130
Very high human development		0.896	78.5	16.5	12.3	43,752	—	—
High human development		0.754	74.7	14.2	8.3	15,167	—	—
Medium human development		0.636	67.4	11.9	6.9	6,353	—	—
Low human development		0.518	61.3	9.5	4.9	3,009	—	—
World		0.732	71.4	12.8	8.6	16,752	—	—

Source: UNDP

Information regarding the Human Development Index (HDI) and its three key indicators for G20 countries is presented in Table 1. Among the G20 nations, Australia leads with an HDI value of 0.951, placing it at rank 5. In comparison, India has an HDI value of 0.633, ranking 132nd out of 194 countries. Overall, European nations excel in the Human Development Index, with four of the top five ranks belonging to European countries among the G20 members. Among the Asian participants, Japan performed notably well, achieving an HDI score of 0.925 and ranking 19th. In terms of life expectancy at birth, Japan stands at the top with a score of 84.8 years, closely followed by Australia at 84.5 years, and the Republic of Korea at 83.7 years. Australia also ranks first for expected years of schooling, with an average of 21.1 years, while Turkey follows in second with 18.3 years, and Argentina in third with 17.9 years. India's life expectancy has improved to 67.2 years compared to the previous Human Development Report (HDR). Regarding mean years of schooling, Germany leads with 14.1 years, followed by Canada at 13.8 years, and the United States at 13.7 years. In contrast, India has expected years of schooling and mean years of schooling values of 11.9 and 6.7, respectively. When considering Gross National Income (GNI) per capita, the United States ranks first at \$64,765, Germany second at \$54,534, and Australia third at \$49,238. The descriptive analysis revealed that developed countries, including Australia, Canada, and Germany, excelled in Human Development Index (HDI) rankings. This observation highlights the significant impact of various structural factors identified in previous research. A key determinant of high human development performance across nations is the ongoing investment in public education, robust public health systems, and stable institutional frameworks. Developed nations consistently reap the benefits of superior health and education systems alongside effective public infrastructure (Sen, 1999; Alimoradi, Griffiths and Alijanzadeh, 2025a). Empirical studies have confirmed the significant influence of health and education expenditures (Jalil and Kamaruddin, 2018). In contrast, emerging economies like South Africa, India, and Indonesia exhibit lower HDI rankings, not solely due to economic factors, but also because of disparities in access to healthcare infrastructure and quality education (Hou, Walsh and Zhang, 2015).

Table 2. G20 Average Annual Human Development Index growth from 1990 to 2021 (in per cent)

Country	Change in HDI rank 2015-2021	1990-2000	2000-2010	2010-2021	1990-2021
Australia	3	0.35	0.30	0.27	0.31
Germany	-5	0.70	0.41	0.16	0.41
Canada	-2	0.34	0.23	0.25	0.27
United Kingdom	-3	0.70	0.57	0.17	0.47

Country	Change in HDI rank 2015-2021	1990-2000	2000-2010	2010-2021	1990-2021
Japan	0	0.37	0.24	0.27	0.29
Korea (Republic of)	3	1.13	0.76	0.35	0.74
United States	-3	0.22	0.22	0.10	0.18
France	-3	0.65	0.38	0.27	0.43
Italy	-1	0.78	0.48	0.13	0.45
Saudi Arabia	2	0.84	1.02	0.64	0.83
Argentina	-4	0.75	0.68	0.09	0.49
Turkey	6	1.11	1.12	1.03	1.08
Russian Federation	-2	-0.15	0.84	0.29	0.33
China	19	1.90	1.70	0.97	1.50
Mexico	-8	0.69	0.51	0.15	0.44
Brazil	1	1.08	0.63	0.38	0.69
South Africa	-4	0.02	0.64	0.50	0.39
Indonesia	3	1.24	1.10	0.55	0.95
India	-1	1.24	1.59	0.88	1.22
Very high human development		0.52	0.50	0.29	0.43
High human development		1.16	1.14	0.68	0.98
Medium human development		1.11	1.41	0.81	1.10
Low human development		1.15	1.80	0.75	1.22

Source: UNDP

The average growth rate of the Human Development Index (HDI) for G20 countries from 1990 to 2021 is presented in Table Two. The data reveals that, with the exception of Russia, all members experienced positive growth rates in HDI during the first decade. However, for the majority of these nations, growth rates have declined from the initial decade to the final one. Notably, Russia, India, Turkey, and Saudi Arabia exhibited upward growth among G20 countries in the first two decades, although their growth rates also decreased in the last decade. Overall, China recorded the highest growth rate throughout the three decades at 1.50 per cent, followed by India at 1.22 per cent and Turkey at 1.08 per cent. In contrast, the United States had the lowest growth rate at just 0.18 per cent. When we analyze India's HDI growth rate between 1990 and 2000, it becomes evident that India outperformed 16 other G20 countries, with the exception of China and Indonesia. Between 2000 and 2010, India ranked second across all countries in terms of HDI growth rate, again only behind China. The period from 2010 to 2021, however, has been significantly impacted by the global pandemic, which has adversely affected all nations. According to the HDR 2021-2022 data, the HDI growth rates of all countries, including India, have faced a decline. Despite being ranked third in HDI growth from 1990 to 2021, India has also witnessed a reduction in its growth rate.

The results indicated that emerging economies, such as China and India, are experiencing more rapid growth compared to developed economies like the United

States and European nations. This phenomenon is significantly related to the concept of catch-up effects. (Paliova, McNown and Nülle, 2019) show that low- and middle-income countries tend to experience faster growth in Human Development Index (HDI), particularly when greater investments are directed towards health and education sectors.

3.2. Social Progress Index SPI performing of G 20 countries

The Social Progress Index (SPI) is a significant measure of development that evaluates the extent to which a country meets the social and environmental needs of its citizens. It assesses 54 different indicators in three main areas: basic human needs, foundations of human well-being, and opportunities. Researchers analyzed the SPI performance of G-20 countries and found the following results.

Table 3. *G20 Social Progress Index and its Three dimensions (2021)*

Countries	Tiers	Social Progress Index		Basic Human Needs		Foundation of Wellbeing		Opportunity	
		Score	Rank	Score	Rank	Score	Rank	Score	Rank
Canada	1	88.48	8	88.36	28	89.23	7	87.8	8
Germany	1	88.44	9	90.02	11	86.37	18	88.9	4
Australia	1	88.20	11	89.26	17	87.95	13	87.4	10
Japan	1	88.13	12	91.70	3	90.00	6	82.7	19
Korea Republic of	1	86.31	17	90.26	9	86.89	16	81.8	24
United Kingdom	1	86.28	18	88.77	25	87.10	14	83.0	18
France	1	86.27	19	88.14	30	86.63	17	84.1	15
Italy	2	85.10	22	89.21	19	83.80	27	82.3	22
United state	2	85.04	24	87.42	34	84.15	26	83.5	16
Argentina	2	78.54	41	82.00	69	76.21	44	77.4	34
Russia	3	72.12	60	80.93	79	76.07	45	59.4	71
Brazil	3	71.25	62	80.43	82	72.23	60	61.1	68
Mexico	3	71.07	65	80.30	85	70.08	68	62.8	64
South Africa	3	68.82	75	70.46	116	67.70	76	68.3	47
Turkey	3	66.47	87	82.67	66	67.15	80	49.6	116
Indonesia	3	66.28	88	78.03	99	65.03	92	55.8	86
China	4	64.92	97	83.50	61	65.43	90	45.8	126
Saudi Arabia	4	63.68	101	83.26	63	66.02	84	41.8	144
BHARAT (India)	4	58.80	112	72.39	109	50.69	137	53.3	97

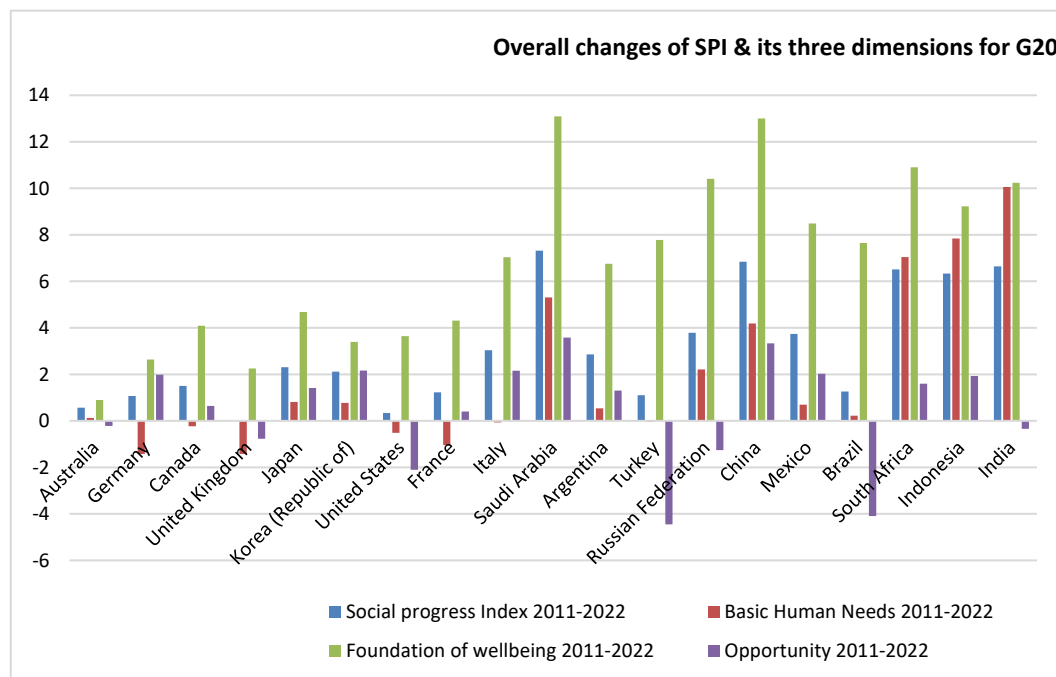
Source: Social Progress Imperative Database

Table three presents the social progress index (SPI) for G20 nations, along with its three components. Among the 19 members, seven are classified in the first tier, three in the second tier, six in the third tier, and three in the fourth tier. Canada leads the SPI rankings with a score of 88.48, ranking eighth overall, followed closely by Germany, Australia, and Japan. India has a score of 58.80 and ranks 112th. Japan excels in meeting basic human needs, achieving a score of 91.70 out of 100 and securing the third position. It is followed by the Republic of Korea, Germany, and

Australia. Conversely, South Africa lags behind with a score of 70.46 and a rank of 116. In the foundation of well-being category, Japan received an impressive score of 90.00, placing sixth, with Canada, Australia, and the United Kingdom also performing well. India, on the other hand, scored 50.69 and ranked 137th. Lastly, in the opportunity dimension, Germany performed admirably, earning a score of 88.9 and a rank of 4, while Canada, Australia, and France also scored higher. In stark contrast, Saudi Arabia recorded a low score of 41.8 and ranked 144th.

This result suggests that nations with comparable HDI values or income levels can exhibit significant disparities in social progress outcomes. For instance, Saudi Arabia and China rank lower on the Social Progress Index (SPI) despite being comparable to developed countries such as Australia, Canada, and several European nations in terms of economic development. These findings support the argument that economic growth alone is insufficient to enhance social progress; they indicate that economic development does not automatically translate into social advancement. Countries that excel in the SPI are often characterized by robust governance, comprehensive social policies, and a strong emphasis on social equity. This interpretation aligns with the research by (Paliova, McNown and Nülle, 2019).

Chart 1. Overall Changes of Social Progress Index and Its Three Dimensions for G20 Countries



Source: Social Progress Imperative Database

The chart illustrates the progress of the Social Progress Index (SPI) and its three dimensions from 2011 to 2022. It clearly indicates that all G20 members have made strides in their SPI scores, which range from 0.02 to 7.32. Saudi Arabia recorded the highest growth rate, while the United Kingdom had the lowest. Among the G20 nations, four Asian countries—Saudi Arabia, China, India, and Indonesia—showed the most significant improvements, achieving scores of 7.32, 6.84, 6.64, and 6.33, respectively. In contrast, European nations, while generally showing less progress, still maintain higher overall scores. The chart reveals that some nations exhibited negative values for basic human needs, while others showed positive values; negative values denote regression, whereas positive values signify advancement. India experienced the most rapid growth with a remarkable score of 10.05, while Germany and the United Kingdom recorded the largest negative values at -1.42. All G20 countries experienced positive growth in the foundations of well-being, with Asian nations surpassing their European counterparts in this regard. For example, Saudi Arabia (13.09), China (13.00), and India (10.23) achieved the highest scores, while South Africa also performed well with a score of 10.905. Australia had the lowest progress rate at 0.895. In terms of opportunity progress, China demonstrated notable positive improvement, whereas Brazil faced significant negative changes.

3.3. Taxonomic Measures of G20 Countries

In this section, researchers utilized ten economic and socio-economic indicators to assess the level of development in G20 countries. These indicators encompass GDP per capita (constant 2015 US\$), GDP growth (annual %), agriculture, forestry, fishing value added (% of GDP), industry (including construction) value added (% of GDP), unemployment rate (% of total labor force), inflation consumer prices (annual %), access to electricity (% of population), mobile cellular subscriptions, life expectancy at birth (total years), and mean years of schooling. The researchers employed the taxonomic measures of the Hellwig Method to analyze these indicators.

Table 4. *Taxonomic measures of G20 countries*

Countries	The Hellwig Method	
	Score	Rank between G20
Australia	0.217	14
Germany	0.232	13
Canada	0.246	9
United Kingdom	0.237	11
Japan	0.242	10
Korea (Republic of)	0.275	3
United States	0.256	4

Countries	The Hellwig Method	
	Score	Rank between G20
France	0.206	16
Italy	0.256	5
Saudi Arabia	0.255	6
Argentina	0.117	18
Turkey	0.234	12
Russian Federation	0.251	8
China	0.448	1
Mexico	0.207	15
Brazil	0.149	17
South Africa	-0.151	19
Indonesia	0.255	7
Bharat (India)	0.307	2
Average	0.223	
Standard Deviation	0.111591	

Source: Authors' calculation

Table four provides valuable insights into the levels of development and their rankings among G20 countries based on taxonomic measures for the year 2021. The analysis reveals a range of economic development levels among these nations, as assessed by selected indicators. In 2021, the average value of the synthetic measure calculated using Hellwig's method was 0.223. Notably, China recorded the highest value at 0.448, followed by India, the Republic of Korea, the United States, and Italy, which had values of 0.307, 0.275, 0.256, and 0.256, respectively. In contrast, South Africa exhibited the lowest level at -0.151, with Argentina, Brazil, France, and Mexico following closely behind at 0.117, 0.149, 0.206, and 0.207, respectively. The disparity in the synthetic measure values highlights significant differences in economic development among G20 nations, with countries demonstrating higher values showing markedly better performance than those with lower scores. The findings from the taxonomic measure notably diverge from the rankings based on the Social Progress Index (SPI) and the Human Development Index (HDI). This variation can be attributed to the inclusion of macroeconomic indicators in this method, while distributional aspects and social outcomes are not considered. Consequently, China and India rank favorably due to their rapid economic growth, characterized by significant infrastructure development and industrial expansion.

Table 5. Comparison of Development Levels and Ranking by HDI, SPI GII, and the Hellwig Method for the G20 Countries (2021)

Countries	Human Development Index		Gender Inequality Index		Social Progress Index		Hellwig Method	
	Score	Rank between G20	Score	Rank between G20	Score	Rank between G20	Score	Rank between G20
Australia	0.951	1	0.073	4	88.20	3	0.217	14
Germany	0.942	2	0.073	4	88.44	2	0.232	13
Canada	0.936	3	0.069	3	88.48	1	0.246	9
United Kingdom	0.929	4	0.098	6	86.28	6	0.237	11
Japan	0.925	5	0.083	5	88.13	4	0.242	10
Korea (Republic)	0.925	5	0.067	2	86.31	5	0.275	3
United States	0.921	6	0.179	7	85.04	9	0.256	4
France	0.903	7	0.083	5	86.27	7	0.206	16
Italy	0.895	8	0.056	1	85.10	8	0.256	5
Saudi Arabia	0.875	9	0.247	10	63.68	18	0.255	6
Argentina	0.842	10	0.287	12	78.54	10	0.117	18
Turkey	0.838	11	0.272	11	66.47	15	0.234	12
Russian Federation	0.822	12	0.203	9	72.12	11	0.251	8
China	0.768	13	0.192	8	64.92	17	0.448	1
Mexico	0.758	14	0.309	13	71.07	13	0.207	15
Brazil	0.754	15	0.390	14	71.25	12	0.149	17
South Africa	0.713	16	0.405	15	68.82	14	-0.151	19
Indonesia	0.705	17	0.444	16	66.28	16	0.255	7
Bharat (India)	0.633	18	0.490	17	58.80	19	0.307	2

Note: Ranking is done among the G20 countries

Source: UNDP, Social Progress Imperative Database, and authors' calculation

The results derived from the Hellwig method were contrasted with the HDI, GII, and SPI. Table five displays a comparison of development levels and rankings based on the HDI, GII, SPI, and Hellwig's method for the G20 countries in 2021. As shown in table five, Australia, Germany, and Canada ranked first, second, and third in HDI with index values of 0.951, 0.942, and 0.936, respectively. Conversely, India, Indonesia, and South Africa occupied the lowest three positions, reporting index values of 0.633, 0.705, and 0.713, respectively. Following the top three countries are the United Kingdom, Japan, South Korea, the United States, France, Italy, Saudi Arabia, Argentina, Turkey, the Russian Federation, China, Mexico, and Brazil.

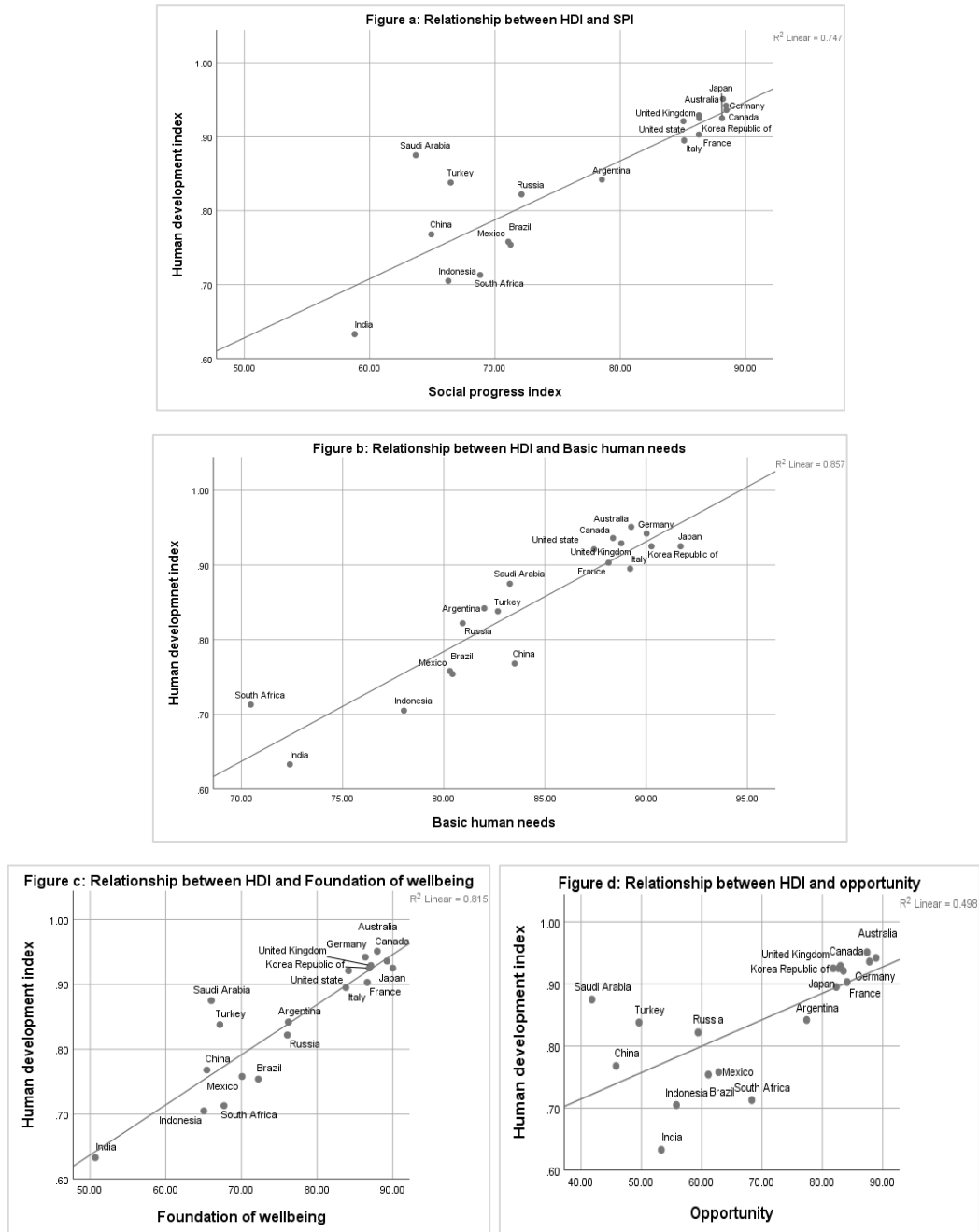
When examining the Gender Inequality Index (GII), it's crucial to highlight that Italy, the Republic of Korea, and Canada occupy the top three positions, with index values of 0.056, 0.067, and 0.069, respectively. Conversely, India, Indonesia, and South Africa are at the bottom, with index values of 0.490, 0.444, and 0.405, respectively. Additionally, following Canada, the next noteworthy countries

include Australia, Germany, Japan, the United Kingdom, the United States, China, the Russian Federation, Saudi Arabia, Turkey, Argentina, Mexico, and Brazil. In terms of the Social Progress Index (SPI), Canada, Germany, and Australia lead the rankings, achieving index values of 88.48, 88.44, and 88.20, respectively. On the other end of the spectrum, India, Saudi Arabia, and China find themselves in the last three positions, with index values of 58.80, 63.68, and 64.92, respectively. After Australia, the rankings continue with Japan, South Korea, the United Kingdom, France, Italy, the United States, Argentina, the Russian Federation, Brazil, Mexico, South Africa, Turkey, and Indonesia. According to the Hellwig method, China, India, and the Republic of Korea are ranked first, second, and third, with index values of 0.448, 0.307, and 0.275, respectively. In contrast, South Africa, Argentina, and Brazil occupy the bottom three positions, with index values of -0.151, 0.117, and 0.149, respectively. Following the Republic of Korea, the subsequent countries in the rankings are the United States, Italy, Saudi Arabia, Indonesia, the Russian Federation, Canada, Japan, the United Kingdom, Turkey, Germany, Australia, Mexico, and France.

The comparison of G20 countries across various indices, such as the Human Development Index (HDI), Social Progress Index (SPI), Gender Inequality Index (GII), and the Hellwig index, reveals significant disparities. These differences stem from the distinct dimensions each index examines. For instance, the HDI evaluates three critical aspects: education, health, and income. In contrast, the SPI emphasizes institutional and social outcomes rather than focusing solely on economic factors, while the Hellwig index concentrates on economic and industrial structure. The notable rankings of China and India in the Hellwig index, when compared to their relatively lower positions in the HDI and SPI, underscore the idea that economic indicators alone may not fully capture social progress and inequality. This finding strongly supports the argument that development is a multidimensional concept, extending beyond mere economic metrics. Therefore, a comprehensive assessment must integrate economic, social, and institutional perspectives (Alimoradi, Griffiths and Alijanzadeh, 2025b).

3.3. Relationship Between HDI and SPI of G20 Countries

In this section, we intend to explore the relationship between HDI and SPI, specifically in terms of three aspects: basic human needs, foundation of well-being, and opportunity.

Figure 1. Relationship Between HDI and Social Progress Index with its Three Components

Source: Authors' Calculation

The relationship between the Social Progress Index (SPI) and the Human Development Index (HDI) is illustrated in Figure A. There exists a significant

positive correlation between these two indices, especially in countries with high levels of human development. However, notable discrepancies in social progress are evident among countries with comparable HDI scores. For instance, Saudi Arabia has a human development score similar to that of Italy, France, the United States, Canada, and Japan, yet it performs significantly worse on the Social Progress Index in comparison to its HDI. In India, the weaker correlation indicates the influence of additional factors impacting both HDI and SPI. Following Saudi Arabia, other countries that also score poorly on the SPI relative to their HDI include Turkey, the Russian Federation, and China. Specifically, while Turkey and Argentina show nearly identical HDI ratings, Turkey ranks lower on the SPI compared to Argentina.

The relationship between the Human Development Index and basic human needs among G20 countries is depicted in Figure B. This figure showcases a positive correlation between HDI and the basic human needs index. However, there are substantial differences in basic human needs across nations with remarkably similar HDI values. For example, South Africa has an HDI comparable to that of Indonesia but ranks lowest in basic human needs. Interestingly, India, with a lower HDI than South Africa, performs better in terms of basic human needs. A similar scenario can be observed among high human development nations; for instance, while Saudi Arabia and Italy have nearly identical HDI scores, Italy surpasses Saudi Arabia in the basic human needs index. Notably, some countries, such as China, India, and Japan, score better in fulfilling basic human needs despite having lower HDI values.

Figure C illustrates the relationship between the Human Development Index (HDI) of G20 nations and their foundations of well-being. There is a positive correlation between the foundation of well-being and HDI. However, despite having similar HDI scores, notable differences exist in the foundations of well-being among these countries. For example, Saudi Arabia holds an HDI comparable to that of Italy and France, yet there is a significant disparity in well-being among them. A similar scenario can be observed between Turkey and Argentina. Furthermore, some countries with lower HDI scores than Saudi Arabia, such as South Africa, Russia, Brazil, Mexico, and Argentina, have outperformed it in terms of their foundations of well-being. Notably, India's foundation of well-being is valued at 53.3, which surpasses those of both China and Saudi Arabia.

The positive correlation between the Human Development Index (HDI) and the Social Progress Index (SPI), basic human needs and foundation of wellbeing,

underscores that advancements in human development are typically linked to enhanced social outcomes. However, the variations noted among countries with similar HDI levels indicate that factors such as institutional quality, governance, and policy priorities play a crucial mediating role. For example, the disparity between countries like Saudi Arabia and various European economies, despite comparable HDI scores, exemplifies how differences in social inclusion, environmental policy and civil liberties can affect overall social progress. Similarly, the disparities between Turkey and Argentina reflect the same scenario.

The relationship between Human Development Index (HDI) and opportunity is illustrated in Figure D. While a correlation exists, it is relatively weak. Some nations exhibit similar HDI scores, yet significant disparities in opportunities remain. For example, Saudi Arabia has an HDI score comparable to that of France and Italy, but there are considerable differences in opportunity between Saudi Arabia and the other two countries. A similar situation can be observed with Turkey and Argentina, as they both attained the same HDI score, but Turkey's performance in terms of opportunity is notably worse than that of Argentina. Interestingly, some nations with lower HDI scores excel in opportunity; for instance, South Africa ranks lower in HDI than Mexico, Brazil, Russia, Turkey, China, and Saudi Arabia, yet it surpasses them in opportunity. Additionally, India, which holds the lowest HDI score, has outperformed China, Turkey, and Saudi Arabia regarding opportunity. This relatively weak connection between HDI and opportunity underscores the fact that economic and educational achievements do not automatically translate into equitable access to opportunities. Structural inequalities, labor market dynamics, and institutional barriers may obstruct this progression.

4. Conclusion and suggestion

The current study presents a comparative evaluation of G20 members by utilizing a range of development metrics, including the Human Development Index (HDI), Social Progress Index, Gender Inequality Index, and Hellwig's measure. The findings highlight significant disparities in the development levels of G20 countries. According to the Human Development Report 2021, Australia boasts the highest HDI among G20 members, with a score of 0.951, while India has an HDI of 0.633. Europe outshines other G20 regions, as several of its countries rank among the top. The HDI assesses three critical dimensions of development: health, education, and income. Australia excels in expected years of schooling, achieving 21.1 years, while

Japan leads in life expectancy at birth with 84.8 years. Germany has the highest mean years of schooling at 14.1 years, and the United States records the highest Gross National Income (GNI) per capita at \$64,765.

During the 1990s, most G20 countries, with the exception of Russia, experienced positive growth rates in the Human Development Index (HDI). However, this growth has decelerated over the past two decades. While India, Russia, Turkey, and Saudi Arabia demonstrated improvement between the first and second decades, their growth rates have declined in the most recent decade. China recorded the highest HDI growth rate from 1990 to 2021 at 1.50 percent, followed by India at 1.22 percent and Turkey at 1.08 percent. In contrast, the United States had the lowest growth rate at 0.18 percent. The Social Progress Index (SPI), which evaluates quality of life and well-being, ranks Canada highest among G20 countries with a score of 88.48, while India scored 58.80. Japan excelled in two SPI dimensions: basic human needs (91.70) and foundations of well-being (90.00), whereas Germany ranked highest in opportunity at 88.9. The SPI serves as a comprehensive tool for macro-level analysis and assists policymakers in prioritizing inclusive and sustainable development. According to Hellwig's method, China achieved the highest synthetic measure in 2021 at 0.448, followed by India, South Korea, the United States, and Italy. South Africa ranked the lowest at -0.151, with Argentina, Brazil, France, and Mexico also positioned at lower levels. These disparities highlight significant differences in development among G20 countries.

A comparative analysis of the Human Development Index (HDI), Gender Inequality Index (GII), Social Progress Index (SPI), and Hellwig's method indicates that Australia ranks highest in HDI, followed by Germany and Canada. India has shown relatively strong growth in HDI from 1990 to 2021. Italy leads in GII, with the Republic of Korea and Canada following closely, while India has made improvements in recent years. Canada achieves the highest score in SPI, followed by Germany and Australia, whereas India is showing gradual progress. In Hellwig's ranking, China, India, and the Republic of Korea occupy the top positions, while South Africa, Argentina, and Brazil are ranked lowest. Moreover, the analysis reveals a positive correlation between HDI and SPI, as well as its components, although the relationship between HDI and the opportunity dimension appears to be relatively weaker. Interestingly, countries with similar HDI levels can exhibit significant disparities in SPI performance. For example, Saudi Arabia has an HDI level comparable to Italy, France, the United States, Canada, and Japan, yet it

performs markedly lower in SPI. This finding suggests that HDI alone may not fully encompass broader social progress. Consequently, the results highlight that comparable HDI levels do not necessarily equate to similar outcomes in social progress. Policymakers should, therefore, avoid relying solely on HDI as a development measure and instead consider incorporating multidimensional frameworks such as SPI for a more comprehensive assessment.

The most significant contribution of this study to the literature lies in its integration of various analytical development approaches, encompassing human development measures, social progress indicators, and composite statistical methods like taxonomic measures. This integration offers a comprehensive comparison of G20 countries. The findings facilitate a more nuanced understanding of development that encompasses multiple dimensions, including opportunity, well-being, and freedom, extending beyond mere income. Based on our empirical findings, we recommend that policymakers across the G20 nations strive for a balanced approach to development, placing greater emphasis on investments in education, health, and social infrastructure. For example, India should enhance its investment in health and education while simultaneously addressing its rapid population growth to facilitate overall development. In contrast, Saudi Arabia should focus on ensuring equal opportunities for both men and women to boost overall advancement. Ultimately, this study highlights the importance of multidimensional assessment frameworks in understanding development patterns and provides evidence-based insights to inform policy formulation within G20 economies.

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Declaration of conflicting interests

The Authors declares that there is no conflict of interest.

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Household consumption and monetary policy transmission in non-Euro EU economies: a VECM Comparison of Romania and Poland

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Abstract. *This paper investigates how monetary policy transmits to household consumption in Romania and Poland. A Vector Error Correction Model is estimated for each country over the period 2005Q1-2025Q3. The results reveal fundamentally different transmission paths. In Romania, consumption responds primarily to the interest rate, with ROBOR explaining 17.9% of its variance. Inflation has no significant direct effect. In Poland, the opposite holds: the price channel dominates, with HICP accounting for over half of consumption variance. These asymmetries persist when food and energy inflation are tested separately. Despite sharing similar positions outside the euro area, the two economies transmit monetary impulses through structurally distinct channels. Theoretically, these findings challenge the assumption of uniform monetary transmission across emerging European economies, highlighting a dichotomy between credit-constrained behavior in Romania and price-sensitive, forward-looking adjustments in Poland. From a policy perspective, the results imply that central banks in non-euro economies must tailor their stabilization strategies to domestic structural vulnerabilities rather than adopting uniform approaches.*

Keywords: household consumption, monetary policy transmission, VECM, Romania, Poland.

JEL Classification: E52, E21, E31, C32.

Introduction

Household consumption is the largest component of domestic demand in most European economies. In the European Union, total household expenditure accounted for 51.8% of GDP in 2024 (Eurostat, 2026). This makes consumption a central driver of economic growth, but also a key channel through which macroeconomic shocks propagate across the economy.

In recent years, the European economic environment has been shaped by a succession of disruptions. Episodes of high inflation, adjustments in interest rates, energy price shocks and heightened geopolitical uncertainty have all contributed to increased volatility in household spending decisions. Although price dynamics have moderated compared to the peak of the inflationary cycle, they remain relevant for household behaviour, as they directly affect purchasing power and expectations. The annual inflation rate in the EU stood at 2.3% in December 2025, down by 0.4 percentage points from the previous year (Eurostat, 2026).

However, aggregate EU indicators can be misleading. Behind the average lies substantial heterogeneity across member states. Romania recorded an annual HICP inflation rate of 8.6% while Cyprus stood at just 0.1%. This gap illustrates the need for country-level analysis. At the same time, it should not be interpreted as a direct indicator of living standards, since welfare depends simultaneously on income levels, real wage dynamics and other structural factors. For cross-country comparisons, this paper relies on the Harmonised Index of Consumer Prices (HICP), constructed on a common methodological basis across EU member states (INS, 2026).

The economic relevance of consumption extends beyond its accounting contribution to GDP. Consumption reflects disposable income, labour market conditions, credit access, risk perception and the distribution of inflationary pressure across goods and services. In periods of uncertainty, households tend to postpone discretionary purchases, substitute between spending categories and increase precautionary saving. This makes consumption a barometer of economic confidence and a transmission mechanism through which shocks affect aggregate activity. The link between consumption and monetary policy is particularly important. Monetary policy shapes the financial conditions that govern household decisions. According to the European Central Bank, the transmission mechanism operates through several interconnected channels: the interest rate channel, the cash-flow channel, the balance sheet and wealth channel, and the expectations channel (Baptista et al., 2025). In the post-2022 European context, the recalibration of policy rates has visibly influenced credit demand, debt servicing costs and intertemporal consumption choices.

The research question of this paper is: *To what extent and through which monetary policy mechanisms is household consumption influenced in Romania and Poland, and why does the intensity of these effects differ between the two non-euro EU economies?*

Four testable hypotheses are formulated. First, inflation has a stronger negative effect on real household consumption in Romania than in Poland. Second, an increase in the interbank interest rate reduces real consumption, with the magnitude of the effect being

larger in Romania. Third, the exchange rate amplifies the impact of monetary policy and inflation on consumption, with the effect being more pronounced where exchange rate variations are more strongly reflected in domestic prices. Fourth, consumption responds differently to food and energy inflation in Romania compared to Poland, reflecting differences in the composition of the consumption basket.

The choice of Romania and Poland is grounded in a combination of historical, structural and international criteria. Both economies share a common background of post-socialist transition and European integration, which provides a comparable foundation. Yet their development trajectories have diverged, allowing for a more nuanced analysis of how the same category of policy instrument can produce different effects on consumption. Crucially, both countries conduct monetary policy at the national level, through the National Bank of Romania and Narodowy Bank Polski, outside the operational framework of the euro area. This allows the analysis of consumption and monetary transmission within an integrated European context, but under non-uniform monetary conditions.

The remainder of the paper is structured as follows. Section 1 reviews relevant theoretical and empirical literature. Section 2 describes the data and the econometric methodology. Section 3 presents and discusses the results. Section 4 concludes.

1. Literature Review

1.1 Consumption in economic theory

In the system of national accounts, the reference indicator for household consumption is Household Final Consumption Expenditure (HFCE), defined as total spending by households on goods and services intended to satisfy individual needs. In parallel, Household Final Monetary Consumption Expenditure (HFMCE) isolates the monetary component of consumption, excluding elements such as own-account production or imputed consumption (Eurostat, Glossary: HFCE, Eurostat, Glossary: HFMCE). The distinction between the two is relevant both for formal mathematical coherence and for empirical analyses that require differentiation between consumption actually transacted on the market and components that do not involve monetary transactions.

From a structural perspective, consumption is analysed through the Classification of Individual Consumption by Purpose (COICOP), which groups household expenditure into functional categories such as food, clothing, housing and recreation (Eurostat, COICOP manual). This classification allows for the differentiated identification of macroeconomic shock impacts on various consumption components. The functional analysis of consumption is essential for understanding the mechanisms through which inflation, income variations or fiscal changes unequally affect different segments of aggregate demand.

In the logic of national accounting, household consumption is a structural element of the expenditure approach to GDP, alongside investment, government spending and net export. It is precisely this positioning that gives consumption a central analytical function. Variations in consumption transmit rapidly into final demand and into the level of

aggregate economic activity, making it a benchmark for integrating macroeconomic performance and the composition of growth, including in cross-country comparisons (Eurostat, GDP and main components). Within the conceptual framework of national accounts, household consumption is recorded as final use pertaining to the institutional sector “households”, as opposed to intermediate consumption, which is associated with the production process. The separation of the two ensures the coherence of aggregate and prevents double counting, clearly establishing what falls within the sphere of final demand and what represents productive inputs (OECD and European Commission, System of National Accounts 2008).

At the same time, consumption aggregates provide a systemic indicator of material living standards, as they capture the use of goods and services oriented towards satisfying individual needs. Institutions underline the utility of consumption in evaluating economic performance beyond the strict perspective of production (Lequiller and Blades, 2014).

1.2. Theoretical models of consumption behaviour

The theoretical understanding of consumption has evolved substantially over time. In the Keynesian framework, consumption depends predominantly on current income through a positive but sub-unitary marginal propensity to consume. Consumption is expressed as $C = a + bY$, where a represents autonomous consumption, independent of income, and b represents the marginal propensity to consume, indicating the proportion in which an income increase is reflected in higher consumption expenditure. This formulation underpins the role of consumption in the multiplier mechanism and in aggregate demand formation (Keynes, 1936).

Statistical evidence at the EU level suggests that, beyond the aggregate role of consumption, its structure changes over time. According to Eurostat, between 2014 and 2024 the share of household expenditure in GDP remained relatively stable at the total level, but distinct variations appeared across categories. Certain services recorded increases while some goods declined, indicating gradual reorientation of the consumption basket and confirming the dynamic character of consumption behaviour.

The modern theoretical framework depart from Keynesian static model by introducing intertemporal optimization. The permanent Income Hypothesis (Friedman, 1957) and the Life-Cycle Hypothesis (Modigliani, 1954) argue that households base consumption decisions on long-run income expectations, seeking to smooth consumption over time. Temporary income shocks are partially absorbed through saving of financial asset adjustments, making consumption less volatile than current income. The fundamental difference from the Keynesian model lies in the fact that consumption is determined not only by current income but by the anticipated trajectory of resources over the long term.

However, the applicability of these frameworks depends critically on the development of financial markets and household access to credit. In Poland, household exposure to variable-rate instruments, particularly mortgage loans, means that policy rate changes transmit relatively quickly to interest payments and disposable income through a cash-flow mechanism (Greszta et al., 2023). In Romania, structural features of financial intermediation may limit the scope for perfect intertemporal adjustment, leaving a larger

share of consumption sensitive to current conditions and uncertainty (Chen et al., 2025). Differences are also observable at the level of household balance sheet space. Data compiled from international sources indicate a higher household debt-to-GDP ratio in Poland than in Romania, at approximately 22-23% versus 15-16% of GDP. This suggests a stronger interaction between credit, interest rate and consumption in the case of Poland, but also a potentially greater vulnerability to interest rate shocks for borrowers exposed to variable rates (Eurostat, 2025a; Eurostat, 2025b). At the same time, recent episodes of high inflation in the EU have disproportionately affected lower-income households, which allocate a larger share of their budget to essential goods. When a large part of the budget is rigid, consumption adjustment becomes forced rather than planned intertemporally (Eurostat, Living conditions statistics at regional level).

1.3. Monetary policy transmission to consumption

Monetary policy influences consumption by modifying the financial conditions faced by households, particularly the level of interest rates, the cost and availability of credit, relevant returns for saving, and through the expectations channel. According to the European Central Bank, the transmission mechanism operates through several interconnected channels that shape household consumption and saving decisions. In Europe, the effects of monetary policy decisions became visible in the post-2022 period, when rate recalibration simultaneously influenced credit demand, debt servicing and choices between present consumption and saving (ECB, Transmission mechanism of monetary policy).

A significant strand of recent literature shifts the analysis from aggregate functions towards the mechanisms through which monetary policy affects consumption via household balance sheets and financial frictions. This approach emphasizes that transmission is not uniform across agents or across economies. Consumption becomes not only the result of income and preferences, but also of the structure of household assets and liabilities, interest rate exposure and differentiated access to financing. Slacalek, Tristani and Violante (2020) show that the effect of monetary policy on consumption can operate through intertemporal substitution, net interest rate exposure, and broader general equilibrium channels such as labour income, collateral and asset prices. This perspective is useful for the Romania-Poland analysis because it suggests that differences in indebtedness, rate type and portfolio structure can alter consumption sensitivity to monetary tightening, even when the direction of the shock is identical. The credit channel literature argues that monetary policy shocks are amplified through household, firm and bank balance sheets. For the household sector, the transmission mechanism manifests prominently through credit demand and financing constraints (Ciccarelli, Maddaloni and Peydró, 2015). This framework is relevant for European economies where bank intermediation plays a major role, because credit restriction directly affects financing-sensitive consumption such as durable goods and housing, and indirectly affects confidence and saving behaviour.

A complementary line of research highlights the distributional dimension of transmission. Aggregate consumption can mask divergent reactions between household group, and income and wealth distribution can modify the effectiveness of the consumption channel (Voinea, Lovin and Cojocaru, 2018). In particular, evidence for Romania suggests that

inequality can influence monetary policy transmission precisely through the consumption channel, since households in different segments of the distribution have different propensities to consume and different degrees of access to financing.

Recent contributions further emphasise that the transmission of monetary policy to consumption does not depend exclusively on the modification of interest rates, but also on the level of uncertainty accompanying monetary tightening episodes. Uncertainty can amplify prudential reactions and induce stronger adjustments in household expenditure (Priya and Sharma, 2025). The interest rate channel interacts with the expectations channel: when households interpret monetary tightening as a signal of a riskier macroeconomic context, the probability of postponing discretionary consumption and increasing saving rises, even if current income does not adjust immediately. For non-euro EU economies, the literature also identifies cross-border spillovers. Euro area monetary policy shocks can produce detectable effects on output, prices and financial conditions in non-euro European economies, with different responses between Western and Central-Eastern Europe (Potjagailo, 2017). These spillovers modify both the cost of financing and inflation expectations, influencing household consumption decisions even in the absence of a common monetary policy. Benecká, Fadıjeva and Feldkircher (2020) show that the magnitude and speed of adjustment differ between economies, supporting the idea that consumption analysis in the EU must account not only for domestic determinants but also for cross-border transmission channels.

1.4. Empirical evidence

Several empirical studies have examined monetary policy transmission in the two economies under analysis, as well as in the broader Central and Eastern European region.

For Romania, Popescu (2012) applies recursive VAR and structural VAR to assess the effects of monetary policy under the inflation targeting regime. The main findings indicate a negative response of consumer prices, GDP and the monetary aggregate M3 to a monetary policy shock. However, the study also finds that the impact of short-term interest rate shocks remains limited in explaining fluctuations in consumer prices, production and the exchange rate. This is consistent with the view that monetary transmission in Romania operates through indirect and institutionally mediated channels rather than direct household responses.

Andries (2008) applies identified VAR methodology to Romanian data from 2000 to 2007 and confirms that monetary transmission operates with significant lags and that the effect of the interest rate on production and prices is limited. More recently, Negrea, Giurgiu and Benea (2024) assess the impact of the National Bank of Romania policy rate on household final consumption expenditure, government consumption, gross capital formation, exports and imports, using Eurostat data from 2003 to 2023. Their analysis provides direct evidence on the relationship between monetary policy and consumption in Romania over a recent period.

For Poland, Greszta et al. (2023) provide a comprehensive assessment of the monetary policy transmission mechanism, explicitly treating the interest rate-exchange rate-credit

triad. Their working paper, published by Narodowy Bank Polski, represents the most recent institutional review of what is known about monetary transmission in Poland.

At the regional level, Égert and MacDonald (2008), in an OECD working paper surveying the monetary transmission mechanism across Central and Eastern Europe, conclude that the interest rate channel remains relatively weak in several CEE countries. They further note that the exchange rate channel cannot be fully separated from the interest rate channel, and that the credit channel is limited because both commercial banks and non-financial corporations can escape domestic monetary conditions by borrowing from foreign parent institutions. The asset price channel is found to be weak due to shallow stock and bond markets and low household financial asset holdings.

Despite this body of evidence, a direct comparison of household consumption responses to monetary policy between Romania and Poland, using a VECM framework with separate specifications for total, food and energy inflation, remains absent from the literature. This paper aims to address that gap by estimating country-specific models and comparing the channels through which monetary impulses reach consumption in each economy.

2. Data and Methodology

2.1. Data sources and variables definitions

The empirical analysis uses quarterly data from Romania and Poland over the period 2005Q1-2025Q3, yielding 83 observations per country. All data are sourced from Eurostat, the National Bank of Romania and publicly available financial databases. Table 1 summarizes the variable, their sources and the transformations applied.

Table 1. *Variable definitions*

Variable	Description	Source	Transformation
ln_consumption	Household final consumption expenditure (HFCE), chain-linked volumes, 2015=100	Eurostat (namq_10_gdp)	Natural logarithm
ln_income	Gross disposable income of households (B6G, S14_S15), deflated by HICP (2015=100)	Eurostat (nasq_10_nf_tr, prc_hicp_midx)	Deflated, then natural logarithm
HICP	Harmonised Index of Consumer Prices, annual rate of change (%)	Eurostat (prc_hicp_manr)	None
ROBOR_3M and WIBOR 3M	3- month interbank offered rate (%)	BNR/ Stooq	None
ln_exchange	Nominal exchange rate, nominal currency per euro	Eurostat (ert_bil_eur_q)	Natural logarithm

Source: author

Household consumption is measured in real terms using chain-linked volumes, which remove the distortion of price changes and capture the actual volume of goods and services consumed. The gross disposable income of households was obtained in nominal terms and deflated using the HICP index to ensure consistency with the real consumption measure. The 3- month interbank rate was selected as the monetary policy proxy because it is the principal reference index for variable-rate consumer and mortgage loans in both countries and thus reflects most directly the cost of credit faced by households. Inflation and the interbank rate are expressed in percentage points and are not logarithmised, as they already

represent rates. The natural logarithm is applied to consumption, income and the exchange rate to allow the interpretation of estimated coefficients as elasticities and to stabilise variance.

Three specifications of the inflation variable are employed. The baseline model uses total HICP inflation. Two alternative models replace it with HICP food and non-alcoholic beverages inflation and HICP electricity, gas and other fuels inflation, respectively. This approach allows for testing whether consumption responds differently to sectoral price pressures, in line with Hypothesis 4.

2.2. Econometric methodology

The econometric framework is based on the Vector Error Correction Model (VECM), which is appropriate when the variables of interest are non-stationary in levels but share long-run equilibrium relationships, that is, when they are cointegrated (Lütkepohl, 2005). The VECM captures both the short-run dynamics and long-run cointegrating relationships among the variables and allows for the identification of channels through which monetary policy shocks transmit to consumption.

The estimation procedure follows a standard sequence of steps. First, the order of integration of each variable is assessed using the Augmented Dickey-Fuller (ADF) test, supplemented by the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test where results are ambiguous. The VECM requires all endogenous variables to be integrated of order one, $I(1)$, meaning they are non-stationary in levels but stationary in first differences.

Second, the optimal lag length for the underlying VAR is determined using information criteria, including the Akaike Information Criterion (AIC), the Hannan-Quinn criterion (HQ) and the Schwarz Bayesian criterion (SC). Third, the Johansen trace and maximum eigenvalue tests are applied to determine the number of cointegrating relationships, that is, the cointegration rank.

Fourth, the VECM is estimated separately for each country. The general form of the model is: $\Delta y_t = \alpha \beta' y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t$, where y_t is the vector of endogenous variables, β represents the cointegrating vector capturing the long-run equilibrium relationship, α is the vector of adjustment coefficients indicating the speed at which each variable corrects towards equilibrium, Γ_i captures the short-run dynamics, and ε_t is the error term.

Fifth, impulse response functions (IRF) are computed to trace the dynamic response of consumption to a one-standard-deviation shock in each of the other variables over a 20-quarter horizon. Sixth, forecast error variance decomposition (FEVD) is used to quantify the proportion of consumption variance attributable to each variable. Finally, Granger causality tests are performed to assess the predictive power of each monetary policy variable for consumption.

Model adequacy is assessed through a Portmanteau test for residual autocorrelation, the Jarque-Bera test for multivariate normality and a multivariate ARCH test for heteroscedasticity. The entire analysis is conducted in R version 4.5.3 (R Core Team, 2026), using

the packages *urca* (Pfaff, 2008) for cointegration testing and VECM estimation, and *vars* for lag selection, impulse response functions and variance decomposition.

2.3. Limitations

Several limitations should be acknowledged. The quarterly frequency imposes aggregation that may obscure higher-frequency dynamics. The gross disposable income variable includes non-profit institutions serving households, alongside the household sector, due to data availability constraints at quarterly frequency. The sample of 83 observations, while sufficient for VECM estimation, limits the number of endogenous variables and lags that can be included without excessive loss of degrees of freedom. Finally, the analysis does not include credit volume as an endogenous variable, which would have been relevant for Hypothesis 2, but was excluded to preserve model parsimony given the sample size. Differences in intermediation structure and credit composition are instead discussed qualitatively when interpreting the results.

3. Results and Discussion

3.1. Unit root tests

The order of integration of each variable was assessed using the Augmented Dickey-Fuller test. Table 2 reports the test statistics and conclusions for both countries, in levels and in first differences.

Table 2. *ADF test results*

Variable	RO Level	RO Conclusion	RO Diff.	PL Level	PL Conclusion	PL Diff.
ln_consumption	-0.921	I(1)	-6.038***	-1.208	I(1)	-7.947***
ln_income	-0.755	I(1)	-8.184**	-0.361	I(1)	-7.115***
HICP	-2.576	I(1)	-4.039***	-3.032*	Borderline	-3.911***
ROBOR_3M/ WIBOR_3M	-1.961	I(1)	-5.762***	-2.486	I(1)	-4.378***
ln_exchange	-1.326	I(1)	-8359***	-2.936*	Borderline	-7.406***

Note: Critical value at 5%: -2.890. *** indicates stationarity in first differences.

Source: author

For Romania, all five variables are clearly non-stationary in levels and stationary in first differences, confirming they are I(1). For Poland, HICP and the exchange rate are borderline, with test statistics marginally exceeding the 5% critical value (-3.032 and -2.936 versus -2.890). To resolve this ambiguity, the KPSS test was applied. The KPSS test has the reverse null hypothesis: it tests whether the series is stationary. Results reject stationarity for both HICP ($p=0.040$) and the exchange rate ($p=0.010$), supporting their treatment as I(1). This is consistent with standard practice when ADF and KPSS yield conflicting results at the boundary (Lütkepohl, 2005).

3.2. Lag selection and cointegration

The optimal lag length was determined using information criteria applied to a preliminary VAR in levels. For Romania, the Hannan-Quinn and Schwarz criteria both indicated one lag, while AIC suggested eight. A lag of two was selected as a compromise, providing

sufficient short-run dynamics without excessive parameter consumption given the sample size. For Poland, three of the four criteria indicated two lags. Both models therefore use two lags.

The Johansen trace and maximum eigenvalue tests were applied to determine the cointegration rank. Table 3 reports the results.

Table 3. *Johansen cointegration test (trace statistic)*

Hypothesis	RO Test stat.	5% c.v.	PL Test stat.	5% c.v.
$r = 0$	92.02**	76.07	126.67**	76.07
$r \leq 1$	57.17**	53.12	72.49**	53.12
$r \leq 2$	33.50	34.91	46.80**	34.91

Note: ** indicates rejection of the null hypothesis at the 5% level.

Source: author

For Romania, the trace test rejects $r = 0$ and $r \leq 1$, but does not reject $r \leq 2$. The maximum eigenvalue test rejects only $r = 0$. For Poland, the trace test rejects up to $r \leq 2$, but the eigenvalue test rejects only $r = 0$.

When the trace and maximum eigenvalue tests yield conflicting results, it is standard econometric practice to consider both small sample properties and the economic interpretability of the vectors. The trace test is known to occasionally over reject the null hypothesis in finite samples or in the presence of structural volatility (such as the 2008 financial crisis). Therefore, we follow the more conservative maximum eigenvalue test and set the cointegration rank to one ($r = 0$) for both countries. This methodological choice is heavily supported by economic theory: it allows us to isolate a single, meaningful long-run equilibrium relationship representing the macroeconomic consumption function, thereby ensuring a coherent and direct comparison between the Romanian and Polish models.

3.3. VECM estimation results

Table 4 presents the cointegration vectors (long-run equilibrium relationships) for both countries.

Table 4. *Cointegration vector (β), normalized on consumption*

Variable	Romania	Poland
ln_income	0.626	2.331
HICP	-0.022	-0.319
ROBOR_3M/WIBOR_3M	0.041	0.320
ln_exchange	1.145	0.952

Source: author

The long-run income elasticity of consumption is substantially higher in Poland (2.33) than in Romania (0.63). The inflation coefficient is much larger in Poland (-0.319 versus -0.022), suggesting that price changes matter more for long-run consumption equilibrium in Poland. The interest rate and exchange rate also enter the cointegrating relationship with larger coefficients in Poland.

Table 5 reports the key short-run coefficients from the consumption equation of each VECM.

Table 5. *Short-run VECM coefficients (consumption equation)*

Variable	Romania Coeff.	Romania p-value	Poland Coeff.	Poland p-value
ECT	+0.134	0.001 ***	-0.006	0.000 ***
HICP (lag 1)	+0.003	0.268	-0.005	0.065 *
ROBOR/WIBOR (lag 1)	-0.012	0.001 **	+0.009	0.064 *
ln_exchange	+0.109	0.512	-0.008	0.908
ln_income	-0.011	0.857	+0.009	0.939

Note: *** $p < 0.001$, ** $p < 0.05$, * $p < 0.1$

Source: author

The error correction term (ECT) differs markedly between the two countries. In Poland, ECT is negative and highly significant (-0.006), indicating that consumption gradually corrects towards its long-run equilibrium. Approximately 0.6% of any disequilibrium is corrected each quarter. This is consistent with forward-looking household behaviour.

In Romania, the ECT is positive (+0.134) and significant. This means that consumption does not self-correct when it deviates from equilibrium. Instead, the adjustment comes through other variables in the system. The ROBOR equation shows an ECT of 5.34, indicating that it is the interest rate that reacts most strongly to disequilibrium. This is consistent with the view that in Romania, correction operates through institutional intervention by the central bank rather than through voluntary household adjustment.

The most important short-run coefficient for Romania is ROBOR, which is negative and significant (-0.012, $p = 0.001$). An increase in the interbank rate reduces consumption in the following quarter. This confirms Hypothesis 2 for Romania. In Poland, neither HICP nor WIBOR reaches conventional significance at the 5% level, though both are marginally significant at 10%.

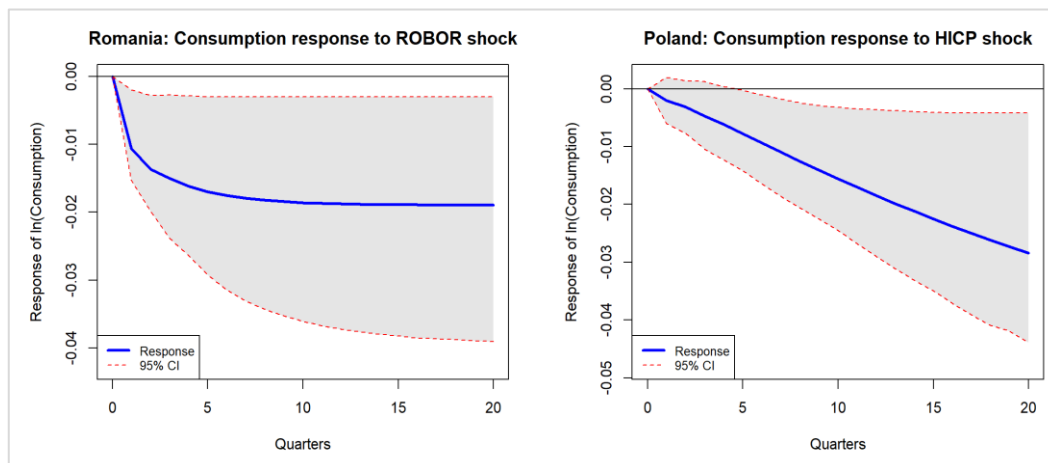
3.4. Impulse response functions

Impulse response functions trace the dynamic reaction of consumption to a one-standard-deviation shock in each variable over 20 quarters. The key findings are as follows. For Romania, a shock to ROBOR produces a significant and persistent negative response in consumption. The effect builds over approximately 6 quarters and stabilises at around -0.02, with the 95% confidence interval remaining entirely below zero. Shocks to HICP, the exchange rate and income do not produce significant responses, as confidence intervals include zero throughout.

For Poland, a shock to HICP produces a strong and persistent negative response. Consumption declines continuously, reaching approximately -0.03 after 20 quarters. The confidence interval moves entirely below zero after approximately 5 quarters. Shocks to WIBOR, the exchange rate and income do not produce significant consumption responses.

These results point to fundamentally different transmission channels. In Romania, monetary policy reaches consumption through the interest rate. In Poland, it operates through prices.

Figure 1. Impulse response of consumption to ROBOR shock (Romania, left) and to a HICP shock (Poland, right)



Source: authors' estimation using R 4.5.3

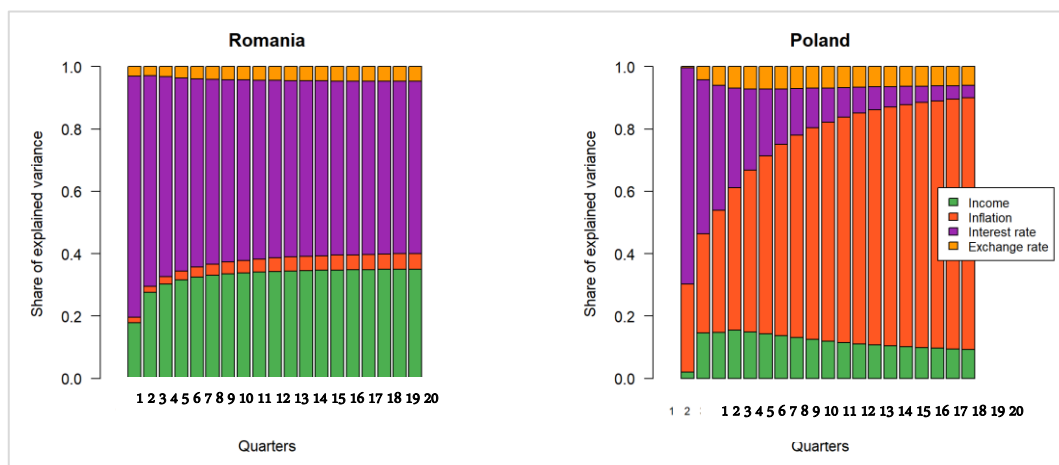
Figure 1 illustrates the contrasting transmission paths in the two economies. In Romania (left panel), consumption responds immediately and negatively to a ROBOR shock. The decline is steep in the first 5 quarters, reaching approximately -0.015 and continues to deepen gradually before stabilizing at around -0.019 after 10 quarters. The entire response path remains below zero. The upper bound of the 95% confidence interval runs very close to the zero line but stays marginally below it for most of the horizon, confirming that the effect is statistically significant. The lower bound extends to approximately -0.04, indicating considerable uncertainty about the exact magnitude but not about the direction of the effect.

In Poland (right panel), consumption responds to a HICP shock with a gradual but persistent decline. Unlike the Romanian case, the initial response is close to zero for the first 2-3 quarters, after which the negative effect builds progressively. By quarter 10, consumption has declined by approximately -0.01, and by quarter 20 the cumulative response reaches approximately -0.028. The upper confidence bound crosses below zero after approximately 5 quarters, from which point the effect becomes statistically significant. The widening confidence interval at longer horizons reflects increasing estimation uncertainty, which is typical for impulse response analysis.

3.5. Forecast error variance decomposition

The forecast error variance decomposition quantifies the proportion of consumption variance attributable to each variable over a 20-quarter horizon.

Figure 2. *Forecast error variance decomposition of consumption: normalised contribution of explanatory variables, 20-quarter horizon*



Source: authors' estimation using R 4.5.3

Figure 2 presents the normalised variance decomposition, showing only the contribution of explanatory variables to consumption variance. The visual contrast between the two countries is striking. In Romania (left panel), the interest rate (purple) is the dominant explanatory factor throughout the entire horizon, accounting for roughly 55% of the explained variance from the early quarters onward. Income (green) is the second most important contributor, growing from approximately 18% in the initial quarters to about 35% at the 20-quarter horizon. Inflation (red) and the exchange rate (orange) remain marginal throughout, barely visible in the chart.

In Poland (right panel), the composition is fundamentally different. In the first few quarters, the interest rate (purple) accounts for most of the explained variance. However, inflation (red) grows rapidly and progressively dominates the chart. By quarter 10, inflation already accounts for roughly half of the explained variance, and by quarter 20 it represents approximately 80%. The interest rate contribution shrinks correspondingly, becoming a narrow band. This progressive takeover by the inflation component visually captures the core finding of this paper: in Poland, price dynamics are the primary driver of consumption fluctuations over the medium term.

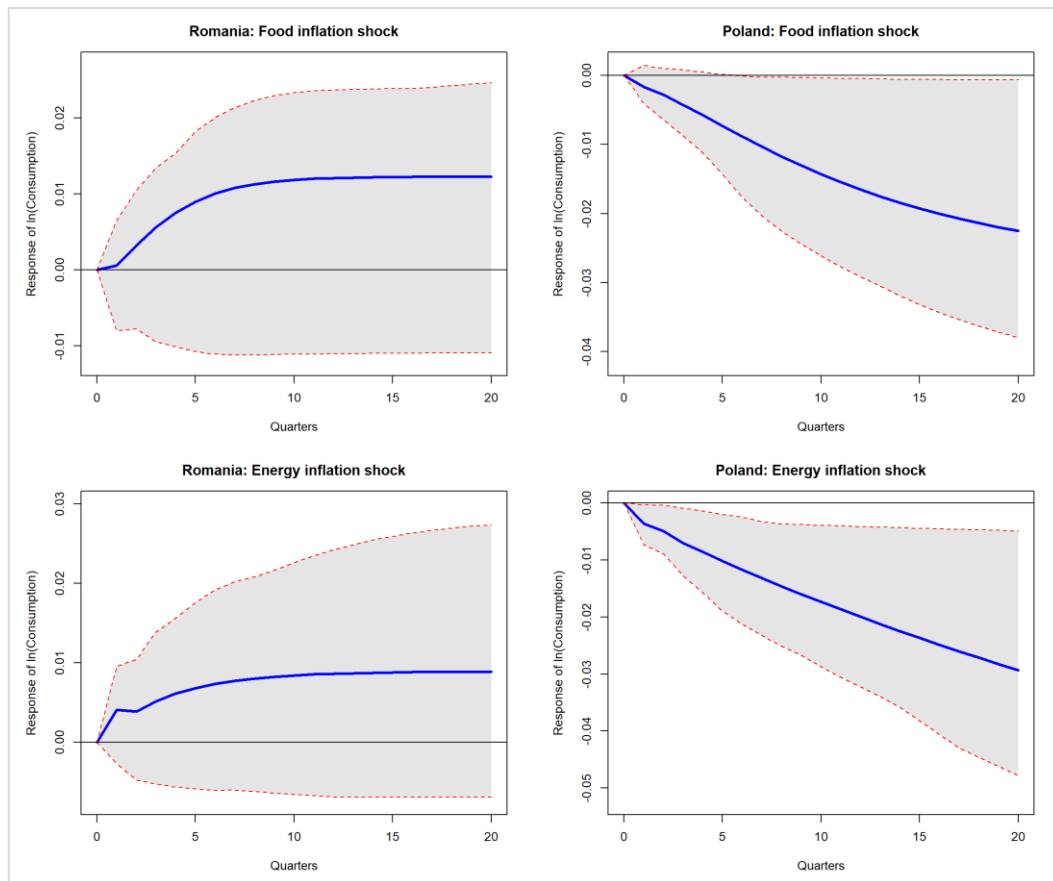
3.6. Alternative specifications: food and energy inflation

To test Hypothesis 4, the baseline model was re-estimated replacing total HICP with food inflation and energy inflation separately.

In Romania (left panels), consumption responds positively to both food and energy inflation shocks, reaching approximately +0.012 and +0.009 respectively. However, in both cases the confidence bands are wide and clearly include zero throughout the entire horizon. The grey shaded area extends substantially above and below the response line, indicating that these positive point estimates are not statistically distinguishable from zero.

The result is consistent across both inflation types: Romanian consumption does not respond significantly to sectoral price shocks.

Figure 3. Impulse response of consumption to food inflation (upper panels) and energy inflation (lower panels), Romania (left) and Poland (right), 95% bootstrap confidence interval



Source: authors' estimation using R 4.5.3

In Poland (right panels), the pattern is reversed. A food inflation shock produces a gradual negative response that reaches approximately -0.022 by quarter 20. The upper confidence bound hovers near zero and crosses below it after approximately 8 quarters, confirming statistical significance at longer horizons. The energy inflation response is stronger and more immediate. Consumption begins declining from the first quarter and reaches approximately -0.029 by quarter 20. The upper confidence bound drops below zero earlier, around quarter 3-4, indicating that the energy inflation effect is both larger in magnitude and significant earlier in the horizon than the food inflation effect. This is consistent with the sharp energy price increases experienced in Poland during 2022-2023 following the partial liberalization of the energy market.

3.7. Diagnostic tests

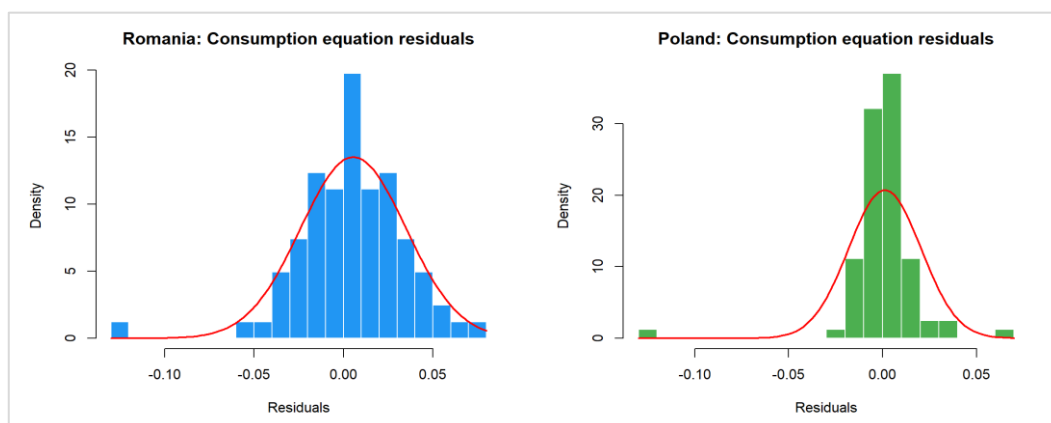
Table 8. *Diagnostic tests*

Test	H_0	Romania p-value	Poland p-value	Conclusion
Portmanteau	No autocorrelation	0.059	0.349	Pass
Jarque-Bera	Normality	<0.001	<0.001	Fail
ARCH	No heteroscedasticity	0.371	0.371	Pass

Note: The Portmanteau and ARCH tests use a threshold of $p > 0.05$ to confirm the absence of misspecification. The Jarque-Bera test uses $p > 0.05$ to confirm multivariate normality.

Both models pass the autocorrelation and heteroscedasticity tests. The Jarque-Bera test rejects multivariate normality for both countries. However, inspection of the residual distributions of the consumption equation reveals approximately normal shapes with excess kurtosis attributable to extreme observations during the 2008-2009 financial crisis and the 2020 COVID-19 pandemic. VECM estimators remain asymptotically consistent under non-normality. (Lütkepohl, 2005).

Figure 4. *Distribution of consumption equation residuals with theoretical normal density (red curve), Romania (left) and Poland (right)*



Source: authors' estimation using R 4.5.3

Figure 4 displays the distribution of the consumption equation residuals for both countries, overlaid with the theoretical normal density curve in red. In Romania (left panel), the histogram shows an approximately symmetric distribution centred around what the normal density would predict, indicating excess kurtosis. A single isolated observation is visible near -0.12, separated from the main body of the distribution. This outlier almost certainly corresponds to the sharp consumption contraction in 2020Q2 during the COVID-19 lockdowns.

In Poland (right panel), the distribution shows a similar pattern but with more pronounced leptokurtosis. The central bars are considerably taller than the normal curve, and the tails contain a few scattered observations, including one near -0.12. The overall shape remains approximately normal despite these features. In both countries, the deviations from normality are concentrated in the tails and the peak, not in the overall shape, which supports

the conclusion that the Jarque-Bera test rejection is driven by a small number of extreme crisis-period observations rather than by fundamental misspecification of the model.

3.8. Granger causality

Bivariate Granger causality tests were conducted to assess whether each monetary policy variable has predictive power for consumption. In Romania, only ROBOR significantly Granger-causes consumption ($p=0.048$). In Poland, no single variable reaches significantly at the 5% level in a bivariate setting, though income is marginally significant ($p=0.069$). In the multivariate framework, all monetary variables Granger-cause the system in both countries, indicating that their predictive power operates through the interaction of variables rather than in isolation.

3.9. Discussion

The central finding of this paper is that Romania and Poland transmit monetary policy to household consumption through fundamentally different channels. In Romania, the dominant mechanism is the interest rate channel. An increase in ROBOR raises the cost of variable rate loans, directly reducing the disposable income of indebted households and compressing consumption. Inflation, by contrast, does not directly affect consumption. Its effects operate indirectly: rising prices trigger a policy response from the National Bank of Romania, which raises ROBOR, and it is the interest rate increase that ultimately reduces consumption. This indirect chain explains why HICP has no significant effect in the impulse response functions, while ROBOR does.

In Poland, the price channel dominates. Households appear to adjust consumption directly in response to price changes, reducing spending when inflation rises. The interest rate plays a secondary role. This difference may reflect structural characteristics of the two economies. Romanian households are more exposed to variable-rate credit indexed to ROBOR, making them particularly sensitive to interest rate movements. Polish households, while also exposed to variable-rate instruments, may have a stronger propensity to adjust consumption in response to perceived erosion of purchasing power.

The positive ECT for Romania (+0.134) deserves specific and nuanced interpretation, as it departs from standard self-correcting equilibrium models. First, from a theoretical perspective, this indicates that consumption does not self-correct when it deviates from its long-run path. Following the rule of thumb consumers framework (Campbell and Mankiw, 1989), Romanian households appear to face tighter liquidity constraints and hold fewer precautionary savings compared to their Polish counterparts, limiting their capacity for forward-looking intertemporal smoothing. Consequently, when out of equilibrium, the correction is outsourced to the institutional framework: the National Bank of Romania intervenes via the interest rate (ROBOR), which exhibits a missive corrective response (ECT of 5.34).

However, while this institutional explanation is highly plausible, the unusual positive sign requires acknowledging alternative econometric interpretations. A positive ECT could also reflect temporary model misspecification due to omitted variables, such as the exclusion of credit volume, which is crucial in a bank-centric economy. Furthermore, the presence of

major unmodelled structural breaks (e.g., the 2008-2009 financial crisis and the 2020 COVID-19 pandemic) might temporarily distort the adjustment parameters, pushing consumption on a divergent short-term path before institutional mechanisms force a macroeconomic correction.

The results are broadly consistent with existing literature. Popescu (2012) found limited direct effects of interest rate shocks on consumer prices and output in Romania, supporting the view that transmission operates through indirect channels. Égert and MacDonald (2008) concluded that the interest rate channel cannot be separated from the exchange rate channel. The present analysis adds to this evidence by showing that, at the level of household consumption specifically, the interest rate channel is not weak in Romania, it is in fact the dominant channel, but it operates through credit rather than through direct substitution effects.

4. Conclusions

This paper investigates the transmission of monetary policy to household consumption in Romania and Poland over the period 2005Q1-2025Q3. A Vector Error Correction Model was estimated separately for each country, using five endogenous variables: real household consumption, real gross disposable income, HICP inflation, the 3-month interbank rate and the exchange rate. Alternative specifications with food and energy inflation were also estimated.

The central finding is that the two economies transmit monetary policy to consumption through fundamentally different channels. In Romania, consumption responds primarily to the interest rate. ROBOR is the only variable that significantly affects consumption in the short run, and it accounts for 17.9% of consumption variance over a 5-year period. Inflation has no significant direct effect. In Poland, the opposite holds. Inflation is the dominant channel, accounting for over 50% of consumption variance, while the interest rate plays a marginal role.

Regarding the four hypotheses, the results are as follows.

Hypothesis 1, which posited that inflation has a stronger negative effect on consumption in Romania than in Poland, is not confirmed. The effect is in fact stronger in Poland. In Romania, inflation does not significantly affect consumption directly. Its impact operates indirectly, through the central bank's interest rate response.

Hypothesis 2, which posited that an interest rate increase reduces consumption with a larger effect in Romania, is confirmed. ROBOR has a significant negative coefficient in the consumption equation for Romania, while WIBOR is not significant for Poland. The impulse response analysis shows a persistent and significant negative reaction of Romanian consumption to an interest rate shock, with no comparable effect in Poland.

Hypothesis 3, which concerned the amplifying role of the exchange rate, is not confirmed. The exchange rate does not produce a significant direct effect on consumption in either country in the short run. However, the cointegrating relationship suggests that the exchange

rate plays a role in long-run equilibrium, likely operating indirectly through inflation and interest rate.

Hypothesis 4, which posited that consumption responds differently to food and energy inflation across the two countries, is confirmed. Romanian consumption does not respond significantly to any type of sectorial inflation. Polish consumption responds negatively and significantly to both food and energy inflation, with the energy effect being the strongest.

The paper makes several contributions. It provides a direct comparative analysis of monetary policy transmission to household consumption between Romania and Poland, which was previously absent from the literature. It identifies the interest rate channel as the dominant transmission mechanism in Romania and the price channel as the dominant mechanism in Poland. It also demonstrates that these asymmetries persist across different inflation categories. The findings carry implications for monetary policy design. In Romania, the strong sensitivity of consumption to ROBOR suggests that interest rate decisions have a direct and powerful impact on household welfare through credit costs. Policymakers should account for this when calibrating the pace and magnitude of rate adjustments. In Poland, the dominance of the price channel implies that maintaining price stability has a more immediate effect on consumption than interest rate management.

Future research could extend this analysis by incorporating credit volumes and household debt structure as endogenous variable, using monthly data to capture higher-frequency dynamics, or applying structural VAR identification strategies to separate supply-side from demand-side shocks. A broader comparison across multiple non-euro EU economies could further test whether the interest rate versus price channel distinction generalises beyond Romania and Poland.

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Behavioral biases in public digital investment decisions: a comparative analysis of convergence patterns in the European Union

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Abstract. *This paper explores cross-country patterns in public investment in information technologies across EU Member States and asks whether these patterns are consistent with behavioral and institutional explanations of digital divergence. Drawing on Prospect Theory and bounded rationality, the study employs descriptive and comparative statistical analysis of public data from Eurostat, the Digital Economy and Society Index (DESI), the Worldwide Governance Indicators, and Eurobarometer (2014–2024). Behavioral concepts are operationalized through a small set of explicitly defined proxies, most notably the volatility of ICT investment as a signature of loss aversion and the distance between strategic targets and historical implementation rates as a signature of optimism bias. The analysis reveals systematic asymmetries between a digital frontier group and catching-up economies in IT investment volatility, digital adoption, and institutional quality. These patterns do not identify causal mechanisms, but they suggest that behavioral and governance gaps reinforce digital divergence, challenging the equalizing ambitions of the EU's post-2022 industrial policy reorientation toward strategic autonomy.*

Keywords: behavioral economics, digital investment, EU convergence, institutional quality, strategic autonomy.

JEL Classification: D91, H54, O38, O43, F15.

Introduction

The European Union's convergence project faces a paradox as it enters the second half of the 2020s. The Treaties require member states to pursue economic, social, and territorial cohesion (European Commission, 2024a). However, scientific evidence since 2014 illustrates what Darvas (2023) calls fractured convergence: nominal income disparities are narrowing, while structural, technological, and institutional disparities are deepening. This "Dual Transition", that is, the simultaneous green and digital transformation envisaged in the Digital Decade Policy Program (Decision (EU) 2022/2481), was conceived as the growth engine for the next cycle (European Commission, 2022). However, a growing body of evidence suggests that this may not eliminate the historical divide between the center and the periphery of European capitalism (Aghion, Antonin, and Bunel, 2019; Van Ark, 2021).

Strategic autonomy exacerbates the problem. The term is used here in a concrete, post-2022 sense: since the Versailles Declaration of March 2022, EU industrial policy has shifted from market completion toward publicly supported capacity building in areas such as semiconductors, artificial intelligence, cloud computing, and quantum computing (Draghi, 2024). Most of these capabilities are concentrated in a small group of "core" member states. Meanwhile, the economies of Central and Eastern Europe that are trying to close the gap risk becoming digital consumers rather than digital producers. A policy intended to protect the Union from external shocks may end up exacerbating its internal divisions. The connection between this macro-political shift and the behavioral argument of the paper is direct: strategic prioritization under deep uncertainty concentrates the limited attention of decision-makers on a handful of salient technologies, and this is precisely the condition under which bounded rationality and salience-driven investment choices are most likely to distort public portfolios (Gabaix, 2014).

The argument draws on three areas of the literature that are typically addressed separately. The first is the macroeconomics of ICT investment (Brynjolfsson and Hitt, 2003; Jorgenson, Ho, and Stiroh, 2008), which establishes when digital spending translates into productivity. The second is behavioral economics (Kahneman and Tversky, 1979; Thaler and Johnson, 1990; Barberis, 2013), which explains why decisions under uncertainty depart from the rational benchmark. The third is new institutional economics (North, 1990; Acemoglu and Robinson, 2012), which explains why national responses differ in the face of seemingly similar shocks. Combining the three perspectives is necessary because the digital divide in the EU cannot be explained solely by income differences. Bulgaria, for example, has an ICT sector that accounts for approximately 9.6% of GDP (Eurostat, 2024a), yet its digital performance in the public sector remains among the weakest in the EU.

A clarification of terms is needed at the outset. Throughout the paper, *behavioral proxies* are observable, aggregate indicators used as indirect signatures of cognitive biases that cannot be measured directly at the level of government decision-makers. The volatility of public ICT investment, for instance, is read as a signature consistent with loss aversion and reactive budgeting, while the distance between official digital targets and historically achieved implementation rates is read as a signature consistent with optimism bias. This use of aggregate signatures follows the direction suggested by Camerer (2019), who notes

the scarcity of behavioral evidence in macro-political contexts. Such proxies are indicative rather than conclusive; the methodology section specifies, for each of them, the variable used, its source, the behavioral concept it represents, and the main alternative explanations that must be weighed against the behavioral reading.

The paper addresses three questions, ordered from description to explanation to policy. The first is descriptive: do public IT investment patterns in the digital frontier economies—Sweden, Denmark, Finland, and the Netherlands—differ systematically from those in the catching-up economies—Romania, Bulgaria, Poland, and Croatia—in terms of both level and volatility? The second is explanatory: to what extent are the observed differences consistent with an interaction between behavioral biases—loss aversion, overconfidence, status quo bias, herd behavior—and institutional quality, once alternative explanations are taken into account? The third is normative: what do the observed patterns imply for the Digital Decade’s cohesion objective and for the EU’s broader pursuit of strategic autonomy, and what would a behaviorally informed policy response look like?

A comparative dataset for eight Member States is considered, covering the period 2014–2024 and incorporating Eurostat series on ICT and digital literacy, DESI scores reflecting pre- and post-2022 methodologies, the Worldwide Governance Indicators, and Eurobarometer waves on digital perceptions at the national level. At the public policy level, it proposes a series of behavioral recommendations for catching-up member states, which go beyond the usual advice to “spend more / spend better.”

Literature review

The macroeconomic claim that ICT investments boost productivity has been validated by growth accounting studies conducted since 2000. Brynjolfsson and Hitt (2003) showed that computerized capital is significantly more productive over five- to seven-year periods, as investments in organizational change, training, and process redesign take time to yield results. Jorgenson, Ho, and Stiroh (2008) extended this finding to a multinational context, demonstrating that ICT-using sectors accounted for the bulk of productivity growth in the United States after 1995, while Europe’s deficit in ICT capital accumulation accounted for a significant portion of the transatlantic productivity gap.

Two more recent studies clarify the public policy implications. Van Ark (2021) documents a slowdown in the returns on digital investments in many advanced economies after 2010, attributing it to the failure of complementary investments in intangible assets to keep pace with the deployment of hardware infrastructure. Brynjolfsson, Rock, and Syverson (2019) formalize this phenomenon as the J-curve of productivity: general-purpose technologies reduce measured productivity during the deployment phase, before boosting it during the benefits-reaping phase. The implication for catching-up EU economies is discouraging: a country that enters the J-curve late, with weak complementary assets, may bear the costs of digital transformation without ever reaching the benefit-reaping phase. Acemoglu and Restrepo (2021) add a distributional nuance: when automation outpaces the creation of new labor-intensive tasks, the aggregate productivity dividend is captured by capital owners, not diffused more widely.

Taken together, these contributions argue that, when it comes to public investment in IT, what matters is not so much the level of spending as its consistency over time, its complementarity with intangible capital, and its integration into capable and efficient institutions. The implication is somewhat more severe than it initially appears: the simple story of convergence—that poorer countries should invest more in ICT because returns are higher there—no longer holds once institutional or behavioral frictions become constraining.

Behavioral economics, in its modern form, emerged with the publication of “Prospect Theory” (Kahneman and Tversky, 1979), which identified three deviations from expected utility theory: reference-dependent valuation, loss aversion—with losses weighing, on average, about twice as much as equivalent gains—and probability weighting. Each of these components has a direct counterpart in public budgeting. Reference dependence implies that ministries evaluate proposals against inherited baselines rather than against absolute returns. Loss aversion implies that cutting a visible ongoing program is politically far more painful than forgoing a larger future benefit, which favors procyclical cuts to “invisible” investment lines such as software, maintenance, and training. Probability weighting implies that rare but salient failures—a data breach, a collapsed IT project—are overweighted relative to the diffuse, slow-moving benefits of digitalization. Subsequent work extended the framework to dynamic contexts: Thaler and Johnson (1990) showed that past outcomes shape the willingness to accept new risks through “endowment” and “break-even” effects, producing a path dependence in risky choices that closely resembles the cyclical patterns observable in public budgeting.

The most important reference for the purposes of this paper remains Barberis (2013). He argues that the empirical performance of Prospect Theory is strongest precisely in domains characterized by rare, high-stakes decisions made under conditions of real uncertainty—a description that fits almost perfectly with sovereign decisions regarding multi-year digital strategies. Gabaix (2014), in turn, introduces a sparse-max form of bounded rationality: agents allocate their limited attention to only a few features of the decision-making environment, rationally ignoring the rest. Applied to the public ICT sector, the sparse-max model predicts that ministries will focus on visible and easily communicable indicators—broadband coverage, e-government portals—while underinvesting in less spectacular but critical areas for productivity. The prediction maps onto an observable asymmetry in the EU context: connectivity targets, which are easy to measure and communicate, tend to be met or overshot, while interoperability frameworks and the digital skills of civil servants—less visible but arguably more binding constraints—remain chronically underfunded (European Commission, 2023a).

Camerer (2003; 2019) extends the perspective of behavioral economics to strategic and social contexts, while Fehr and Schmidt (1999) show that preferences for fairness and aversion to inequality can override purely material incentives in contexts involving public goods or investments—a finding that becomes relevant whenever the allocation of EU funds is perceived as inequitable across regions. The literature, however, remains predominantly microeconomic, and its application to public sector budget decision-makers requires inferring biases from aggregate behavioral signatures rather than from controlled experiments.

The third strand stems from institutional economics. North (1990) argues that institutions determine transaction costs and, consequently, the feasibility of long-term investments. Acemoglu and Robinson (2012) operationalize this idea in a comparative framework, arguing that inclusive political and economic institutions support technological adoption, while more restrictive institutions hinder it. Aghion, Antonin, and Bunel (2019) explicitly link the institutional argument to the digital transition, showing that creative destruction in ICT-intensive sectors requires both competitive product markets and a state capable of managing them in the long term. A complementary perspective comes from studies on the “China shock” (Autor, Dorn, and Hanson, 2020), which document that, even where aggregate adjustment is effective, persistent regional losers can emerge when local labor markets and institutions fail to reallocate workers and capital. By analogy, the European Union’s digital “shock”—the simultaneous implementation of the Recovery and Resilience Facility, NextGenerationEU, and the Digital Decade—risks producing digital winners and losers both within and between Member States, without automatic correction mechanisms.

These three strands are combined here into a single analytical framework, which can be stated as a narrative causal chain. ICT investment generates productivity only when it is sustained over time and complemented by intangible assets (first strand). Whether it is sustained depends on decisions taken under uncertainty by boundedly rational agents, whose reference dependence, loss aversion, and limited attention systematically tilt allocations toward salient, short-horizon projects (second strand). Whether those tilted allocations translate into actual investment outcomes depends on the institutional environment, which can either filter biases out—through multi-annual budgeting, independent evaluation, and professional bureaucracies—or amplify them, when such procedural safeguards are absent or weak (third strand). The feedback also runs backwards: volatile, bias-driven investment erodes exactly the administrative and human capabilities that would otherwise discipline future decisions. The empirical sections that follow do not test this chain formally; they ask whether the cross-country patterns visible in public data are consistent with it.

Methodology

This paper employs a descriptive and comparative statistical methodology applied to a sample of eight European Union member states and a panel of eleven annual observations for each country. The analysis aims to identify comparative patterns regarding public investment, the pace of policy adoption, and the relationship between stated strategies and what is actually implemented on the ground. The indicators used are interpreted as behavioral proxies in the sense defined in the introduction: they are read as aggregate signatures consistent with specific biases, not as direct measurements of them.

The research design is that of a comparative case study, an approach that allows for the combination of quantitative indicators with an interpretation of the institutional context specific to each country. This choice is grounded in the tradition of comparative political economy, in which variations among institutional models are analyzed in relation to distinct national configurations and divergent development trajectories (Hall and Soskice, 2001).

The selection logic is a hybrid one. Within each group, cases follow a most-similar-systems logic: they share the initial conditions that matter for the analysis. Across the two groups, the comparison follows a most-different-systems logic, contrasting configurations that differ sharply in institutional quality and digital performance while operating under the same EU policy framework—the same funding instruments, targets, and reporting obligations.

The first group—referred to throughout as the digital frontier group—includes Sweden, Denmark, Finland, and the Netherlands: countries characterized by high institutional quality, consensus-based policymaking, and a well-established tradition of public sector digitization. The Netherlands is not a Nordic country in the geographic sense, and its welfare state architecture differs from the Scandinavian model; it is included because, on every dimension relevant to this analysis—governance effectiveness scores, DESI performance, and the maturity of public sector digitization—it clusters consistently with the three Nordic members rather than with any other EU grouping (European Commission, 2022; Kaufmann and Kraay, 2024). Precisely to avoid the geographic connotation, the group is labelled “digital frontier” rather than “Nordic.” Significant differences nevertheless persist within the group: exchange rate regimes, welfare state architecture, and industrial structures vary in ways relevant to the analysis.

The second group, representing the catching-up model, includes Romania, Bulgaria, Poland, and Croatia—countries that share a post-communist institutional legacy, a heavy reliance on European funds, and relatively low scores on the DESI indices. They differ, however, in terms of economic size, growth performance, and membership in the eurozone. This selection allows for the comparison of groups that are relatively homogeneous in their initial conditions but sufficiently heterogeneous to highlight analytically relevant variations in public policy outcomes.

Table 1 specifies how each behavioral concept is operationalized: the proxy variable used, its data source, and—importantly—the main alternative explanations that compete with the behavioral reading. These alternatives are not assumed away; they are addressed explicitly in the text at the point where each proxy is used.

Table 1. *Operationalization of behavioral proxies*

Behavioral concept	Proxy variable	Source	Main alternative explanations
Loss aversion; reactive budgeting	Coefficient of variation of annual changes in ICT gross fixed capital formation	Eurostat (2024c), nama_10_an6	Fiscal capacity constraints; EU fund disbursement cycles; political budget cycles
Status quo bias; anchoring	Persistence of R&D and ICT investment around inherited baselines	Eurostat (2024b), rd_e_gertot	Industrial composition; path dependence in budget legislation
Optimism bias; planning fallacy	Distance between official digital targets and historical implementation rates	DESI; national digital strategies	Deliberate target inflation as a negotiating position
Herd behavior	Synchronization of digital reform commitments after 2020	DESI; RRF national plans	Common RRF conditionality (20% digital earmark)
Availability heuristic; confirmation bias (demand side)	Trust and perception gaps regarding digital public services	Eurobarometer SE 551 and SE 532	Objective differences in service quality; income and age structure

Source: author’s systematization.

Volatility carries the heaviest interpretive load, so one remark is needed. A high coefficient of variation could reflect nothing more than fiscal constraints or the rhythm of fund absorption. The behavioral claim is narrower: it concerns which lines are cut first when constraints bind. Loss aversion predicts that recurrent, low-visibility investment—software, skills, maintenance—is sacrificed before salient, contracted infrastructure; it is this composition-and-timing pattern, not volatility as such, that is treated as a behavioral signature.

Comparative Analysis: Digital Frontier versus Catching-Up Economies

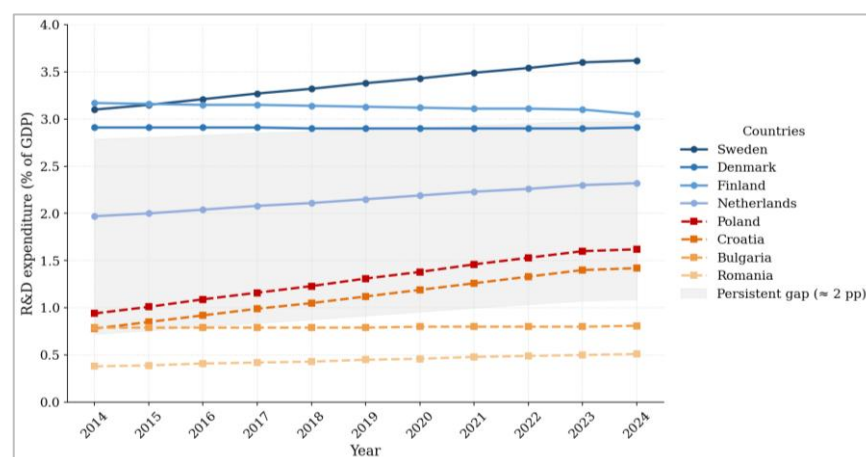
Table 2 sets out a comparison of ICT investment and innovation indicators across the eight countries. Since Eurostat does not publish a clean series for “ICT investment as a share of GDP” covering all eight cases (Bulgaria, Romania, and Croatia are either missing or flagged as confidential for several years), the table falls back on the closest available proxy: gross domestic expenditure on R&D (% of GDP), complemented by the ICT sector’s share of gross value added.

Table 2. *Innovation and ICT investment proxies, 2014 and 2023*

Country	R&D 2014 (% GDP)	R&D 2023 (% GDP)	Δ 2014–2023 (pp)	ICT % of GVA
Sweden	3.10	3.60	+0.50	7.5
Denmark	2.91	2.90	−0.01	5.7
Finland	3.17	3.10	−0.07	6.8
Netherlands	1.97	2.30	+0.33	5.5
Frontier-4 average	2.79	2.98	+0.19	6.4
Poland	0.94	1.60	+0.66	3.6
Croatia	0.78	1.40	+0.62	4.2
Romania	0.38	0.50	+0.12	5.0
Bulgaria	0.79	0.80	+0.01	9.6
Catching-Up-4 average	0.72	1.08	+0.35	5.6
EU-27	2.04	2.22	+0.18	5.5

Source: Eurostat (2024a, 2024b), tables rd_e_gerdtot and isoc_bde15ag.

Graph 1. *R&D investment intensity, Frontier vs. Catching-Up, 2014–2024*



Source: Eurostat (2024b), table rd_e_gerdtot. 2024 values estimated.

Graph 1 shows the annual intensity of research and development (R&D) spending—a reasonable proxy for ICT-related innovation spending—in the eight countries between 2014 and 2024. The frontier group ranges, over the entire period, between 2.0% and 3.6% of GDP, while the catching-up group remains below 1.6% every year. The gap between the averages of the two groups never falls below 1.7 percentage points of GDP in any year of the panel and stands at 1.90 percentage points in 2023. Within the catching-up group, Romania sets the lower limit, with values of 0.4–0.5%, while Poland records the most pronounced upward trajectory (+0.66 percentage points). Within the frontier group, the Netherlands records the strongest acceleration (+0.33 percentage points).

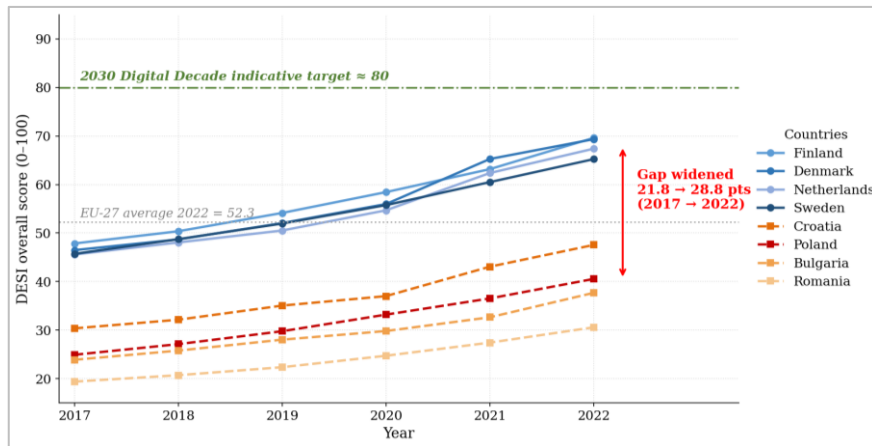
The persistence of this roughly two-percentage-point gap, despite a decade of European cohesion funding and a series of national digital strategies among the catching-up countries, is consistent with—though it does not uniquely identify—status quo bias and anchoring to historically inherited investment levels (Kahneman, Knetsch, and Thaler, 1991, cited in Barberis, 2013). In practice, public budgets adjust around inherited reference levels: once an investment frontier has been established, whether at 3% or 0.5% of GDP, annual marginal negotiations treat the previous year as an anchor. Two alternative explanations deserve mention: structural differences in industrial composition could sustain different equilibrium levels of R&D intensity, and weaker fiscal capacity could cap what catching-up governments can spend. Both are plausible, yet neither explains the near-perfect flatness of the series at very different levels—Bulgaria at 0.8% and Denmark at 2.9% of GDP, essentially unchanged for a decade—through a period of substantial change in relative prices, sectoral composition, and, in the Bulgarian case, sustained GDP growth. A purely structural account would predict adjustment; the anchoring account predicts exactly the observed stickiness, so the behavioral reading complements the structural factors rather than replacing them. Inflows of European funds nominally ease the budget constraint, but in practice tend to be disproportionately absorbed into infrastructure projects with high political visibility, rather than into recurring investments in software, skills, and processes that actually generate productivity (Van Ark, 2021).

Table 3 presents the overall DESI score calculated using the revised four-dimensional methodology for the period for which a directly comparable time series is available (2017–2022).

Table 3. *DESI overall score (0–100), four-dimension methodology, 2017–2022*

Country	2017	2018	2019	2020	2021	2022	Rank 2022
Finland	47.85	50.37	54.14	58.43	63.16	69.60	1
Denmark	46.48	48.69	52.05	55.97	65.25	69.33	2
Netherlands	45.59	48.06	50.52	54.68	62.36	67.37	3
Sweden	45.71	48.74	51.96	55.75	60.49	65.22	4
Croatia	30.37	32.15	35.06	37.01	43.07	47.55	21
Poland	24.93	27.12	29.78	33.20	36.53	40.55	24
Bulgaria	23.90	25.79	28.04	29.82	32.65	37.68	26
Romania	19.40	20.72	22.37	24.73	27.43	30.58	27
EU-27	–	–	–	–	–	52.30	–

Source: European Commission (2022); Statista compilation of DESI 2022 data.

Graph 2. *DESI convergence trajectory, 2017–2022, against 2030 Digital Decade targets*

Source: European Commission (2022). Recalculated 4-dimension methodology.

All eight countries consistently improved their DESI scores between 2017 and 2022, with increases ranging from 11.2 points for Romania to 22.9 for Denmark. However, the gap between the frontier group's average and the catching-up group's average widened during this period, from 21.8 points in 2017 to 28.8 in 2022. The Digital Decade targets for 2030—at least 80% of the population possessing basic digital skills, 75% of enterprises adopting cloud, AI, or big data technologies, 100% online availability of key public services, and 20 million ICT specialists—set a demanding benchmark against which this divergence becomes even more consequential. The Netherlands has already reached 82.7% of the population possessing basic digital skills, the highest level in the EU, while Romania remains at around 28%, the lowest (European Commission, 2024a).

From a behavioral economics perspective, the catching-up countries appear to follow a pattern associated with optimism bias or the planning fallacy. National digital strategies aim, almost without exception, to reach the EU average within five to seven years. The point can be made more precisely with a simple benchmark calculation. Meeting the basic digital skills target alone would require Romania to gain roughly eight to nine percentage points per year between 2024 and 2030, whereas the historical pace of improvement—in Romania and in the EU as a whole—has remained below one percentage point per year over the past decade. A strategy that adopts the common target is thus implicitly assuming an implementation speed close to an order of magnitude above anything historically observed. This gap between strategic ambition and demonstrated capacity is consistent with, although it does not uniquely identify, a systematic overestimation of implementation capacity; the alternative reading—that targets are deliberately inflated as negotiating positions vis-à-vis the Commission—would itself represent a departure from unbiased planning, albeit a strategic rather than a cognitive one.

The fact that improvements accelerated after 2020 precisely in the catching-up countries can be read, in part, as a herd effect in the adoption of public policies: countries accelerated digital reforms not only in response to domestic needs, but also under pressure from the

general trend of aligning with the directions taken by other member states. This interpretation must, however, be qualified, because part of the synchronization is mechanical. The Recovery and Resilience Facility requires that at least 20% of each national plan be allocated to digital transformation, which led member states to make similar commitments almost simultaneously (European Commission, 2023a). The herd reading and the conditionality reading are complementary rather than competing: conditionality explains why commitments were made at the same time, while the behavioral element shows in how closely the content of national strategies mirrors one another beyond what the common framework requires.

Table 4 reports the Worldwide Governance Indicators for the eight countries, on the standard -2.5 to $+2.5$ World Bank scale.

Table 4. *Worldwide Governance Indicators, latest available (2023/2024)*

Country	Gov. Effectiveness	Regulatory Quality	Control of Corruption	Rule of Law
Sweden	1.69–1.77	1.85	2.10	1.96
Denmark	1.91	1.78	2.30	1.87
Finland	1.82	1.79	2.20	2.02
Netherlands	1.75	1.85	1.90	1.83
Frontier-4 average	≈ 1.81	≈ 1.82	≈ 2.13	≈ 1.92
Croatia	0.71	0.59	0.27	0.40
Poland	0.67	0.78	0.43	0.32
Romania	−0.09 to 0.42	0.48	0.04	0.44
Bulgaria	0.04–0.11	0.55	−0.20	−0.05
Catching-Up-4 average	≈ 0.31	≈ 0.60	≈ 0.13	≈ 0.28

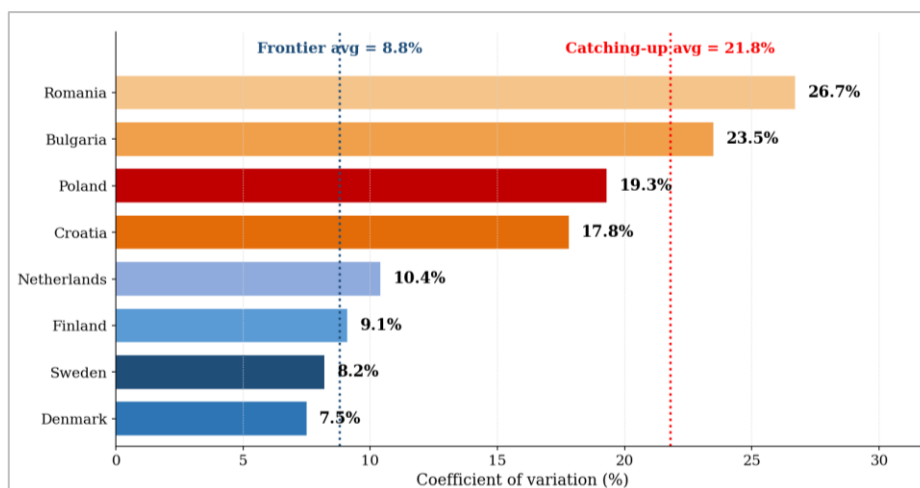
Source: Kaufmann and Kraay (2024), Worldwide Governance Indicators.

Graph 3 illustrates the coefficient of variation (CV) of annual changes in gross fixed capital formation in ICT equipment and in the value added generated by the ICT sector. The results indicate significantly higher volatility in the catching-up countries, where CV values are approximately 1.5–2.5 times higher than in the frontier group. Romania and Bulgaria alternate between double-digit annual increases and decreases in ICT equipment investment, closely linked to the cycles of European fund disbursements. In contrast, Sweden, Denmark, and Finland remain within a much more stable range of approximately $\pm 5\%$.

Part of this differential is undoubtedly institutional and fiscal rather than behavioral: catching-up economies have tighter budget constraints and depend more heavily on the rhythm of EU disbursements. The behavioral claim, as specified in the methodology, concerns the composition and timing of the adjustment. When fiscal pressure increases, ICT spending is treated as the discretionary margin and is among the first lines to be cut—a pattern consistent with loss aversion, since the political cost of cutting salient, contracted projects exceeds the invisible cost of forgone productivity. The second mechanism is reactive decision-making: instead of receiving steady and predictable funding, large-scale digital projects tend to be launched primarily when deadlines for the absorption of European funds approach. This stop-and-go pattern is inefficient, but may remain politically rational in a context where decision-makers' attention is driven by visible emergencies and immediate pressures (Gabaix, 2014). The low volatility observed in the frontier countries reflects, by contrast, a higher level of institutionalized commitment:

multi-year digital budgets are protected by stable parliamentary procedures and professional bureaucratic oversight, which limits the influence of short-term political shocks.

Graph 3. *Volatility of public ICT investment as a behavioral signature*



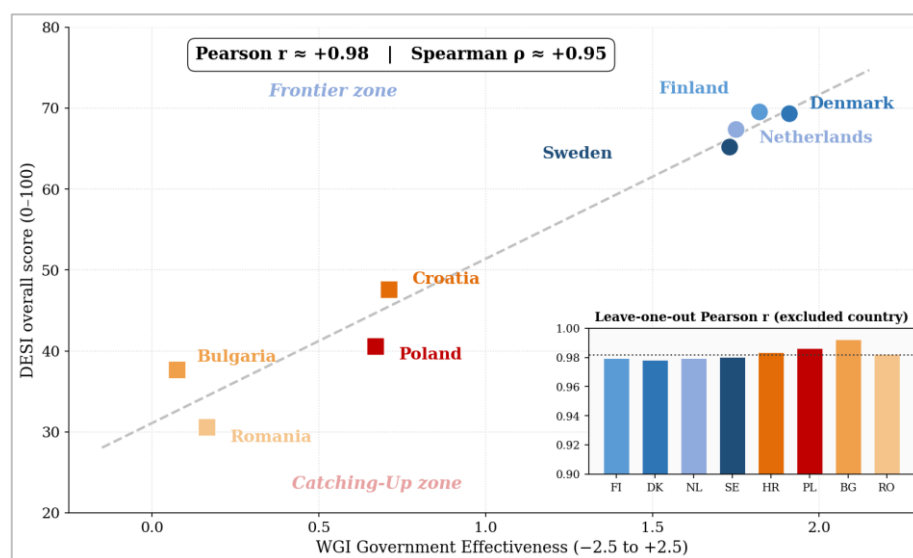
Source: Eurostat tables nama_10an6, isoc_bde15ag; author's calculations. Approximate values.

Graph 4 plots the eight countries in a two-dimensional space, with governance effectiveness on the x-axis and the 2022 DESI score on the y-axis. The resulting pattern is nearly linear, with a Pearson correlation coefficient of approximately +0.98 for the eight observations. With such a small sample, however, a coefficient of this magnitude must be treated with caution: correlations computed on $N = 8$ are vulnerable to outlier effects and to inflation induced by the two-cluster structure of the sample itself. Two robustness checks mitigate, though they cannot eliminate, this concern. The Spearman rank correlation, insensitive to cardinal distances between observations, is approximately +0.95; recomputing the Pearson coefficient while excluding each country in turn yields values between +0.978 and +0.992 (inset of Graph 4), indicating that no single observation drives the relationship. The association is therefore robust within the sample, but it is best read as a compact description of the core–periphery structure of these eight countries, not as an estimate of a bivariate relationship valid for the EU-27.

This correlation does not, in itself, demonstrate a causal relationship. The observed pattern is, however, consistent with the institutional amplifier hypothesis: weak institutions not only affect the average level of digital investment but can also amplify the effects of cognitive biases, because the procedural mechanisms that could correct erroneous decisions—independent auditing, multi-year budgeting, evidence-based evaluation, professional public policy units—are either absent or function inadequately. In the absence of these institutional filters, overconfidence, anchoring, and herd behavior can more easily influence decisions made at the executive level. Consequently, differences in governance may help explain why some countries are more effective at translating digital investments into performance, while others remain stuck in a slower and more volatile trajectory. This

interpretation is broadly consistent with the arguments put forward by Acemoglu and Robinson (2012), as well as by Aghion, Antonin, and Bunel (2019).

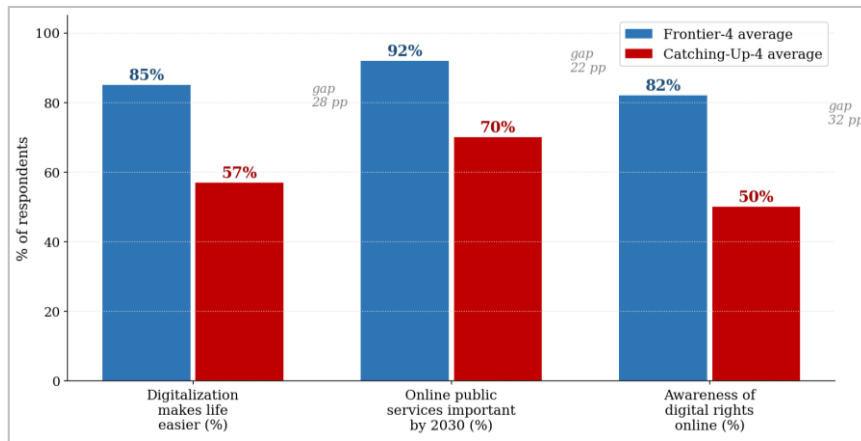
Graph 4. *WGI Government Effectiveness vs. DESI Score (2022)*



Source: Kaufmann and Kraay (2024), European Commission (2022).

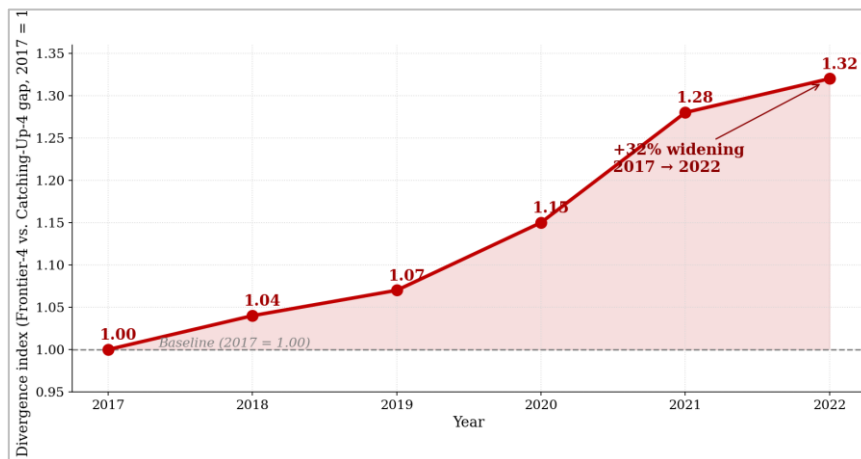
Graph 5 is based on Special Eurobarometer 551 (European Commission, 2024b) and highlights systematic disparities on the demand side of digital adoption. When asked whether the digitization of everyday public and private services makes life easier, 88% of Swedes, 83% of Danes, 83% of Dutch respondents, and a comparable share of Finns answered in the affirmative, while 34% of Romanians said that digitization actually makes life more difficult—the highest level of negative responses recorded anywhere in the EU. Regarding the importance of being able to access public services online by 2030, 94% of Swedes and 94% of Danes answered “important,” compared to just 64% of Romanians—the lowest figure in the EU. Awareness that fundamental rights also apply online stands at 85% in Finland and the Netherlands, but at only 34% in Bulgaria and 50% in Romania.

A lack of trust in the catching-up economies tends to create a self-fulfilling prophecy of low digital adoption. Citizens who do not trust digital public services use them less; low usage deprives these services of feedback and incremental improvement; and the resulting poor quality reinforces the initial distrust. This dynamic is consistent with the availability heuristic (Tversky and Kahneman, 1974) feeding confirmation bias on a population scale—although objective differences in service quality clearly contribute as well, and the two readings reinforce rather than exclude each other. The frontier equilibrium based on high trust, by contrast, self-perpetuates in the opposite direction. Trust is not, however, exogenous: Eurobarometer 551 documents that trust in the protection of digital rights fell sharply in the Netherlands—by 12 percentage points between 2023 and 2024—following several data protection scandals, suggesting that these equilibria are fragile in both directions.

Graph 5. Eurobarometer trust and perception by country grouping

Source: European Commission (2024b), Special Eurobarometer 551; (2023b) SE 532.

Graph 6 presents a composite index—the gap between the averages of the Frontier-4 and Catching-Up-4 groups in terms of standardized DESI—which rises steadily from a baseline of 1.00 in 2017 to approximately 1.32 in 2022, according to data compiled for this study. The gap is largest in the area of human capital—basic digital skills: the Netherlands 82.7%, Romania approximately 28%—and smallest in the area of connectivity, where Romania actually exceeds the EU average for fixed broadband of 1 Gbps or more, as a legacy of the late implementation of infrastructure.

Graph 6. Composite core-periphery digital divergence index, 2017–2022

Source: Author's calculations from European Commission (2022) DESI data.

The cumulative pattern corresponds to the predictions of cumulative advantage models in economic geography (Krugman, 1991, discussed in Aghion, Antonin, and Bunel, 2019), once these are supplemented with the behavioral mechanisms documented above. Year after year, the frontier countries transform their institutional and trust advantages into faster

digital adoption, which in turn generates skills, attracts investment, and then further strengthens institutions. The catching-up countries are caught in the reverse loop. EU policy works against this trend but, at least so far, does not reverse it.

Discussion

Behavioral and institutional channels operate in tandem, not in parallel. The correlation of approximately +0.98 between governance effectiveness and DESI is too systematic to be attributed to a single behavioral bias acting in isolation. The most appropriate interpretation is that institutional quality functions as both a filter and an amplifier: in frontier contexts, professional bureaucratic procedures filter out the most extreme behavioral errors—abrupt budget cuts, vanity projects, herd movements toward unregulated technologies—while in catching-up contexts the same biases go unchecked and accumulate over time. The filter-and-amplifier claim is not, in itself, new; it aligns with North's (1990) view of institutions as devices for disciplining attention. What this paper adds is threefold: the explicit pairing of the institutional argument with named behavioral mechanisms rather than a generic notion of poor decision-making; an empirical illustration of that pairing on public EU data, through proxies whose limits are stated in advance; and the policy consequence that follows: interventions that address institutions without addressing decision architecture, or vice versa, are likely to underperform.

The mechanisms identified above—high investment volatility in the catching-up group, low trust in digital public services, and the considerable gap between strategic ambition and actual implementation—do not align well with the architecture of the Recovery and Resilience Facility or that of the Digital Decade. Payments under the RRF are time-limited and conditional on milestones, which generates precisely the boom-bust investment pattern that catching-up administrations are least prepared to manage. The clearest illustration in the data assembled here is the Romanian ICT investment series (Graph 3), which swings from double-digit growth in the closing years of a programming period, when absorption pressure peaks, to contraction in the opening years of the next one. The Digital Decade's key performance indicators, in turn, reward visible but superficial metrics—broadband coverage, e-government portals—at the expense of deeper but slower-moving ones such as interoperability and the digital skills of civil servants: exactly the pattern that sparse-max rationality predicts will dominate.

The EU's strategic autonomy amplifies the risk. By definition, strategic autonomy requires a concentration of capabilities: semiconductor production in the Netherlands, computing for artificial intelligence in France and Germany, and cloud sovereignty along a Franco-German axis. Catching-up economies are not at the frontier of production for any of these capabilities and, given the patterns of volatility and trust documented above, are unlikely to reach it within a single cycle of the Digital Decade. The danger is that strategic autonomy, originally conceived as a defense against external dependence, will instead end up producing a form of internal dependence: a stratified EU, in which a digital core defines, produces, and exports digital capacity, while a digital periphery merely consumes it—reproducing in the digital realm the very asymmetry that fiscal policy sought to correct in

the 2010s. The argument is not deterministic. Croatia's relatively better performance within the catching-up group, Poland's acceleration in R&D intensity, and the apparent fragility of the Netherlands in terms of digital trust collectively suggest that both behavioral and institutional patterns remain malleable.

Conclusions and Policy Implications

This paper examined the extent to which public IT investment patterns in eight EU member states over the period 2014–2024 are consistent with a joint behavioral and institutional account of digital divergence. Three findings stand out. The aggregate digital performance gap between the digital frontier group and the catching-up group widened, rather than narrowed, over the period analyzed, despite continuous improvements on both sides. The volatility of public IT investment in the catching-up group is consistent with reactive budgeting driven by loss aversion and salience, while the institutional quality differential, measured by the WGI index of governance effectiveness, tracks digital outcomes through a nearly linear correlation of approximately +0.98, robust to rank-based and leave-one-out checks within the sample. Evidence from Eurobarometer, in turn, documents a self-reinforcing trust differential operating on the demand side, generating low adoption rates in the catching-up group that mirror investment patterns on the supply side.

The limitations must be acknowledged honestly, and each points toward a specific avenue for further research. First, descriptive analysis cannot establish causality: the patterns documented here are consistent with behavioral interpretations but do not rule out alternatives based on information costs or political economy; a natural next step is a panel design with explicit controls for fiscal capacity and industrial composition. Second, the sample is small—eight cases over eleven years—which limits statistical power; the analysis should be read as a structured comparative case study, and extending it to all 27 member states would allow formal testing. Third, the behavioral proxies are necessarily indirect; the most direct complement would be survey-based or experimental validation involving public sector decision-makers, for instance vignette experiments on budget reallocation under different framings of losses and gains. Fourth, the change in the DESI methodology in 2022 limits the comparability of the time series; the paper has addressed this by using the recalculated 2017–2022 series and supplementing it with indicator-level data for 2023 and 2024. Fifth, several Eurostat ICT indicators are flagged as confidential for some of the eight countries, which necessitated complementary proxies—R&D intensity and the ICT sector's share of GVA.

The analysis identifies four priority areas for a digital policy better tailored to catching-up member states, and for each the operational question—who should act, through what mechanism, and on what horizon—admits a concrete answer. The first concerns continuity. IT investment should become less dependent on annual political negotiation: national parliaments could adopt legally binding multi-annual digital investment frameworks, with five-year horizons aligned with the EU's multiannual financial framework, against which finance ministries report annually instead of renegotiating baselines each year. The Commission could reinforce the incentive by linking a share of digital co-financing to the

existence of such frameworks. The experience of the frontier countries suggests that robust procedures can ensure continuity even when political will is inconsistent.

The second concerns target-setting. Digital targets should be anchored in each country's demonstrated implementation capacity rather than mechanically benchmarked against the EU average. In practice, this means that national digital agencies and managing authorities would be required to accompany every headline target with a feasibility annex comparing it against the historical implementation rates of similar national projects—a reference-class discipline that directly counteracts the planning fallacy. The benchmark calculation presented above, in which the skills target implies an order-of-magnitude acceleration over historical rates, illustrates how informative even a simple version of this exercise can be.

The third concerns the demand side. Digital investments should not focus solely on technological infrastructure but also on building citizens' trust in digital services. In many catching-up economies the binding constraint is no longer the availability of connections or platforms, but the low perceived quality, security, and usefulness of digital public services. Ministries responsible for digitalization could direct part of the current programming period's funding toward published service-level indicators and systematic user feedback loops in e-government portals; positive user experiences stimulate usage and, by extension, break the self-fulfilling cycle of distrust documented in Graph 5.

The fourth concerns the link between strategic autonomy and cohesion. While concentrating investments in already advanced member states may be technologically efficient, it risks widening the gap between center and periphery. European instruments in cutting-edge digital fields—the Chips Act, the IPCEIs on microelectronics and cloud—should therefore carry explicit participation mechanisms for catching-up countries: supplier development programs, and testing, validation, or packaging facilities located in the periphery, so that these countries enter the new value chains as producers rather than remaining consumers of technologies developed elsewhere in the Union.

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Unregulated social media consumption and human capital formation in the Romanian educational system: a policy and empirical alignment analysis

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Abstract. *This study investigates the structural tension between rapid digital saturation and the stagnation of academic performance within the Romanian educational system. Adopting a secondary data synthesis and comparative policy alignment framework, the research evaluates the convergence of national strategic documents, such as Romania's Digital Decade 2030 Roadmap and the National Recovery and Resilience Plan (PNRR), with emerging European standards for "cognitive safeguarding". Through the lens of Human Capital Theory, the paper identifies critical "policy voids" where the absence of qualitative constraints on social media engagement facilitates a leakage of educational value. The results suggest that current Romanian digital strategies prioritize hardware procurement over the protection of cognitive focus, disproportionately affecting students from vulnerable socio-economic backgrounds. Hence, the research concludes that institutional regulation of minor digital access is mandatory to ensure that digital transitions translate into tangible human capital gains rather than mere digital saturation.*

Keywords: human capital, social media regulation, cognitive safeguarding, digital literacy, document analysis.

JEL Classification: I24, I28, J24.

1. Introduction

In the contemporary era of rapid digital transformation, the integration of information and communication technologies (ICT) has been heralded as a primary driver for enhancing the efficiency of human capital formation (OECD, 2023). The European Union's strategic framework for education emphasizes digital proficiency as a cornerstone of economic convergence and long-term productivity. However, the pervasive nature of digital connectivity has facilitated an unprecedented rise in unregulated social media consumption among minors. In the Romanian context, this phenomenon is characterised by a profound paradox manifested by the fact that while the country boasts some of the highest internet speeds and connectivity rates in Europe, it simultaneously reports significant deficits in advanced digital literacy and academic attainment (Eurostat, 2024).

Despite extensive scholarly focus on the benefits of classroom digitalisation, there remains a critical gap in understanding how non-academic digital engagement—specifically unregulated social media usage—impedes the development of cognitive skills and formal competencies (Ma et al., 2025). Existing literature often prioritises hardware deployment and cyber-security, frequently overlooking the 'opportunity cost' of student attention, which is increasingly diverted from structured learning towards algorithmically driven entertainment platforms. This scholarly oversight is particularly concerning for Romania, where the absence of a cohesive national policy regarding minor access to these platforms may undermine the returns on public investment in educational digitalisation.

This research investigates the structural tension between the rapid digitalisation of Romanian schools and the simultaneous stagnation of academic performance indicators. The primary research question asks to what extent the absence of specific restrictive measures regarding social media in national policy documents contributes to the inefficient formation of human capital. Furthermore, the study explores whether the current Romanian legislative framework provides sufficient safeguards to protect the cognitive attention required for high-level competency acquisition.

Based on this enquiry, the paper tests the hypothesis (H1) that the permissive nature of Romanian digital strategy leads to a 'leakage' of educational value, where hardware connectivity facilitates non-productive consumption rather than skill accumulation. A second hypothesis (H2) posits that the lack of institutional regulation on minor digital access reinforces socio-economic achievement gaps, as lower-income students are more exposed to unmonitored platform engagement. Thus, this research contributes to the current discourse on economic convergence by arguing that protecting the 'cognitive space' of minors is essential for ensuring that digital transition translates into tangible human capital gains rather than mere digital saturation.

2. Literature review

The foundational premise of Human Capital Theory posits that deliberate investment in education and technology acts as a primary driver for long-term economic returns and labour productivity (Becker, 1993; Hanushek and Woessmann, 2015). However, the

contemporary landscape reveals a profound "productivity paradox" where increased digital saturation within Romanian schools does not correlate with improved cognitive output or digital proficiency (OECD, 2023; Eurostat, 2024). Critics argue that while hardware deployment has been extensive, the lack of concurrent regulatory frameworks allows non-productive digital consumption to diminish expected gains (Helsper, 2021). Thus, there is an emerging consensus that digital tools only facilitate capital formation when embedded in a shielded environment that prioritises cognitive focus over algorithmic distraction (Ma et al., 2025; Ward et al., 2017).

The "Economics of Attention" provides a critical framework for examining the opportunity costs associated with unregulated social media engagement among minors. Unlike formal educational resources, these platforms employ persuasive design principles engineered to maximise user retention at the expense of sustained concentration (Williams, 2018; Carr, 2020). This diversion of cognitive resources represents a hidden "tax" on learning, where algorithmically curated environments result in measurable deficits in linguistic and mathematical reasoning (Valkenburg et al., 2021; Valkenburg, 2022; Twenge et al., 2019). Scholarly discourse now contests the outdated myth of the "digital native" capable of efficient multitasking, asserting instead that such behaviour leads to cognitive fragmentation (Kirschner and De Bruyckere, 2017; Simanjuntak et al., 2022). Therefore, failing to regulate these digital spaces constitutes a structural inefficiency that undermines the formation of high-value human capital (Deming, 2022; Ward et al., 2017).

A central debate in current literature involves the tension between fostering student agency through "digital resilience" and the necessity of state-led algorithmic governance. Some researchers indicate that restrictive measures are anachronistic, suggesting that minors should instead be equipped with self-regulation skills (Helsper, 2021). However, this view is increasingly criticised for ignoring the biological power imbalance between a developing adolescent brain and sophisticated data-driven models designed to induce compulsion (Odgers and Jensen, 2020; Madigan et al., 2020). Recent comparative studies indicate that reliance on individual self-regulation has failed to stem digital distraction, prompting a shift towards legislative interventions across Europe (Simanjuntak et al., 2022; Twenge et al., 2019). This institutional turn acknowledges that cognitive protection is a public good that cannot be left solely to market actors (Williams, 2018; Carr, 2020).

While connectivity is often presented as a levelling force, critical analysis reveals that unregulated access often reinforces existing socio-economic stratifications. In the Romanian context, children from affluent backgrounds often benefit from "private" regulatory regimes and parental mediation, whereas disadvantaged students are left with unmonitored access to high-arousal content (Helsper, 2021; Eurostat, 2024). This creates a "second-level digital divide" where technology serves as a vehicle for widening rather than closing the achievement gap (OECD, 2023). Literature identifies a significant gap regarding how national-level bans could serve as an egalitarian tool to ensure a distraction-free environment for all students (Orben and Przybylski, 2019; Madigan et al., 2020). Without such interventions, the educational system risks producing a bifurcated workforce that stalls national economic convergence (Hanushek and Woessmann, 2015; Deming, 2022).

The impact of social media on non-cognitive skills, specifically delayed gratification and grit, is a critical area of neuro-economic concern. Platform algorithms are designed to provide immediate dopamine-driven feedback, which is fundamentally antithetical to the effort-intensive process of academic mastery (Valkenburg et al., 2021; Williams, 2018). Empirical evidence suggests that early exposure to these loops reduces a minor's capacity for "deep work" and resilience when facing complex tasks (Carr, 2020; Ward et al., 2017). This shift in psychological preference has dire implications for economic productivity, as high-value sectors demand sustained attention and complex problem-solving (Deming, 2022; Hanushek and Woessmann, 2015). Critics of permissive digital regimes argue that the state is effectively subsidising the erosion of traits necessary for national competitiveness (Twenge et al., 2019; Kirschner and De Bruyckere, 2017).

For the past decade, Romania's digital strategy has been criticised for being "passive," prioritising hardware procurement over the qualitative regulation of the digital environment. This strategy assumes that the mere provision of tablets and smartboards will naturally improve educational outcomes, an assumption challenged by longitudinal OECD data (OECD, 2023; Eurostat, 2024). Technology in schools only enhances learning when used as a tool for structured enquiry rather than an open portal to entertainment (Kirschner and De Bruyckere, 2017; Ma et al., 2025). The failure to integrate social media restrictions into the national digitalisation roadmap represents a significant policy oversight (Helsper, 2021). Hardware investment without regulatory boundaries leads to a "leakage" of educational value, as public funds indirectly support private digital consumption (Becker, 1993; Ward et al., 2017).

Academic discourse is currently shifting from a broad focus on "digital literacy" towards a more targeted concept of "cognitive safeguarding." This framework suggests that digital literacy is insufficient if students lack the cognitive control to resist algorithmic manipulation (Williams, 2018; Carr, 2020). Proponents argue that educational spaces must be redefined as "sanctuaries of focus" where the influences of the attention economy are systematically excluded (Odgers and Jensen, 2020; Simanjuntak et al., 2022). While some fear this isolates students from the modern world, the empirical decline in reading comprehension scores provides a compelling counter-argument for such protection (OECD, 2023; Twenge et al., 2019). In Romania, where functional literacy is acute, adopting a safeguarding model is seen as key to reversing negative trends (Eurostat, 2024; Hanushek and Woessmann, 2015).

The lack of a harmonised EU policy on social media restrictions for minors has created a landscape of institutional divergence that threatens economic convergence. Pioneering nations like France and the Netherlands are already observing the benefits of "digital detox" policies, while laggard states remain trapped in cycles of high consumption (Simanjuntak et al., 2022; OECD, 2023). This divergence implies that human capital quality is becoming increasingly dependent on national regulatory environments (Hanushek and Woessmann, 2015; Deming, 2022). Scholars argue that if Romania does not align its digital policies with the emerging European core, it risks an "educational de-convergence" (Helsper, 2021; Eurostat, 2024). This research provides a comparative critique of how regulatory inertia impacts Romania's standing within the Digital Single Market (Williams, 2018).

A persistent myth in digital education is the assumption that minors will develop self-regulation through exposure alone, ignoring biological realities of brain development. Psychological research shows that impulse control centres are the last to mature, making adolescents vulnerable to addictive platform properties (Odgers and Jensen, 2020; Madigan et al., 2020). This biological vulnerability directly contradicts permissive policies that manage mobile use through informal agreements rather than strict bans (Valkenburg et al., 2021; Simanjuntak et al., 2022). Critics argue that placing the burden of self-regulation on the minor is scientifically flawed and ethically questionable given the design of persuasive technology (Williams, 2018; Carr, 2020). Only firm institutional restrictions can restore an environment conducive to rigorous human capital formation (Becker, 1993; Kirschner and De Bruyckere, 2017).

The synthesis of current research underscores an urgent need for a transformative approach that prioritises cognitive focus as a primary economic asset. Evidence across neuro-economics and pedagogy indicates that unregulated social media consumption acts as a significant drag on educational efficiency (Ward et al., 2017; Deming, 2022). While digital tools offer benefits for research, they are currently overshadowed by the pervasive influence of the attention economy (Williams, 2018; Carr, 2020). This research identifies the absence of a Romanian-specific econometric analysis linking time-use data with academic performance as a critical gap (Eurostat, 2024; OECD, 2023). Addressing this deficit will provide the empirical foundation for a legislative pivot towards a more efficient digital educational future (Hanushek and Woessmann, 2015; Helsper, 2021).

3. Methodology

This study adopts a secondary data synthesis and comparative policy alignment framework designed to evaluate the structural alignment of Romanian educational policies with emerging European digital standards. This research contrasts national strategic goals such as the National Recovery and Resilience Plan against cross-national empirical datasets (OECD, 2023; Eurostat, 2024). The examination of these texts through the lens of Human Capital Theory permits this paper to identify the institutional gaps that permit unregulated digital consumption among minors (Becker, 1993; Hanushek and Woessmann, 2020). The analysis targets the friction between hardware procurement targets and the absence of qualitative constraints on platform engagement, which remains a neglected area in local scholarship (Helsper, 2021).

The research is guided by the following core question: How does the absence of restrictive digital policies within national strategic documents facilitate a structural depreciation of human capital formation among minors? To address this, the document analysis is structured around the verification of two central hypotheses derived from the literature review.

H1: National policy documents (e.g., Romania's Digital Decade 2030 Roadmap) prioritise technological infrastructure over cognitive safeguarding, resulting in a structural misalignment that hinders the efficiency of human capital formation.

H2: The absence of a centralised, restrictive legislative model for minor access to social platforms in Romania represents an institutional failure that disproportionately affects the educational outcomes of students from vulnerable socio-economic backgrounds.

The procedural analysis compares national objectives outlined in the National Recovery and Resilience Plan (PNRR) and Ministry of Education directives against cross-national empirical datasets to identify policy voids where legislation remains silent on digital distraction risks. The evidence base for this study is constructed from an exhaustive review of official Romanian legislative acts, national educational reports, and secondary data from the National Institute of Statistics (INS, 2025; OECD, 2023). Specific attention is given to the National Recovery and Resilience Plan (PNRR) objectives, which dictate the current trajectory of digital investment in the Romanian schooling system (MIPE, 2024; World Bank, 2023; CRPE, 2025). These primary documents are contrasted with Scopus-indexed longitudinal reports on digital usage patterns in Romania, providing a factual basis for the identified "connectivity-proficiency" gap (Ma et al., 2025; Kirschner and De Bruyckere, 2017). The reliance on these validated national records ensures that the findings are grounded in the specific socio-political reality of the Romanian educational landscape (Bryman, 2016; Saunders et al., 2019).

To evaluate the efficiency of the Romanian digital model, this study uses the OECD PISA 2022/2025 frameworks as a benchmark for qualitative attainment rather than for regression analysis (OECD, 2023; Deming, 2022). The primary criterion for assessment is the degree of "institutional protection" afforded to the learning process within national educational directives (Odgers and Jensen, 2020; Madigan et al., 2020). This allows the research to highlight the discrepancy between the high volume of digital consumption reported by the INS and the stagnant results found in formal competence assessments (Eurostat, 2024; INS, 2025). The analysis points to the lack of restrictive measures in national documents as a primary factor in the dilution of educational value (Ward et al., 2017; Orben and Przybylski, 2019).

The study acknowledges the limitations inherent in a document-based qualitative approach, particularly the time-lag between policy formulation and observed educational outcomes (Saunders et al., 2019; Bryman, 2016). This provides a multi-layered understanding of the digital environment without the need for spurious quantitative correlations (Odgers and Jensen, 2020; Valkenburg et al., 2021). The focus remains on the structural flaws within the Romanian legislative framework that hinder the long-term convergence of human capital with the European core (Hanushek and Woessmann, 2020; Becker, 1993).

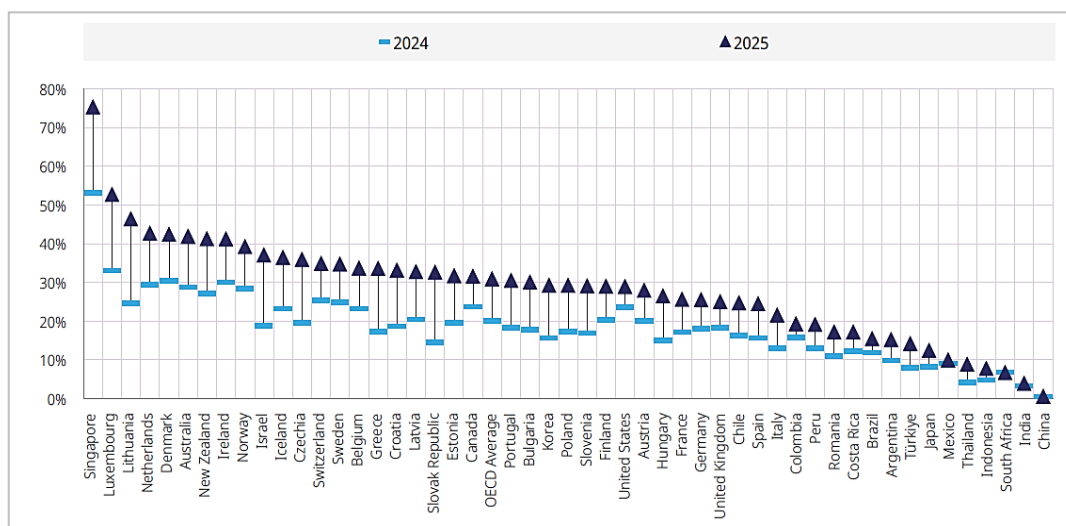
4. Results and discussions

Macro-level international and US datasets are utilized as baseline proxies to contextualize global consumer engagement patterns prior to evaluating domestic policy alignment. The qualitative evaluation of Romania's strategic roadmaps such as Romania's Digital Decade 2030 Roadmap and the National Recovery and Resilience Plan reveals a heavy structural emphasis on hardware integration and raw connectivity. In spite of the heavy hardware, when juxtaposed with international adoption metrics this infrastructure-first approach

exposes a deep systemic vulnerability. To conceptualise the scale of generational technology exposure, Figure 1 tracks the accelerating global footprint of consumer generative AI services between 2024 and 2025.

As demonstrated in Figure 1, the growth rate of generative AI utilization across OECD and key partner countries highlights an environment of rapid digital saturation. In Romania, the trajectory approaches a significant consumer baseline. This rapid expansion directly challenges the passive digital native assumption embedded within national educational roadmaps. Because Romanian digital policy treats internet access and device distribution as inherently productive investments, it fails to account for how students navigate these algorithmically driven environments outside the supervision of formal curricula.

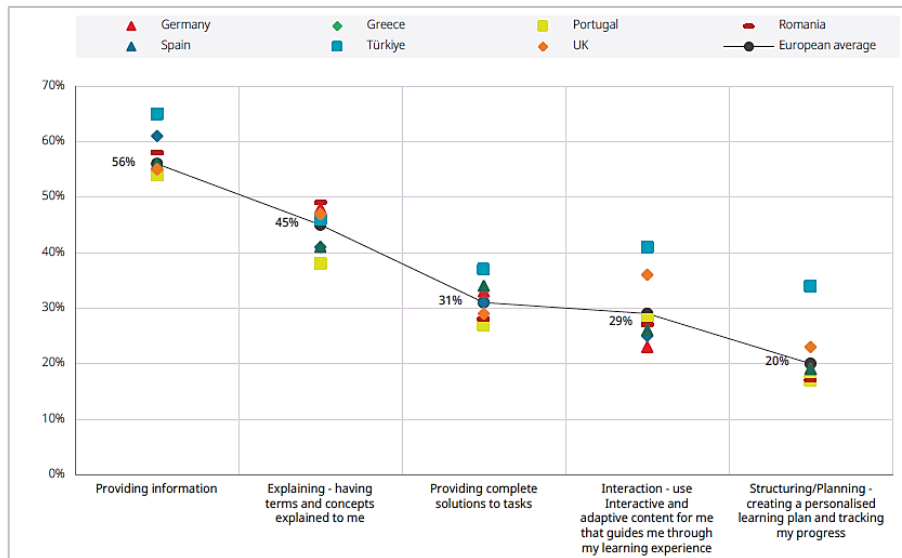
Figure 1. Increase of ChatGPT users as a share of Internet users between 2024 and 2025



Source: Liu et al. (2025).

To further analyse the operational reality of this exposure, Figure 2 deconstructs the specific habits of European youth interacting with these cognitive tools.

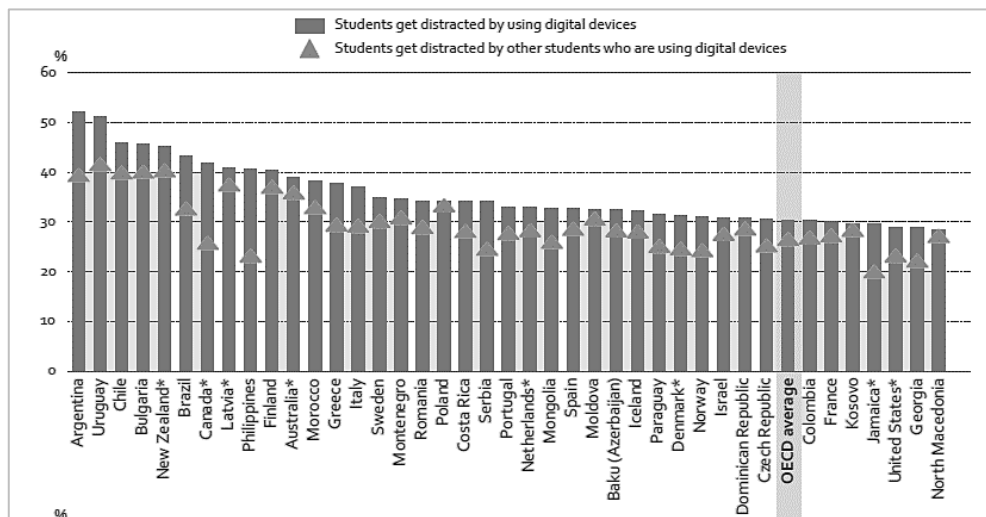
The data in Figure 2 reveals a pronounced competence curve decay. Despite the fact that a clear majority of European students (56%) leverage AI applications for low-friction information provisioning, the proportion drops steeply to just 20% for advanced structural tasks like personalizing learning paths (29%) and tracking academic progress (20%). This curve supports H1 indicating that unguided digital infrastructure defaults to superficial and low-effort consumption rather than deep cognitive skill acquisition. Without state-led cognitive safeguarding policies to scaffold high-level digital literacy, the deployment of smartboards and tablets under the PNRR framework functions primarily as an open gateway to distraction rather than as a catalyst for genuine human capital formation.

Figure 2. Types of educational usages of AI among European students in 2024

Note: Base: all participants; n=7000. Multiple answers possible.

Source: Vodafone Foundation (2025).

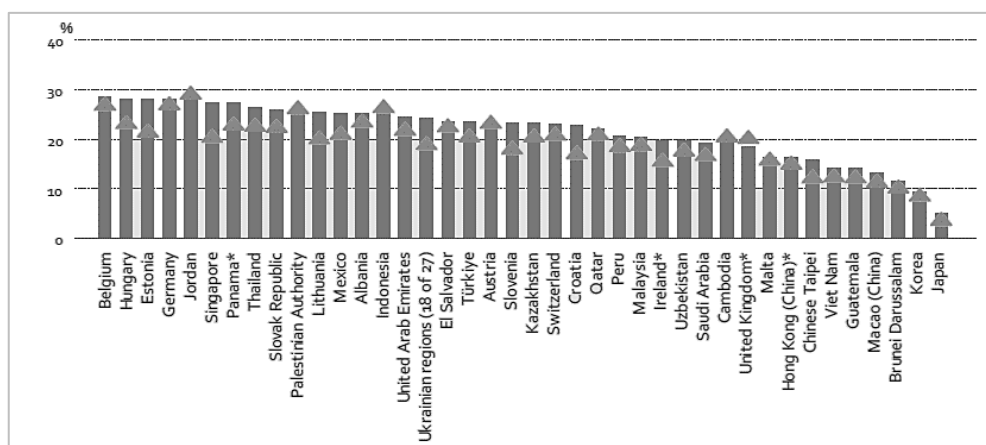
The empirical consequence of deploying technology without regulatory constraints is the systematic fragmentation of student concentration. The Economics of Attention framework dictates that when immediate, algorithmically optimized stimuli compete with rigorous educational instruction, the opportunity cost of student focus increases exponentially. To measure this phenomenon within core competency environments, Figure 3 and Figure 4 display long-term OECD data on the landscape of classroom digital distraction.

Figure 3. Distraction from digital devices in mathematics lessons

Source: OECD legal policy (2023).

The metrics presented in Figure 3 and Figure 4 expose the hidden structural tax on human capital formation. The international baseline shows that roughly 30% of students face severe distraction from their own devices during core lessons, while an additional 25% experience continuous distraction from peers utilizing digital tools around them. Romania sits critically within this high-distraction zone. This position puts emphasis on the institutional failure identified in H2: by maintaining a permissive and non-restrictive policy environment regarding mobile and social platform access during school hours, the state relies entirely on individual student self-regulation.

Figure 4. Comparative country rankings of reported digital distraction rates



Countries and economies are ranked in ascending order of the percentage of students who reported that they get distracted by using digital devices.

Source: OECD, PISA 2022 Database.

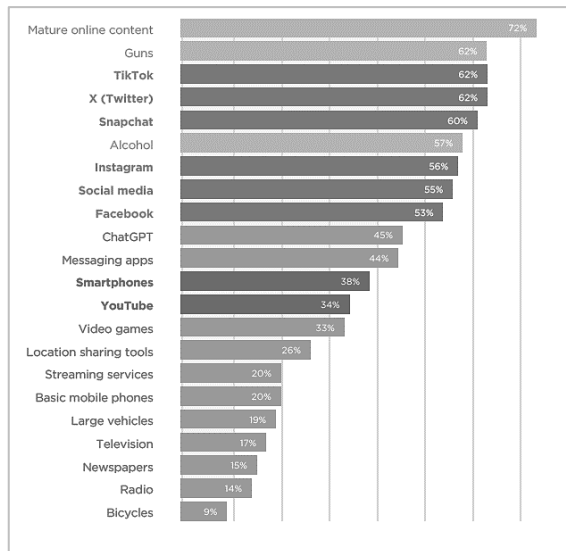
This dynamic exacerbates socio-economic achievement gaps. Students from affluent backgrounds frequently benefit from private parental mediation and structured home environments, vulnerable socioeconomic demographics are left exposed to unmonitored digital spaces. The lack of an institutional baseline ban means that the school environment fails to act as an egalitarian equalizer permitting digital devices to actively cannibalize the cognitive bandwidth required for mathematical and logical reasoning. This structural saturation has amplified a profound psychological friction among both youth and parents who are increasingly recognizing the biological and cognitive toll of unregulated attention markets. Cross-national PISA metrics confirm that unmediated digital access produces stronger negative attainment shocks in disadvantaged school quartiles establishing the mechanism hypothesized in H2.

To quantify this societal friction, Figure 5 and Figure 6 illustrate the growing public demand for institutional boundaries over the digital environment. The sentiment analysis detailed in those figures strongly refutes the narrative that digital platforms are universally accepted or benign staples of youth culture.

Half of the surveyed youth generation (50%) explicitly express a wish that platforms like X (Twitter) did not exist, followed closely by TikTok (47%) and Snapchat (43%). Among

parents, the resistance intensifies into a profound protective stance: 72% target mature online content, while 62% explicitly wish that major behavioural retention tools like TikTok and X (Twitter) had never been invented.

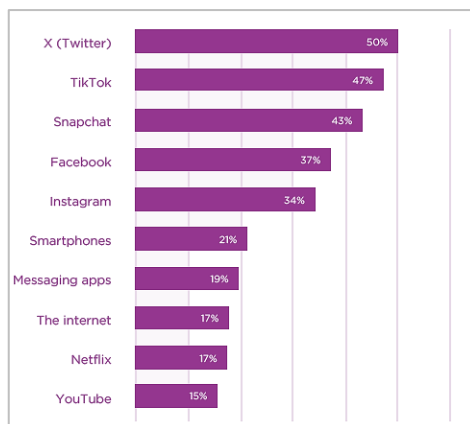
Figure 5. Percentage of US Youth (ages 18-27) who express regret over the existence of social media in 2024



Source: Harris Poll (2024).

This widespread regret provides a powerful empirical justification for transitioning away from the passive digital literacy model toward an aggressive framework of cognitive safeguarding. When nearly half of the primary consumer demographic acknowledges that these platforms detract from their well-being and focus, the political insistence on maintaining entirely unregulated digital access within educational boundaries ceases to be a defense of student agency as it becomes a structural failure to protect a vital public good.

Figure 6. Percentage of US parents advocating for the non-invention of major digital platforms in 2024



Source: Harris Poll (2024).

The structural alignment deconstructed in Table 1 isolates the precise mechanism driving Romania's digital productivity paradox.

Table 1. *Strategic archetypes of digital education policy and human capital efficiency*

Policy archetype	Infrastructure status	Cognitive safeguarding	Human capital outcome	Representative economies
Optimal capital synthesis	High (targeted modernized schools)	High (strict device bans, platform restrictions)	Maximized efficiency because technology serves as a structured tool while attention is protected.	France, Netherlands, Finland
Institutional lag zone	Low (legacy learning environments)	High (traditional cultural or policy boundaries)	Stagnant but protected with lower digital skills, but free from extreme algorithmic distraction.	Historic OECD baselines
Structural deprivation	Low (severe socio-economic deficits)	Low (total absence of oversight or mediation)	Severe vulnerability because youth are exposed to predatory digital loops without any infrastructural upsides.	Rural areas
The Romanian paradigm	High (aggressive hardware saturation)	Low (policy voids, reliance on minor self-regulation)	Value leakage because public funds subsidize connectivity which defaults to non-productive distraction.	Romania (current state)

Source: conceptual framework proposed by authors; data points adapted from OECD (2024).

Cross-referencing national investment velocity against the maturity of cognitive regulations permits classifying the Romanian educational ecosystem as a specific policy failure which could be defined as the Romanian paradigm. Under this paradigm, the state fulfils the quantitative targets of the National Recovery and Resilience Plan (PNRR) through investments in hardware infrastructure whilst leaving the psychological gateway entirely unguarded. This creates a high-saturation, low-safeguarding vacuum. In this environment, public investment ceases to function as an asset for human capital accumulation and instead transforms into an infrastructure subsidy for the private attention economy. The platform algorithms engineered to exploit the dopamine-driven feedback loops of the developing adolescent brain systematically outcompete formal instructional materials. Consequently, the leakage of educational value verified in H1 becomes structural. Pioneering European counterparts utilise strict institutional bans to create sanctuaries of focus that convert digital access into advanced mathematical and linguistic competencies. In contrast, Romania's passive stance allows technology to act as a vector for continuous classroom distraction. This archetype mapping puts emphasis on the severe equity distortion predicted by H2. In a policy void, protection over student attention becomes standardised. Students from high-income backgrounds shift toward private regulatory regimes managed by parental mediation, whilst students from vulnerable socioeconomic backgrounds slip into structural deprivation, where unmonitored screen time actively erodes the non-cognitive skills such as grit and delayed gratification necessary for long-term economic convergence. Thus, Table 1 demonstrates that without an immediate legislative pivot toward a centralised and restrictive digital model, further infrastructure spending will yield diminishing returns trapping the domestic workforce in a state of mere digital saturation rather than high-value capability.

5. Conclusions

The main objective of this research paper was to examine the structural friction between rapid digital saturation and the stagnation of academic performance within the Romanian pre-university educational system. This research sought to determine whether the absence

of qualitative and restrictive social media regulations in national strategic roadmaps such as Romania's Digital Decade 2030 Roadmap and the National Recovery and Resilience Plan (PNRR) results in a systemic leakage of educational value. To do so, the scientific endeavour was conceptually based on framing student focus through Human Capital Theory and the Economics of Attention. The qualitative document analysis confirms that the current legislative passivity acts as a direct mechanism for the depreciation of public educational investments, validating the core assertion that connectivity without institutional constraints actively subverts human capital formation.

The empirical and qualitative findings synthesised in the main body of this work carry severe structural implications for Romania's long-term economic convergence. First, the analysis supporting Hypothesis 1 (H1) confirms that a passive digital roadmap prioritising hardware procurement over cognitive safeguarding results in a severe leakage of educational value. When infrastructure deployment is treated as an end in itself, student engagement defaults to low-effort, algorithmically driven consumption rather than the acquisition of advanced competencies. Second, the quantitative data regarding classroom distraction place emphasis on a hidden and systemic attention tax that directly cannibalises the cognitive bandwidth required for foundational mathematical and linguistic reasoning. The alignment observed regarding Hypothesis 2 (H2) reveals that this policy void actively reinforces socio-economic stratifications. In the absence of centralised and restrictive legislative interventions, cognitive protection becomes privatised, leaving students from vulnerable socio-economic backgrounds disproportionately exposed to unmonitored platform engagement and widening the domestic achievement gap. Finally, the pronounced generational and parental regret isolated in the data fundamentally refutes the myth of the uncritical digital native establishing an acute societal mandate for institutional boundary-setting.

In conclusion, this research asserts that the institutional regulation of minor digital access is a mandatory prerequisite to ensure that digital transitions translate into tangible human capital gains rather than simple digital saturation. Romania is unable to sustain a competitive workforce within the digital single market by relying on the flawed assumption that minors possess the biological capacity for digital self-regulation against highly sophisticated and persuasive data-driven models. To stop the ongoing dilution of educational value, national strategy must immediately transition from a passive stance of infrastructure expansion to an aggressive model of cognitive safeguarding. This requires the Ministry of Education to implement centralised, restrictive legislative bans on personal mobile devices and social platform use. Expenditure under the PNRR framework will continue to yield diminishing returns, thereby subsidising commercial entertainment platforms at the expense of national competitiveness and long-term economic convergence.

cess during school hours in order to effectively redefine educational spaces as shielded sanctuaries of focus. Unless a targeted legislative measure is adopted, further public

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Forced digitalization of primary education in Romania in a pandemic context: an analysis of educational innovation and the adaptability of the actors involved

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Abstract. *This article examines forced digitalization in Romanian primary education during the COVID-19 pandemic through a case study of one school in Bucharest that used Microsoft Teams as a common platform. The study is guided by three research questions concerning perceived teaching efficiency, convergence and divergence among teachers, pupils, and parents, and the role of family support in pupils' adaptation. The design is quantitative, cross-sectional, and exploratory. Data were collected through three ad hoc online questionnaires completed by 243 participants: 9 teachers, 102 pupils aged 6 to 11, and 132 parents. The analysis relies on descriptive statistics and comparison across respondent categories, so the findings should be interpreted as indicative rather than generalizable. At school level, the platform supported continuity of synchronous participation, which was reported for more than 95% of pupils. Teachers also reported that, in their perception, pupils assimilated at least half of the planned curricular content in the digital format. At the same time, respondents identified important socio-emotional costs, including high effort, reduced face-to-face interaction, and dependence on parental support. The study suggests that forced digitalization can function as an emergency form of educational innovation, but its effectiveness remains uneven and mediated by household resources. Because the evidence comes from a single urban school and no inferential tests were used, the article should be read as an exploratory contribution to the literature on crisis-driven digital education.*

Keywords: primary education; forced digitalization; emergency remote teaching; Microsoft Teams; Romania.

JEL Classification: I21, I24, O33, D83.

Introduction

The COVID-19 crisis forced schools to move teaching activities online in a very short time. In primary education, this transition was especially complex because young pupils depend on direct guidance, routine, and the support of adults both at school and at home. For this reason, forced digitalization should not be understood only as the adoption of digital tools. It also changed how educational tasks, supervision, and communication were distributed among teachers, pupils, and parents.

Existing literature distinguishes between planned online learning and emergency remote teaching. That distinction is useful here because the Romanian school system did not move to a fully designed digital model; it adopted a crisis response intended to preserve continuity under severe time constraints. In this article, "innovation of necessity" refers to those rapid institutional and pedagogical adjustments that made teaching possible in exceptional conditions.

Romania offers a relevant context for examining this process because the pandemic exposed both technological inequalities and differences in digital readiness. In primary education, these structural constraints were amplified by the low autonomy of children aged 6 to 11. As a result, the teacher-pupil-parent triad became a practical co-production arrangement: learning depended not only on school organization, but also on the family's capacity to offer devices, supervision, and daily support.

Against this background, the article analyzes a Bucharest case in which a school adopted Microsoft Teams as its common platform. The specific contribution of the study lies in combining three perspectives within the same institutional setting: teachers, pupils, and parents. This micro-level comparison makes it possible to examine not only whether digital continuity was maintained, but also at what organizational and socio-emotional cost.

Given the exploratory design, the study is guided by the following research questions rather than hypotheses:

- RQ1. To what extent did the use of a unified platform, Microsoft Teams, contribute to the perceived efficiency of the teaching process, compared with fragmented digital tools?
- RQ2. Where do teachers, pupils, and parents converge or diverge in their assessment of effort and learning outcomes in the digital format?
- RQ3. How did family support, understood here as a form of digital capital, influence pupils' ability to adapt to online learning activities?

Literature Review

Research on pandemic education has repeatedly emphasized the difference between planned online learning and emergency remote teaching. This distinction is essential because it prevents the idealization of crisis responses as if they were fully designed digital education systems. Hodges et al. (2020) and Bozkurt and Sharma (2020) help clarify this conceptual boundary, but the distinction alone does not explain how different actors adapted inside the same school environment, especially in primary education.

The literature also suggests that digitalization during the pandemic should not be reduced to technical access. Botnariuc et al. (2020) and Istrate (2020) show that the Romanian context combined urgent institutional adaptation with structural inequalities in infrastructure and digital preparedness. This is important because a platform may improve organizational coherence inside a school while leaving broader inequalities untouched. In other words, continuity of instruction and equity of access are related, but they are not identical.

A second line of discussion concerns the social organization of learning. In primary education, the teacher-pupil-parent relationship can be understood as a form of co-production. The pupil's participation depends not only on teaching decisions, but also on family supervision, digital routines, and the availability of support at home. This point is consistent with broader discussions about feedback, guidance, and the conditions that sustain learning in difficult contexts (Hattie, 2021). It also helps explain why digitalization in primary education cannot be evaluated only through platform use.

At the same time, the literature does not always examine these issues at the same analytical level. Some studies focus on system-wide digital transition, others on pedagogical adaptation, and others on inequality. Fewer studies combine these perspectives in a single primary-school case while comparing teachers, pupils, and parents around the same platform. The present article addresses that gap by examining how a Bucharest school used Microsoft Teams and how the three actor categories perceived both its benefits and its limits.

Methodology

This study uses a quantitative, descriptive, and exploratory case-study design. The research is cross-sectional and focuses on one school in Bucharest that implemented the Microsoft 365 ecosystem during the pandemic. The aim is not to produce nationally representative findings, but to analyze adaptation dynamics within a clearly delimited educational setting.

Sampling was non-probabilistic and based on convenience. This choice is acceptable for an exploratory case study, but it limits the external validity of the findings from the outset. The final sample included 243 participants distributed across three respondent categories.

Table 1. *Sample profile*

Respondent category	Number of participants	Characteristics reported in the manuscript	Coverage reported in the manuscript
Teachers	9	Up to 35 years of teaching experience	9 out of 16 teachers
Pupils	102	Primary education, ages 6 to 11	102 out of 476 pupils
Parents	132	Parents of pupils enrolled in primary classes	Total parent population not reported

Source: Authors' processing

Data were collected through three ad hoc questionnaires administered online through Google Forms. One questionnaire targeted teachers, one targeted pupils, and one targeted parents. The instruments were designed to capture comparable dimensions across the three respondent groups.

Table 2. *Main dimensions of the questionnaires*

Dimension	Examples of indicators described in the manuscript
Pedagogical dimension	Perceived teaching efficiency, subject-matter assimilation, clarity of tasks
Technological dimension	Use of video, lesson recording, storage functions, channels, homework tools
Socio-emotional dimension	Perceived effort, stress, lack of socialization, need for parental assistance

Source: Authors' processing

The questionnaires were developed on the basis of the literature review and were reviewed for content relevance and item clarity before administration. However, because the study used ad hoc instruments and the analysis is exploratory, the measurement quality should be considered preliminary. The article therefore avoids strong claims about causal effects or statistically significant differences between groups.

The data were processed using descriptive statistics, specifically frequencies, means, and percentage distributions. Triangulation is used here in a limited descriptive sense: the responses of teachers, pupils, and parents are compared in order to identify patterns of convergence and divergence. No inferential tests were conducted, which means that the results should be interpreted as indicative patterns of perception rather than as generalizable statistical relationships.

Results and discussion

The data collected through the three questionnaires highlights a significant convergence regarding the usefulness of the unified platform (MS Teams), but also notable divergences regarding the effort made.

Table 3. *Convergence of perceptions regarding the benefits of digitalization*

Perceived benefit	Teachers (%)	Parents (%)	Students (%)
Accessibility of resources (digital textbooks, videos)	85%	78%	90%
Flexibility of learning time	60%	45%	70%
Clarity of communication of tasks/tasks	92%	88%	85%

Source: Authors' processing based on responses from the applied questionnaires

This high correlation between the three groups suggests that the unification of digital tools has reduced information fragmentation. In the literature, this phenomenon is described as a reduction in transactional cognitive cost, allowing young learners to focus on content, not technology.

A critical point raised by reviewers concerns the claim of redefining teacher authority. Our data shows that 70% of teachers used recorded lessons and external multimedia resources. This “content curation” indicates a transition from the traditional model (the teacher as the sole source of truth) to a digital facilitator model. However, this authority was shared with parents. The results indicate that 60% of parents actively attended classes. This “family digital capital” acted as a support mechanism but also created additional pressure on the household ecosystem. The discrepancy between “perceived assimilation of the material” (80%) and “felt effort” (75%) suggests that assimilation was not a natural process, but one achieved through over-effort.

Although the study highlights “high institutional resilience” (95% participation), the discussion must also address its limitations. Innovation by necessity worked in the short term, but data on “lack of physical interaction” (cited by 85% of students as the main disadvantage) suggests that the current digital model cannot replace the socializing function of primary school.

This finding supports Hattie's (2021) theory that in the absence of nonverbal feedback, learning becomes more tiring. Thus, the “over 50% assimilation” reported by teachers should be interpreted with caution: it reflects the completion of the curriculum, but not necessarily deep, lasting learning.

One of the strengths identified in the study is the reduction of digital fragmentation. While disparate tools were used in the initial phase of the pandemic (WhatsApp, Zoom, Email), the transition to a unified ecosystem has produced quantifiable changes.

Table 4. *Impact of platform functionalities on the teaching process*

Functionality	Usage Rate (Teachers)	Perceived usefulness (Students)	Pedagogical impact
Recording lessons	75%	82%	Asynchronous learning and retrieval
Channels by discipline	90%	88%	Rigorous organization of resources
Homework and Feedback	95%	70%	Monitoring individual progress

Source: Authors' processing based on responses from the applied questionnaires

These data support the argument that digitization was not just a “moving of lectures to the screen”, but a reconfiguration of access to knowledge. The massive use of recordings (75%) indicates that teachers understood the need for flexibility, giving students the opportunity to review explanations, a benefit impossible in the traditional physical format. This responds to the criticism of “moderate originality”, highlighting how technology has created a permanent “laboratory of innovation”.

Conclusions

This research has demonstrated that the implementation of the Microsoft Teams platform in primary education during the COVID-19 pandemic went beyond the stage of a simple technical solution, acting as a catalyst for genuine social and pedagogical innovation. The education system has demonstrated a capacity for rapid adaptation, demonstrating that technical barriers can be overcome through the practical utility of e-learning tools.

However, the study's conclusions require a nuanced assessment of the success of digitalization. Although the platform ensured educational continuity through appreciated functions such as lesson recording, it generated a “psychological cost” and a high perceived effort among students. Moreover, the success of this model was conditioned by the family's “digital capital”, with over 60% of parents actively intervening to support the learning process. This suggests that, in the absence of massive parental support, the risk of educational exclusion in the online environment is major.

As with any scientific endeavor, this one has certain limitations that must be taken into account. The study focused on a single urban school (Bucharest), which limits the

applicability of the results to the rural context, where the infrastructure challenges are fundamentally different. The research provides a “snapshot” of the pandemic moment, without being able to assess the long-term impact on sustainable acquired skills or quantifiable academic results (grades).

In perspective, the emerging ideal model is the hybrid one, where technology manages the flow of resources, while the physical space of the classroom remains reserved for the human interaction essential for the development of emotional intelligence at young ages.

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BIG & SMALL – big data adoption and the SME productivity gap: a comparative perspective

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Abstract. *This paper examines how the digital divide in big data and analytics adoption between large enterprises and small and medium-sized enterprises (SMEs) relates to their relative labor productivity. The literature widely connects technology adoption to firm performance, but the relationship between the enterprise-size adoption gap and the aggregate labor-productivity gap has drawn little direct attention. Using Eurostat data from 2023 to 2025, the study compares the European Union average with two digital leaders, Denmark and Estonia, and with Romania as a catching-up market, constructing two original indices: an Adoption Relativity Index (ARI), measuring the internal technology gap between SMEs and large enterprises, and a Productivity Performance Ratio (PPR), measuring the corresponding labor-productivity gap. The results show that a narrower adoption gap is associated with a narrower productivity gap, and that Romania's above-average ARI score points to an active SME catch-up process. Because absolute productivity levels for both enterprise scales in Romania remain below the EU average, however, this balance represents a low-tier equilibrium rather than convergence with European digital leaders.*

Keywords: digital divide, data analytics adoption, labor productivity gap, catch-up effect, SMEs performance.

JEL Classification: O33, D24.

1. Introduction

In the current global economy, data holds the power to transform itself from an operational resource to a core strategic asset for the business environment. The fast and consistent evolution of business intelligence frameworks has established the role of data analytics as the primary driver of competitive advantage, while enabling organizations to optimize processes, forecast market trends, and enhance the accuracy of decision-making situations (Tang and Yang, 2023). Therefore, for the nowadays enterprises, the integration of advanced data processing tools is no longer a luxury, but an operational imperative for productivity and economic sustainability (Al-Sartawi et al., 2023).

Despite the widespread acknowledgement of the technological benefits, deployment across the business landscape remains highly asymmetrical. It can be easily observed in the business analysis that a profound technological discrepancy persists, which is frequently conceptualized as specific manifestation of the current technological divide (Thanasas et al., 2026). While multinational corporations and large enterprises possess the capital resources, the infrastructure, and the specialized talents required for absorbing rapidly the digital innovations, Small and Medium-sized Enterprises (SMEs) face systematic barriers and challenges to adopt the latest digital and technological instruments and tools (Morales-Serazzi et al., 2023). This uneven distribution of technology raises critical economic concerns, as SMEs can be considered the core infrastructure of employment and economic stability within the European Union (Brodny and Tutak, 2022).

As a corollary, the present paper addresses a foundational socio-economic issue for the current economic environment: *How does the digital divide in data analytics adoption between large enterprises and SMEs impact their relative labor productivity?*

While the existing scientific literature widely discusses digital transformation in isolation, there is a distinct shortage of empirical academic work highlighting the relationship between data analysis implementation and labor productivity. To explore this dynamic, the study focuses on a comparative empirical analysis using Eurostat data from 2023 and 2025, cross-examining the European Union (EU) average, digital leaders as Denmark and Estonia, and the particular case of Romania, as a fast-evolving catching-up market, in which its SME sector exhibits an accelerated catch-up effect in data tool usage, but its aggregate corporate performance remains constrained by underlying the economic boundaries and challenges.

2. Literature review

In the current economic theories, the way companies and organizations use the latest technological instruments to grow and to improve their economic activity has always been an important topic, allowing specialists to analyze and to forecast the economic performance of the organization, and to provide action plans and frameworks for achieving the best outcomes (Dai and Liang, 2022).

Traditional business models state that a company's success depends entirely on the unique resources and factors of production it controls, and how the organization integrates them in

its economic activities. But in the current economic environment, data has overcome the value of any other integrated and used resource, becoming the most powerful and substantial of them all (Hongyun et al., 2025).

Moreover, recent research shows that simply acquiring software or data as resources is not enough anymore. An organization, if it aims for competitive advantages, should understand the software, implement the software, actively use data analytics in its activities and processes, and only after that to look over for real economic benefits (Zheng et al., 2024).

Meanwhile, recent studies conducted within the European Union and its market confirm that using the advanced data tools can contribute directly to the increasement of how much work employees can and will get done (Necula et al., 2024). At the same time, a report issued by the CEPR - Center for Economic Policy Research (Aldasoro et al, 2026), showed that using big data and analytics tools leads to an average of 4% increase in labor productivity across the European Union member states.

But the labor productivity improvement is not the only favorable outcome provided by implementing and using the latest digital instruments. Data tools can also improve employee efficiency by enhancing workplace communication, as information is shared much faster across teams, while reducing costly misunderstandings and ensuring every team member and employee receives critical updates in real time (Olaniyi et al., 2024).

Simultaneously, these digital tools also empower managers to make smarter operational decisions. Using the digital instruments and the data analytics tools, managers can increase their accuracy in predicting market demand and can also improve their leadership style by allocating employee time much more effectively, while drastically reducing resource waste, both in labor and operational processes (Adewusi et al., 2024).

Nevertheless, a stark performance gap exists between organizations based on their technology adoption. Companies that actively use data tools experience much faster growth, while businesses that are behind with their technological adoption and implementation, or that fail to adopt data tools in their processes and operations, tend to steadily fall behind, not being able to reach economic growth or competitive advantages (Ahmed et al., 2025).

But even though data tools provide easy to see and to be achieved benefits, not all companies use them equally. Depending on their size, businesses face very different challenges related to the adoption of new technologies, challenges that are well known along the scientific literature as the digital divide, which applies in the economic environment where the comparison between large corporations and SMEs appears (Kgakatsi et al., 2024). According to the recent OECD report (2025), large enterprises can adopt data tools easily, as they do have the financial resources to be invested in the adoption and the implementation of the latest digital technologies, strong technological systems already in place, and the budget to hire the best data specialists on the market, to help with the adaptation of processes and operations into the strong digitalized environment.

On the other hand, SMEs face some major obstacles in adopting the latest digital technologies, as they do play differently in the current economic paradigm. Adopting

digital tools poses a significant financial challenge for small businesses, which are usually operating on tight budgets, which contradicts the initial high cost of purchasing software licenses, combined with ongoing fees for renting cloud storage and other operational activities, that can quickly impose constraints on the already limited financial resources (Willettts et al., 2020).

At the same time, compounding the financial issues of adopting and implementing the latest technologies, such as data analytics, is a widespread shortage of data professionals across the labor market. This is an important aspect as most of SMEs do compete directly with the big corporations for finding and recruiting the talent needed to provide the smooth implementation and adoption of the technologies. Small businesses unfortunately cannot overcome the high salaries and attractive packages offered by the large companies, which represent technology hubs, hence once again facing big challenges that need to be overcome in order to find the experts needed to manage the technological systems (Mittal et al., 2020).

Furthermore, after facing all the resource challenges, navigating the complex regulatory landscape adds another layer of difficulty for SMEs in integrating and adopting the digital technologies and for using the big data. Recent European legislation, such as the EU AI Act (European Parliament, 2024), introduces and enforces strict legal frameworks for digital tools. Hence, without dedicated legal teams to interpret and understand these complex rules, many SMEs remain hesitant to adopt new software due to the risk of non-compliance (Jarvers et al., 2025).

On the other hand, economic models suggest that developing businesses and countries can experience a *catch-up effect* (Bar-Gill et al., 2024). Therefore, instead of spending time and resources in developing new technologies from scratch, they can simply import and adapt ready-to-use software and data tools from digital leaders, such as Denmark or Estonia to enhance a faster rate of growing.

Thus, data from 2023 to 2026 shows that this catch-up process is not the same for every SME, big organization, or country by itself, especially in the economic landscape of Central and Eastern Europe. The European Commission's Digital Decade Report (2026) highlights a strange contradiction regarding Romania's environment, that even if it has built some of the fastest internet networks in Europe, local businesses are not using digital tools to their full potential. Over the latest years, Romania has developed a two-tiered digital economy, where a highly digital sector made up for large multinational corporations that match the Western Europe's productivity standards meets the local small business sector that still uses traditional methods and avoids advanced data analytics (Vuta et al., 2022).

The case of Romania provides an insight into the situation in which there is a country that might look advanced on paper regarding the current economic paradigm, due to fast internet or basic digital skills, can still face a deep divide in advanced data processing and using the latest digital technologies in business processes and operations. Measuring how this divide impacts employee productivity is essential to understanding if SMEs can really survive in the modern global digitalized economy.

3. Methodology

To provide a structured answer to the studied phenomenon, the empirical investigation is guided by the core research objective: To quantify the operational magnitude of the digital divide in data analytics tool adoption between large companies and SMEs, while evaluating the alignment between national technology adoption discrepancies and structural labor productivity, alongside the velocity of the catch-up effect within emerging markets compared with the regional digital leaders.

For achieving the research objective, the current study utilizes secondary empirical data extracted from institutional databases compiled by Eurostat, between 2023 and 2025. The data has been harmonized to facilitate the cross-variable analysis, while the focus has been driven to a comparative analysis between Romania, the European Union as EU27 aggregate, and the digital benchmarks of the European single market, Denmark and Estonia.

4. Results and discussions

To translate raw technological adoption percentages and structural economic outputs into comparable variables, the study has been conducted by deploying two primary metrics: Adoption Relativity Index (ARI), and Productivity Performance Ratio (PPR).

The Adoption Relativity Index (ARI), as shown in equation (1), represents a metric that serves as a direct indicator of the internal digital divide, as instead of looking at a country's overall digitalization, it evaluates equity.

$$ARI = \frac{\% \text{ of SMEs using Data Analytics}}{\% \text{ of Large Enterprises using Data Analytics}} \quad (1)$$

An ARI score closes to 1.00 implies that small businesses (SMEs) are adopting data analytics at the exact same pace as large corporations, signaling a healthy economic ecosystem. On the other hand, a declining or low ARI score identifies a widening technological gap, where large enterprises gain competitive advantage by monopolizing advance data instruments, whereas SMEs remain structurally isolated in the current digital economy paradigm.

At the same time, the Productivity Performance Ratio (PPR) reflects the economic output gap between enterprise categories, as calculated by equation (2).

$$PPR = \frac{\text{Average Labor Productivity of SMEs (EUR per employee)}}{\text{Average Labor Productivity of Larger Enterprises (EUR per employee)}} \quad (2)$$

The PPR metric measures the financial value generated per SME employee relative to an employee in a large enterprise or a big organization. A rising PPR indicates structural economic convergence, meaning small firms are successfully optimizing their workforces and closing the efficiency gap with market leaders.

By analyzing the correlation between these two indicators, the fundamental economic premise can be explored, identifying whether closing the digital divide (a rising ARI) serves as a necessary mechanism for narrowing the macroeconomic labor productivity gap (a rising PPR).

As presented in Table 1, where the data has been retrieved from Eurostat (2026a), the structural divide between small and large businesses across all evaluated regions in 2025 is persistent. While large enterprises consistently present high digital intensity, almost reaching saturation, as shown for Denmark (96.45%) and Estonia (91.61%), SME technological integration remains heavily constrained. At the same time, on average, the European Union, considered as EU27, displays a massive adoption gap of 43.44 percentage points, highlighting that advance business intelligence tools, such as data analytics, remain primary concentrated within larger corporate structures.

Table 1. *Centralized Data Analytics Adoption Rates by Enterprise Size (averages)*

Country / Region	SMEs (10–249 employees) (%)	Large Enterprises (250+ employees) (%)	Adoption Gap (pp)	ARI
Denmark	58.82	96.45	37.63	0.609
Estonia	55.11	91.61	36.50	0.601
EU27	38.59	82.03	43.44	0.470
Romania	34.02	66.02	32.00	0.515

Source: Authors' own contribution.

However, a comparative evolution reveals a unique structural paradox applying to Romania, which although trails the EU27 average in overall adoption rates, its internal adoption gap stands at 32.00 percentage points, which is mathematically narrower than both the EU27 baseline, and the digital European leaders, such as Denmark (37.63 pp). This compressed gap does not signify that Romanian SMEs are outperforming the dominant western markets but is rather highlighting Romania's two-tiered digital economy, where large enterprises also underperform (66.02%) relative to their European competitors (82.03%).

Nevertheless, the fact that Romanian SMEs reached a level of 34.02% data analytics utilization rate in 2025 provides strong empirical evidence of the continuous catch-up effect present in the Romanian economic environment, where small local businesses are actively utilizing country's fast digital networks to modernize their systems and to narrow the structural technological divide.

At the same time, when analyzing the 2025 data, the EU27 exhibits an ARI score of 0.470 which confirms that at a macroeconomic single market level, European SMEs are adopting data analytics at less than half the rate of large enterprises. In contrast, digital leaders like Denmark (0.609) and Estonia (0.601) show the highest levels of technological balance. The results reveal that their small business ecosystems have developed the financial and human capital that was needed to actively keep up the transformation pace with larger corporations.

Once again, Romania presents a highly compelling economic circumstance. Its ARI score of 0.515 places the country significantly ahead of the EU27 average (0.470), establish a higher level of proportional equity between enterprises sizes, supporting the presence of a targeted catch-up effect in the Romanian market. However, because ARI represents a relative ratio, Romania's higher value is partially driven by the lower adoption baseline of its large companies (66.02%). Hence, while the country demonstrates positive trends in

digital balance, public policies should focus on boosting data usage across all enterprise scales to ensure this balance to real macroeconomic growth.

At the same time, the values presented in Table 2, collected from Eurostat (2026b), and compiled by the authors, provides a clear, macroeconomic overlook of the labor productivity gap across different enterprise scales. While cross-examined with the technological data from Table 1, these productivity values offer a perspective on how the digital divide directly mirrors structural economic performance.

Table 2. *Labor Productivity Gap and Performance Ratios by Enterprise Size (values stated in thousands of EUR per employee, excepting the PPR)*

Country / Region	SME Productivity (10–249 employees)	Large Enterprises Productivity (250+ employees)	Productivity Performance Ratio (PPR)
Denmark	71.96	125.08	57.53%
Estonia	45.42	54.44	83.43%
EU27	58.41	86.80	67.29%
Romania	28.11	41.84	67.18%

Source: Authors' own contribution.

As the baseline discrepancy, it is easily observable that across all countries, including the EU27 average, large enterprises generate higher economic value per employee than SMEs. This aligns smoothly with the scientific literature, which highlights that large enterprises and big organizations benefit easier from economies of scale and advanced digital frameworks.

At the same time, Denmark demonstrates the highest overall productivity values, while maintaining a lower Productivity Performance Ratio (PPR) of 57.53%, showing that even if the Danish SMEs are highly advanced, their large corporations are exceptionally productive, driving the baseline at a high point. On the other hand, Estonia, the other digital model of the European Union, displays a remarkable PPR of 83.43%, confirming that its high technology equity (ARI of 0.601) facilitates the framework for small business to perform almost as good as its large corporations.

Meanwhile, Romania is highlighting its strategic position, by exhibiting an aggregate baseline that is lower than the EU27 average, with SMEs generating 28.11 thousand EUR per employee and large firms generating 41.84 thousand EUR per employee. However, Romania's Productivity Performance Ratio (PPR) stands at 67.18%, which is almost identical with the EU27 average baseline (67.29%).

Hence, when Romania's position is evaluated, the relationship between digital adoption and economic convergence becomes evident. Romania's ARI score (0.515) sits above the EU average, meaning that the internal technological gap between SMEs and large enterprises is relatively narrow. This balanced digital adoption directly supports the country's productivity structure, as Romanian SMEs are successfully holding their ground, keeping the productivity ratio at the same level with the European Union's baseline.

Nevertheless, because the overall financial figures for both sectors in Romania are standing below the EU average, this balanced structure can only indicate a low-tier equilibrium. The data proves that while the catch-up effect is actively facilitating Romanian SMEs to close

the technology gap, national policy must focus on boosting the absolute intensity of data utilization.

Simply having a balanced ration in Romania's case, it is not enough. To achieve true economic convergence with the Western Europe, or the European digital leaders, both small and large Romanian enterprises must scale up their integration of advance business intelligence tools, driven by the digital transformation and the implementation of the latest digital technologies into the economic environment.

5. Conclusions

The present study explored how the digital divide in data analytics adoption impacts the structural labor productivity gap between SMEs and large firms. The calculated indicators are providing direct answers to the main research question of the study. They prove that a country's internal technology equity, measured by the Adoption Relativity Index (ARI), strongly influences its economic balance, which has been measured by the Productivity Performance Ratio (PPR).

Hence, the findings reveal that a narrower technological divide directly supports better performance, enhancing economic growth and competitive advantages. EU's digital frontrunners, such as Denmark and Estonia, utilize high technology equity to keep small businesses performance close to large enterprises. In this context, Romania demonstrates a clear macroeconomic catch-up effect, shown by its above the average ARI score of 0.515 and its PPR score of 67.18%, confirming that small domestic businesses are actively benefiting from country's fast digital infrastructure, that at the same time is narrowing the internal divide. However, because absolute productivity numbers for both business scales remain below the European Union (EU27) baseline, this balance represents a low-tier equilibrium.

On the other hand, despite its robust empirical framework, the current study is bounded by two primary limitations: the macro-level Eurostat aggregation scale, which groups all SMEs into a single category (10-249 employees), omitting micro-enterprises under 10 employees, and the exclusion of other external economic variables, such as national policies and management quality.

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Machiavellianism in the shadow economy: a contemporary influence on fiscal stability

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Abstract. *This paper argues that the popularised, pejorative sense of “Machiavellian”, the doctrine that ends license means, is precisely the self-rationalisation employed by actors in the shadow economy. By re-reading Machiavelli’s own conceptual vocabulary (virtù, fortuna, his functional critique of institutions) as an analytic lens on tax evasion and informality, the paper proposes a theoretical account of why economic actors circumvent fiscal obligations and what distinguishes this explanation from existing tax-morale and institutional-quality frameworks. The conceptual argument further connects Machiavellian informality to divergent fiscal capacity across EU Member States, contributing to the conference theme of economic convergence and resilience.*

Keywords: machiavellianism, shadow economy, fiscal resilience, economic convergence, institutional quality.

JEL Classification: H26, E26, A12, D91, O43.

1. Introduction

The term “Machiavellian” has appeared across academic literature and common discourse to characterise deliberate, morally questionable conduct driven exclusively by outcomes and self-interest. As the term gained wider currency, its original meaning became increasingly detached from Machiavelli himself, the political philosopher who gave the term its name. This paper argues that this designation has been appropriated and reshaped in ways that serve the interests of those operating within the informal economy. Modern economic conditions are marked by significant systemic strains, including disrupted supply chains, mounting geopolitical instability, and enduring informal activity. A critical insight is that economic actors engage in deliberate, calculated reasoning when navigating opportunities for tax non-compliance. This observation poses a normative challenge: by identifying the underlying motivations driving such behaviour, policymakers may design targeted interventions capable of producing meaningful change. Empirical evidence suggests that across EU member states, the size of the informal economy ranges from 8% to 35% of GDP, with tangible consequences for public revenues and the delivery of state services (Schneider, 2010). More recent estimates from Medina and Schneider (2018), covering data through 2015/2016, confirm that significant cross-country variation persists across Member States.

2. The Emergence of the Term “Machiavellian”

2.1. Niccolò Machiavelli and His Work

Niccolò Machiavelli was born in 1469 in Florence, during a period when Italy was experiencing political instability. Principalities and republics were rivals, leading foreign powers to intervene, which brought fragility to these city-states. Following the return to power of the Medici family, Machiavelli was removed from his position as Florentine chancellor after 14 years of diplomatic service. He retired to his home in Sant’Andrea in Percussina, where he wrote the most important works of his political philosophy: ‘The Prince’ (1513, published posthumously in 1532), ‘Discourses on Livy’, and ‘Florentine Histories’.

In ‘The Prince’, Machiavelli argues that a leader must possess *virtù* to shape the course of events in his favour and that of the people. This central concept represents several capacities a leader must have: flexibility according to the situations they face, the ability to change their behaviour, duality, pragmatism, and military competence.

In most cases, Machiavelli was misunderstood, and from this the term ‘Machiavellian’ originated. The first accusations appeared after his death in 1527, and his most bitter critics were religious and political leaders from France and England, they were the ones who transformed his name into a negative adjective. Today, the term describes behaviour that

pursues the attainment of power at any cost, regardless of the consequences. In 1970, Christie and Geis operationalised this popular notion through the Mach IV Scale in ‘Studies in Machiavellianism’, a 20-item questionnaire measuring cynicism and manipulativeness (Christie and Geis, 1970).

The central concept of Machiavelli’s work is *virtù*, signifying the leader’s ability to act flexibly, to foresee dangers, and to plan for the state’s success. Machiavelli believed that *virtù* was the only force that could counteract *fortuna*, the whims of fate. Modern psychology has reduced and reinterpreted these ideas such that *virtù* has been understood as personal cunning, even though the philosopher was referring to the common good.

3. Machiavellianism and Underground Power

The relationship between “Machiavellianism” and underground power is by no means accidental. What distinguishes a Machiavellian reading from existing frameworks is its focus on the *justificatory logic* of informal actors: tax-morale scholarship (Kirchler, 2007; Torgler, 2007) explains *when* and *how much* citizens comply, while institutional-quality research (Hellman, Jones and Kaufmann, 2003; Schneider, 2010) maps the systemic conditions for non-compliance. Neither framework addresses the cognitive script, the self-authorising narrative, through which actors rationalise circumventing the rules. The Machiavellian lens fills precisely this gap.

Consider first the relationship between necessity and the law. According to Machiavelli, when the people and the state are under threat, ordinary norms can be suspended. The same logic operates in the shadow economy: an entrepreneur who feels under fiscal pressure tends to frame rule-breaking as a matter of survival. Kirchler (2007) documents how adversarial interactions with tax authorities increase evasion, but does not account for why actors experience such pressure as a licence to evade. The Machiavellian script, ends justify means, provides that missing rationalisation.

The second connection runs through *fortuna* and *virtù*. People who possess *virtù* are prepared for any unforeseen situation. In the shadow economy, informal entrepreneurs do exactly this, developing adaptation strategies, bypassing laws, and building alternative networks specifically to protect their businesses from market instability. Institutional theory identifies these networks as symptoms of weak governance; the Machiavellian reading adds that actors who build them understand themselves as virtuous agents, nimble navigators of *fortuna*, rather than as rule-breakers.

The third connection is the functional critique of institutions. Machiavelli does not judge the ruler who acts as described in ‘The Prince’, but only those who destroy institutions for personal gain. This distinction maps onto what Hellman, Jones and Kaufmann (2003) call state capture: powerful interest groups, oligarchs or large firms, ‘privatise’ public decision-

making in Eastern European economies, while presenting themselves as competent actors simply adapting to a dysfunctional environment.

4. Economy and Geoeconomic Fragmentation

Putnam (1993) argues that democratic institutions depend fundamentally on the level of social capital and civic traditions present in a society. Civic engagement, political equality, solidarity, trust, and structures of association all determine whether governance becomes efficient and honest or degenerates into corruption and inefficiency. As Putnam demonstrates, even well-designed Western legal frameworks fail when transplanted into societies lacking these civic traditions.

In contemporary EU policy, the “Twin Transition” refers to the joint green and digital transformation of the European economy, a concept distinct from Putnam’s social-capital framework. Both dimensions, however, presuppose a degree of fiscal capacity and institutional trust that the shadow economy directly erodes. Where Machiavellian informality is widespread, states lack the revenue base to invest in either the ecological or the digital transition, producing divergent trajectories of fiscal resilience among Member States.

The informal economy has faced renewed pressure since 2020. Observers have noted that the pandemic and subsequent geopolitical disruptions may have expanded informality, as trade flows became harder to monitor and firms sought to shelter certain operations from regulatory scrutiny, though robust cross-country data for this period remain limited (Medina and Schneider, 2018).

5. The Shadow Economy and Fiscal Instability

The consequences of shadow economy activity are perhaps most apparent in the erosion of public fiscal receipts. This shortfall translates directly into the chronic underfunding of essential services such as education and healthcare, while the state, in seeking to offset the gap, shifts an increasing fiscal burden onto law-abiding taxpayers, a dynamic that progressively undermines confidence in the tax system itself. In the eighteenth chapter of 'The Prince', Machiavelli advances the proposition that a ruler is not bound by his commitments when honouring them would prove detrimental to his position. This argument has since been distorted by participants in the informal economy, who invoke it as a justification for personal gain, overlooking the fact that Machiavelli's reasoning was exclusively concerned with the ruler's responsibility toward the collective good and the stability of the state (Machiavelli, 2017).

Viewed through a Machiavellian framework, this amounts to a calculated distortion: those operating in the shadow economy appropriate the rhetorical weight of the argument while discarding its fundamentally civic dimension.

6. Public Policies

From a Machiavellian perspective, the state must possess its own *virtù* to make economic actors understand the gravity of their actions. This may be accomplished through a calibrated combination of incentivisation and coercion, striking an equilibrium that encourages voluntary compliance among business actors without generating the antagonistic relationship which, as Kirchler (2007) demonstrates, is liable to exacerbate non-compliance. Machiavellianism takes root in weak institutions; therefore, these must be strengthened. Overhauling public administration constitutes the foundational measure in this regard: so long as bureaucratic structures remain susceptible to corruption, legislative frameworks will retain little more than symbolic force. These dynamics carry immediate implications for the trajectory of economic convergence within the European Union. Member States in which Machiavellian informality is entrenched accumulate structural deficits in fiscal capacity, widening the gap with higher-trust economies and undermining the resilience that the conference theme identifies as a central challenge.

7. Conclusion

The present paper has contended that ‘Machiavellianism’, understood in its widely disseminated, pejorative form, constitutes a philosophical framework uniquely capable of exposing the self-legitimising rationale underlying informal economic conduct, in a manner that prevailing tax-morale and institutional-quality approaches fail to capture. While informality may be understood as a calculated adaptation to deficient institutional environments, it is equally a form of conduct that economic agents rationalise through a rhetorical framework that the Machiavellian tradition inadvertently furnished. Addressing this phenomenon effectively demands that the state fundamentally rethink the terms of its relationship with citizens as fiscal subjects, reconstituting the implicit compact that underpins tax compliance. Transparency, social equity, and mutual trust are the foundational conditions, and the resilience of a political and economic regime ultimately depends on the state's capacity to generate consent and legitimacy. At the level of the European Union, the normative conclusion is unambiguous: achieving meaningful convergence in fiscal capacity demands not merely structural and administrative reform, but a deeper, culturally embedded renewal of civic confidence in public institutions.

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AI-augmented governance and economic convergence in the European Union: evidence from emerging markets

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Abstract. *This paper examines the relationship between artificial intelligence (AI), governance modernization, and economic convergence within the European Union in the context of geopolitical fragmentation and the Twin Transition. While existing research has extensively explored digital transformation, governance, and convergence separately, limited attention has been given to their interaction in emerging European economies.*

Using a qualitative-comparative approach based on institutional and macroeconomic analysis, the study assesses how differences in digital readiness, innovation capacity, and institutional quality influence the convergence effects of AI adoption. The findings suggest that AI-augmented governance can enhance institutional efficiency, productivity growth, and macroeconomic resilience, thereby supporting economic convergence. However, unequal technological capabilities and digital asymmetries may also reinforce divergence between advanced and emerging Member States.

The paper argues that the convergence potential of artificial intelligence depends not only on technological adoption but also on coordinated European investment, human-capital development, and institutional adaptability. AI should therefore be understood as a strategic economic and governance instrument whose effects are conditioned by the inclusiveness of digital transformation.

Keywords: Artificial Intelligence; Economic Convergence; European Union; Digital Governance; Strategic Autonomy.

JEL Classification: O33, F15, E61, H11, C88.

1. Introduction

The European Union is currently experiencing a period of profound economic and institutional transformation driven by geopolitical fragmentation, rapid technological advancement, the reconfiguration of global supply chains, inflationary pressures, and the transition towards a digital and climate-neutral economy. The combined effects of the COVID-19 pandemic, the energy crisis triggered by the Russian-Ukrainian conflict, and the increasing fragility of global economic interdependence have significantly reshaped the operational environment of the European economy (European Commission, 2023; International Monetary Fund, 2024). Within this context, economic convergence—historically regarded as one of the fundamental objectives of European integration—faces new challenges associated with technological asymmetries, institutional disparities, and uneven adaptation capacities among Member States.

A central element of this transformation is the Twin Transition, which refers to the simultaneous digital and green modernization of production systems, governance structures, and labor markets (European Commission, 2021a). While these developments create opportunities for productivity growth, industrial modernization, and sustainable development, they also reveal significant differences in digital infrastructure, innovation capacity, institutional quality, and fiscal flexibility across the European Union. Consequently, the benefits of digital transformation are not distributed equally, raising concerns regarding the persistence or even intensification of structural disparities between advanced and emerging European economies.

Within this broader context, artificial intelligence (AI) has emerged as one of the most influential technologies shaping contemporary economic and institutional development. Advances in machine learning, predictive analytics, automation technologies, and large-scale computational infrastructures increasingly affect productivity dynamics, governance frameworks, macroeconomic coordination, and industrial competitiveness (Brynjolfsson and McAfee, 2014). As a result, AI should no longer be viewed solely as a technological innovation but also as a strategic economic and governance instrument with the potential to influence long-term development trajectories.

The growing relevance of artificial intelligence is closely connected to the European Union's ambition to strengthen strategic autonomy and technological sovereignty. Disruptions in global supply chains, semiconductor shortages, cybersecurity vulnerabilities, and increasing geopolitical competition among major global powers have highlighted Europe's dependence on external technological ecosystems (European Commission, 2023). In response, European institutions have intensified efforts to enhance digital competitiveness through initiatives such as the Digital Compass 2030, the European Chips Act, and the Artificial Intelligence Act (European Parliament, 2024).

However, the diffusion of AI capabilities across the European Union remains uneven. Economically advanced Member States generally benefit from stronger innovation ecosystems, higher research and development expenditure, advanced digital infrastructures, and greater institutional readiness to integrate AI technologies into governance and industrial systems. In contrast, many emerging European economies

continue to face structural barriers related to lower levels of technological investment, weaker innovation ecosystems, institutional inefficiencies, and limited digital literacy (OECD, 2024). Under these circumstances, artificial intelligence may function simultaneously as a mechanism for convergence and as a potential source of divergence.

From a governance perspective, AI-driven systems offer important opportunities for institutional modernization and macroeconomic resilience. Artificial intelligence can enhance administrative efficiency, optimize fiscal coordination, strengthen crisis-anticipation mechanisms, and improve public-service delivery through predictive analytics and automated decision-support systems (Sun and Medaglia, 2019). For emerging European economies characterized by administrative inefficiencies and institutional constraints, such technologies may contribute to accelerated modernization and improved convergence prospects.

At the same time, existing research highlights significant risks associated with AI-driven transformation, including labor-market polarization, technological displacement of employment, cybersecurity vulnerabilities, algorithmic opacity, and the concentration of digital power among technologically dominant actors (Acemoglu and Restrepo, 2018). Unequal access to digital infrastructure, advanced computational resources, and innovation capabilities may therefore exacerbate regional inequalities and challenge the cohesion objectives traditionally pursued by the European Union.

Although contemporary literature provides extensive insights into digital transformation, technological competitiveness, governance modernization, and economic convergence, these dimensions are often examined separately. Limited attention has been devoted to understanding how AI-augmented governance influences convergence dynamics within emerging European economies under conditions of geopolitical fragmentation, strategic autonomy, and the Twin Transition. Addressing this gap is increasingly important given the growing role of artificial intelligence in European economic and institutional policymaking.

Against this background, the present study investigates the extent to which AI-augmented governance can contribute to economic convergence within the European Union. More specifically, the paper examines whether artificial intelligence can strengthen institutional efficiency, productivity growth, macroeconomic resilience, and strategic autonomy, while also assessing the risk that technological asymmetries may reinforce divergence between advanced and emerging Member States.

The analysis is guided by four research questions. First, to what extent can AI-augmented governance mitigate institutional inefficiencies in emerging European economies? Second, how do technological asymmetries influence convergence dynamics within the European Union? Third, can artificial intelligence strengthen macroeconomic resilience and strategic autonomy? Finally, does the digital transition risk intensifying divergence between core and peripheral Member States?

The paper contributes to the existing literature by integrating perspectives from convergence theory, institutional economics, and digital governance into a unified analytical framework for examining the role of artificial intelligence in the European

Union. Particular attention is given to emerging European economies, where technological capacity and institutional adaptability play a critical role in determining convergence outcomes. The study argues that artificial intelligence should be understood not only as a productivity-enhancing technology but also as a strategic economic and governance instrument whose impact on convergence depends on technological inclusiveness, institutional quality, and coordinated European investment.

2. Literature Review

2.1. Economic Convergence and Structural Asymmetries in the European Union

Economic convergence has long represented one of the fundamental objectives of European integration. Rooted in neoclassical growth theory, convergence suggests that less-developed economies can achieve faster growth than advanced economies through capital accumulation, technological diffusion, and productivity improvements (Solow, 1956). Building upon this perspective, Barro and Sala-i-Martin (1992) introduced the concept of β -convergence, arguing that poorer economies tend to grow more rapidly than wealthier ones, provided that institutional conditions and resource allocation mechanisms support efficient development.

However, the contemporary literature increasingly recognizes that convergence is neither automatic nor uniform across regions. Several scholars distinguish between absolute convergence, conditional convergence, and club convergence. While absolute convergence assumes that all economies eventually converge towards similar income levels, conditional convergence emphasizes the importance of structural characteristics such as institutional quality, human capital, and technological capabilities. Club convergence further suggests that economies with similar structural conditions tend to converge among themselves while remaining separated from less developed groups (Barro and Sala-i-Martin, 1992).

Within the European Union, convergence has historically been supported through cohesion policy, trade integration, labor mobility, and structural funding mechanisms (Molle, 2007). The enlargement towards Central and Eastern Europe was largely justified by the expectation that participation in the Single Market would accelerate modernization and reduce developmental disparities. Empirical evidence indicates that several emerging economies experienced significant improvements in GDP growth and productivity following EU accession (Rapacki and Próchniak, 2009).

Nevertheless, recent research challenges the assumption that economic integration alone is sufficient to guarantee convergence. Stiglitz (2019) argues that globalization and technological change often generate asymmetric benefits that favor economies with stronger institutions, advanced innovation ecosystems, and greater adaptive capacity. Similarly, Rodrik (2011) highlights that economic integration may reinforce structural divergence when not accompanied by coordinated industrial policies and redistributive mechanisms.

Recent crises, including the COVID-19 pandemic, the Eurozone sovereign debt crisis, and growing geopolitical fragmentation, have further exposed persistent asymmetries within

the European economy (European Commission, 2023). Differences in technological readiness, energy dependency, innovation capacity, and institutional resilience continue to shape the ability of Member States to adapt to external shocks. Consequently, contemporary convergence increasingly depends not only on market integration but also on governance quality, technological competitiveness, and institutional adaptability.

Against this background, the growing importance of artificial intelligence introduces a new dimension to convergence dynamics. Differences in AI adoption, digital infrastructure, and technological capabilities may either accelerate productivity catch-up in emerging economies or reinforce existing disparities between advanced and peripheral Member States. Understanding this relationship is therefore essential for evaluating the future trajectory of economic convergence within the European Union.

2.2. Artificial Intelligence and Digital Transformation

Artificial intelligence has emerged as one of the most transformative technologies of the digital era, influencing productivity, industrial competitiveness, governance systems, and labor markets (Brynjolfsson and McAfee, 2014). Advances in machine learning, predictive analytics, automation technologies, and large-scale computational infrastructures have expanded the capacity of organizations and governments to process information, optimize decision-making, and improve operational efficiency.

From a theoretical perspective, technological revolutions have historically acted as catalysts for structural economic transformation. Perez (2002) argues that major technological paradigms reshape institutional arrangements, production systems, and competitive advantages, generating both opportunities and adjustment challenges. Within this framework, artificial intelligence represents more than a technological innovation; it constitutes a general-purpose technology capable of influencing multiple sectors simultaneously.

Existing literature highlights several potential benefits associated with AI adoption. Intelligent systems can improve productivity through automation, process optimization, predictive capabilities, and enhanced data management (OECD, 2024). Furthermore, artificial intelligence may contribute to innovation, administrative modernization, and greater macroeconomic resilience by improving forecasting capabilities and supporting evidence-based decision-making.

However, the literature also presents a more critical perspective regarding the long-term implications of AI-driven transformation. Acemoglu and Restrepo (2018) argue that automation may contribute to labor-market polarization and technological displacement, particularly among routine and low-skilled occupations. Other scholars emphasize risks related to digital inequality, algorithmic bias, cybersecurity vulnerabilities, and the growing concentration of technological power among a limited number of global actors (Zuboff, 2019).

These contrasting perspectives suggest that the effects of artificial intelligence are highly dependent on institutional and policy conditions. Mazzucato (2021) argues that technological transformation should not be viewed exclusively as a market-driven process

but rather as a development trajectory shaped by state capacity, public investment, and industrial policy. Consequently, the economic benefits associated with AI adoption are likely to vary significantly across countries depending on their innovation ecosystems, regulatory frameworks, educational systems, and technological readiness.

Within the European Union, these considerations are particularly relevant given the significant differences in digital maturity across Member States. While advanced economies generally possess stronger innovation ecosystems, greater research and development capacity, and more developed digital infrastructures, emerging economies often face structural constraints that may limit the diffusion and effectiveness of AI technologies (OECD, 2024). As a result, artificial intelligence may simultaneously function as a driver of productivity growth and modernization, while also creating new forms of technological asymmetry capable of influencing convergence dynamics across the European Union.

2.3. AI-Augmented Governance and Strategic Autonomy

The integration of artificial intelligence into governance systems has generated increasing academic and policy interest due to its potential to transform public administration, regulatory processes, and economic coordination. AI-augmented governance can be broadly understood as the use of intelligent computational systems to support decision-making, public-service delivery, fiscal management, and regulatory oversight. Rather than replacing public institutions, artificial intelligence increasingly functions as a complementary tool capable of enhancing administrative capacity and institutional effectiveness.

Existing literature identifies several dimensions through which AI can influence governance outcomes. First, AI supports administrative automation by reducing bureaucratic complexity and improving the efficiency of routine public-sector operations. Second, predictive policymaking enables governments to anticipate economic, social, and fiscal developments through real-time data analysis. Third, AI contributes to regulatory enforcement by improving monitoring capabilities, detecting irregularities, and supporting compliance mechanisms (Meijer and Bolívar, 2016). Together, these applications have the potential to increase responsiveness, transparency, and policy effectiveness.

At the European level, AI-driven governance is increasingly linked to the broader objective of strategic autonomy. Growing geopolitical fragmentation, supply-chain disruptions, semiconductor shortages, and cybersecurity vulnerabilities have reinforced concerns regarding Europe's technological dependence on external actors (European Commission, 2023). Consequently, the European Union has adopted a series of initiatives—including the Digital Compass 2030, the European Chips Act, and the Artificial Intelligence Act—to strengthen technological sovereignty while maintaining democratic accountability and regulatory standards (European Parliament, 2024).

However, the relationship between AI adoption and strategic autonomy remains uneven across Member States. The capacity to develop and deploy advanced AI systems depends on factors such as research and development expenditure, digital infrastructure, institutional quality, and innovation ecosystems. As Mazzucato (2021) argues,

technological leadership is strongly influenced by strategic public investment and state capacity rather than by market forces alone.

This divergence is illustrated in Table 1. Countries such as Germany, France, and the Netherlands exhibit higher levels of digital readiness, stronger research capacity, and more advanced AI ecosystems. In contrast, Romania and Bulgaria continue to display lower levels of digital maturity and innovation investment. These differences suggest that the pursuit of strategic autonomy may generate asymmetric outcomes unless coordinated European policies address technological disparities between advanced and emerging economies.

Consequently, AI-augmented governance should be understood not only as a mechanism for improving public-sector performance but also as a strategic factor influencing competitiveness, resilience, and convergence dynamics within the European Union.

2.4. Artificial Intelligence, Labor Markets, and Social Sustainability

The impact of artificial intelligence on labor markets represents one of the most debated dimensions of contemporary technological transformation. While AI-driven automation can enhance productivity, accelerate innovation, and improve operational efficiency, its effects on employment and social cohesion remain subject to considerable academic debate (Brynjolfsson and McAfee, 2014).

Optimistic perspectives emphasize the capacity of artificial intelligence to create new economic opportunities, increase labor productivity, and support the emergence of high-value industries. In this view, technological progress stimulates economic growth while generating demand for new skills and occupations. Such developments may contribute to long-term competitiveness and improve living standards across the European Union.

In contrast, critical perspectives highlight the risks associated with technological displacement and labor-market polarization. Acemoglu and Restrepo (2018) argue that automation disproportionately affects routine and low-skilled occupations, potentially increasing inequality and reducing employment opportunities for vulnerable groups. The benefits of AI adoption are therefore unlikely to be distributed evenly across sectors, regions, or demographic categories.

These concerns are particularly relevant within the European Union, where significant differences exist in educational attainment, digital literacy, workforce adaptability, and innovation capacity. Emerging economies with lower levels of technological readiness may face greater adjustment costs during the digital transition. At the same time, demographic aging and labor shortages across many European countries increase the strategic importance of intelligent automation systems capable of mitigating workforce decline (European Commission, 2023).

The literature increasingly suggests that the long-term socioeconomic effects of artificial intelligence depend on complementary investments in human capital. Workforce reskilling, lifelong learning, digital literacy programs, and educational modernization have become essential prerequisites for ensuring that productivity gains translate into inclusive economic

development. Without such measures, technological progress may contribute to widening inequalities rather than fostering convergence.

Furthermore, critical scholars challenge the assumption that technological innovation alone can resolve complex economic and social problems. Morozov (2013) describes this tendency as "technological solutionism," arguing that sustainable development requires broader institutional coordination, democratic accountability, and redistributive mechanisms. Consequently, artificial intelligence should be viewed as an enabling technology whose outcomes are conditioned by governance quality, policy choices, and institutional capacity.

Overall, the literature indicates that artificial intelligence functions simultaneously as a driver of modernization and a potential source of structural divergence. Its long-term impact on economic convergence within the European Union ultimately depends on the interaction between technological adoption, institutional quality, human-capital development, and coordinated public investment.

Table 1. *Comparative Digital and Innovation Indicators within the European Union*

Country	DESI Index Ranking (2024)	RandD Expenditure (% GDP)	AI Readiness Level	GDP per Capita (EUR)
Netherlands	High	2.3%	Advanced	57,000
Germany	High	3.1%	Advanced	52,000
France	High	2.2%	Advanced	44,000
Poland	Medium	1.4%	Moderate	22,000
Romania	Low	0.5%	Emerging	18,000
Bulgaria	Low	0.8%	Emerging	16,000

Source: European Commission Digital Economy and Society Index (DESI, 2024); Eurostat (2024); OECD AI Policy Observatory (2024).

Note: DESI rankings reflect countries' overall digital performance, including digital infrastructure, digital skills, business digitalization, and digital public services. AI Readiness levels are derived from the OECD AI Policy Observatory and indicate the capacity of countries to develop, adopt, and integrate artificial intelligence technologies through institutional quality, innovation ecosystems, digital infrastructure, and research capabilities.

The data presented in Table 1 reveal substantial differences in digital readiness and innovation capacity across the European Union. Advanced economies such as Germany, France, and the Netherlands combine higher levels of R&D expenditure with stronger AI readiness and higher income levels, creating favorable conditions for the adoption of AI-driven governance systems. In contrast, Romania and Bulgaria continue to display lower levels of digital maturity and innovation investment, which may limit their ability to fully benefit from artificial intelligence technologies. Poland occupies an intermediate position, illustrating the potential for technological catch-up among emerging economies. These disparities suggest that the convergence effects of artificial intelligence are likely to depend on the interaction between technological capacity, institutional quality, and investment intensity.

3. Research Methodology

This study employs a qualitative-comparative research design to examine the relationship between artificial intelligence, governance modernization, and economic convergence within the European Union. Given the interdisciplinary nature of the research topic, the methodological framework integrates perspectives from institutional economics, political economy, digital governance, and macroeconomic resilience studies. The objective is not to establish causal relationships through econometric modeling, but rather to explore how differences in technological capacity and institutional readiness may influence convergence dynamics in the context of AI adoption.

The research adopts a predominantly deductive and exploratory approach. The deductive component is grounded in convergence theory, which emphasizes the importance of technological modernization and institutional quality as determinants of long-term economic development (Barro and Sala-i-Martin, 1992). Building upon this theoretical foundation, the study examines whether AI-augmented governance can strengthen institutional efficiency and contribute to convergence processes within the European Union. The exploratory component reflects the relatively recent integration of artificial intelligence into governance systems and the limited availability of long-term empirical evidence regarding its economic consequences (OECD, 2024).

The unit of analysis consists of selected European Union Member States characterized by different levels of digital development, innovation capacity, and economic performance. Particular attention is given to emerging economies from Central and Eastern Europe, especially Romania and Poland, which are compared with more technologically advanced economies such as Germany, France, and the Netherlands. These countries were selected through purposive sampling in order to capture variations in digital readiness, research and development intensity, AI adoption capacity, and institutional quality. This comparative approach allows the study to explore how technological asymmetries may influence convergence outcomes across different development contexts.

The analysis relies primarily on secondary data obtained from highly reputable institutional and academic sources. These include publications, policy reports, statistical datasets, and macroeconomic indicators produced by the European Commission, Eurostat, the European Central Bank, the OECD, the International Monetary Fund, the World Economic Forum, and the European Investment Bank. The use of these sources enhances the reliability, comparability, and policy relevance of the analysis.

Methodologically, the study applies a structured comparative analysis. Rather than focusing on a single country case, the research compares groups of advanced and emerging economies using a set of common indicators related to digital readiness, innovation performance, institutional capacity, governance quality, and macroeconomic resilience. The comparative assessment is supported by the indicators presented in Table 1 and by evidence derived from the existing academic and institutional literature.

The analytical framework is organized around four interconnected dimensions.

The first dimension examines institutional modernization and governance efficiency. Existing research suggests that AI-driven governance systems can improve administrative responsiveness, optimize fiscal coordination, reduce bureaucratic inefficiencies, and enhance public-service delivery through predictive analytics and automated decision-support mechanisms (Sun and Medaglia, 2019).

The second dimension focuses on technological asymmetry and divergence risk within the European Union. Differences in digital infrastructure, innovation ecosystems, research capacity, and access to technological investment may significantly influence the distribution of productivity gains associated with artificial intelligence (Mazzucato, 2021).

The third dimension investigates macroeconomic resilience in the context of geopolitical fragmentation and strategic autonomy. Artificial intelligence increasingly contributes to crisis anticipation, supply-chain coordination, economic forecasting, and adaptive governance through the processing of real-time information (European Commission, 2023).

The fourth dimension addresses labor-market transformation and social sustainability. AI-driven automation may simultaneously generate productivity gains and labor-market disruption, particularly among routine and low-skilled occupations vulnerable to technological substitution (Acemoglu and Restrepo, 2018). Consequently, workforce adaptability, digital literacy, educational modernization, and reskilling capacity are treated as critical variables influencing convergence potential.

Based on these analytical dimensions, the study develops a conceptual framework in which artificial intelligence functions as an intermediary factor linking governance modernization, productivity growth, and economic convergence. At the same time, the framework recognizes that technological asymmetries and unequal digital capacities may create divergence effects, particularly among Member States with different levels of institutional and technological development.

Although the study benefits from the use of high-quality institutional data and a comparative analytical perspective, several limitations should be acknowledged. First, the rapid evolution of AI technologies creates uncertainty regarding their long-term economic implications. Second, differences in the measurement of AI readiness and digital performance across countries limit full comparability. Third, because the adoption of AI within governance systems remains relatively recent, some long-term institutional and convergence effects cannot yet be empirically assessed. Nevertheless, the methodological approach provides a coherent framework for examining the potential relationship between artificial intelligence, governance modernization, and economic convergence within the European Union.

Figure 1. *Theoretical Framework of AI-Augmented Convergence Dynamics*

Source: Author's elaboration based on OECD (2024), European Commission (2023), and Acemoglu and Restrepo (2018).

The revised framework conceptualizes artificial intelligence as an intermediary factor linking governance modernization and economic convergence within the European Union. Unlike linear interpretations of technological development, the model recognizes a reciprocal relationship between AI adoption and governance quality. While artificial intelligence can enhance administrative capacity, institutional efficiency and policy effectiveness, the successful implementation of AI systems also depends on the quality of existing institutions, regulatory frameworks, and governance structures.

The framework further highlights the role of several moderating factors, including digital infrastructure, innovation ecosystems, investment intensity, policy coordination, and human-capital development. These variables influence the extent to which artificial intelligence contributes to productivity growth and macroeconomic resilience. Consequently, the economic effects of AI adoption are expected to vary significantly across Member States according to their technological readiness and institutional capacity.

At the same time, the model incorporates a divergence pathway that reflects the risks associated with uneven digital transformation. Differences in technological capabilities, innovation capacity, and access to digital infrastructure may limit the ability of emerging economies to benefit from AI-driven modernization. Under such conditions, artificial intelligence may reinforce existing disparities rather than promote convergence.

The comparative indicators presented in Table 1 provide preliminary evidence of these asymmetries. Advanced economies such as Germany, France, and the Netherlands display stronger digital readiness and innovation capacity than emerging economies such as Romania and Bulgaria. These differences suggest that the convergence effects of artificial intelligence depend not only on technological adoption itself but also on broader institutional and developmental conditions.

Several methodological limitations should nevertheless be acknowledged. First, the rapid evolution of artificial intelligence technologies creates uncertainty regarding their long-term economic and institutional effects. Second, differences in the measurement of AI readiness and digital performance across Member States complicate the construction of fully standardized comparative datasets. Third, because the integration of AI into governance systems remains relatively recent, some long-term convergence and resilience outcomes cannot yet be empirically validated.

Despite these limitations, the proposed framework offers a coherent analytical foundation for examining the interaction between artificial intelligence, governance modernization, strategic autonomy, and economic convergence within the contemporary European Union.

4. Artificial Intelligence and Economic Convergence in the European Union

4.1. AI-Augmented Governance and Institutional Modernization

The integration of artificial intelligence into governance systems is increasingly reshaping the institutional architecture of modern economies. Within the European Union, AI-driven

governance solutions are progressively adopted in areas such as fiscal administration, regulatory compliance, public-service delivery, predictive policymaking, and crisis management (OECD, 2024). Consequently, artificial intelligence should be understood not merely as a technological innovation but as a governance instrument capable of improving institutional effectiveness and strengthening macroeconomic coordination.

The potential benefits of AI-enhanced governance are particularly relevant for emerging European economies. Several Central and Eastern European countries continue to face challenges related to bureaucratic complexity, administrative fragmentation, and limited institutional efficiency. In such contexts, intelligent automation systems can contribute to the modernization of public administration by streamlining administrative procedures, improving expenditure monitoring, and supporting evidence-based decision-making through real-time data analysis (Sun and Medaglia, 2019).

However, the ability to successfully implement AI-driven governance varies considerably across Member States. Countries with advanced digital infrastructures, strong innovation ecosystems, and higher institutional quality are generally better positioned to integrate artificial intelligence into public administration. For example, Germany and the Netherlands have invested extensively in digital public services and innovation ecosystems, while Romania and Bulgaria continue to face constraints related to digital readiness and institutional capacity (European Commission, 2024; OECD, 2024). These differences suggest that AI-driven governance may contribute to convergence only when accompanied by broader institutional modernization and investment efforts.

Therefore, the relationship between artificial intelligence and convergence is mediated by existing structural conditions. AI technologies can accelerate institutional modernization in emerging economies, but their effectiveness depends on the quality of governance, digital infrastructure, and administrative adaptability.

4.2. Artificial Intelligence and Productivity Dynamics

Productivity growth remains one of the principal drivers of long-term economic convergence. According to convergence theory, less-developed economies can reduce developmental gaps through technological diffusion and productivity catch-up mechanisms (Barro and Sala-i-Martin, 1992). Within the digital economy, artificial intelligence increasingly represents a key source of productivity enhancement across both public and private sectors.

AI-enabled systems improve productivity through process automation, predictive maintenance, supply-chain optimization, advanced data analytics, and operational efficiency improvements. Brynjolfsson and McAfee (2014) argue that intelligent automation reduces transaction costs while enhancing organizational flexibility and innovation capacity. As a result, artificial intelligence has the potential to strengthen competitiveness and accelerate economic growth.

Nevertheless, the distribution of productivity gains remains highly uneven across the European Union. Advanced economies generally benefit from stronger research ecosystems, greater AI investment capacity, more sophisticated industrial structures, and higher levels of digital readiness. Emerging economies often encounter limitations related to lower research and development expenditure, weaker innovation ecosystems, and reduced technological investment.

Table 2 highlights these structural differences.

Table 2. *Structural Factors Influencing AI-Driven Productivity Convergence*

Factor	Advanced Economies	Emerging Economies
Digital Infrastructure	Highly developed	Uneven development
AI Investment Capacity	Strong	Limited
Institutional Efficiency	High	Moderate / Low
Innovation Ecosystems	Advanced	Emerging
Workforce Digital Skills	High	Uneven
Productivity Gains from AI	Accelerated	Gradual

Source: Author's synthesis based on OECD (2024), Eurostat (2024), and European Commission (2023).

The evidence summarized in Table 2 suggests that the productivity effects of artificial intelligence are strongly influenced by pre-existing structural conditions. Advanced economies possess complementary assets that facilitate AI adoption and maximize productivity gains. By contrast, emerging economies often experience a slower diffusion of digital technologies and face greater challenges in transforming technological adoption into measurable productivity improvements.

Poland provides an illustrative example of gradual technological catching-up through sustained investment in digital infrastructure and innovation capacity. Romania, despite recent progress in digital services, continues to face constraints associated with lower research intensity and uneven technological development. In contrast, Germany and the Netherlands demonstrate how mature innovation ecosystems can accelerate the productivity benefits associated with artificial intelligence adoption.

Consequently, artificial intelligence may simultaneously act as a driver of convergence and divergence. When supported by coordinated investment, institutional modernization, and workforce development, AI can facilitate productivity catch-up in emerging economies. However, persistent technological asymmetries risk concentrating productivity gains within already advanced economic centers, thereby reinforcing existing disparities across the European Union.

4.3. Artificial Intelligence and Macroeconomic Resilience

Macroeconomic resilience has become an increasingly important objective of European economic policy following the succession of crises associated with the COVID-19 pandemic, energy-market volatility, inflationary pressures, and geopolitical fragmentation. In this context, resilience refers to the capacity of economic systems and institutions to

anticipate, absorb, and adapt to external shocks while maintaining functional stability and long-term growth potential (European Central Bank, 2024).

Artificial intelligence is increasingly recognized as a tool that can strengthen macroeconomic resilience through predictive economic analysis, inflation monitoring, supply-chain management, fiscal optimization, and crisis-response coordination. The ability to process large volumes of real-time information allows governments and institutions to identify emerging risks more rapidly and improve policy responsiveness during periods of uncertainty.

The importance of these capabilities has grown in parallel with the European Union's pursuit of strategic autonomy. Geopolitical fragmentation, friend-shoring strategies, and disruptions in global production networks are reshaping trade patterns and industrial competitiveness (International Monetary Fund, 2023). In this environment, countries with advanced digital infrastructures and data-driven governance systems are generally better equipped to respond to external shocks and maintain macroeconomic stability.

However, the contribution of artificial intelligence to resilience is not unconditional. While AI can improve forecasting and coordination capabilities, it also creates new vulnerabilities related to cybersecurity risks, technological dependency, and informational asymmetries. Consequently, resilience within the digital economy depends not only on technological adoption but also on institutional oversight, regulatory capacity, and technological sovereignty.

The experience of recent crises suggests that economies combining strong digital capabilities with effective governance structures are more likely to maintain institutional flexibility and economic stability. Therefore, artificial intelligence should be viewed as a complementary component of resilience-building strategies rather than as a standalone solution to economic vulnerability.

4.4. Strategic Autonomy and Divergence Risk

The relationship between artificial intelligence and strategic autonomy has become a central issue within contemporary European economic policy. Traditionally associated with defense and security, the concept of strategic autonomy increasingly encompasses technological infrastructure, semiconductor production, cybersecurity, digital governance, and innovation capacity (Leonard et al., 2021).

European initiatives such as the Artificial Intelligence Act and the European Chips Act seek to strengthen technological sovereignty while preserving democratic accountability and regulatory transparency (European Parliament, 2024). These initiatives reflect growing concerns regarding Europe's dependence on external technological ecosystems and the strategic importance of maintaining domestic innovation capabilities.

Nevertheless, the pursuit of strategic autonomy may produce uneven outcomes across Member States. Advanced economies generally possess greater fiscal flexibility, stronger research ecosystems, and higher investment capacity, enabling them to develop and deploy

AI technologies more effectively. Emerging economies, by contrast, often face constraints related to technological infrastructure, innovation financing, and research capacity.

The opportunities and risks associated with AI-driven transformation are summarized in Table 3.

Table 3. *Opportunities and Risks Associated with AI-Augmented Governance*

Opportunities	Risks
Administrative efficiency	Algorithmic opacity
Productivity growth	Labor displacement
Improved crisis management	Cybersecurity vulnerabilities
Better fiscal coordination	Technological dependency
Faster public service delivery	Digital inequality
Enhanced macroeconomic resilience	Regional divergence

Source: Author's synthesis based on OECD (2024), European Parliament (2024), and Acemoglu and Restrepo (2018).

Table 3 illustrates the dual nature of artificial intelligence within the European Union. On the one hand, AI can improve administrative performance, strengthen crisis-management capacity, and support economic competitiveness. On the other hand, unequal access to technological resources may reinforce existing asymmetries between advanced and emerging economies. Consequently, strategic autonomy should not be understood exclusively as a technological objective but also as a cohesion challenge requiring coordinated European investment and policy support.

The analysis suggests that artificial intelligence can strengthen Europe's competitiveness and resilience. However, without inclusive technological development and effective policy coordination, AI-driven transformation may unintentionally deepen regional disparities and undermine convergence objectives.

4.5. Labor Markets, Social Sustainability, and Inclusive Convergence

The impact of artificial intelligence on labor markets remains one of the most debated aspects of contemporary technological transformation. While AI-driven automation has the potential to increase productivity and accelerate innovation, it may also generate labor-market disruption and contribute to employment polarization (Acemoglu and Restrepo, 2018).

Technological change is expected to increase demand for highly specialized skills related to data analysis, artificial intelligence management, cybersecurity, and digital coordination. As a result, educational modernization, workforce reskilling, and lifelong learning have become critical determinants of competitiveness within the digital economy.

According to the World Economic Forum (2025), technological transformation will simultaneously create and eliminate millions of jobs globally. However, the effects of these changes will vary substantially across countries and sectors. Economies that successfully adapt their educational systems and workforce-training strategies are more likely to capture the benefits associated with AI adoption while minimizing social disruption.

Within the European Union, differences in digital literacy, educational attainment, and workforce adaptability create significant variations in the capacity to respond to technological change. Advanced economies generally possess stronger institutional mechanisms for workforce reskilling and technological adaptation, whereas emerging economies may face greater challenges in managing labor-market transitions.

These considerations highlight the importance of social sustainability within the broader convergence process. Economic convergence cannot be assessed exclusively through GDP growth or productivity indicators. Long-term convergence also requires social cohesion, workforce adaptability, institutional trust, and equitable access to technological opportunities.

Consequently, the convergence effects of artificial intelligence depend not only on technological adoption but also on investments in human capital and social inclusion. Without coordinated efforts to strengthen digital literacy, educational modernization, and workforce adaptability, AI-driven transformation risks reinforcing existing inequalities and limiting the capacity of emerging economies to benefit from technological progress. Conversely, inclusive digital-transition strategies can transform artificial intelligence into a catalyst for sustainable convergence across the European Union.

5. Policy Implications

The findings of this study suggest that the relationship between artificial intelligence and economic convergence within the European Union depends on the interaction between technological capacity, institutional quality, governance adaptability, and coordinated strategic investment. As digital transformation increasingly shapes productivity, competitiveness, and resilience, traditional convergence policies based primarily on market integration and structural funding require substantial adaptation to the realities of the digital economy.

The analysis indicates that artificial intelligence can contribute to institutional modernization, productivity growth, and macroeconomic resilience. However, the benefits associated with AI adoption are unevenly distributed across Member States due to significant differences in digital infrastructure, innovation capacity, research intensity, and institutional readiness. Consequently, the future of European convergence increasingly depends on the ability of policymakers to ensure that technological transformation remains inclusive rather than concentrated within already advanced economies.

5.1. Strengthening Digital Infrastructure and Innovation Capacity

The first policy priority concerns coordinated European investment in digital infrastructure and innovation ecosystems. The comparative analysis presented throughout this study demonstrates that countries with stronger digital capabilities and higher research and development expenditure are better positioned to benefit from AI-driven transformation.

Therefore, European cohesion policy should prioritize investments in advanced digital infrastructure, AI research centers, cybersecurity capabilities, cloud-computing systems, and digital public-administration modernization. Particular attention should be directed towards emerging economies characterized by lower levels of digital readiness and innovation capacity. Such investments should be viewed not only as technological expenditures but also as long-term instruments for reducing structural disparities and supporting convergence within the European Union.

5.2. Human Capital Development and Workforce Adaptability

The second policy priority concerns education, workforce adaptability, and digital skills development. Artificial intelligence is transforming labor-market requirements and increasing demand for advanced technological competencies. At the same time, automation may disproportionately affect workers employed in routine and low-skilled occupations (Acemoglu and Restrepo, 2018).

As highlighted by the World Economic Forum (2025), economies capable of adapting their educational systems and workforce-training strategies are more likely to capture the benefits associated with technological transformation. Consequently, European digital policy should promote lifelong learning, workforce-reskilling programs, digital literacy initiatives, and interdisciplinary education combining technological, economic, and governance-related competencies.

Educational modernization should extend beyond technical specialization and incorporate ethical, institutional, and regulatory dimensions necessary for the responsible deployment of artificial intelligence within democratic societies.

5.3. Strategic Autonomy and Technological Sovereignty

A third policy implication relates to strategic autonomy and technological sovereignty. Increasing geopolitical fragmentation, semiconductor dependency, cybersecurity risks, and global technological competition have exposed Europe's vulnerability to external technological ecosystems (International Monetary Fund, 2023).

While initiatives such as the Artificial Intelligence Act and the European Chips Act represent important steps towards strengthening European technological sovereignty (European Parliament, 2024), regulatory frameworks alone are insufficient. Strategic autonomy also requires sustained investment in semiconductor production, AI innovation ecosystems, cybersecurity infrastructure, sovereign cloud technologies, and advanced research capabilities.

Without complementary industrial and technological investment, the European Union risks remaining dependent on external technologies despite possessing increasingly sophisticated regulatory frameworks.

5.4. Democratic Governance and Inclusive Digital Transformation

The final policy implication concerns the governance of artificial intelligence itself. The increasing use of automated decision-making systems raises important concerns regarding algorithmic transparency, accountability, digital inequality, surveillance risks, and the concentration of informational power (Cath et al., 2018).

For AI-driven governance to remain socially legitimate, technological efficiency must be balanced with democratic safeguards, ethical standards, and effective institutional oversight. Policymakers should therefore ensure that AI adoption is accompanied by transparency mechanisms, accountability frameworks, and regulatory protections that preserve public trust.

Ultimately, the future of European convergence will depend not only on the pace of technological adoption but also on the inclusiveness of digital transformation. Artificial intelligence possesses considerable potential to strengthen modernization, resilience, and competitiveness across the European Union. However, without coordinated investment, institutional adaptation, and equitable access to technological opportunities, AI-driven transformation may reinforce existing asymmetries and undermine the cohesion objectives that remain central to the European integration project.

6. Conclusion

This study examined the relationship between artificial intelligence, governance modernization, and economic convergence within the European Union in the context of geopolitical fragmentation, digital transformation, and increasing strategic competition. The analysis demonstrated that artificial intelligence is evolving beyond its role as a technological innovation and increasingly functions as a strategic economic and governance instrument capable of influencing institutional performance, productivity dynamics, and long-term convergence trajectories across Member States.

The findings suggest that AI-augmented governance can contribute to institutional modernization by improving administrative efficiency, enhancing fiscal coordination, strengthening crisis-management capabilities, and supporting evidence-based policymaking through predictive analytics and real-time data processing. In this respect, the first research question is addressed by demonstrating that artificial intelligence has the potential to mitigate institutional inefficiencies, particularly in emerging European economies characterized by administrative fragmentation and limited governance capacity.

The study further highlights the importance of technological asymmetries in shaping convergence outcomes. The comparative analysis indicates that advanced economies benefit from stronger innovation ecosystems, greater digital readiness, and higher research and development capacity, while emerging economies continue to face structural constraints related to technological investment and institutional adaptation. Consequently, the second research question is addressed by showing that technological disparities

significantly influence the ability of Member States to benefit from AI-driven transformation.

Regarding the third research question, the analysis suggests that artificial intelligence can strengthen macroeconomic resilience and support strategic autonomy through improved forecasting capabilities, crisis anticipation mechanisms, and digital coordination systems. However, these benefits depend on the existence of robust institutional frameworks, technological sovereignty, and adequate investment in digital infrastructure.

The fourth research question concerns the potential divergence effects of the digital transition. The findings indicate that artificial intelligence may simultaneously function as a mechanism of convergence and divergence. While coordinated investment, technological inclusion, and institutional modernization can facilitate productivity catch-up and economic resilience, unequal access to digital infrastructure, innovation ecosystems, and advanced technological capabilities may reinforce structural disparities between core and peripheral Member States.

The principal contribution of this study lies in the development of an interdisciplinary analytical framework that integrates convergence theory, institutional economics, and digital governance perspectives to examine the role of artificial intelligence within the European Union. Unlike much of the existing literature, which often analyzes digital transformation, governance modernization, and economic convergence separately, this research explores their interaction within a unified framework focused on emerging European economies. In doing so, the study contributes to a broader understanding of how artificial intelligence may influence both economic integration and divergence dynamics within the European project.

The findings also suggest that the traditional model of European convergence can no longer rely exclusively on market integration and fiscal coordination. In the context of the Twin Transition and growing geopolitical fragmentation, convergence increasingly depends on technological competitiveness, institutional resilience, innovation capacity, workforce adaptability, and strategic autonomy. Therefore, the long-term success of European integration will require coordinated investments in digital infrastructure, AI innovation ecosystems, cybersecurity capabilities, educational modernization, and institutional capacity building.

Ultimately, the future impact of artificial intelligence on economic convergence will depend on the European Union's ability to ensure that technological transformation remains inclusive, democratically accountable, and accessible across all Member States. While AI possesses considerable potential to strengthen modernization, resilience, and competitiveness, insufficient investment and unequal technological development may exacerbate existing disparities and undermine the cohesion objectives that remain central to European integration.

Future research may extend the present analysis through quantitative assessments of AI-related convergence indicators, econometric investigations of digital productivity gaps, and

longitudinal studies examining the institutional effects of AI-driven governance systems across European economies. Such approaches would provide valuable empirical evidence regarding the long-term relationship between artificial intelligence and economic convergence within the European Union.

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Examining the income inequality and poverty trends in Romania

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Abstract. *This paper examines the recent dynamics of income inequality and poverty in Romania in comparison with the European Union, focusing on their main determinants. The analysis combines descriptive and comparative approaches with correlation techniques to explore the relationship between social indicators and key variables such as education, labour market conditions, and institutional quality. The results show that, although Romania has recorded a significant reduction in income inequality and a moderate decline in the poverty rate over the last decade, major challenges persist, particularly in rural areas and among vulnerable groups. The findings highlight the important role of social transfers in reducing inequality, but also their limited effectiveness in addressing relative poverty. At the same time, education and institutional quality are critical factors negatively associated with poverty and inequality.*

Keywords: inequality, poverty, institutions, social transfers, Gini coefficient.

JEL Classification: D63, I32, O17, F43.

1. Introduction

Inequality and poverty represent two of the most persistent and significant social imbalances that continue to affect the future of humanity. Poverty is recognized as a main determinant of premature mortality (Himmelstein and Woolhandler, 2025) and being also linked to inequality through its determinants (Amponsah et al., 2023).

In this context, poverty reduction and eradication have become central priorities on the agenda of all international organizations. The 2030 Agenda for Sustainable Development, developed by the United Nations (UN), proposes an action plan aimed at economic, social, and human development, especially in underdeveloped and developing countries. At the level of the European Union, Member States continue to implement policies and measures aimed at combating poverty; nevertheless, substantial disparities persist both across Member States and within countries at the regional level.

The relevance of examining this topic derives from the significant social challenges experienced by Romania over recent decades, which highlight the necessity of analyzing the evolution of social indicators, identifying their main determinants, and exploring potential policy solutions to address these challenges effectively.

The main objective of this paper is to investigate the dynamics of poverty and inequality in Romania, by examining the evolution of relevant social indicators, identifying the key determinants underlying these phenomena, and evaluating potential policy directions for fostering social inclusion and sustainable human development.

2. Literature review

Inequality is natural and is a consequence of human differences (age, physical characteristics or differences in health) that shape the opportunities that individuals have access to. In particular, inequality becomes unjust when it is a result of extractive institutions, respectively of government policies that unequally impact the social classes in a country (Acemoglu and Robinson, 2012; Mizuno et al., 2017; Jianu, 2020), while institutions refer to their academic meaning, respectively to the informal rules (unwritten rules that guide human behavior in which the cultural factor plays an important role) or formal rules (regulations in force or other legislative norms) that orient human actions (North, 1989).

However, the impact of education on poverty/inequality or other determinants depends on the quality of formal and informal institutions within a country. Therefore, institutions influence poverty and inequality both directly (Tebaldi and Mohan, 2010; Aracil et al., 2022; Jianu and Tudorache, 2025; Jula et al., 2025) and indirectly by modifying the impact of other variables on both indicators.

Inequality is closely associated with poverty through the instruments that influence its size, which have an impact on both imbalances. Although certain situations may reveal divergent dynamics between inequality and poverty, these indicators generally tend to evolve in the same direction. Clearly, inequality and poverty negatively impact the sustainability of

economic growth, but their eradication remains at the stage of utopian discussion, which does not have sufficient arguments to justify such a policy. Furthermore, within certain limits, inequality may generate positive effects on economic growth by encouraging risk-taking behavior, stimulating participation in economic activities, and enhancing labour productivity (Jianu et al., 2021; Motahar and Mamipour, 2025).

Over the last decade, the intensity of social risks and imbalances manifested in Romania have slightly diminished in intensity, but they persist and continue to affect the quality of life, especially in rural areas (Istrate and Horea-Serban, 2018; Tudorache, 2021; Tudorache, 2024). The impact of education on poverty/inequality or other determinants, however, depends on the quality of formal and informal rules within a country. Therefore, institutions influence poverty and inequality both directly (Jianu and Tudorache, 2025) and indirectly by modifying the impact of other variables on the two indicators.

3. Methodology

This section describes the methods applied to support the analysis of the income inequality and poverty trends in Romania during the period 2015-2024. In this end, we used comparative and temporal analysis to study the developments of the social indicators, with a particular focus on people at risk of poverty rate and income inequality. In particular, we used the following indicators:

- people at risk of poverty rate - Eurostat;
- in-work at risk of poverty rate - Eurostat;
- S80/S20 share - Eurostat;
- Gini coefficient - Eurostat;
- the percentage of income by quintile - Eurostat;
- the share of VAT paid by households in the gross income obtained per household by quintile - Eurostat;
- the share of population over 18 years old exposed to the risk of poverty by level of education - Eurostat;
- the share of people with tertiary education earning incomes of at least 130% of the national median equivalent income - Eurostat;
- early leavers from education and training rate (18-24 years) - Eurostat;
- the share of people having basic digital skills - Eurostat;
- NEETs rate (15-29 years) - Eurostat;
- corruption control index - World Bank;
- regulatory quality index - World Bank;
- government effectiveness index - World Bank;
- political stability and absence of violence/terrorism index - World Bank;
- rule of law index - World Bank;
- voice and accountability index - World Bank.

While we advanced our analysis from a general to a more granular level (from national to regional, and from total rates to specific rates by category, namely age, gender, and education level), we also tested the relationship between the poverty rate and income inequality and their relevant determinants using a Pearson correlation matrix.

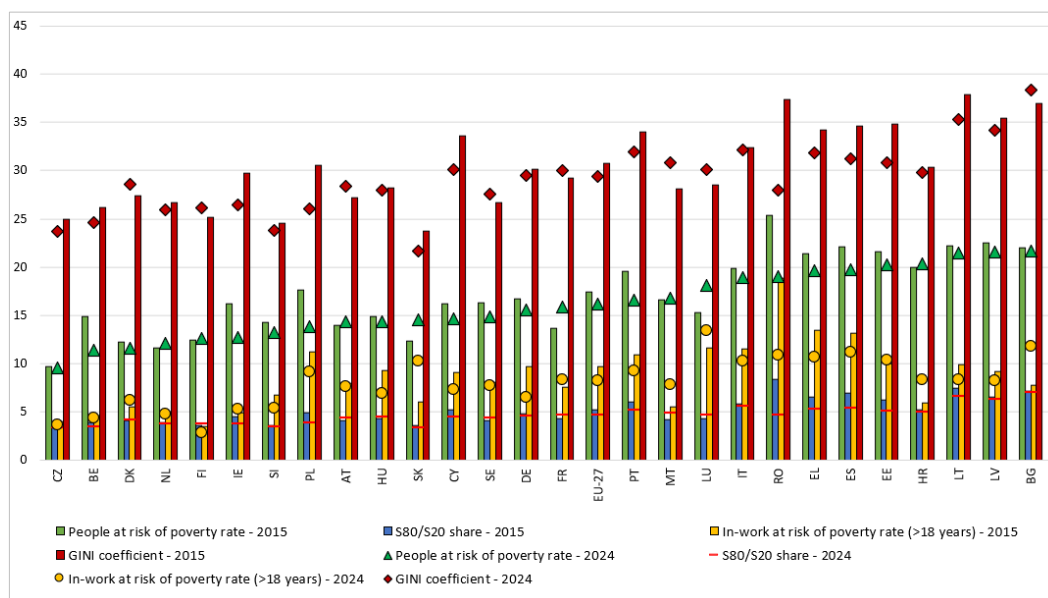
4. Results and interpretations

This section presents the empirical results obtained and their interpretation. The analysis indicates that Romania recorded a reduction in the at-risk-of-poverty rate (*Figure 1*) by 6.4 percentage points (pp) between 2015 and 2024, the largest fall in the EU, followed by Poland (-3.8 pp), Belgium and Ireland (-3.5 pp both). This favourable dynamic was also reflected in the reduction in the people at risk of poverty rate in employment by 7.9 pp over the same period (from 18.8% in 2015 to 10.9% in 2024 - the largest adjustment in the EU). Despite these improvements, Romania continues to report one of the highest poverty rates in the EU, while the in-work at risk of poverty rate reported for Romania is the fourth highest in the Union, after Spain (11.2%), Bulgaria (11.8%) and Luxembourg (13.4%).

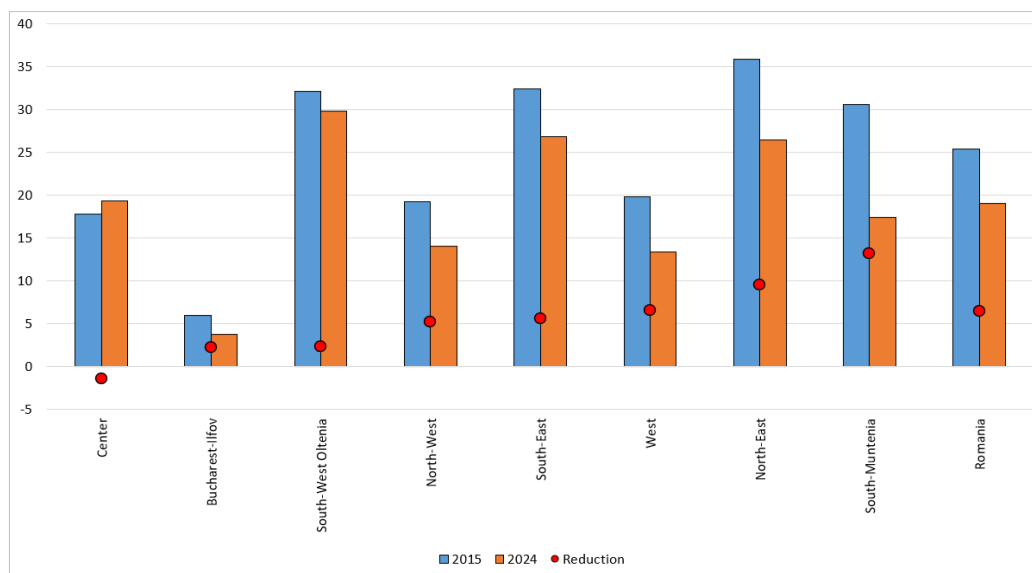
Regarding the S80/S20 share (which captures the ratio between the percentage of income obtained by the fifth quintile and that of income obtained by the first quintile), a reduction of 3.7 pp have been observed in the analysed period (which reflects a decrease in income inequality - the largest adjustment in the EU), this being also reflected in the largest reduction in the Gini coefficient in the EU (-9.4 points in the case of Romania compared to -1.4 points in the case of the EU-27).

At the national level (*Figure 2*), the data indicate that the largest reductions in the poverty rate were recorded in the South Muntenia region (-13.2pp) and the North-East (-9.5pp). The Center region was the only one to record an increase in the poverty rate (+1.5pp), while the Bucharest-Ilfov Region remained the best performing region in 2024 (3.7% poverty rate).

Figure 1. Dynamics of social indicators 2015 vs. 2024 in Romania



Source: Own calculations using Eurostat database

Figure 2. People at risk of poverty rate by development region

Source: Own calculations using Eurostat database

Over the years, poverty has been significantly influenced by both gender and age. Although progress has been made in reducing gender inequality, these disparities continue to generate important challenges from the perspective of poverty risk. *Figure 3* shows that Romania performs less favourably than the EU across all analysed age groups, excepting the categories 20–24 years and 65+ years.

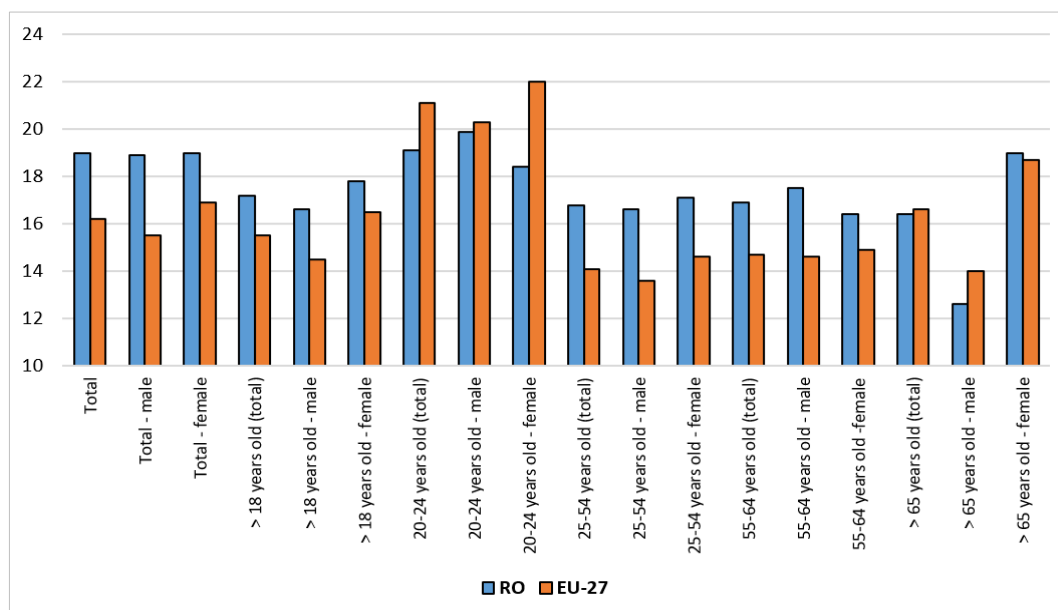
These categories are also the most vulnerable categories, given that young people aged 20–24 are in the process of transitioning from education to the labour market, and in most cases this period coincides with securing their first job. In Romania, the data analysed for 2024 show a higher poverty rate for men (also due to the higher school dropout rate among males, which has stronger effects during this period) than for women (19.9% vs. 18.4%), a situation contrary to that observed in the European Union (22% for women and 20.3% for men).

The analysed data also indicate a difference of 6.4 pp between the poverty rate recorded for men aged over 65 (12.6%) and that for women (19%), which can be explained by changes in household composition at older ages, as well as by the fact that women receive lower pensions than men, given their lower wages and shorter contribution periods (e.g., due to parental leave). In this context, ILO data show that in only 11 countries worldwide (Bahrain, the Bahamas, Ecuador, Honduras, Kiribati, the Marshall Islands, Panama, the Philippines, Qatar, Thailand, and Samoa) the average wage earned by women is higher than that earned by men, according to the most recent available statistical data.

Social vulnerability to poverty and inequality risks is also directly reflected in the distribution of national equivalent income by quintiles. From this perspective, particular attention should be given to the shares of total income received by the first and fifth

quintiles, as these indicators provide important insights into the degree of income concentration and social inequality within a country.

Figure 3. *People at risk of poverty rate by age and gender (2024)*



Source: Own calculations using Eurostat database

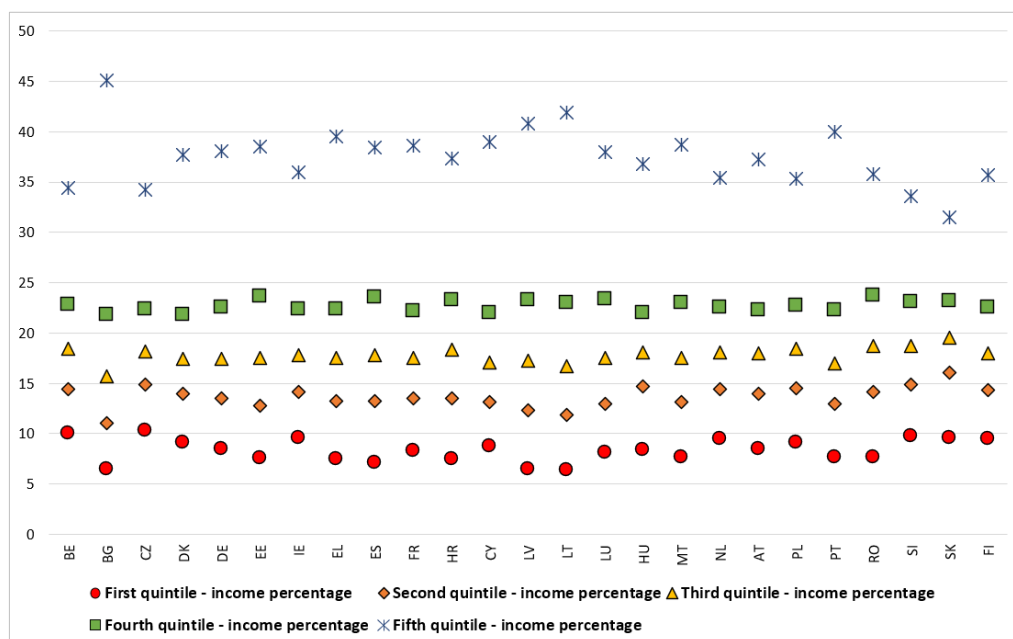
According to Eurostat (*Figure 4*), in 2024, at the level of Romania, individuals belonging to the fifth quintile obtained 35.8% of the national income, which shows that the richest 20% of Romanians (from the perspective of the incomes obtained) earn slightly more than one third of the national income, while individuals in the first quintile had a contribution of 7.7% to the national income (the seventh lowest rate in the EU).

From the perspective of the share of income obtained by the last two quintiles in equivalent income at the national level, Romania is positioned slightly below the specific EU-27 value (59.5% vs. 60.4%); the challenges are more related to the first quintiles, which present a low share of income obtained in the national one, highlighting the difficulty of escaping poverty for the respective categories. For this reason, Romanians in the first quintile are much more sensitive to economic policy measures than those in the last quintiles, which is also reflected in a set of experimental data published by Eurostat for the year 2020 (*Figure 5*). According to these, in 2020, 26.1% of the gross income obtained by households in quintile 1 was used to pay value added tax on consumption, Romania being surpassed only by Hungary in this regard (33.6%), which also applies the highest standard VAT rate in the EU (27%).

However, Romania records the second highest share of household consumption in GDP within the European Union (2024 data – 61.8%), after Greece (67.4%). In Romania's case, the share of core basic consumption (in order to capture the core of basic consumption, food and non-alcoholic beverages, as well as expenditure on utilities, were considered) in

final household consumption is the highest in the EU (50.2%), according to data published by Eurostat for 2024. This positioning is caused by the low level of incomes compared to other Member States, as well as by the high level of food and utility prices relative to existing incomes, which generally leads to the allocation of income toward meeting basic needs.

Figure 4. *The percentage of income obtained by each quintile in national income (2024)*



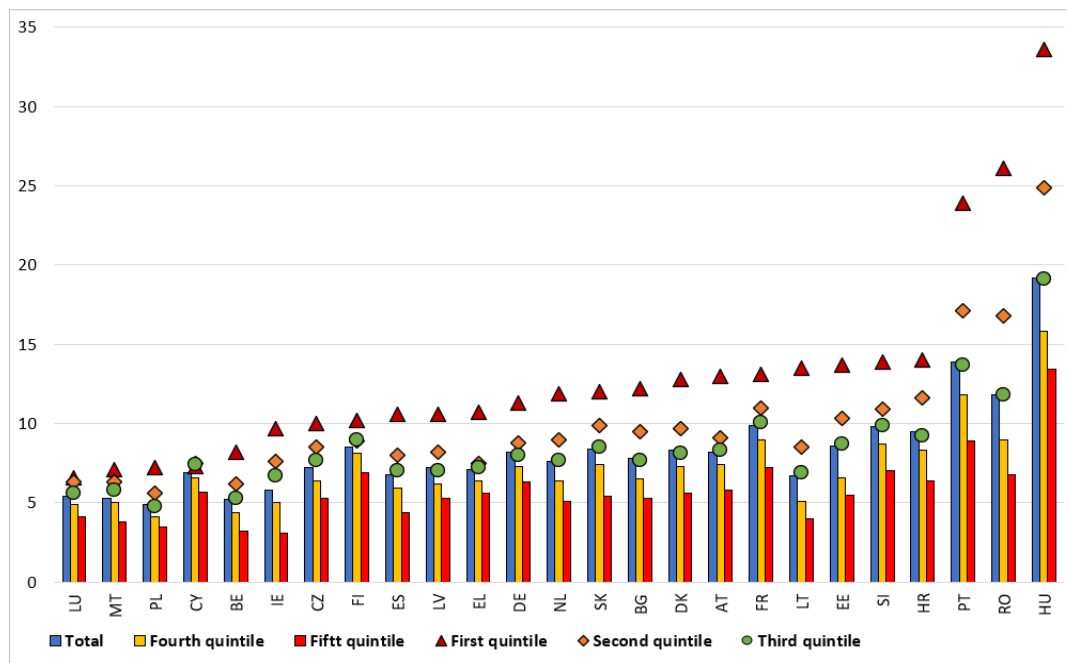
Source: Own calculations using Eurostat database

The data show that VAT exerts greater pressure on single-person households than on two-person households. In the case of single-person households, the cost of living represents a higher share of household income, whereas in two-person households, autonomous consumption is supported by both individuals, thus reducing the burden on individual income. For the reasons outlined above, in 2020, Romania recorded the second-highest share of single-person household expenditure on VAT in gross income (19.4%), being surpassed only by Hungary (27.7%) and ranking ahead of Portugal (16.6%), according to *Figure 6*. In the latter case, VAT exerts greater pressure on households consisting of one adult with dependent children (16.9%). On the other hand, Malta (5.3%), Poland (6.1%), and Belgium (6.2%) report the lowest VAT pressure on the budgets of single-person households.

Although in recent years social indicators have followed a favorable adjustment trajectory, in Romania social challenges persist and are amplified by the high level of poverty in rural areas (45% of the population living in rural areas - the second highest rate in the EU, after Slovakia, according to World Bank data for 2024) which are exposed to the risk of severe material deprivation. In this context, it is worth noting that Romania continues to record the highest rate of severe material deprivation in the EU in 2024 (17.2% vs. 6.4% for the

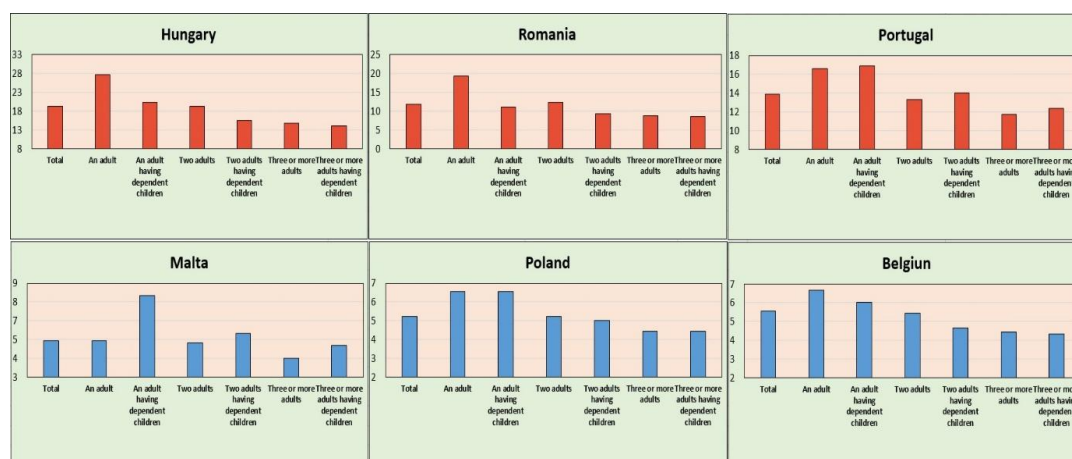
EU-27), but also the highest share of the population that does not have a bathroom, shower or toilet connected to water in the household (13.9% in 2023, but decreasing from the rate of 21.2% reported for 2020).

Figure 5. Share of VAT paid by households in gross income obtained by quintile (2020)



Source: Own calculations using Eurostat database

Figure 6. Percentage of VAT paid by households in gross income obtained by households according to the number of members per household

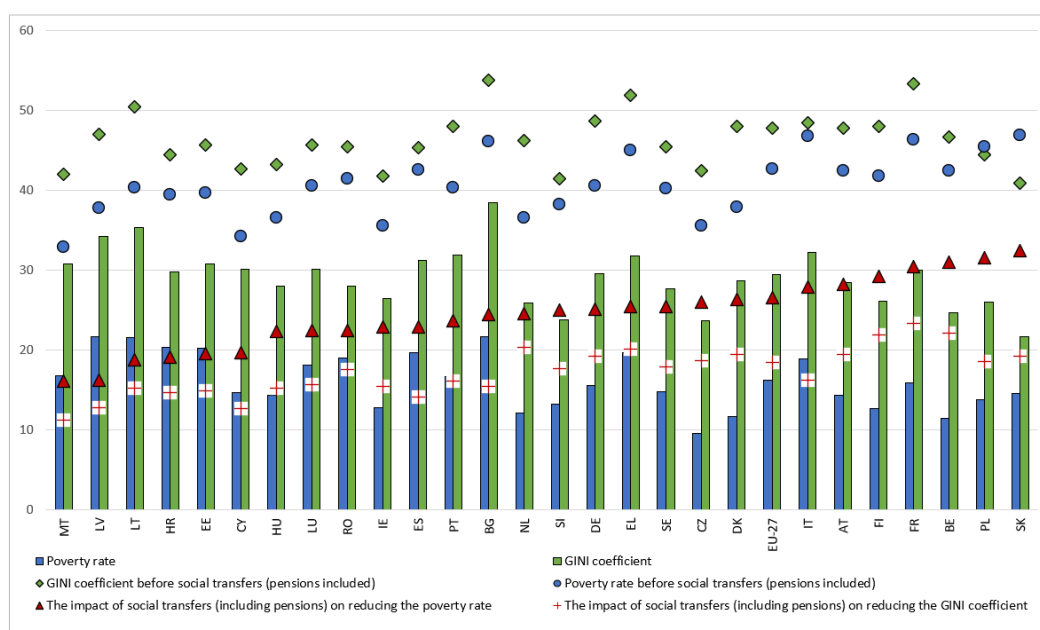


Source: Own calculations using Eurostat database

Social transfers are both criticized and supported in the economic literature, but regardless of the discussion of their efficiency, it must be taken into account that, from the perspective of their purpose (namely to correct inequalities produced by the market and institutions, as well as to stabilize the economy during unfavorable economic periods through automatic stabilizers – e.g., unemployment benefits), they are legitimate.

Figure 7 presents the share of the population at risk of poverty, as well as income inequality measured by the Gini coefficient, before and after social transfers (including pensions), in order to highlight the impact of these instruments on both indicators. The data for 2024 confirm the relatively low effectiveness of social transfers in Romania in reducing the poverty rate, although their impact is more favorable in terms of reducing income inequality. Specifically, Romania reduces the at-risk-of-poverty rate from 41.4% to 19% following social transfers (the seventh lowest reduction in the EU), while other Member States achieve stronger effects. In this context, the best-performing countries in terms of poverty reduction through social transfers are Belgium (31 pp), Poland (31.6 pp), and Slovakia (32.4 pp), whereas the weakest effects are observed in Lithuania (18.8 pp), Latvia (16.2 pp), and Malta (16.1 pp).

Figure 7. *The impact of social transfers on poverty/inequality reduction (2024)*



Source: Own calculations using Eurostat database

Regarding the impact of social transfers on the reduction of the Gini coefficient, the results are more favorable in the case of Romania (compared to the impact exerted on poverty), but the positioning is relatively close to the specific impact of the EU-27 (reduction of the Gini coefficient by 17.5 deviation points in the case of Romania, compared to its reduction by 18.4 deviation points in the case of the EU-27). Even if the general expectation is related

to a similar impact, in reality, although beneficiaries experience an improvement, not all social transfers will reposition them above the relative poverty threshold (60% of the equivalent income at national level), especially if the value of social transfers is modest, but any financial support provided to support individuals below the poverty threshold will determine the reduction of income inequality, reflected in the Gini coefficient.

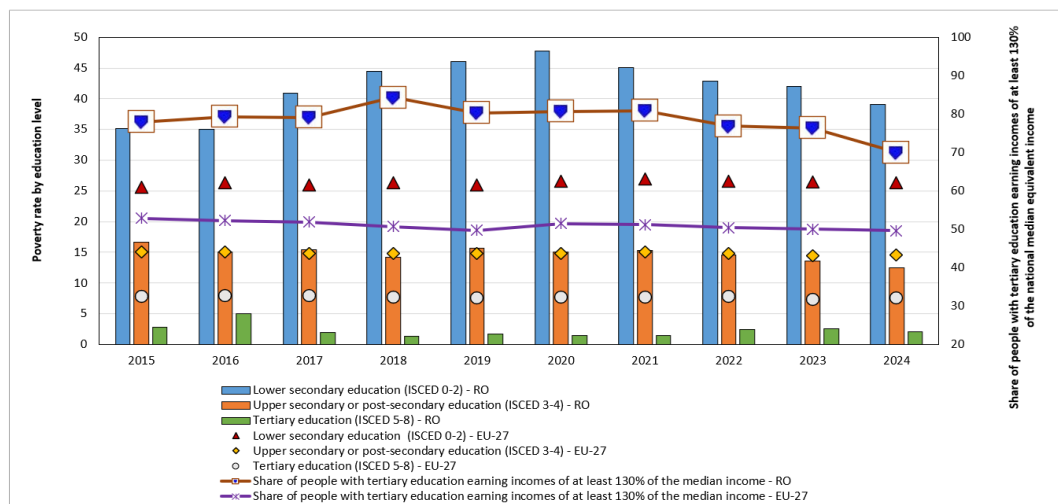
However, the impact of social transfers on poverty and inequality reduction remains more modest in Romania compared to other Member States, against the background of relatively low government spending on social protection (partly constrained by income levels). In 2023, Romania recorded the fourth lowest share of social protection expenditure in GDP (12.8%), exceeding only Hungary (12.3%), Malta (9.7%), and Ireland (8.1%), and remaining significantly below the levels observed in countries with strong social protection systems, such as Finland (25.7%), France (23.3%), and Austria (21.4%).

In terms of their efficiency and impact on the poverty rate, social transfers need to play a decisive role in supporting the transition to the labour market, where possible, by encouraging beneficiaries to participate in vocational training courses or volunteering programmes (activities recognized as professional experience), as well as by granting employment bonuses to stimulate the retention of employee status. Moreover, it is necessary to ensure the objective application of the conditions for granting social transfers, which makes it essential to strengthen administrative integrity and control mechanisms in order to improve the targeting of eligible beneficiaries.

Education is one of the factors with the capacity to correct social imbalances; however, in some cases, its effectiveness depends largely on cultural factors and on the mix of formal and informal rules promoted at the state level. *Figure 8* highlights a higher level of social vulnerability among individuals who have completed lower secondary education compared to those who have completed upper secondary or tertiary education. In both Romania and the EU-27, it can be observed that the differences between the poverty rates associated with the latter two levels of education are much smaller than those between the rates related to the two forms of secondary education shown in *Figure 8*. These differences can also be explained by the fact that completing upper secondary education represents a major step in meeting minimum employment requirements, while labour market integration is much more difficult and limited for individuals who have only completed lower secondary education.

Over the past ten years, both in the EU and in Romania, the poverty rate among individuals with upper secondary or tertiary education has decreased, while the share of individuals with lower secondary education who are at risk of poverty has increased, highlighting the growing skills gap for integration into the EU labour market. In relative terms, in 2024, Romania ranked more favourably than the EU in terms of the poverty rate among individuals with tertiary education (2.1% in Romania vs. 7.6% in the EU-27), as well as in terms of the share of individuals with tertiary education earning at least 130% of the median income (70% in Romania vs. 49.6% in the EU-27).

Figure 8. Share of population over 18 years old exposed to the risk of poverty according to the level of education and income obtained by people with tertiary education



Source: Own calculations using Eurostat database

The analysed data highlight the higher competitiveness of individuals with tertiary education compared to those with secondary education in terms of earnings; however, it should be noted that the significant difference between the data for Romania and the EU-27 can be explained by the large gap in tertiary education attainment rates. In Romania, in 2024, only 23.2% of individuals aged 25–34 held a diploma attesting the completion of tertiary education, according to Eurostat, a share 20.9 percentage points lower than the EU-27 average. This aspect justifies the higher rewards for tertiary graduates in Romania, given their relatively low share, but does not necessarily indicate a stronger impact compared to other countries, as many individuals below the poverty line do not pursue tertiary education. The impact is more pronounced for those who are close to the poverty threshold and manage to attain tertiary education.

The impact of education on poverty and inequality, as well as on other determinants, depends on the quality of formal and informal rules within a state. Therefore, institutions influence both poverty and inequality directly (Jianu & Tudorache, 2025), and indirectly, by shaping the impact of other variables on these two indicators. In this context, a set of factors was identified as having the potential to influence poverty and inequality, in order to examine the statistical relationship (using Pearson correlation) between the position of EU Member States in terms of these imbalances and their position in relation to the education system (early school leaving / participation in vocational training), the labour market (NEET rate), and the quality of institutions or governance indicators (control of corruption, regulatory quality, government effectiveness, political stability and absence of violence/terrorism, rule of law, as well as voice and accountability). To this end, the indicators presented in *Table 1* were selected, which also shows the statistical correlations between the positioning of Member States with respect to the analysed factors for 2023.

Table 1. *The correlation matrix between poverty rate/income inequality and their determinants (2023)*

Corelație	A	B	C	D	E	F	G	H	I	J	K
A	1.0000	0.8965	0.2230	-0.5033	0.4908	-0.3642	-0.3169	-0.3822	-0.3470	-0.3727	-0.3315
B	0.8965	1.0000	0.3061	-0.4788	0.4750	-0.4040	-0.3284	-0.4057	-0.3054	-0.3648	-0.3623
C	0.2230	0.3061	1.0000	-0.2129	0.3235	-0.0967	-0.1961	-0.1996	-0.2309	0.0011	-0.0684
D	-0.5033	-0.4788	-0.2129	1.0000	-0.6521	0.6571	0.6833	0.7647	0.4629	0.6714	0.6746
E	0.4908	0.4750	0.3235	-0.6521	1.0000	-0.6379	-0.6328	-0.6873	-0.6088	-0.6683	-0.5490
F	-0.3642	-0.4040	-0.0967	0.6571	-0.6379	1.0000	0.9478	0.9248	0.4555	0.9284	0.9039
G	-0.3169	-0.3284	-0.1961	0.6833	-0.6328	0.9478	1.0000	0.9195	0.5310	0.9155	0.8621
H	-0.3822	-0.4057	-0.1996	0.7647	-0.6873	0.9248	0.9195	1.0000	0.5811	0.9001	0.8686
I	-0.3470	-0.3054	-0.2309	0.4629	-0.6088	0.4555	0.5310	0.5811	1.0000	0.5500	0.3831
J	-0.3727	-0.3648	0.0011	0.6714	-0.6683	0.9284	0.9155	0.9001	0.5500	1.0000	0.8713
K	-0.3315	-0.3623	-0.0684	0.6746	-0.5490	0.9039	0.8621	0.8686	0.3831	0.8713	1.0000

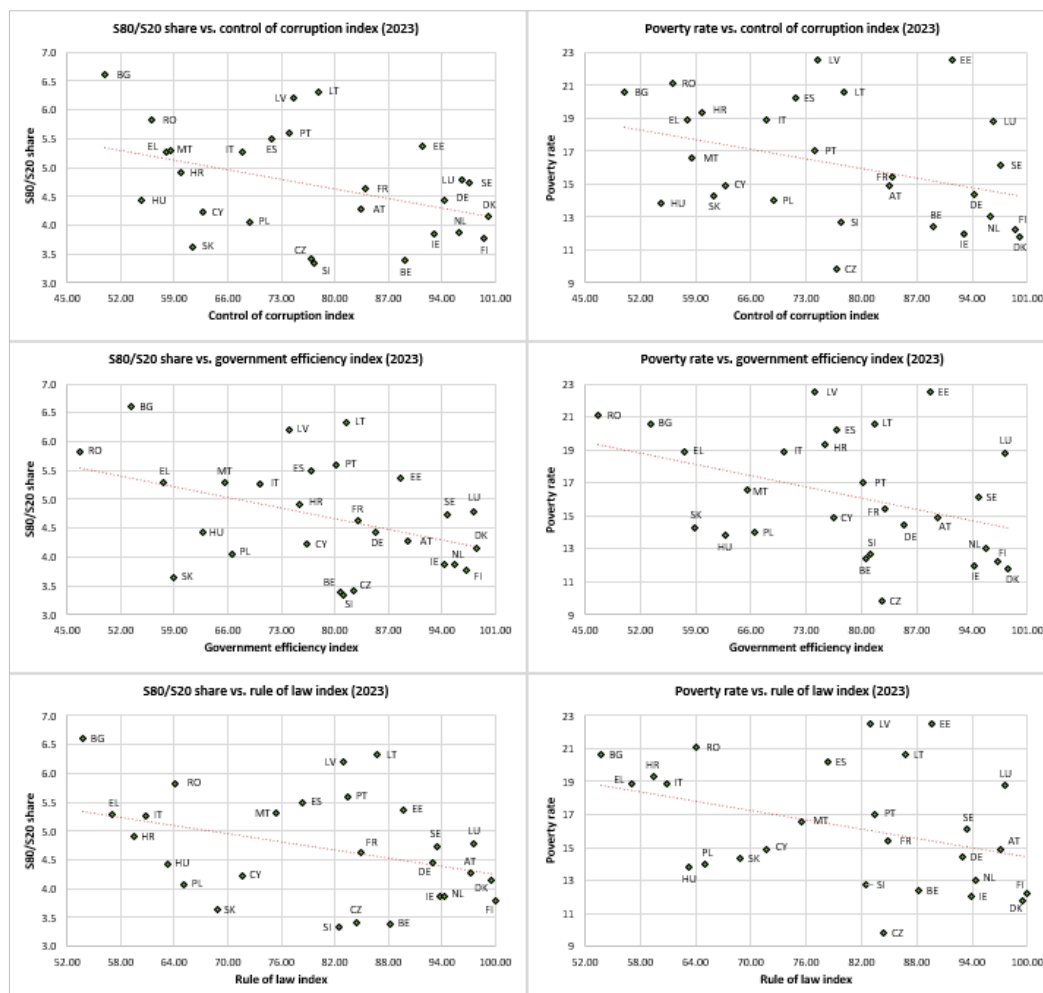
Note: A – People at risk of poverty rate; B - S80/S20 share; C - Early leavers from education and training rate (18-24 years); D – the share of people having basic digital skills; E - NEETs rate (15-29 years); F - Corruption control index; G - Regulatory quality index; H - Government effectiveness index; I - Political stability and absence of violence/terrorism index; J - Rule of law index; K - Voice and accountability index.

Source: Own calculations using Eurostat and World Bank database

Therefore, *Table 1* shows a strong statistical association between income inequality (captured by the S80/S20 share) and the population at risk of poverty rate, on the one hand, and the NEET rate, on the other (47.50% and 49.08%). This supports the hypothesis that this group is among the most vulnerable to social risks. At the same time, these variables are negatively associated with the positioning of Member States in terms of indicators capturing the quality of institutions (with negative correlations of at least 60% for each good governance indicator, except for voice and accountability, which records a correlation of -54.90%). Moreover, the share of individuals with basic digital skills is significantly and negatively associated with both income inequality (-50.33%) and poverty (-47.88%), while the relationship between these two social imbalances and the rate of early leaving from education or vocational training programmes is positive, but modest. It should be noted, however, that correlation does not imply causality. In this context, the correlation matrix also shows that institutions are statistically associated with the determinants of the two social imbalances analysed, which strengthens the relationship between institutions and inequality/poverty. Other studies (Jianu, 2019) show that the impact of economic crisis episodes on the unemployment rate is higher in countries with extractive institutions than in those with inclusive institutions.

Subsequently, the strongest statistical correlations were identified between the indicators capturing the quality of institutions (namely the control of corruption index, government effectiveness index, and rule of law index) and the S80/S20 ratio and the poverty rate, these being presented in *Figure 9*.

Figure 9. The relationship between the positioning of EU member states from the perspective of the most relevant indicators capturing the quality of institutions and that from the perspective of the poverty/inequality rate



Source: Own calculations using Eurostat and World Bank database

The data presented in *Figure 9* highlight the unfavourable position of Romania in terms of the government effectiveness index, the control of corruption index, and the rule of law index, as well as the way these challenges are exacerbated by the high poverty rate and the elevated S80/S20 share. In this context, *Figure 9* confirms the negative statistical association between the quality of institutions and the extent of income inequality and poverty, as reflected by the negative slope observed in all graphs. This points to the need for further efforts to improve the national institutional framework, which influences society's participation in economic activities.

Addressing these challenges can also be supported by promoting a more robust justification of legislative initiatives, through the inclusion of their impact on income distribution and

relative poverty in the explanatory act accompanying the proposed legislation. It is clear that, in many cases, the estimated impact will be limited due to data constraints or other issues affecting the reliability of statistical series; however, a minimum standard of quality should be established for the technical calculations.

At the same time, it is necessary to strengthen the role of the Economic and Social Council in advancing legislative initiatives in order to improve the quality of normative acts. In this context, although the Council acts as a consultative body to the Government and Parliament, procedural mechanisms should be introduced to ensure that its opinions - especially negative ones - are taken into account in a substantive manner within the legislative process. One possible approach would be to apply the “comply or explain” principle to negative opinions issued by the Council. Accordingly, in the documents resulting from parliamentary debates, parliamentary committees should provide clear arguments justifying the approval of legislative initiatives that have received a negative opinion from the Council.

5. Conclusions

In the last decade, the intensity of social risks and imbalances in Romania have slightly decreased in intensity; however, these challenges continue to affect quality of life, especially in rural areas, these challenges being exacerbated by institutional deficiencies, the low rate of tertiary education attainment, the small share of individuals possessing basic digital skills, as well as other economic factors such as the high share of basic consumption within household expenditure (a situation explained by high prices relative to incomes for goods included in the basic consumption).

The reduction in income inequality has been more pronounced in Romania than the decline in the poverty rate, with social transfers playing an important role in this regard. However, their effectiveness proves modest from the perspective of relative poverty, given that the support provided only helps individuals close to the relative poverty threshold (60% of the national equivalent income) to exit the poverty category. At the same time, their effectiveness in reducing income inequality (Gini coefficient) is higher, as any financial support reduces income inequality (to a greater or lesser extent), but does not help individuals far below the relative poverty threshold to leave this category.

The available data also indicate the relatively higher competitiveness of Romanian workers with tertiary education compared to the average European Union citizen, as the share of individuals earning at least 130% of the national median income is 20.4 percentage points higher in Romania. This difference may be explained by the low tertiary educational attainment rate, which contributes to labour market polarization, as well as by the lower overall income levels in Romania relative to the European Union average. Furthermore, tertiary education graduates who remain in the country's labour market are generally those who succeed in obtaining jobs offering remuneration aligned with their expectations and qualifications.

In order to enhance the effectiveness of policies aimed at moderating income inequality and poverty, it is necessary to improve the efficiency of social transfers by identifying new forms of incentivizing labour market integration and by objectively applying eligibility criteria for receiving them. At the same time, improving the quality of the set of formal and informal rules (institutions) that shape human behaviour is required.

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Strategic convergences in European labor markets: the synergistic role of human capital and digital transformation in Industry 5.0

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Abstract. *In a landscape marked by accelerated economic transformation and technological innovation across Europe, the synergy between human capital and digitalization is redefining work paradigms and regional economic convergence. This article explores the strategic convergence between human skills — creativity, critical judgment, and contextual intuition — and advanced technological capabilities, such as automation and artificial intelligence, framed by the transition toward Industry 5.0. Drawing on empirical datasets from Eurostat covering the 2015–2024 period, the study examines labor market dynamics across a selection of European economies, capturing both advanced and emerging states. The empirical analysis evaluates key indicators including task standardization levels, labor productivity, unit labor costs, and Gross Value Added (GVA). The findings reveal patterns of economic convergence between Central/Eastern and Western European countries, highlighting how the strategic integration of digital tools alongside continuous human capital enhancement fosters sustainable competitive advantages and organizational resilience. Consequently, the paper provides a balanced framework for human–machine collaboration, emphasizing the essential role of adaptive leadership and lifelong learning in mitigating structural disparities in the European labor market.*

Keywords: Strategic convergence, European labor markets, Economic convergence, Human-technology synergy, Labor productivity, Industry 5.0.

JEL Classification: J24, J21, O33, O15.

Introduction

The accelerated technological transformations and the increasing volatility of the financial markets due to geopolitical factors and the increasingly rapid dynamics of the global economy, define a new strategic framework for economic organizations. Technology has been the main driving force behind the evolution of financial markets in recent decades. The emergence and development of artificial intelligence (AI) in combination with human capital remain the indispensable factors in managing ambiguity, formulating ethical judgments and contextually interpreting market signals. This volatile and complex context motivates the need for this study, which investigates how market uncertainties can be mitigated by exploiting the convergence between the human factor and AI-based technologies.

Human capital and artificial intelligence should not be seen as opposing forces, but as complementary elements that can act synergistically to give organizations flexibility and competitive advantages.

The article aims to address an emerging theme in the economic literature: the strategic convergence between human capital and artificial intelligence in the financial sector. The objectives of the scientific approach are:

1. Identify and analyze the commonalities between human skills and AI capabilities in decision-making processes in modern economic organizations.
2. Exploring how this convergence can lead to sustainable competitive advantages for European organizations in Romania and the EU.
3. Investigate the role of adaptive leadership and lifelong learning in facilitating the effective integration of AI (Gilbert, 2020).

In the European context, the effective use of AI in finance is closely linked to the development of skills and support infrastructures. Andreoni and Anzolin (Andreoni, 2019) stresses that the opportunities generated by the Fourth Industrial Revolution are not evenly distributed: the effective adoption of new technologies requires organisations with strong core and intermediate capacities, supported by reliable infrastructures (energy, standards, connectivity), conditions that are often lacking in many economies in transition.

Therefore, for emerging markets, an incremental process of technology integration and continuous upskilling of the workforce is essential, rather than expecting a sudden and complete change. Only through gradual adaptations of existing systems and the development of new capabilities can organizations fully reap the benefits of the new industrial revolution. With these considerations in mind, the present study is guided by the following research question: How does the strategic integration of artificial intelligence and human capital contribute to the performance and adaptability of European organizations in the context of the transition to Industry 5.0?

The empirical analysis is based on publicly available datasets from Eurostat and national statistical offices, covering the period 2015–2024. The sample includes 16 European economies, including EU Member States and non-EU candidate/EFTA countries such as Norway and Serbia). EU countries selected based on data availability and relevance in terms of financial market structure. The analysis controls for sectoral composition, education system quality, and innovation capacity, to account for potential confounding variables.

Literature review

Building on the strategic relevance outlined in the introduction, this section explores key theoretical developments regarding the intersection between AI and human capital in financial markets. Financial markets, traditionally influenced by human expertise. The convergence between AI and the financial sector generates both significant opportunities such as advancement in predictive analytics, risk management, and trading strategies. These developments raise key questions related to algorithmic bias, the adaptation of the regulatory framework, and the ethical implications of automated financial decisions (Moch, 2023).

Artificial intelligence in the financial sector has become a catalyst for change in financial markets through its predictive analytics, machine learning, and real-time processing of big data. Studies indicate that the use of AI in financial decisions leads to increased operational efficiency and reduced risks (Dahmani, 2024).

Outside the borders of financial markets, the influence of AI extends to the entire economy, also affecting the level of natural resources, having a significant impact on various industries such as agriculture, energy, mining, and environmental conservation.

The incorporation of AI technology in various industries has a much higher potential in increasing efficiency, optimal use of resources, and adopting sustainable methodologies. However, it also presents difficulties in terms of job displacement, ethical concerns in resource extraction, and the overall environmental impact of AI-based processes (Goralski, 2020). Concurrently, the literature highlights the role of human capital as a vector of organizational adaptability. (Lee, 2017) introduces the concept of technological "windows of opportunity", emphasizing that in times of paradigm shift, new market entrants can match or even surpass incumbents if they leverage their human resources strategically. In the same vein, (Andreoni, 2019) It is stressed that the effective uptake of emerging technologies in countries in transition depends on intermediate industrial skills and a strong digital infrastructure.

The fundamental transformations of financial markets in the context of the Fourth Industrial Revolution have led to an increase in interest in how artificial intelligence (AI) can be integrated into organizational strategies to sustain competitive advantage. At the same time, the literature emphasizes that technology, although essential, is not sufficient in itself; human capital remains a fundamental pillar in the effective use of AI in the financial context.

Emerging literature on the transition to Industry 5.0 suggests a rebalancing between technology and the human factor (Wang, 2023). If the Industry 4.0 paradigm emphasized automation and efficiency, Industry 5.0 brings the employee back to the forefront as the main element, human-machine collaboration and social sustainability (Zizic, 2022). These concepts are essential in today's financial markets, where automated decisions require completion through ethical judgment, contextual intuition, and adaptive leadership.

The concept of augmented intelligence resulted from the combination of AI and human capital, in which organizations become able to learn and adapt in real time. Augmented

Intelligence is a concept that describes the synergistic collaboration between human and artificial intelligence, with the aim of amplifying and supporting human cognitive and decision-making capabilities, not replacing them. This adaptability is becoming a key strategic asset in global financial ecosystems, especially in emerging markets, where competitiveness no longer derives only from infrastructure, but from the ability to intelligently integrate resources (human and digital).

Table 1. *Artificial Intelligence vs Augmented Intelligence*

Feature	Artificial Intelligence (AI)	Augmented Intelligence (Alg)
Purpose	Task automation	Assistance and improvement of human decisions
The role of man	It is potentially eliminated/substituted	It is central and decision-making
Accent	Speed, efficiency, range	Collaboration, contextual understanding
Example	Autonomous robots, trading algorithms	Digital assistants, strategic analysis platforms

Source: Authors' own research

Another common point in the analyzed literature is the importance of adaptive leadership in supporting the transition to sustainable digital models. Adaptive leadership involves mobilizing people to face complex challenges and find new solutions, when traditional or authoritarian responses are no longer enough. The leaders of financial organizations must mediate change, create organizational cultures open to learning and collaboration, and avoid internal polarization generated by superficial technological implementations (Dahmani, 2024).

The importance of adaptive leadership is also highlighted by recent literature, which shows that the success of digital transformations depends to a large extent on leaders' ability to manage organizational change and cultivate new ways of collaborating (Moch, 2023). Even when management makes sustained efforts to mitigate the disruptive effects of the transition to the Industry 5.0 era, internal adjustments take time, and leaders must orchestrate interactions and processes that facilitate an effective exchange of knowledge in the digital environment. In summary, the strategic convergence between human capital and artificial intelligence represents a promising direction of response to the volatility of today's financial markets. By articulating the above motivation, objectives, and research questions, the study is firmly anchored in contemporary theoretical foundations and aims to contribute to the literature by highlighting how human-AI synergy can improve the performance and resilience of organizations in European financial market.

Table 2. *Adaptive Leadership*

Feature	Explanation
Learning capacity	Leaders continuously learn and cultivate an environment where the team does the same.
Accepting uncertainty	They don't look for "right" solutions from the start, but experiment and adapt.
Collective involvement	Problems are addressed together with the team, not imposed from the top down.
Distinction between technical and adaptive problems	Technical problems have known solutions, adaptive ones require innovation and a change of mindset.

Source: Author's own processing

This theoretical review supports the study's basic hypothesis: the convergence of AI and human capital can generate a sustainable competitive advantage for financial organizations, especially in emerging economies navigating the transition to Industry 5.0. The integration of these two resources is not just a technological solution, but an organizational

transformation strategy, with systemic implications on resilience and performance in unstable environments (Aldieri, 2022).

With the constant changes registered at the level of society, the leadership system is gradually transforming, in reaction to constraints of any kind, starting with climatic, demographic and culminating with social and economic changes (Greene, 2020). Lately, there is a demand for a rapid improvement of services using a new approach that meets the dynamic demands of the market. Leading a team is a big responsibility, a process that must be carefully modeled and guided with caution to identify the needs of the team, but especially to communicate and maintain a common vision with the company's vision (Uhl-Bien, 2007).

It is necessary to adapt the leadership system from the industrial era to the knowledge era, the leadership models of the past years have been integrated to cope with the conjuncture and the respective context, but for the current period there have been no modern models of leadership that can sustain the radical changes of perspectives and cope with the current circumstances (Davenport, 2001) & (Osborn, 2002).

Due to the financial crises and the pandemic, there is a need to implement a system that incorporates a diversified and complex management, foldable on existing problems and especially that can coordinate and adapt to existing economic situations (Linsky, 2002).

Methodology

This paper aims to highlight how human capital, in synergy with emerging technologies such as artificial intelligence, influences strategic convergence between European economies. The analysis is based on data retrieved from Eurostat, the World Bank, and national statistical offices, covering the period 2014–2024. The countries selected for analysis include both economically advanced EU Member States (e.g., France, Germany, the Netherlands) and emerging economies (e.g., Romania, Bulgaria, Poland), based on criteria such as data availability, diversity of occupational structures, and pace of digitalization. The main objective was to understand how the indicators of occupational standardization, productivity and unit labor costs are articulated in a dynamic context, influenced by digitalization and automation.

The first set of data analysed reflects the distribution of the employed population according to the level of standardisation of work tasks – from occupations with a 'very high' level of standardisation to those with a 'non-existent' level. The related graph highlights the structural disparities between European states. Thus, in developed economies, such as France, Germany and the Netherlands, the proportion of occupations with a low degree of standardization is significantly higher, suggesting a workforce mainly engaged in complex, creative or knowledge-based activities dimensions that are difficult to automate. On the other hand, in countries such as Romania and Bulgaria, occupations with a high degree of standardization predominate, which implies an increased exposure to the risk of replacement by technology.

In order to minimize bias, the analysis accounts for structural differences among countries, including educational attainment, sectoral employment composition, and level of digital infrastructure development. These control variables help isolate the impact of human capital and AI-driven transformation on labor market dynamics.

The hypothesis tested in this case was that countries with developed economies have a higher share of employees in poorly standardized occupations. The analysis confirmed the hypothesis, while suggesting the urgent need for reskilling and professional adaptation in emerging economies to avoid the negative effects of automation.

The second graph follows the evolution of productivity indices and unit labour costs in the period 2019–2024. The choice of this indicator is methodologically justified by its importance in measuring economic efficiency and competitiveness on the labor market.

The data clearly show that developing countries, such as Romania, Bulgaria or Poland, have recorded spectacular increases in both indicators. For example, Romania marked an increase of over 58% in the analyzed period. This phenomenon highlights a trend of economic convergence, in which these economies are closing the gap with Western states.

The last set of analyses focused on investigating the correlation between gross value added (GVA) and labour productivity. The choice of these indicators is essential in a paper that explores the transformations of the labor market in the context of AI, since GVA represents the direct expression of the economic output per employee. The overall Pearson pooled correlation was first calculated for the entire sample ($r = 0.89$), followed by an analysis on regional clusters of countries to highlight structural differences. The calculation of the Pearson correlation coefficient resulted in a value of $r = 0.89$, suggesting a strong positive relationship between productivity and the economic value generated. This result supports the idea that investments in human capital development and the integration of advanced technologies not only increase productivity, but also contribute to sustainable economic growth.

Results and discussions

In this section, the author presents the main empirical findings derived from the comparative analyses conducted across selected European countries. The results are critically examined in light of the research hypotheses formulated in the methodological framework, aiming to determine their validity. Particular attention is paid to identifying patterns of strategic convergence between advanced and emerging economies within the European space, as reflected through the dynamics of labor standardization, productivity growth, and unit labor costs.

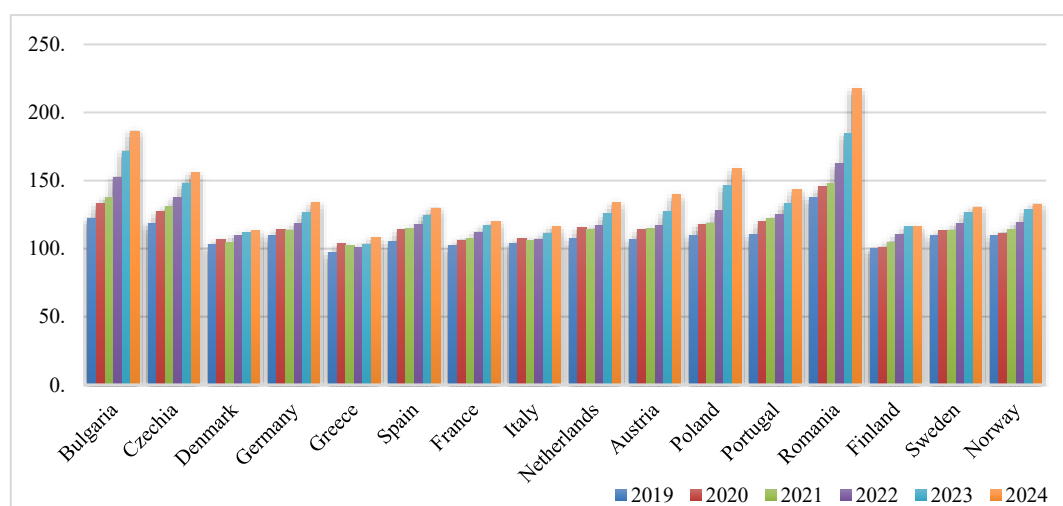
The results not only provide evidence on the synergies between human capital and artificial intelligence, but also allow for a realistic assessment of disparities and commonalities in economic structure and performance. Where applicable, the findings are discussed in relation to existing literature in the field of labor economics and technological transformation, ensuring a robust foundation for interpretation. This comparative

dimension offers added value, as it helps situate the current research in the broader scholarly context, identifying both consistencies and divergences from previous studies.

The selection of European countries in this research - ranging from highly developed economies (e.g., Germany, France, Sweden) to emerging ones (e.g., Romania, Bulgaria, Czechia, Poland) was intentional in order to capture both the diversity and the convergence trends within the European economic space. This comparative framework allows for a nuanced analysis of how different levels of economic maturity, institutional development, and investment in human capital influence the integration of artificial intelligence and technological transformation into national labor markets.

The reference period, 2015–2024, was chosen to ensure both retrospective and prospective relevance. It captures the aftermath of the Eurozone crisis, the acceleration of digitalization in the 2010s, the disruption caused by the COVID-19 pandemic, and the subsequent recovery period, which includes unprecedented investments in digital and green transitions via the EU Recovery and Resilience Facility. Moreover, the availability of consistent statistical data across this time frame enhances the robustness of the comparative analysis.

Figure 1. *Labour productivity and unit labour costs*



Source: Authors' own computation from Eurostat database.

The graph and related data reflect the dynamics of labour productivity and unit labour costs in the 16 European economies, including EU Member States and non-EU candidate/EFTA countries such as Norway and Serbia). These two indicators are essential for assessing economic competitiveness and labour market efficiency.

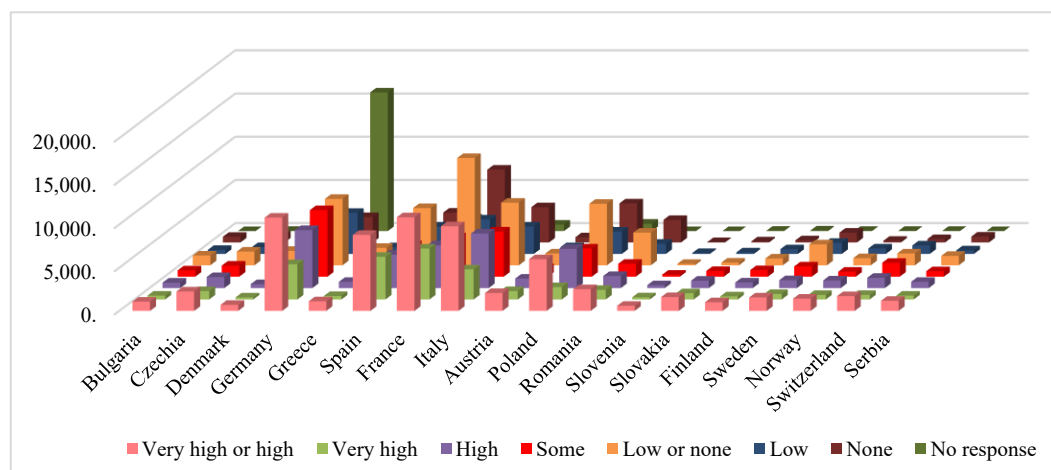
Eastern European countries, especially Romania, Bulgaria, Poland and the Czech Republic, are recording the most spectacular increases in values from 2019 to 2024. For example, Romania rises from 137,450 in 2019 to an impressive 217,718 in 2024, which indicates a rapid increase in labor productivity, but also a possible increase in wage costs. This evolution reflects both investments in modernisation and technology, as well as economic convergence compared to the EU average.

In countries such as France, Germany, Italy and Austria, the dynamics are more moderate. For example, France goes from 102,007 in 2019 to 119,934 in 2024, and Germany from 109,719 to 133,862. These developments reflect a mature economy with a strengthened industrial base, where productivity growth is achieved more slowly, but within a stable and sustainable framework. This pattern is characteristic of developed countries, where growth rates tend to stabilize. Denmark, Finland, Norway and Sweden demonstrate a steady evolution, with a moderate increase in values, but maintaining a relatively high position in the ranking. For example, Norway is growing from 109,737 in 2019 to 132,669 in 2024.

It reflects a combination of economic efficiency, wage stability and balanced social policies, maintaining competitiveness without compromising social equity. Compared to countries such as Greece, Spain, Italy and Portugal, which show an upward evolution, but slower compared to other regions. Greece, for example, is growing from 97,363 in 2019 to just 108,349 in 2024. This trend may reflect the persistence of structural difficulties and budgetary constraints, but also a gradual recovery from the economic crisis of the previous decade.

The analysis highlights a clear process of economic convergence in which emerging economies in Eastern Europe are rapidly catching up with the west of the continent, both in terms of labour productivity and wage costs. On the other hand, developed countries maintain balanced and sustainable growth, while southern Europe continues to face challenges in boosting the labour market. These trends underline the importance of public policies geared towards innovation, education and investment in human capital to sustain long-term economic growth.

Figure 2. *Employed persons by level of standardization of tasks, economic activity and occupation*



Source: Authors' own computation from Eurostat database.

The data presented show significant variations between European countries in terms of the degree of standardisation of tasks performed by employed persons. These differences reflect the economic structure, the degree of industrialization, the level of automation and the specifics of the labor market in each country.

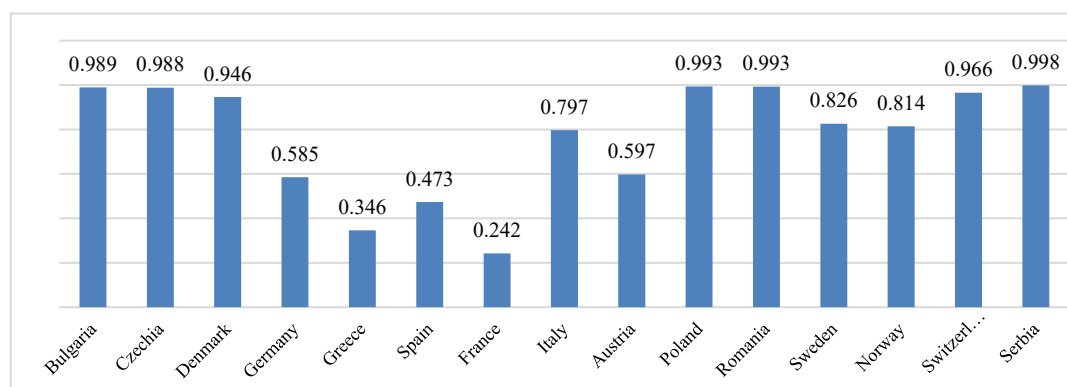
France and Germany stand out for the highest absolute values in the "Very High" and "High" categories in terms of standardization of tasks, with more than 10,000 people reported. This suggests a highly industrialized economy with clearly defined work processes, probably influenced by the presence of a developed manufacturing sector and strict organizational rules. Italy and Spain show high values in the 'Very High' and 'High' categories, but there are also significant shares at the 'Low' level. This indicates a diversity of jobs, with the presence of both well-standardised occupations and more flexible or informal ones, probably reflecting a dual economy between modern and traditional sectors.

Nordic countries such as Denmark, Finland, Sweden and Norway have a balance between high and low levels of standardisation. For example, in Sweden and Norway there are also significant shares in the "None" or "Low" category, which can be associated with a flexible work model, oriented towards innovation and autonomy in the workplace, characteristic of the Nordic economies. In the case of Central and Eastern Europe we have a heterogeneous distribution, in countries such as Romania, Bulgaria, Slovakia and Poland, the data show a relatively balanced distribution between all categories. However, there are increased values in the 'Low' and 'Very low' categories, which could indicate the presence of economic sectors where work is less standardised, possibly due to a high share of the informal economy or a less regulated occupational structure (Caputo, 2021).

We also have cases that derive from the rule, France, for example, has the highest absolute value in the "No response" category, which may be relevant from the perspective of data collection and may indicate a resistance or methodological difficulty in obtaining accurate information from respondents.

The comparative analysis reveals significant differences in the structure of work in European countries. Western economies, especially France and Germany, exhibit a high degree of standardization, suggesting well-defined industrial and organizational processes. The Nordic countries adopt a mixed model, favouring flexibility, while Eastern Europe indicates greater diversity, with the presence of less regulated occupations. These results provide a comprehensive picture of the dynamics of the European labour market, reflecting historical, economic and cultural influences on work organisation (Anghelache, 2018).

Figure 3. *Correlation between GVA and productivity*



Source: Authors' own computation from Eurostat database.

The analysis of the correlation between gross value added (GVA) and labour productivity reveals the existence of several distinct economic models in Europe. The Eastern European model is clearly illustrated by countries such as Romania, Serbia, Poland and Bulgaria, where correlations exceed the threshold of 0.98. This very high level indicates a direct dependence between the increase in labour productivity and the evolution of GVA. In these economies that are still in a transition process, work efficiency has an immediate and visible impact on the economic value generated.

Also, the sectoral structure dominated by industry and agriculture emphasizes this direct link, since these areas are naturally more sensitive to the output of labor. In contrast, the West-European model, represented by countries such as France, Greece, Spain or Germany, shows correlations below 0.6, which suggests that GVA is also influenced by other factors, such as capital investment, advanced technologies or the high value-added services sector. In these cases, the increase in labor productivity is not the only driver of economic value, other elements such as innovation or spending on research and development playing an important role. Special cases emerge in the analysis: France, with a correlation of only 0.24, seems to reflect a complex economic model, where productivity does not automatically generate economic value, possibly due to rigidities in the labor market or the high share of the public sector.

These results underline the diversity of economic development models in Europe and suggest that the relationship between productivity and value added needs to be interpreted in the structural and institutional context specific to each economy. This correlation was made between the economic indicators for each developed or developing country over a determined period of time, starting with 2015-2024. The results show quite clearly how the intensity of the relationship between these indicators varies in the European space.

And in the case of the Nordic states, advanced economic models suggest the existence of fairly developed tertiary sectors, which can influence the added value in different industries, which means that GVA can be influenced by both intangible factors such as innovation, investments in tech, not only by gross labor productivity, and labor markets become much more flexible, given investments in automation and reduce dependence on human productivity, expressing structural flexibility. State interventions can also alter the direct relationship between productivity and other economic factors and implement some redistributive policies as is the case in Finland.

Discussion

The results of the comparative analyses carried out in this research reveal a series of strategic convergences between the labor markets of European states at different levels of economic development. These convergences are relevant in the broader context of structural transformations in financial markets, where the role of human capital and artificial intelligence is becoming increasingly important.

The first set of data, on the level of standardization of tasks, economic activities and occupations, provides an insight into the degree of automation and formalization of work

in various states. The highest values are recorded in France and Germany, where a considerable percentage of the workforce operates under conditions of 'very high' or 'high' standardisation. This reflects a more advanced integration of digital technologies and automated processes, with direct implications for economic competitiveness. On the other hand, countries such as Bulgaria and Greece have higher shares of employees in sectors with "little or no standardization," suggesting a less tech-savvy economy that is more dependent on manual labor.

This indicator was included in the methodology because it reflects the adaptability of human capital to technological processes and, implicitly, the ability of an economy to integrate innovation and automation strategically. In the context of financial convergences, the level of standardisation influences both labour costs and the investment attractiveness of an economy.

The second analysis, on labour productivity and unit labour costs, aligns with the existence of significant growth trends in emerging countries, especially Romania and Bulgaria.

Romania, for example, registers an increase of over 80.000 in the period 2019–2024, which indicates a significant improvement in work efficiency. The real increase from 137,450 to 217,718 suggests a percentage of over 58.4% (and in absolute figures it is approximately 80.000 index units). This evolution, although positive, must also be analyzed in the light of the increase in wage costs, which can diminish competitiveness in the absence of a balance between technology, qualification and efficiency. In contrast, mature economies, such as Germany and Denmark, show more stable developments, reflecting an already strengthened maturity of human capital and efficiency.

These two indicators: productivity and labor cost, are essential in the research methodology because they express the efficiency of integrating human capital into the economic chain and its ability to generate added value in a dynamic environment, influenced by digital transformations. In this context, artificial intelligence can act as an accelerator of convergence, supporting both the efficiency and adaptability of the workforce. Regarding the analysis of the unemployment rate, the results show that the level of investment in education and vocational training has a significant impact on the transition of young people into the labour market.

Countries such as Denmark, Sweden and the Czech Republic maintained low youth unemployment rates over the period analysed, suggesting a good correlation between the education system and labour market requirements. In contrast, Greece and Bulgaria have recorded high levels of unemployment, which raises questions about the effectiveness of vocational integration policies and the adequacy of the qualifications offered by education systems.

This finding supports the hypothesis that investment in human capital is not sufficient in itself, but must be accompanied by effective transition mechanisms to the labor market, in which technology and AI can play a key role, either through digital employment platforms or through trainings adapted to the new requirements of the digital economy.

The correlation of the data highlighted a positive relationship between the increase in gross value added (GVA) and the increase in productivity, especially in countries where strategic investments were made in digitalisation and training. This suggests the idea that the synergy between human capital and technology is not just a theoretical trend, but has practical applicability in the economic convergence of the Member States.

In conclusion, the research results support the idea that the strategic integration of artificial intelligence in tandem with human capital development can act as a converging force in European financial markets. Countries that manage to implement coherent policies in this regard will become leaders in adapting to new economic paradigms, while others risk falling behind in the absence of structural reforms.

Conclusion

In conclusion, this paper has achieved its purpose of analyzing the strategic convergences of the dynamics of the European financial markets, focusing on the interaction between human capital and artificial intelligence, seen as vectors of structural transformation and competitiveness. The research demonstrates that the integration of human and machine capabilities is not only feasible but strategically essential in achieving resilient and adaptive financial ecosystems.

The study was based on a series of comparative analyses between several European states at different stages of economic development, for example Romania, Bulgaria, Denmark, Norway, Sweden, Germany, in a relevant reference range, the period also covering the years before and after the pandemic crisis (2015-2024), in order to capture the post-crisis developments in particular, the digital transition and the adaptation of different economic systems to the emergence of new technological paradigms.

The first significant conclusion emphasizes the importance of standardizing the entire economic activity, thus reflecting the level of digitalization and automation of the workforce. Advanced economies such as France and Germany have been found to have a high share of employees engaged in standardised 'high' tasks, implying an economic structure that is less adapted to innovation and automation.

Another direction of the research aimed at the analysis of labor productivity and unit labor cost. The results show a trend of progressive productivity growth in Eastern European countries, especially Romania and Bulgaria, which are catching up with the EU average.

However, this economic convergence needs to be carefully managed, as rising labour costs can compromise competitiveness if it is not supported by digitalisation and higher qualifications. Thus, the results validate the hypothesis that a sustainable convergence in the dynamics of financial markets requires investments in both human capital and technology; two elements that, together, define the new economic paradigm.

This research, while providing valuable insight into the relationship between human capital, artificial intelligence and the dynamics of financial markets, has certain limitations. First, the selection of European countries was based on the availability of data and their

economic relevance, but this may restrict the applicability of the results to other regions or economies. The time frame analyzed, while sufficient to highlight significant trends, does not entirely capture the recent impact of emerging technologies such as AI.

Another limitation is the level of data aggregation, which may omit structural differences between sectors or regions. Also, the correlations identified do not necessarily imply causation, and external factors, such as national policies or economic crises, may influence the interpretation of the results. For the future, the research can be extended by including a larger number of states, by analyzing additional indicators related to innovation, digitalization and the efficiency of investments in education, but also by applying more advanced methods that capture more precisely the causal relationships.

Overall, the research suggests that the integration of artificial intelligence into economic processes is not a threat to the labour market, but a catalyst for transformation and efficiency, provided that public policies support education, reskilling and innovation. Human capital cannot be replaced, but transformed, and this transformation becomes the key to competitiveness in the new dynamics of European financial markets.

Economic convergence can no longer be assessed solely by classical macroeconomic indicators. In the new digital context, the quality of human capital, the rate of innovation and the ability to integrate AI become essential pillars for the sustainability and resilience of economic systems.

Statements

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Human capital as a catalyst for sustainable economic development in emerging economies

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Abstract. *This paper explores the impact of the human capital paradigm on sustainable economic development in emerging economies, focusing on the interdependence between education, vocational training and long-term economic growth. The human capital paradigm emphasizes the importance of investing in human resources as a key driver of productivity and economic competitiveness. In the context of emerging economies, this paper looks at how human capital development through quality education and lifelong learning can drive the transition to a more diversified and innovative economy, promoting sustainable development. It also investigates the specific challenges and opportunities faced by these economies in implementing this paradigm, taking into account labour market demands, rapid digitalisation and demographic changes. The study combines theoretical and empirical analysis, with examples from various emerging economies, to highlight the crucial role of human capital in achieving a sustainable and resilient economic model.*

Keywords: Human capital, Emerging economies, Sustainable economic development, Education and training, Economic growth.

JEL Classification: O15, O11, Q01, J24.

Introduction

In recent decades, the concept known as economic development has evolved over time beyond the modest accumulation of capital and the growth of the gross domestic product, towards a sustainable approach that seeks to integrate the social and economic dimensions, but also those dedicated to the study of the environment. These concerns constitute a modern model of thinking, focused on the study of sustainable development. This model of thinking focuses not only on the short-term prosperity component, but also on the level of intergenerational equity, social inclusion and protection of natural resources. (OECD 2022)

At the same time, human capital has become a central resource for increasing economic competitiveness and innovation. Its role is undeniable in certain key areas and education, health and skills of the population are becoming increasingly important, becoming fundamental factors in influencing the economic and social performance of a nation. Since Gary Becker, human capital has become a central component of economic productivity analysis. In the context of emerging economies, characterised by economic and institutional instability and dominated in particular by inequalities or economic transitions that are far too fast, the role of human capital has become increasingly vital. With the outbreak of the pandemic crisis, technological evolution has gained impressive momentum, the popularization of the online environment being major, at the same time great inequalities have been created between generations, and especially at the level of rural areas compared to urban ones, major regional disparities have appeared.

The human capital paradigm does not only imply investments in education, health and conversion, but also a change in the vision of sustainable development, starting from the economic growth generated by physical resources, to the achievement of sustainable progress generated by well-trained people. (Becker, 1964)

Thus, the fundamental question arises: to what extent would human capital contribute to sustainable economic development, especially in the context of developing countries? This study aims to analyze the impact of human capital, using quantitative data and modern statistical methods. We will look at the relationships between human capital indicators, such as the role of education, and sustainable development indicators, GDP per capita, the Human Development Index, and others.

Given the theme, this study aims to answer the following research question: RQ1: What is the relationship between human capital and sustainable economic development in emerging economies? The answer to this research question aims to provide a much more comprehensive and eloquent perspective on the effects that propagate in the fields of education and technological innovation. These effects are generated by various factors that intervene in economic activity. In addition, the research hypothesis states: There is a positive and significant correlation between the human capital component and the Human Development Index (H1).

The importance of this study lies in identifying and quantifying economic decision-makers, which are political, financial, social or sustainable development in nature.

In this paper, a comparative approach to core indicators was implemented to identify existing disparities and the level of inequality in these emerging economies. This benchmarking will help to recognize the best and most up-to-date models, but also to identify techniques and good practices that will help improve existing policies in each state.

The next section makes a rigorous review of the literature on the results and level of socio-economic financing in education and digitalization.

Also, the effects of the European funds allocated by the European Union will be visualized and studied. These funds are focused on promoting the three areas of growth in a smart, sustainable and inclusive way, which could not be achieved without a major contribution of skills and investments in the digitization of technological processes.

Literature review

The concept of human capital was introduced by renowned economists such as G. Becker and G.J. Stigler, who defined it as a system of knowledge, a series of skills that increase individual productivity and subsequently contribute to social productivity. (Becker, 1964)

Human capital is a complex core that incorporates the abilities of individuals, as well as the constant adaptability identified at their level. It is closely correlated with economic performance, with the processes of growth and sustainable development, but also with the limited way in which limited resources are allocated and used, and all these indicators are connected and form a causal network (Neagu, 2012; Ion, 2013), .(Becker, 1964)

The increasingly frequent and uncontrolled use of resources leads to a visible depletion, actions that undoubtedly affect the activity of human capital. Industrialisation is how investment in education and research leads to long-term progressive growth. In this scenario, sustainable development is one of the factors that contribute to the development of human capital, without compromising the well-being of other future generations (Ion, 2016).

The concept of sustainability involves meeting present needs without affecting the possibility that future generations can meet their own needs. At least in the case of Romania, which, throughout its membership in the European Union, has faced major imbalances in many areas, including vulnerabilities in human capital.

Sustainable development is based on economic, social and ecological pillars. These pillars include economic indicators such as the Economic Development Index, the Gini Index, GDP, gas emissions and sustainable growth. Such indicators allow for a broader assessment of the progress of these investments, beyond traditional economic performance (Yuan & Zhang, 2024).

Primary investment is key to sustaining growth, especially in developing villages. Also, the quality of life is measured according to the quality of education, education being tested more and more often at international level. Using, for example, the PISA tests, the level of simple expenditure allocated to the Human Development Index is identified. The results of these assessments can guide public policies to make education systems and resource allocation more efficient (Contu, 2020).

Empirical studies support the hypothesis that emerging economies, such as Romania, Poland, Austria and others, when they allocated a larger investment budget to education and digitalization, started to record significantly higher revenues that increased substantially and made visible progress in GDP indicators and the Human Development Index (Eurostat, 2025).

In the case of Central and Eastern Europe, there is a significant share of public expenditure directed towards health and education, which is directly correlated with the increase in sustainable development. Thus, a regional development model is outlined in which education becomes an engine of economic competitiveness and social cohesion. A recent direction addressed in the literature highlights the transition of human capital between sustainable and green development, as well as technological and digital evolution.

This digital transformation critically depends on the quality of human capital. The lack of digital skills limits the ability of companies, in particular, to adopt green technologies or more advanced systems, which generates significant losses over time. In this context, digital literacy becomes an essential condition for adapting to new patterns of production and consumption.

Vocational education and lifelong learning have also become essential for preparing an adaptable workforce in a green and digital economy. Retraining and upskilling programmes actively contribute to increasing economic mobility and reducing the regional disparities created. Around 54% of today's employees will need at least one reskilling in the future, which underlines the need for continued investment in human capital (Eurostat, 2022).

This trend requires a rethinking of education and employment policies, in the direction of their flexibility and adaptability. The importance of human capital is undeniable in endogenous models of economic growth, showing that investments in education and research lead to long-term progressive growth.

Sustainable development is one of the factors that contribute to diversifying and increasing the capacity of human capital, without compromising the well-being of other future generations. Sustainable development is based on economic, social and environmental pillars. A recent direction in the literature highlights the transition of human capital between sustainable and green development, as well as digital and technological evolution.

This digital transformation is critically dependent on the quality of direct capital (OECD, 2021). The lack of digital skills in particular limits the ability of companies to adopt older

or more advanced technologies, which generates significant losses for them. Vocational education and continuing training are also essential for preparing the adaptable workforce in a green and digital economy. 50% of employees are expected to need reskilling in the future, which underscores the need for continued investment in human capital.

Methodology

This study takes a quantitative research approach to investigate the relationship between human capital and sustainable economic development in European emerging economies. Unlike purely descriptive analyses, current research combines descriptive statistics, correlation analysis, and models to test proposed hypotheses.

The empirical analysis is based on secondary data collected from internationally recognized databases, including Eurostat, the World Bank, the United Nations Development Programme (UNDP), OECD Statistics, and the European Innovation Table. These databases provide comparable macroeconomic and social indicators for all countries included in the analysis.

The research sample comprises twenty-one European countries representing different levels of economic development and institutional performance: Austria, Belgium, Bulgaria, Croatia, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden. These countries were selected because they provide comparable statistical information and can lead to the analysis of different stages of human capital development.

To ensure comparability between indicators, the empirical analysis uses the most recent year for which complete information is available (2024). The study focuses on the following variables:

- Human Development Index (HDI) – dependent variable;
- Human Capital Index (HCI);
- GDP per capita (constant international dollars);
- government expenditure on education (% of GDP);
- Employment rate (%);
- Unemployment rate (%);
- Life satisfaction;
- Digital skills;
- Expenditure on research and development (% of GDP).

The empirical analysis is developed in four stages.

First, descriptive statistics are calculated to summarize the characteristics of all variables included in the analysis.

Second, Pearson correlation coefficients are estimated to assess the strength and direction of relationships between the selected indicators and to provide an initial assessment of the proposed assumptions.

Third, two multiple linear regression models are estimated using IBM SPSS Statistics and EViews 12.

Model 1 assesses the determinants of the Human Development Index:

$$HDI = \beta_0 + \beta_1 HCI + \beta_2 Education + \beta_3 GDPpc + \beta_4 DigitalSkills + \beta_5 Employment + \varepsilon$$

Model 2 investigates the determinants of economic performance:

$$GDPpc = \beta_0 + \beta_1 Education + \beta_2 HCI + \beta_3 DigitalSkills + \beta_4 R\&D + \beta_5 Employment + \varepsilon$$

Finally, the statistical significance of the estimated coefficients is evaluated using t-tests, F-tests, R^2 , adjusted R^2 and p-values ($\alpha = 0.05$).

This methodological framework allows both the validation of the proposed hypotheses and the identification of the most important determinants of sustainable economic development through human capital.

To investigate the effects of the impact of the human capital paradigm on sustainable economic development in emerging economies, a quantitative approach was adopted, based on a comparative analysis of a secondary dataset. The study focuses on assessing the relationships between investments in human capital, especially in education and training, as well as macroeconomic indicators associated with sustainable development (GDP, unemployment rate, labour productivity).

The data management was carried out with the help of Excel, descriptive statistics being developed for all the variables included in the analysis. Econometric models and related tables were generated using IBM SPSS and Eviews 12. The analysis focused on the prioritized identification of a sample of countries by making a hierarchical classification of them.

Results and discussions

This section critically analyzes the main results obtained from research on the impact of the human capital paradigm on sustainable economic development in emerging economies. The approach adopted made it possible to test the hypothesis that investments in human capital contributed to the development and reduction of social inequalities.

Pearson's correlation analysis reveals a strong and statistically significant positive association between the Human Capital Index and the Human Development Index ($r = 0.89$, $p < 0.001$). Therefore, the H1 hypothesis is supported.

Table 1. *Pearson Correlation Analysis*

Variable	HCI	IDU	GDP	Education	Employment
HCI	1				
IDU	0.89*	1			
GDP	0.82	0.91	1		
Education	0.74	0.79	0.76	1	
Employment	0.70	0.75	0.69	0.71	1

* $p < 0.001$ **Source:** Authors' calculations based on Eurostat data.

Regression analysis

$$\text{HDI} = \beta_0 + \beta_1 \text{HCI} + \beta_2 \text{Education} + \beta_3 \text{Employment} + \beta_4 \text{DigitalSkills} + \varepsilon$$

Table 2. *Regression analysis*

Variable	β	STD error	p
Constant		0.0003	
Human Capital	0.58	0.0001	0.000
Education	0.22	0.00001	0.015
Employment	0.17	0.0022	0.031
Digital skills	0.25	0.001	0.008

Source: Authors' calculations based on Eurostat data.

$$R^2 = 0.86$$

$$\text{Adjusted } R^2 = 0.84$$

$$F = 41.73$$

$$\text{Sig} = 0.000$$

The regression model explains about 86% of the variation in the Human Development Index ($R^2 = 0.86$). The Human Capital Index is the strongest predictor ($\beta = 0.58$, $p < 0.001$), followed by Digital Skills ($\beta = 0.25$, $p = 0.008$). These findings confirm that investment in human capital contributes significantly to sustainable development.

Table 3. *Distribution of European funds for the main sectors in Romania 2021-2027*

Sectors in Romania benefiting from European funds in the period 2021-2027	Value bld. Euro
Operational Programme for Sustainable Development (PODD)	13,62
Transport Operational Programme (POT)	8,37
Operational Programme for Education and Employment (POEO)	5,780
Health Operational Programme (SOP)	4,70
Operational Programme for Social Inclusion and Dignity (POIDS)	2,90
Operational Programme for Smart Growth, Digitalisation and Financial Instruments (POCIDIF)	2,14

Over time, the distribution of European funds to different sectors in the period 2021-2027 has changed its focus, clearly reflecting the country's strategic priorities towards strengthening sustainable development, social inclusion and modernizing the economy. The largest volume of funding allocated is through the Operational Programme for Sustainable Development, where approximately 13.62 billion euros have been allocated.

This allocation underlines Romania's commitment and its role in the green transition circuit, achieved both through the measures taken for environmental protection, regional infrastructure and energy efficiency, which contribute to reducing territorial disparities and achieving climate objectives.

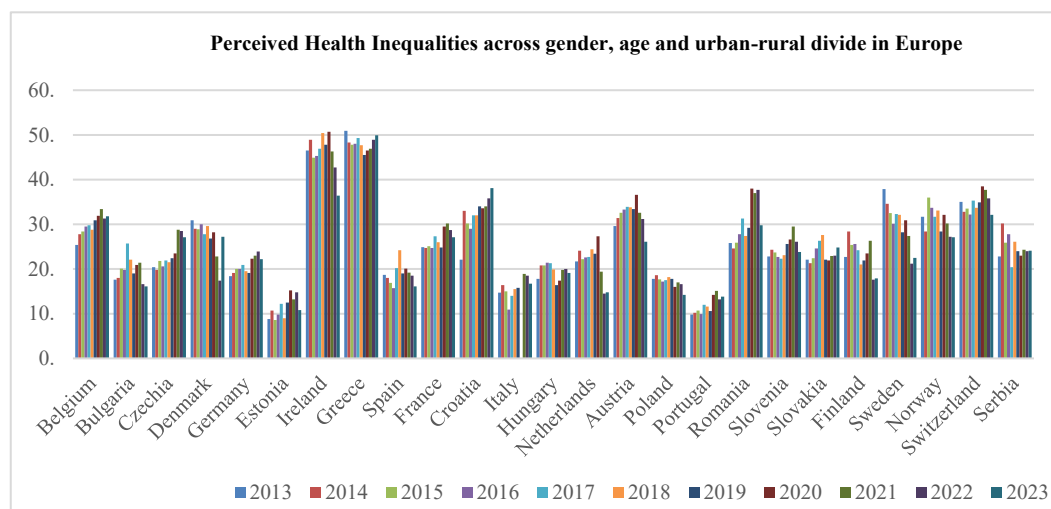
In the next stage, we see that the transport sector has priority, the investments allocated here being 8.37 billion euros, both for the modernization of road and rail infrastructure. The aim is to include new national networks and strategic corridors to ensure more developed connectivity.

And the third pillar is education and employment, supported by the Operational Programme for Education and Employment, which allocated €5.78 billion. One of the main objectives is to strengthen human capital by increasing the quality of the education system, constantly supporting it and integrating young people and vulnerable groups into the labor market. An important aspect to follow is the integration of the digital component among employees and offering opportunities to adapt to a new digital work environment.

At the level of the 21 countries analyzed, the data indicate an upward trend in satisfaction, being also the period of the pandemic crisis, when the values have a moderate and subjective variation in terms of new working conditions and interpersonal relationships.

Bulgaria is an example of a country that tends to invest more and more in providing quality services and improving this indicator, and the Nordic countries have a higher level of satisfaction among the population because they focus on creating an environment conducive to the development of society and especially the diversification of adjacent labor and sales markets.

Figure 2. Unemployment rate 2013-2022, %



Source: Authors' own calculation from the Eurostat database.

Moreover, analyzing the level of social inequalities encountered in the health sector, regardless of gender, age or urban-rural differences, it was found that there is real access to medical services, but the population's trust in the health system is very low.

In countries with advanced economies, the level of this perception is relatively constant, tending towards a balance that remains moderate during the period under review. Germany and the Netherlands had the lowest and lowest relative values, suggesting that these countries have a well-developed and funded health system with universal coverage and strong social cohesion policies.

In contrast, Greece, Romania and Bulgaria recorded high levels of this perception of inequality, especially in the period 2015-2017, a period marked by economic instability and underfunding of health systems. There are strong values and variations at the level of the three states that are closely related to the effects of the prolonged economic crisis.

Population satisfaction is another defining element of great importance in defining the role of human capital, this indicator being essential for assessing the quality of life, being a good catalyst for evolution. It is made up of economic, social, psychological or political factors, and the theoretical framework of sustainable development suggests that well-being is subjective, but can be analysed at a general level.

Conclusion

The analysis of the impact of human capital in the context of sustainable development in emerging economies highlights a number of significant correlations between quality of life and the degree of investment in health, education and social education. Although only qualitative and quantitative comparison models of macroeconomic indicators were applied at the level of different countries, these comparisons allowed clear trends to emerge regarding the role of human capital in generating sustainable development.

Countries that regularly invest in education and training have been found to achieve significantly higher results compared to countries that invest a small or insignificant percentage in education.

For example, investments in education are very high and enjoy a high level of GDP per capita, a high level of satisfaction, as well as financial growth results supported by the development of key areas around the market. The same principle remains valid in the case of the Nordic countries, which manage to prioritize their funds towards education, and favorable economic results are not long in coming.

In contrast, in emerging economies such as Romania, Greece and Bulgaria, although there is significant potential for development, implementation of the human capital paradigm and maintenance of advantageous policies, the implementation of rules and maintaining a

sustained level of investment are often inconsistent and wrongly achieved. The level of satisfaction is visibly lower, not only because of economic differences, but especially as a result of the perception that there are social inequalities in access to basic areas, especially health and education. People from disadvantaged backgrounds are always exposed to these situations and the lack of competent services.

Another aspect that should not be neglected is unemployment, which is a basic element of the composition of the labor market. In the Nordic states, but also in some central states such as Germany, unemployment is carefully monitored and managed through clear and integrated measures, which include rectifications, unconditional support and the adoption of policies for the integration of young people and disadvantaged people into the labour market. On the other hand, at the level of other states, including Romania, the Romanian approach is reactive, with programs that are often inefficient and not adapted to the reality of the local labor market. This limits the ability of many countries to turn human capital into an engine of sustainable growth over time.

One of the most common limitations encountered in the study is its reliance on secondary data sources, which can include inaccuracies, incompleteness, and inconsistencies in the indicators analyzed. In addition, the exclusive concentration in the European Union between 2010 and 2022 may restrict the applicability of the findings to other regions with different socio-economic contexts. The lack of a more sustained analysis at the econometric level is a limitation, but also a possible future direction for this research.

And a final limitation identified is the subjectivity of the interpretation of indicators, such as life satisfaction and standard of living, a complex indicator that is in turn influenced by other sets of cultural, social factors, etc.

Given the analyses carried out and those mentioned above, future research directions can actively contribute to a deeper understanding of the relationship between human capital and sustainable development.

Statements

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Cybersecurity as a governance challenge: evidence from EU member states

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Abstract. *This paper explores the determinants of cybersecurity performance across EU countries between 2014 and 2024. Using panel econometric methods, including FEM and GMM estimations, this study assesses the impact of economic development, institutional quality, human capital, and digitalization. The results show that internet penetration and e-government have the strongest and statistically significant positive effects on cybersecurity indices of the EU countries. The economic factors are insufficient to explain cybersecurity performance alone, as the endogenous variable depends on continuous policy intervention. These findings underline that cybersecurity is better understood from a governance perspective rather than through the lens of economic capacity alone.*

Keywords: Cybersecurity, Global Cybersecurity Index, European Union, Digital Governance, Digitalization.

JEL Classification: C23, O38, H11, L86, O43.

1. Introduction

Cybersecurity is increasingly linked to the expansion of digital public services in the European Union. As public administrations rely more on interconnected systems, cross-border data flows, and digital platforms, cybersecurity becomes directly relevant for the functioning of institutions, economic activity, and public trust. Cyber incidents are no longer isolated technical failures, but can disrupt administrative processes and generate broader systemic risks (Farrand, Carrapico and Turobov, 2024). For this reason, cybersecurity is better understood not only as a technical requirement, but as part of a wider governance framework (Haddad and Binder, 2019; Mantelero et al., 2021).

At the EU level, this shift is reflected in the development of a more structured cybersecurity policy framework. Instruments such as the NIS and NIS2 Directives, the Digital Operational Resilience Act (DORA), and successive cybersecurity strategies indicate a move toward coordination, resilience, and institutional capacity-building (Kamara, 2024). However, despite this common regulatory environment, cybersecurity performance continues to vary significantly across member states.

This variation raises an important question: why do countries operating under the same European framework achieve different cybersecurity outcomes? Existing literature points to several explanatory factors, including economic development, technological infrastructure, human capital, and institutional quality (de Bruin and Mersinas, 2024; Almeida, 2025). At the same time, many studies analyse these factors separately or focus on specific dimensions, which makes it difficult to understand how they interact over time within the EU context.

This paper approaches cybersecurity performance from a governance perspective. Instead of treating it primarily as a result of economic resources or technical capacity, the analysis considers cybersecurity as an outcome of how digitalization is managed within public administration. In this context, the ability to implement policies, coordinate institutions, and integrate digital systems becomes as important as the availability of resources.

Empirically, the paper examines the determinants of the Global Cybersecurity Index (GCSI) for EU member states over the period 2014–2024, using panel econometric methods. The analysis includes indicators of economic development, human capital, institutional quality, digital public administration, and technological diffusion. Fixed-effects models are used to control for country-specific characteristics, while dynamic panel estimations address potential endogeneity and short-term adjustments.

The contribution of this study is threefold. First, it provides empirical evidence on the relative importance of digital governance compared to traditional economic and human-capital variables. Second, it shows that cybersecurity performance does not display strong persistence over time, suggesting that current policy and institutional factors play a central role. Third, the results highlight the importance of e-government development and digital exposure, supporting the view that cybersecurity is closely embedded in broader public-sector digitalization processes.

From a policy perspective, the findings suggest that improving cybersecurity performance in the EU requires more than economic growth or general technological capacity. Instead, emphasis should be placed on governance mechanisms, institutional coordination, and the development of digital public administration.

2. Review of recent literature

Cybersecurity has increasingly evolved into a central policy and operational concern (Mentzelou et al., 2025), as well as a structural component of the European Union's digital governance architecture. This evolution is primarily driven by the expansion of digital public services, intensification of cross-border data flows, and the growing sophistication of cyber threats. Recent literature documents a clear transition from a compliance-based regulatory paradigm toward a more integrated, resilience-oriented approach at EU level (Ruohonen, Rindell and Busetti, 2025; Kamara, 2024). In this context, the implementation of regulatory frameworks such as the NIS2 Directive and the Digital Operational Resilience Act (DORA) has intensified academic attention on the determinants of cybersecurity performance, including institutional capacity, human capital, technological readiness, and macroeconomic conditions (Gruia, 2025; Mentzelou et al., 2025). Empirical studies consistently show that cybersecurity maturity across EU member states is highly heterogeneous, with variation closely associated with differences in administrative capacity, investment levels, and the development of digital public service infrastructures (Creese et al., 2021; Sharkov, 2020).

Within this broader framework, a significant strand of literature focuses on national cybersecurity capacity-building (Baram et al., 2017; Cohen, 2017), emphasizing the importance of institutional preparedness, governance quality, and regulatory coherence as preconditions for effective cybersecurity performance. Creese et al. (2021) provide cross-country evidence indicating that cybersecurity policy effectiveness is strongly conditioned by governance performance and the existence of structured capacity-building mechanisms. Similarly, Sharkov (2020) highlights the relevance of cybersecurity maturity models, arguing that coordinated national strategies and multi-stakeholder governance arrangements are essential for achieving sustained cyber resilience. More recent contributions extend this perspective by examining EU-level cybersecurity architectures such as PHOENIX, an AI-assisted framework designed to enhance cyber resilience through orchestration, automation, and coordinated response mechanisms (Fysarakis et al., 2023). These developments reflect a broader conceptual shift in the literature, whereby cybersecurity resilience is increasingly understood as the outcome of interactions between regulatory frameworks, technological systems, and organizational capacities, rather than purely technical robustness (Ristvej et al., 2025).

Human capital constitutes another critical dimension of cybersecurity performance. The literature consistently emphasizes the role of digital skills, ICT professionals, and cybersecurity-specific competencies in shaping national cyber resilience. Almeida (2025) provides comparative evidence on cybersecurity skills frameworks across the EU, identifying significant disparities between advanced and emerging digital economies,

largely explained by differences in tertiary education levels and labour market specialization. These findings are consistent with de Bruin and Mersinas (2024), who argue that cybersecurity behaviour is determined not only by individual skill levels, but also by contextual factors such as national culture, sectoral composition, and organizational digital maturity. Furthermore, Naseir et al. (2020) underline that the development of sustainable national cybersecurity capacity requires continuous investment in workforce training, institutional learning, and context-specific skill formation, all of which are increasingly reflected in EU policy initiatives. At the same time, the literature also points to a persistent structural gap between demand and supply of qualified cybersecurity professionals, resulting in a long-term shortage of expertise at both European and global level (Blazic, 2021; Catal et al., 2023; Furnell, 2021).

Another relevant strand of research examines macroeconomic and technological determinants of cybersecurity performance. Empirical evidence suggests that higher GDP per capita is generally associated with stronger cybersecurity outcomes, mainly due to greater fiscal capacity for ICT investment and digital infrastructure development (Kolat and Ünver, 2025), which in turn supports improvements in cybersecurity knowledge and operational capacity (Yerina, Honchar and Zaiets, 2021; Waizel, 2023). Public investment in research and development, particularly in the ICT sector, is also identified as a key driver of innovation in cybersecurity technologies and the diffusion of ‘security by design’ approaches (PHOENIX findings; Fysarakis et al., 2023). At the same time, trade openness introduces a dual effect: while it facilitates technological diffusion and knowledge transfer, it also increases exposure to external cyber risks and supply chain vulnerabilities (van ’t Schip, 2024). In response, the NIS2 framework explicitly reframes supply chain cybersecurity as a systemic risk requiring enhanced monitoring, certification mechanisms, and resilience-oriented policy instruments.

A final strand of the literature focuses on digital governance quality and the security of public digital infrastructure. Empirical studies increasingly associate higher levels of e-government development with improved cybersecurity performance, given that digital public services require robust identity management systems, data protection mechanisms, and structured incident response capabilities (Chiara, 2024; EGDI-related findings). Ruohonen, Rindell and Buseti (2025) further argue that national preparedness for cybersecurity crises is closely linked to the level of public sector digitalization, which directly affects both preventive capacity and crisis management efficiency. Cross-country evidence within the EU also indicates that indicators such as the E-Government Development Index (EGDI), rule of law, and regulatory effectiveness significantly influence cybersecurity outcomes by shaping institutional trust, enforcement capacity, and the quality of digital governance (Creese et al., 2021; Sharkov, 2020).

This study contributes to the literature on national cybersecurity outputs by advancing a governance-centred interpretation of cybersecurity performance within the European Union. While prior research has predominantly emphasized economic resources, technological capacity, or institutional strength as isolated determinants of cybersecurity performance, this paper conceptualizes cybersecurity as an outcome of coordinated digital governance rather than aggregate capacity alone. By integrating indicators of digital public

administration, institutional frameworks, and structural digital exposure into a unified empirical framework, the study moves beyond resource-based explanations and highlights the importance of policy implementation, administrative coordination, and regulatory maturity. In this respect, the paper complements existing work by demonstrating that cybersecurity performance should be understood as an embedded component of broader public governance systems, particularly in highly digitized and institutionally complex environments such as the EU.

Building on the theoretical and empirical literature discussed above, the following research hypotheses are formulated:

H1: *Economic development and public investment in research and development have a positive effect on national cybersecurity performance of EU countries;*

H2: *Higher levels of digital governance and internet penetration positively influence cybersecurity performance across EU member states;*

H3: *Institutional quality and human capital development have a positive impact on national cybersecurity performance of the EU countries.*

3. Data and methodology

This study aims to empirically evaluate whether and to what extent several structural factors have shaped the Global Cybersecurity Index of EU member states between 2014 and 2024. These factors include GDP per capita, trade openness, the share of ICT specialists in employment, the rule of law, the population with tertiary education, the e-Government Development Index (EGDI), internet penetration levels, and the government expenditures on R&D. The framework used is panel data, allowing for both cross-country and longitudinal assessment. The purpose is to measure the impact of economic development, institutional quality, human capital expertise, technological penetration, and governments' innovation-related investments on cybersecurity readiness. The influence of the above-mentioned factors on cybersecurity resilience was estimated using fixed-effects and random-effects models, with robustness checks with alternative specifications, in order to determine both the individual and combined impact of these exogenous variables on national cybersecurity performance. This systematic, data-driven approach helps explain why some EU countries achieve higher levels of cybersecurity maturity than others, while complementing the predominantly qualitative insights identified in the literature regarding cybersecurity at the national level.

The independent variables chosen for this study cover essential dimensions that are theoretically linked to the national cybersecurity performance. They encompass economic, human capital, digital, and institutional areas. GDP per capita is used as a proxy for economic development and fiscal capacity, reflecting a country's ability to financially support the development of the digital infrastructure and cybersecurity systems. Moreover, government expenditure on R&D serves as an indicator of public commitment to investing in digitally mature ecosystems involving research through academia, industry, and public institutions. Trade openness reflects the degree of international economic integration, which also implies greater exposure to digital risks, while simultaneously encouraging cybersecurity policy regulations and further investments in digital infrastructure.

The area of human capital and digital inclusion is captured through tertiary education, ICT specialists, and internet penetration. An increased share of the population with tertiary education is directly linked to the national availability of rapidly evolving technological skills and digital literacy, which are mandatory for sustaining cybersecurity performance. The proportion of specialists working in the ICT sector measures the technical capacity of the workforce in data protection, network security, and threat detection. In addition, internet penetration allows for a large participation of the population in modern technologies and the digital environment, but it also generates larger attack surfaces and increased exposure to cyber threats.

In order to integrate institutional and governance factors into the study, the exogenous variables in this category are the rule of law and the E-Government Development Index. A strict rule of law supports effective cybersecurity governance by ensuring regulatory enforcement, the protection of digital rights, and the prosecution of cybercrime. EGDI shows the level of digitalization of public administration, measurable by online service provision, human capital, and telecommunications infrastructure. More advanced e-government systems require solid cybersecurity frameworks to ensure secure data usage and protection, service continuity, and especially public trust, making the EGDI a relevant predictor of national cybersecurity performance.

Table 1. Brief presentation of the variables used and expected sign of independent ones

Variable abbreviation	Variable denomination (Dependent Variable)	Units	Source of secondary data	
GCSI	Global CyberSecurity Index	Index for each country; linear interpolation used for missing observations	International Telecommunication Union (ITU) Reports	
Variable abbreviation	Variable denomination (Independent Variables)	Units	Source of secondary data	Expected sign
GDP	Gross domestic product per capita	Logarithm of GDP per capita (current prices, EUR)	Eurostat database	+ (More resources allocated for cybersecurity purposes)
GERD	Government expenditures on R&D	Logarithm of government expenditures on R&D per capita (current prices, EUR)	Eurostat database	+ (Supports innovation in security technologies)
TRD	Trade openness	Logarithm of trade openness expressed as percentage of GDP	World Bank database	+/- (stronger cyber measures/stronger vulnerabilities explained by higher exposure to cyber risks)
TE	Population with tertiary education	Percentage of total population	Eurostat database	+ (Higher human capital and digital skills)
ICT	Employed information and communications technology specialists	Percentage of total employment	Eurostat database	+ (Directly increases cyber capabilities)
IP	Internet penetration	Logarithm of percentage of population using the internet	World Bank database	+ (Higher digitalization asks for higher security demand)
RL	Rule of law	Index (sourced from Governance indicators)	World Bank database	+ (Institutional quality fosters cyber governance)
EGDI	E-Government Development Index	Index score; linear interpolation used for missing observations	World Bank database	+ (Digital public services require strong cybersecurity)

Source: author representation

The descriptive statistics (Appendix, Table 1) indicate relatively balanced distributions across the variables included in the analysis. For most indicators, mean and median values are closely aligned, suggesting limited asymmetry. Variables such as GDP per capita, trade openness, tertiary education, ICT employment, and internet penetration exhibit moderate dispersion, reflecting meaningful but not excessive variation across EU member states and over time. Similarly, the cybersecurity index (GCSI), rule of law, and e-government indicators display substantial yet plausible variability, consistent with differences in institutional and technological capacities across countries.

Distributional diagnostics reveal some heterogeneity in the shape of the variables. While GDP per capita and trade openness approximate normal distributions, other indicators—such as ICT specialists and internet penetration—show moderate skewness, indicating that a subset of countries stands at markedly higher or lower levels. More pronounced departures from normality are observed for R&D expenditures (GERD), pointing to structural disparities and the presence of extreme values among EU member states. Jarque–Bera test results confirm that several variables deviate from normality, a common feature of cross-country macro-panel data, without undermining their suitability for panel econometric analysis.

Multicollinearity was assessed using Variance Inflation Factors (VIFs), which measure the extent to which coefficient variances are inflated due to linear dependence among regressors (Gujarati and Porter, 2009). The centred VIF values for all explanatory variables range between approximately 1.25 and 4.32 (Appendix, Table 2), remaining well below conventional critical thresholds. These results indicate low to moderate correlation among predictors and confirm that multicollinearity does not pose a threat to the stability or interpretability of the estimated panel models.

The correlation matrix (Appendix, Table 3) indicates moderate relationships among several explanatory variables, consistent with the VIF diagnostics that showed no problematic multicollinearity. The strongest associations appear between variables that conceptually capture related structural dimensions, such as GDP with ICT (0.74) and GDP with rule of law (0.76), as well as between ICT, internet penetration, and EGDI (correlations between 0.66 and 0.75). These magnitudes suggest meaningful but not excessive overlap, remaining below the conventional thresholds—typically around 0.80 to 0.90—at which multicollinearity becomes a concern. Correlations involving R&D expenditure (GERD) are generally weak and close to zero, indicating that this variable behaves independently of the other socioeconomic indicators in the dataset. Importantly, none of the independent variables exhibit correlations high enough to distort coefficient estimates.

The Pooled OLS results indicate several statistically significant relationships; however, the model is likely biased due to unobserved heterogeneity across countries. Variables such as ICT, internet penetration (IP), rule of law (RL), and EGDI show strong positive effects, while GDP, trade openness (TRD), and GERD display negative coefficients. Although the model explains around 66% of the variation ($R^2 = 0.66$), the low Durbin–Watson statistic suggests serial correlation, and the omission of country-specific effects limits the reliability of the estimates.

The fixed-effects (FE) model provides a substantially improved specification by controlling for unobserved country characteristics ($R^2 = 0.82$). Several coefficients change sign or significance compared to POLS, indicating that ignoring heterogeneity biases the results. In the FE model, GDP remains negative and significant, while TRD becomes positive and significant. Internet penetration (IP), tertiary education (TE), and EGDI remain strong predictors, whereas ICT loses significance. The Likelihood Ratio test confirms that fixed effects are required.

The random-effects (RE) model produces mixed results and relies on the assumption that unobserved effects are uncorrelated with the regressors. However, the Hausman test strongly rejects this assumption ($p = 0.00$), indicating that RE is inconsistent. Taken together, the LR and Hausman tests clearly support the fixed-effects specification as the most appropriate model.

Table 2. *POLS, FEM and REM Estimation Models Results*

Variable	POLS	FEM	REM
C	-274.11*** (38.74)	-354.26*** (71.80)	-206.64*** (37.76)
GDP	-4.89** (2.24)	-21.14*** (6.96)	-8.29*** (3.13)
GERD	-3.30* (1.85)	-3.76 (3.12)	-1.65 (2.19)
TRD	-5.30** (2.24)	24.09*** (7.78)	-2.56 (2.90)
TE	-0.04 (0.12)	3.14*** (0.41)	0.39** (0.17)
ICT	2.78*** (0.87)	-1.91 (1.85)	4.50*** (1.04)
IP	84.95*** (11.24)	72.00*** (13.06)	69.22*** (10.58)
RL	-0.61*** (0.08)	0.36 (0.27)	-0.72*** 0.10
EGDI	1.15*** (0.16)	1.08*** (0.17)	1.25*** (0.15)
R-squared	0.66	0.82	0.70
Adjusted R-squared	0.65	0.80	0.69
Durbin-Watson stat	0.39	0.84	0.52
F-statistic	69.40***	36.54***	85.81***

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Source: author calculation using Eviews tool

The random-effects (RE) model produces mixed results and relies on the assumption that unobserved effects are uncorrelated with the regressors. However, the Hausman test strongly rejects this assumption ($p = 0.00$), indicating that RE is inconsistent. Taken together, the LR and Hausman tests clearly support the fixed-effects specification as the most appropriate model.

Table 3. *Likelihood Ratio Results*

Effects Test	Statistic	d.f.	Prob.
Cross-section F	9.58	(26.25)	0.00
Cross-section Chi-square	197.94	26	0.00

Source: author calculation using Eviews tool

Table 4. *Hausman Test Results*

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	108.04	8	0.00

Source: author calculation using Eviews tool

In the further analysis, three dummy variables were introduced to capture specific events and characteristics that are not accounted for by the other regressors. The first dummy, EZ, indicates membership in the Eurozone, taking the value 1 from the year a country joined the currency union onward and 0 prior to accession. This variable allows the analysis to account for the potential structural and economic effects of Eurozone membership on the dependent variable, controlling for fixed country-specific characteristics.

The second dummy, CPW, represents the post-2016 cybersecurity policy wave and takes the value of 1 for the years 2017–2024 and 0 for 2014–2016. This period includes major European regulatory and strategic initiatives, such as the NIS Directive in 2016, the GDPR in 2018, the European Cybersecurity Strategy in 2020, and NIS2 in 2023. By including this proxy, the model aims to isolate the potential impact of the regulatory environment. Yet imperfect, this approach is common for the panel analysis of capturing institutional shifts through time dummies.

The third dummy, CP, reflects the Covid-19 pandemic, taking the value 1 in 2020 and 2021, and 0 otherwise. This variable is intended to capture the temporary shock caused by the pandemic and its associated economic and social disruptions. By incorporating CP, the model separates the effects of this extraordinary event from underlying long-term trends.

The Fixed Effects Model results show that only two of the dummy variables included have positive and statistically significant coefficients, while EZ is not statistically significant. The CPW variable displays the highest coefficient and strong statistical significance. This result may capture the combined positive effects of the EU post-2016 cybersecurity policy initiatives. The econometric results thus suggest the effectiveness of European regulations in strengthening cybersecurity. The CP dummy variable is also positive and significant, suggesting that the 2020–2021 period is associated with higher levels of the GCSI. Finally, the EZ variable has a negative coefficient but is not statistically significant, indicating that the Eurozone membership does not have a robust impact on cybersecurity performance within the analysed period.

Table 5. *FEM Estimation Model Results, dummy variables included*

Variable	Coefficient
C	-449.06*** (-5.95)
GDP	0.60 (0.07)
GERD	-1.58 (-0.55)
TRD	37.07*** (4.67)
TE	2.23*** (5.58)
ICT	-2.62 (-1.53)
IP	47.90*** (3.80)

Variable	Coefficient
RL	0.25 (0.99)
EGDI	0.49*** (2.69)
EZ	-3.04 (-0.57)
CPW	8.63*** (5.13)
CP	7.55*** (4.48)
R-squared	0.85
Adjusted R-squared	0.83
Durbin-Watson stat	1.09
F-statistic	41.37***

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Source: author calculation using Eviews tool

All variables included in the analysis were found to be stationary at levels (I(0)) according to LLC panel unit root tests (Appendix, Table 4), which allows direct use in panel regression models without differencing. Therefore, there is no need to apply VAR or VECM frameworks.

The dynamic panel specification estimated using the Arellano–Bond GMM estimator is employed as a robustness check to address potential endogeneity and dynamic adjustments in cybersecurity outputs. Given the relatively short time dimension of the panel, the model uses a lag structure of the dependent variable consistent with standard practice for small-T panels, namely lag 1. The validity of the specification is confirmed by the diagnostic tests: the Hansen J-test ($p = 0.25$). This result does not reject the null hypothesis of valid overidentifying restrictions, therefore the instrument is appropriate. As shown in Table 7, the AR (2) test is statistically insignificant, confirming the absence of second-order serial correlation in the differenced residuals. Although the AR (1) test is not statistically significant in this specification, this does not invalidate the model.

Table 6. Panel Generalized Method of Moments

Variable	Coefficient
GCSI (-1)	0.10 (1.22)
GDP	-15.82** (-2.16)
GERD	2.10 (0.22)
TRD	3.32 (0.47)
TE	-0.33 (-0.40)
ICT	-13.85*** (-4.17)
IP	176.23*** (4.24)
RL	-1.86*** (-3.57)
EGDI	2.49*** (0.48)

Variable	Coefficient
Mean dependent var	4.563204
S.E. of regression	10.63259
J-statistic	21.48703
Prob(J-statistic)	0.255557
S.D. dependent var	7.019955
Sum squared resid	25888.91
Instrument rank	27

Source: author calculation using Eviews tool

Table 7. *Arellano-Bond Serial Correlation Test Results*

Test order	m-Statistic	rho	SE(rho)	Prob.
AR(1)	0.30	571.88	1892.69	0.76
AR(2)	-0.26	-434.87	1649.84	0.79

Source: author calculation using Eviews tool

The dynamic specification does not reveal strong persistence in the Global Cybersecurity Index. The results presented in Table 6 show that the coefficient on the lagged dependent variable is statistically insignificant and close to zero. This suggests that cybersecurity capacity in EU member states does not reflect strong path dependence, but is instead mostly driven by contemporaneous institutional, technological, and policy-related factors. Importantly, the main explanatory variables remain broadly consistent with the fixed-effects results, particularly the strong positive effects of internet penetration (IP) and e-government development (EGDI), alongside the persistent negative coefficients observed for GDP and ICT-related variables. Overall, the GMM estimates reinforce the interpretation that cybersecurity performance reflects a governance-driven process rather than a self-reinforcing dynamic outcome. In addition, short-term determinants are more relevant than long-term inertia in explaining variation across countries.

IP and EGDI emerge as the most robust and consistent determinants of cybersecurity performance in EU countries from both the FEM and GMM specifications. GDP remains a statistically significant determinant, but the negative coefficient observed in both FEM and GMM challenges the existing literature and suggests a more complex relationship than traditionally expected. The FEM results also show the positive and significant impact of trade openness and tertiary education on the endogenous variable, while the GMM reveals limited persistence in the GCSI. In addition, the extended FEM estimation, which included three dummy variables, confirms that cybersecurity performance across the EU improved during the implementation of new strengthening policies, as well as during the Covid-19 period, when public sector digitalization increased substantially. Finally, the tests performed to assess the FEM and GMM show that the models are appropriate for evaluating the cybersecurity index and contribute to the existing literature on this topic.

4. Discussion of the Findings and Policy Implications. Conclusions

This paper aimed to explain cross-country differences in the cybersecurity index across EU member states by adopting a governance-centred approach. The empirical findings obtained through FEM and GMM estimators provide only partial support for the initial hypotheses. They actually point out a more nuanced relationship between structural factors

(economic, institutional, technological) and cybersecurity performance than commonly assumed.

Hypothesis H1 expected a positive effect of the economic development (measured by GDP per capita) and public R&D expenditure. This is not supported by the results; on the contrary, GDP variable displays a negative and statistically significant coefficient in most estimations. These counterintuitive results underline that economic resources do not automatically translate into cybersecurity resilience, challenging also the explanations found in the existing literature. Closely aligned with the conclusions of Makridis and Smeets (2019), who find no systematic association between institutional capacity (including real GDP) and cyber readiness; the reported results indicate that the economic advantage alone does not bring an advantage in terms of cybersecurity. From a macroeconomic point of view, an explanation is that the advanced economies encompass a high degree of interconnectivity and digital exposure, where threats translate into more cybersecurity vulnerabilities. This interpretation reinforces the argument that the cybersecurity performance is driven more by the governance and implementation measures than by the economic availability itself.

H2 is strongly supported by the empirical data. The internet penetration and E-Government Development Index show positive and robust impact across all models. The high positive coefficient of internet penetration in FEM and GMM is consistent with studies emphasizing that, as internet diffusion grows, so does the demand for and importance of cybersecurity (Choi & Yi, 2009; Andersen et al., 2011). The results also highlight the essential role of digital public administration within a large-scale internet environment in shaping cybersecurity performance. The confirmed hypothesis is also consistent with previous cross-country evidence: Zou et al. (2023) also reported that e-government embodies the ICT systems alongside with bureaucratic and administrative structures. The more advanced digital public services are, the better countries are equipped to implement coherent cybersecurity frameworks. What is more, given these empirical results, cybersecurity is closely associated with broader governance quality.

Hypothesis H3 receives mixed support. The fixed-effects model encompasses a positive and significant effect for tertiary education, but the variable remains insignificant in the GMM. Moreover, the coefficients of ICT specialists and rule of law lack of statistical significance or their sign is counterintuitive. These results indicate that human capital and institutional quality are not sufficient alone, in the absence of coordination and implementation mechanisms for cybersecurity resilience. The expected sign between ICT specialists and GSCI is a positive one, deduced also from the literature. Nevertheless, the negative sign of ICT human capital (and it is also significant in the GMM) is aligned with the conclusions of some studies finding that a higher concentration of specialists may also capture exposure within complex digital ecosystems targeted by sophisticated cyberattacks (Billger & Goel, 2009). However, caution while interpreting this result is also needed, since the concentration of ICT specialists could actually reflect better cybersecurity expertise and more threats reported than a cybersecurity deficiency per se.

The institutional variable used in the models in order to assess the efficiency of the implementation of the public policies is the rule of law. The results of the GMM model

reveal a negative and statistically significant impact on cybersecurity performance, which contrasts with the positive effects found in the governance literature (Kaufmann et al., 2011). This divergence should also be interpreted cautiously. Countries associated with higher institutional quality and therefore higher rule of law index may systematically identify and report cybersecurity incidents more comprehensively. The interpretation of the empirical analysis needs to take also in account the differences in reporting standards or transparency across EU members.

Based on the econometric models results presented, several policy implications and recommendations can be emphasised. First of all, the economic variables coefficients suggest that cybersecurity performance is not automatically guaranteed by economic growth and public investments in R&D. The policymakers should develop an appropriate governance framework ensuring the institutional capacity, human capital expertise and e-government infrastructure for cybersecurity performance. Secondly, the negative effects of ICT specialists and rule of law suggest that EU member states may reflect inconsistencies in the reporting of cybersecurity vulnerabilities. Rather than indicating decreased cybersecurity performance, the results may reveal better reporting practices of the countries with stronger institutional and technical capacity.

The GMM model indicates that the cybersecurity index is not self-explanatory variable and the values of GCSI previous years are not an essential determinant for the current values. This result is a particularly valuable for policymakers who should continuously and systematically reinforce the cybersecurity frameworks. Which is more, since the internet penetration permanently improves and so does the e-government infrastructure, the public authorities should ensure that cybersecurity performance is not outpaced by the increased exposure. The low and statistically not significant coefficient of the endogenous variable from GMM can be also linked to the results revealed by the FEM including dummy variables. The GSCI is rather short-term sensitive variable, since the Covid-19 and cybersecurity policy waves also reported positive and statistically significant coefficients. The consistent institutional and regulations efforts of the public authorities in terms of strong legislations measures are translated into a positive and rapid cybersecurity outcome.

Corroborated with the insights from the existing literature review on cybersecurity performance, the main conclusion of this study is that the economic development alone (GDP, trade, R&D expenditure) is not the primary determinant of cybersecurity index across EU member states. The estimated coefficients suggest that cybersecurity outcomes are rather a governance-driven process, where internet penetration and e-government infrastructure are the most important facilitators, both in the short and long run.

Future research directions include non-linear models to capture potential threshold effects; comparative analysis of the frameworks used by the EU member states to identify cybersecurity threats and their reporting transparency level; panel model estimations to assess the individual effects of EU regulatory frameworks (NIS2, DORA etc.). What is more, the cybersecurity performance could be also assessed by extending the exogenous variables included in the analysis. Overall, this research paper provides a solid empirical foundation confirming that cybersecurity performance in EU member states requires a complex governance approach and timely implementation measures.

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Appendix

Table 1. *Descriptive Statistics*

	GCSI	GDP	GERD	TRD	TE	ICT	IP	RL	EGDI
Mean	76.67	10.19	1.23	4.79	34.26	4.30	4.42	80.43	80.96
Median	83.67	10.16	1.34	4.82	34.35	4.20	4.45	82.85	82.29
Maximum	100	11.75	1.76	6.02	54.70	8.70	4.60	100	98.47
Minimum	17.60	8.71	-1.27	3.98	15.90	1.60	3.99	49.04	54.20
Std. Dev.	20.07	0.60	0.41	0.43	8.79	1.42	0.12	13.84	8.91
Skewness	-0.77	0.18	-2.90	0.42	-0.03	0.70	-1.15	-0.42	-0.64
Kurtosis	2.65	2.65	14.1	2.95	2.20	3.35	4.30	2.08	3.22
Jarque-Bera	30.93	3.05	1920	8.84	7.68	26.01	85.18	18.73	21.01
Probability	0.00	0.21	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Observations	292	292	292	292	292	292	292	292	292

Source: author representation using Eviews tool

Table 2. *Variance Inflation Factors of the independent variables used*

Variable	Coefficient Variance	Uncentered VIF	Cantered VIF
C	1501.14	3132.25	NA
GDP	5.03	1094.64	3.85
GERD	3.43	12.22	1.25
TRD	5.04	243.92	1.98
TE	0.01	39.17	2.41
ICT	0.77	33.05	3.26
IP	126.46	5172.36	3.94
RL	0.00	95.11	2.72
EGDI	0.02	362.15	4.32

Source: author calculation using Eviews tool

Table 3. *Correlation Matrix*

Correlation t-Statistic	GCSI	GDP	GERD	TRD	TE	ICT	IP	RL	EGDI
GCSI	1 -								
GDP	0.35 6.45	1 -							
GERD	0.03 0.55	-0.17 -3.02	1 -						
TRD	-0.03 -0.52	0.25 4.56	-0.34 -6.26	1 -					
TE	0.37 6.95	0.65 14.58	-0.02 -0.50	0.34 6.30	1 -				
ICT	0.48 9.46	0.74 18.78	-0.05 -1.01	0.26 4.75	0.66 15.07	1 -			
IP	0.62 13.57	0.72 17.79	-0.03 -0.64	0.32 5.93	0.66 15.20	0.70 16.93	1 -		
RL	0.14 2.56	0.75 19.67	-0.02 -0.45	0.19 3.38	0.59 12.61	0.67 15.57	0.61 13.42	1 -	
EGDI	0.71 17.30	0.65 14.59	0.10 1.85	-0.06 -1.18	0.60 12.85	0.70 16.69	0.74 19.27	0.51 10.22	1 -

Source: author calculation using Eviews tool

Table 4. *LLC Unit Root Test Results*

Variable	Test type	Model (Trend/Intercept)	Lag selection	Statistic	p-value	I(0)/I(1)
GSCI	LLC	Intercept + Trend	1	-2.21117	0.0135	I(0)
GDP	LLC	Intercept + Trend	1	-5.83728	0.0000	I(0)
GERD	LLC	Intercept + Trend	1	-24.8985	0.0000	I(0)
TRD	LLC	Intercept + Trend	1	-19.1665	0.0000	I(0)
TE	LLC	Intercept + Trend	1	-7.73745	0.0000	I(0)
ICT	LLC	Intercept + Trend	1	-6.68957	0.0000	I(0)
IP	LLC	Intercept + Trend	1	-6.56224	0.0000	I(0)
RL	LLC	Intercept	1	-4.72255	0.0000	I(0)
EGDI	LLC	Intercept + Trend	1	-7.86411	0.0000	I(0)

Source: author calculation using Eviews tool

Balancing learning and earning: interactions between education, minimum wage, and youth employment in Romania

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Abstract. *Balancing learning and earning has become increasingly complex for recent graduates, as labor markets undergo continuous disruption driven by economic shocks and rapid technological change. Mismatches between the competences acquired through higher education and the skills demanded by employers continue to hinder youth labor market integration in Romania. This paper explores the interaction between education outcomes, minimum wage policies and youth employment, focusing on the institutional factors shaping the school-to-work transition. By adopting a longitudinal institutional perspective covering nearly three decades, the paper contributes to the literature by analyzing these dimensions as an interconnected framework rather than as separate policy domains. The study employs a qualitative comparative analysis of OECD Economic Survey reports on Romania published between 1998 and 2026, complemented by a structured institutional assessment synthesized through a SWOT framework. The findings indicate that a high concentration of workers in the low-wage segment, combined with persistent skills mismatches and a relatively elevated tax wedge, generates significant barriers to youth labor market entry. The findings suggest that effective policy responses require a coordinated institutional framework aligning wage regulation, labor taxation and education systems to support sustainable and inclusive employment outcomes for young graduates.*

Keywords: education, youth employment, minimum wage, earnings, skills mismatches.

JEL Classification: J24, J31, J38, I26, E24.

1. Introduction

The transition from education to the labor market represents a critical stage in the life course of young individuals, with significant implications for both short-term income prospects and long-term career trajectories. In many European economies, this transition has become increasingly complex, reflecting structural changes in labor demand, technological transformation, and evolving skill requirements. In Romania, these challenges are particularly pronounced, as evidenced by persistently higher youth unemployment rates compared to the national average and ongoing difficulties in accessing stable and quality employment opportunities. According to OECD (2024) and European Commission (2022), such outcomes are often associated with structural imbalances, including skill mismatches and institutional constraints affecting labor market entry.

A well-established body of literature emphasizes the central role of education systems in shaping employability. The human capital framework developed by Gary Becker (1964) posits that investments in education enhance individual productivity and, consequently, labor market outcomes. However, empirical evidence suggests that this relationship is not always straightforward, particularly in the presence of mismatches between educational outputs and labor market needs. In the case of Romania, despite the expansion of tertiary education, both horizontal and vertical skill mismatches remain significant, indicating that acquired competences are not fully aligned with employer demand (World Bank, 2018).

In addition to educational factors, labor market institutions play a crucial role in shaping employment opportunities, particularly for young and low-skilled workers. Among these, minimum wage policies have been extensively debated in both theoretical and empirical literature. On the one hand, minimum wages contribute to income protection and the reduction of in-work poverty. On the other hand, they may increase labor costs and potentially affect hiring decisions at the lower end of the wage distribution. Empirical analysis (Neumark & Wascher, 2008) suggests that higher minimum wage may reduce employment opportunities for youth, while studies by Card and Krueger (1995) highlight that such effects are context-dependent and may be limited under certain labor market conditions. Beyond the level of the minimum wage, the broader structure of labor taxation is relevant. High tax wedges may discourage employment by increasing labor costs without proportionally improving net incomes (OECD, 2022). This issue is especially relevant in Romania, where a substantial share of employees is concentrated in the lower segment of the wage distribution, amplifying the impact of both minimum wage policies and labor taxation.

Romania thus represents a relevant case for analyzing the interaction between education outcomes and labor market institutions. Over the past decade, the country has experienced substantial increases in the statutory minimum wage, alongside ongoing reforms in the education system. Additionally, the relatively high share of young people classified as NEET (Not in Education, Employment or Training) points to persistent barriers in the school-to-work transition (Eurostat, 2023).

Against this background, this article examines the interaction between education, youth employment and minimum wage policies in Romania. This paper employs a qualitative

comparative approach, drawing on longitudinal institutional evidence to examine the structural factors shaping the school-to-work transition in Romania.

2. Literature Review

Education and Earning

While financial consideration may not represent the primary motivation for pursuing higher education, given its broader role in developing critical thinking and contributing to societal progress, earnings remain a central factor in shaping educational and career decisions.

However, for many prospect students and graduates, earnings are a critical characteristic when choosing a career path. Some studies reflect that educational programs differ significantly in average earnings level, meaning that the chosen studies do have a role in shaping earning potential (d'Astous & Shore, 2024). Moreover, if a student enters a field where graduates have volatile incomes, that student will likely experience the same volatility, but earning growth over time is not caused by the program someone studies – the degree can affect the starting level, but not necessarily the trajectory of earning (d'Astous & Shore, 2024). Returns to education exhibit significant heterogeneity across individuals. Although those who expect higher returns have a tendency to pursue more education, the factors which influence this are family background and motivation (Sun et al., 2020). While education might raise earnings, by how much actually depends on personal traits and internal motivation (Sun et al., 2020). This view is further supported by evidence suggesting that a match between education and occupation does not automatically mean higher earnings (Chan, 2018).

As macroeconomic theory on labor market suggests, the geographic mobility of workers is not instantaneous (Mankiw, 2021), and inequality in earning partly comes from mobility constraints, not just education. Wages differ widely across regions and the same education can yield quite different incomes depending on location (Zhao et al., 2023). This mainly derives from the fact that bigger cities, in contrast with smaller areas, offer higher wages and better job opportunities. The area where someone uses their education directly influences how much education really pays off (Zhao et al., 2023).

Earnings of graduates can be influenced by external factors that disturb the normal workings of the economy, as illustrated by the COVID-19 pandemic. One study reveals that Canadian graduates dealt with poorer labor market prospects after graduating in that period of recession, as 1 percentage point increase in the unemployment rate at the time of graduation led to an approximately 1.5 to 4 percent decrease in earnings over the first several years (Messacar et al., 2021). Earning inequality has been present in the 2009-2014 “U.S. shale oil and gas boom” and has shown how a shock in one sector can reorganize the entire labor market (Upton & Yu, 2021). This boom first led to a relative increase in wages for less-educated workers, mostly men, and the wage premium linked to higher education declined slightly in the affected regions, which translates into the fact that shifts in the labor demand can compress educational wage differentials by raising the relative price of lower-skilled labor (Upton & Yu, 2021). Nevertheless, higher education ensures resilience against

negative shocks, as one study shows that high-educated households respond better than low-educated ones in times of economic crisis (Dal Bianco & Maura, 2020).

One study on Italy suggests that wage differences exist between people with the same education level, not because they might have different skills, but because the labor market rewards similar people differently (Franzini & Raitano, 2019). Education still leads to higher earnings, especially the higher one, but as more people pursue it, its advantage depends increasingly on labor market demand (Zamfir et al., 2022). Internships can increase earnings after graduation, but they are believed to be harder to access for women and students from less advantaged backgrounds (Luchinskaya & Tzanakou, 2025). As a consequence, those who already have better access gain higher pay, while others are more likely to end up in lower-value experiences, which reinforces the idea of wage inequality early in careers (Luchinskaya & Tzanakou, 2025).

These individual-level determinants of earnings, however, operate within a broader institutional framework shaped by wage regulation and labor taxation policies, which directly influence the employment opportunities available to graduates and the returns they can expect from their educational investments. Understanding how minimum wage policies and labor taxation interact with human capital formation is therefore essential for a comprehensive analysis of youth labor market outcomes.

Earnings: impact of labor taxation and wage policies

The impact of minimum wage policies has been extensively analyzed in the economic literature, particularly from the perspective of their effects on employment among young and low-skilled workers. Neoclassical theory suggests that the imposition of a minimum wage above the equilibrium level leads to a reduction in labor demand, especially for categories with low productivity. This hypothesis is supported by a significant part of the empirical literature (Neumark & Wascher, 2008), but nuanced by contributions emphasizing the role of market imperfections and institutional context in shaping employment effects (Card & Krueger, 1995). In this regard, this alternative perspective reveals that minimum wage increases do not necessarily lead to job losses and may have neutral or even positive effects under conditions of imperfect competition, such as monopsonistic labor markets. Through these contributions, a consensus has emerged in the literature according to which the effects of the minimum wage are context-dependent and cannot be generalized without an institutional analysis (Belman & Wolfson, 2014).

Building on this debate, a key strand of the literature has shifted attention toward the institutional environment in which wage regulations operate. As Douglass North (1990) emphasizes, institutions structure economic interactions and influence market efficiency. Thus, minimum wage policies are not merely a component of a complex institutional system, but are also interconnected with other essential aspects such as labor taxation, education systems and employment policies. Within this broader framework, the total cost of labor becomes a central analytical dimension. Beyond the gross wage, firms face a significantly higher cost of employment, often captured by the concept of the “tax wedge” (OECD, 2022). This reflects the difference between the total cost borne by the employer and the net income received by the employee. High levels of labor taxation, particularly for

low-income earners, increase the cost of hiring and may discourage job creation in entry-level positions (OECD, 2022).

Consequently, the relationship between the minimum wage and labor taxation is crucial for analyzing labor market outcomes, as the tax burden (Nickell & Layard, 1999; OECD, 2022) can amplify the effects of wage regulations. Existing analyses show that a high tax wedge, the effective cost of employment significantly exceeds the net benefit received by the worker, thereby reducing both labor demand and the attractiveness of employment for workers (OECD, 2022). Moreover, the literature highlights the role of wage distribution in determining the impact of the minimum wage, as changes in the minimum wage in contexts with a high concentration of low-income workers generate a broader spillover effect across the entire wage distribution. This phenomenon is associated with wage compression at the bottom of the distribution and influence employment dynamics and labor demand structure (Autor et al., 2016).

Within this framework, young people represent a particularly vulnerable category to changes in labor market regulations. Empirical studies suggest that uniform minimum wage systems, combined with a high tax wedge, can reduce employment opportunities for young workers and limit access to work experience, thereby negatively affecting long-term career and wage trajectories (Neumark & Wascher, 2008).

Despite this extensive literature, a key gap remains insufficiently addressed. Existing studies tend to analyze minimum wage, taxation and education systems either separately or in pairwise combinations, but rarely as a fully integrated institutional framework. As a result, the joint interaction between wage policies, labor taxation and human capital remains under-theorized, particularly in the context of emerging and transition economies, where institutional complementarities may be weaker or more fragmented. The effects of the minimum wage cannot be analyzed in isolation, they must be integrated into a broader institutional framework that includes labor taxation, the education system and labor market policies (International Labour Organization, 2016; OECD, 2021). The institutional analysis of labor costs should be correlated with the way the education system prepares the workforce for labor market requirements. The interaction between acquired skills and the structure of wage costs directly influences employment opportunities, especially for young people, becoming a central element in explaining difficulties in labor market entry. In this regard, the assessment of the education system's adaptability plays a fundamental role in understanding the mechanisms that facilitate or hinder the transition from education to employment (OECD, 2019; World Bank, 2018b).

3. Methodology

3.1. Research design

This paper employs a qualitative research design based on comparative institutional analysis and documentary research. The objective of the study is to examine the interaction between education outcomes, minimum wage policies and youth employment in Romania, through a longitudinal assessment of the institutional developments influencing the school-

to-work transition. The qualitative approach draws on documentary sources to identify recurring structural patterns, persistent challenges and policy complementarities over time (Bowen, 2009).

3.2. Data sources and selection criteria

The analysis relies on secondary data drawn from OECD Economic Surveys on Romania, published in 1998, 2002, 2022, 2024 and 2026. These reports were selected on the basis of two criteria. First, they represent the complete set of OECD Economic Surveys dedicated to Romania published to date, with the aim of providing full institutional coverage of the period analysed, spanning nearly three decades, which enables a longitudinal perspective on the evolution of labor market institutions and education outcomes across distinct economic phases, including the transition period, the European integration process and the most recent challenges related to skills shortages and technological transformation.

The OECD reports were selected as the primary source due to their methodological consistency, international comparability and policy orientation, serving as essential instruments for identifying both persistent and emerging labor market issues. In addition, the incorporation of supplementary data drawn from Eurostat, OECD database and nation institutional reports supported the contextualization of findings within a broader European framework.

3.3. Analytical procedure

The study employs qualitative content analysis combined with a comparative institutional approach (North, 1990). All OECD reports used were manually reviewed and coded thorough thematic categorization, according to several analytical dimensions derived from the research objectives and the existing literature, synthesized in Table 3.1.

Table 3.1. *Analytical dimensions and key topics examined*

Analytical dimension	Key topics examined
Education and skills development	Skills mismatch, tertiary education, vocational education, lifelong learning
Minimum wage policies	Wage regulation, wage distribution, low-wage employment
Labor taxation	Labor costs, tax wedge, incentives for employment
Youth employment	Labor market participation, unemployment rates, NEET rates
Institutional reforms	Labor market policies, education reforms

Source: Authors' own elaboration.

The analytical process involved iterative thematic reading of the selected documents, through which institutional changes and policy recommendations were identified across the period under review. Similarities and differences between reports were subsequently compared in order to assess the evolution of labor market challenges and opportunities over time. Particular attention was paid to the interaction between education outcomes, labor market institutions and wage-setting mechanisms, as these constitute the central analytical framework of the study.

3.4. SWOT framework

The synthesis of findings derived from the comparative analysis involved the use of SWOT framework. Although SWOT analysis is frequently associated with strategic management, it has been applied in academic research as a structured tool for organizing qualitative

evidence and conducting institutional and policy assessments (Helms & Nixon, 2010; Valentin, 2001). The SWOT framework thus facilitated the integration of findings from different periods and policy domains, with the aim of providing a structured assessment of the strengths and weaknesses of the complex interaction between education and employment in Romania, as well as the opportunities and threats associated with future developments. This instrument is not strictly descriptive or classificatory but was employed as a synthesis mechanism facilitating the identification of institutional complementarities, trade-offs and potential policy tensions.

3.5. Limitations

The present paper is subject to several limitations inherent to its research design. First, the exclusive reliance on secondary sources precludes the generation of primary empirical evidence. Second, the qualitative nature of the analysis does not permit causal inference regarding the effects of minimum wage policies or educational reforms on youth employment outcomes. Third, the findings draw primarily on OECD reports, which may reflect particular institutional perspectives and may not fully capture the complexity of the Romanian labor market context. Furthermore, the use of the SWOT framework introduces an element of interpretative judgment in the classification of factors, which is a degree of subjectivity inherent to qualitative research designs. Accordingly, the results should be interpreted as an institutional and policy-oriented assessment rather than as a causal evaluation of labor market outcomes. Future research could complement this approach through econometric modelling or comparative case studies involving transition economies with structural characteristics.

4. Results & Discussions

4.1. Wage distribution and structural concentration in Romania

The analysis of wage distribution in Romania highlights a significant concentration of incomes in the lower segment of the labor market. Data from a macroeconomic report indicate a strongly asymmetric distribution of earnings, with approximately 58% of employees earning net monthly wages below 4,100 RON, while around 3% record net monthly earnings exceeding 14,600 RON (Confederația Patronală Concordia, 2026). This structure suggests the existence of a highly skewed wage distribution, characterized by a concentration of the workforce in the low-income segment and a relatively narrow upper tier. Such a configuration is associated with greater sensitivity to changes in wage policies, particularly with regard to the minimum wage, as a significant proportion of employees are directly or indirectly anchored in the lower segment of the wage distribution.

In addition, data from Eurostat on the structure of earnings show that Romania ranks among the EU Member States with a high share of low-wage earners. The most recent available data, from 2022 (Eurostat, 2022), indicate a value of 23.87% for the indicator “low-wage earners as a proportion of all employees (excluding apprentices)”, a level significantly above the European Union average. This indicator confirms the prevalence of the low-wage segment within total employment and highlights persistent wage inequalities across the labor market.

Overall, these findings highlight the structural challenges of the Romanian labor market, driven by wage polarization: on the one hand, a large mass of workers concentrated in the low-income segment, and on the other hand, a relatively small share of high-paying jobs. In this context, minimum wage policies and the structure of labor taxation become particularly relevant, as they directly affect a substantial proportion of the workforce. Moreover, from the perspective of the transition from education to the labor market, this polarization is especially important, as young individuals are typically concentrated in entry-level jobs, where wage levels are often close to the lower bound of the distribution.

This wage distribution structure reflects not only recent labor market developments, but also broader economic and institutional dynamics shaped over nearly four decades. The persistence of the low-income segment highlights the existence of structural rigidities within the national labor market, indicating the need for a comprehensive analysis that goes beyond purely cyclical factors. In this context, the reports published by OECD provide a valuable framework for understanding how these imbalances have evolved over time and continue to influence the functioning of the Romanian labor market.

4.2. Evolution of the Romanian labor market in the OECD reports (1998-2026): a longitudinal analysis

This section builds on the previous distributional evidence by situating Romania's labor market structure within a long-term institutional and macroeconomic trajectory. The reports published by OECD between 1998 and 2026 provide a comprehensive perspective on the structural transformations of the Romanian economy in the post-transition period, covering developments over nearly three decades. These analyses captured the transition from an economy characterized by structural rigidities and extensive state intervention to one undergoing convergence towards the standards of developed economies. However, the reports consistently identify a set of persistent challenges, particularly related to labor market functioning, income distribution and the integration of vulnerable groups.

The first OECD reports on Romania, published in 1998 and 2002, portray a labor market still affected by the transition to a market economy. This period was marked by privatization and macroeconomic adjustments, which amplified labor market imbalances, leading to rising unemployment, declining real wages and reduced job stability. The reports highlight the presence of significant institutional rigidities that limited the labor market's ability to adjust to new economic conditions, mainly due to insufficiently reformed regulatory frameworks. The low effectiveness of active labor market policies and limited labor mobility contributed to persistent allocative inefficiencies (OECD, 1998, 2002).

At the same time, the economic structure was dominated by low-productivity sectors, resulting in low wage levels and a limited capacity to generate high-quality employment. During this stage, the OECD emphasizes the difficulties faced by young people in entering the labor market, in the context of a misalignment between skills acquired in the educational system and the emerging requirements of a market economy. Additionally, the agricultural sector is identified as a buffer absorbing displaced labor, contributing to the persistence of low-productivity employment and inefficient human capital utilization (OECD, 1998, 2002).

After two decades of substantial economic transformation, the OECD report published in 2022 highlights significant progress in economic convergence, reflected in increases in GDP, productivity and wages. This transformation of the occupational structure is largely driven by the expansion of the private sector and Romania's integration into European production chains. Nevertheless, these developments have not been accompanied by a full resolution of structural labor market imbalances. Significant regional disparities persist, alongside differences across sectors in terms of wage levels and productivity. Moreover, labor market participation remains relatively low for certain groups, particularly young people and low-skilled workers. The report also emphasizes the persistence of skills mismatch, which continues to undermine labor market efficiency. The education system does not adequately respond to labor market needs, hindering the school-to-work transition and leading to suboptimal use of human capital. This issue is particularly relevant for young people, for whom labor market entry is often delayed and fragmented (OECD, 2022).

The reports published by OECD in 2024 and 2026 highlight the continued process of economic convergence, characterized by increases in real wages and improvements in productivity across certain sectors. Romania has recorded one of the fastest increases in the statutory minimum wage among EU Member States over the past decade, with the gross minimum wage rising from approximately 900 RON in 2014 to 4,325 RON in 2026, representing a nominal increase of over 300% (OECD, 2026; Stroe & Vuc, 2025). While this evolution has contributed to reducing in-work poverty, it has also intensified the relevance of the tax wedge, as labor costs for employers have risen proportionally, particularly in sectors with a high concentration of minimum wage workers.

However, these developments are accompanied by the persistence of structural vulnerabilities. One of the key issues identified is the unequal distribution of wages, marked by a significant concentration of employees in the lower income segments. This structure is consistent with empirical evidence on the high share of low-wage earners and reflects the existence of a segmented labor market, in which access to well-paid jobs remains limited for a substantial part of the workforce. At the same time, the integration of young people into the labor market continues to represent a major challenge. The high level of NEET youth together with the difficulties in accessing quality employment, indicates the persistence of structural barriers in the school-to-work transition. These challenges are further amplified by the phenomenon of skills mismatch and the lack of effective transition mechanisms adapted to current labor market needs (OECD, 2024, 2026).

Another important aspect highlighted by the OECD is the relatively high level of labor taxation, particularly for low wages. This contributes to increasing the overall cost of labor for employers and may discourage the creation and uptake of entry-level jobs. In this context, minimum wage policies should be analysed in conjunction with the labor taxation system, in order to avoid adverse effects on employment and to support the effective integration of young people into the labor market (OECD, 2024, 2026).

Against this background, the interaction between education systems and labor market institutions becomes crucial in explaining persistent disparities in youth employment outcomes.

4.3. Education and employment dynamics: Evidence from OECD reports

According to the OECD (2026), the Romanian labor market is characterized by a strong concentration of workers in the lower segment of the wage distribution, with around 58% of employees earning below or close to the statutory minimum wage. This reflects a structurally compressed wage distribution and the persistence of a relatively narrow middle-income segment compared to other European economies. The weakness of the middle class has broader macroeconomic implications, as it constrains domestic demand and undermines living standards across the income distribution. Furthermore, Romania's demographic trajectory adds structural pressure to labor supply: between 1990 and 2024, the working-age population (20-64 years) declined by approximately 2.3 million individuals, a trend which is projected to intensify in the coming decades (OECD, 2026).

Education plays a significant role in shaping labor market outcomes, particularly at the point of entry into employment. The OECD (2026) report indicates that investment in high-quality education from early ages has the potential to reduce inequalities between urban and rural populations and among disadvantaged groups, while generating higher returns on educational investments. In Romania, youth employment outcomes are significantly affected by early school leaving, as only 48% of 25-34-year-olds without an upper-secondary qualification are employed, compared with 79% among those with one (OECD, 2026). This gap illustrates how education attainment functions as a critical determinant of labor market access, reinforcing the human capital framework discussed in the literature review. This issue persists mostly in rural areas, where limited access to quality secondary education amplifies the risk of early school leaving.

Continuous learning and reskilling represent an imperative in a volatile labor market shaped by economic shocks and technological change. However, the low-skilled youth, especially from rural areas, record significantly lower education and training participation rates. This dynamic reflects a structural paradox: those who most need reskilling are least likely to access it, which risks deepening existing inequalities and limiting upward mobility in the wage distribution. Upskilling, counselling, and job-matching services are considered vital measures for ensuring the long-term effectiveness of employment support, enabling workers to transition to better jobs. Although the report suggests that skill mismatches are not as prevalent in Romania as in OECD countries, a significant share of workers are employed in occupations unrelated to their field of study.

This occupational mismatch may generate suboptimal earnings outcomes for a considerable part of the workforce and reduces the effective return on educational investment at the aggregate level. Vocational training and access to higher education need to be further strengthened. Higher education enrollment in Romania remains below the OECD average, partly reflecting systemic weaknesses at the lower levels of the education system. Nevertheless, Romania records above-average shares of STEM and ICT graduates, who benefit from strong employment opportunities and high employment rates after graduation. This suggests that the returns to education in Romania are highly differentiated by field of study, with technical disciplines offering significantly stronger labor market outcomes than others (OECD, 2026). In this context, lifelong learning remains crucial for maintaining competitiveness in the labor market.

In Romania, there is a significant disparity between rural and urban areas: 8% of rural residents and 4% of low-qualified adults participate in education and training programs, compared with 27% of the tertiary-educated and 24% of urban residents (OECD, 2026). The 2024 report reiterates persistent regional disparities: employment opportunities remain highly concentrated in major urban centers, while smaller cities and rural areas continue to face elevated unemployment, low living standards and limited economic opportunities (OECD, 2024). In 2024, 33% of working-age Romanians were out of the labor market, with women disproportionately represented at 43% (OECD, 2024). These figures indicate that labor market exclusion in Romania is not solely an educational phenomenon but is also shaped by geographic and institutional constraints that limit access to employment regardless of qualification level. The report suggests that greater equity in education would contribute to reducing poverty and improving youth employment prospects (OECD, 2024).

The 2022 report indicates persistent difficulties in integrating young people into the labor market, as the NEET rate of the youth (15-24-year-olds) had remained high since 2019 (15%) (OECD, 2022). Lack of qualification represents a key barrier to labor market entry, given the high dropout rates before the upper secondary education level. Important sectors such as constructions, health, education and ICT faced labor shortages driven by skills deficits, a pressure that was temporarily relieved by the contraction of economic activity during the COVID-19 pandemic. The low employability of young graduates is further associated with insufficient socioemotional skills, low motivation, limited problem-solving ability and weak teamwork competence (OECD, 2022). A further challenge concerns the unequal distribution of continuous education participation: higher-skilled workers are significantly more likely to engage in further training than their low-skilled counterparts.

The earlier OECD reports provide important historical context. The 2002 report outlines the importance of policies promoting longer participation in the education system, alongside active counselling and job-search assistance, as mechanisms for facilitating smoother labor market entry (OECD, 2002). In the 1998 report, it is mentioned that Romania had, at that time, the highest level of educational attainment in the Central and Eastern Europe (OECD, 1998). However, the report also mentions that although the labor-market conditions were favorable then, given the education levels in the country, most of the workers would need to reskill and upskill in the long run, due to the evolution of the market and technology (OECD, 1998). Taken together, these longitudinal observations suggest that the education-employment misalignment identified in the earliest OECD assessments has proven remarkably persistent, pointing to deep-seated institutional rigidities that have not been fully resolved despite decades of economic reform.

4.4. Synthesis and policy implications

The longitudinal analysis of OECD reports highlights the economic progress achieved in the Romanian labor market, but also the persistence of structural imbalances. Unequal income distribution, difficulties in young people's integration and skills mismatch reflect systematic limitations of the national institutional framework, pointing to the need for the development of public policies adapted to the current context. From this perspective, new policy measures should move beyond fragmented approaches and aim at more effective coordination between the education system and labor market mechanisms, while

supporting employment in the entry-level segment. In addition, reducing labor taxation for low-income earners may contribute to mitigating these imbalances and improving the allocative efficiency of the labor market.

4.5. SWOT Analysis

To synthesize the empirical findings and the longitudinal evidence derived from OECD reports, a SWOT framework is employed to provide a structured assessment of the main strengths, weaknesses, opportunities and threats characterizing the interaction between education systems, labor market institutions and youth employment outcomes in Romania.

Table 4.1. *SWOT analysis of the school-to-work transition in Romania*

Strengths	Weaknesses
<ul style="list-style-type: none"> ▪ Sustained economic convergence reflected in rising real wages and productivity (OECD, 2022, 2026). ▪ Increasing integration into European production chains and private sector expansion. ▪ Strong performance of STEM and ICT graduates with high employability (OECD, 2026). ▪ Expansion of tertiary education (OECD, 2024). ▪ Institutional progress in labor market regulation and policy framework (OECD, 2022, 2024). 	<ul style="list-style-type: none"> ▪ High concentration of workers in the low-wage segment (Confederația Patronală Concordia, 2026). ▪ High tax wedge for low-income earners (OECD, 2022). ▪ High NEET rates and difficulties in youth labor market integration (Eurostat, 2023). ▪ Skill mismatch and weak school-to-work transition mechanism (World Bank, 2018). ▪ Persistent regional disparities between urban and rural labor markets (OECD, 2024).
Opportunities	Threats
<ul style="list-style-type: none"> ▪ Development of dual and vocational education systems to improve school-to-work transition (OECD, 2026). ▪ Expansion of active labor market policies targeting youth employment (OECD, 2024). ▪ Digitalization and growth in high-productivity sectors (European Commission, 2022). ▪ Lifelong learning and reskilling policies in response to technological change. ▪ Better alignment between education outcomes and labor market needs (World Bank, 2018). 	<ul style="list-style-type: none"> ▪ Demographic decline and shrinking labor force (OECD, 2026). ▪ Continuous outward migration (brain drain) driven by wage differentials (European Commission, 2022). ▪ Vulnerability to economic shocks affecting youth employment (International Labour Organization, 2022). ▪ Persistence of wage inequality and labor market segmentation. ▪ Automation and technological change disproportionately affecting low-skilled jobs (OECD, 2019). ▪ Risk of reinforcing low-wage equilibrium without structural reforms (OECD, 2022).

Source: Authors' own elaboration.

The results of the SWOT analysis suggest the presence of a dual dynamic in the Romanian labor market, characterized by structural progress and the persistence of important institutional imbalances. While economic convergence and improvements in education outcomes support labor market integration, factors such as skill mismatch and wage polarization disproportionately affect young people. At the same time, emerging opportunities are accompanied by significant risks, including demographic decline, labor migration and the impact of technological transformations. These findings emphasize the need for integrated policies aligning education with labor market and wage-setting structures.

5. Conclusions

The present paper addressed an identified gap in the literature by examining minimum wage policies, labor taxation and education outcomes as an interconnected institutional framework rather than as isolated policy domains, with a specific focus on the Romanian transition economy context. The analysis focused on the interaction between education, minimum wage policies and youth employment in Romania, based on the factors that shape

the transition from education to the labor market. While Romania has experienced significant economic and wage growth, these developments have been accompanied by persistent structural imbalances, particularly in terms of wage distribution and youth labor market integration.

The findings indicate that a high concentration of workers in the low-wage segment increases the sensitivity of the labor market to minimum wage adjustments. At the same time, the relatively high level of labor taxation for low-income earners raises the total cost of labor and may discourage employment in entry-level positions. These two mechanisms interact to generate compounded barriers for young labor market entrants, who are disproportionately concentrated in the lower segment of the wage distribution.

The policy implications derived from this analysis point to the need for a coordinated institutional approach to labor market reform. Specifically, minimum wage policies should be designed and adjusted in conjunction with the labor taxation structure, in order to avoid adverse employment effects. Reducing the tax burden for low-income earners would lower labor costs for employers while improving net earnings for workers, thereby supporting both job creation and labor market participation among young graduates. Furthermore, strengthening the alignment between education system and labor market requirements remains essential for improving school-to-work transition outcomes.

From a theoretical perspective, this study contributes to the institutional literature by demonstrating that education outcomes, wage-setting mechanisms and labor taxation should be analyzed as interdependent institutional arrangements rather than isolated policy domains. This integrated perspective is particularly relevant for transition economies, where institutional complementarities may be weaker or more fragmented and where misaligned policies are most likely to generate adverse outcomes for vulnerable groups such as young labor market entrants.

The findings of this study highlight the importance of addressing labor market challenges through a coordinated institutional framework, in which wage policies, fiscal measures, and the education system are aligned to support efficient and inclusive employment outcomes. Several directions for future research emerge from this analysis. First, primary data collection through employer or graduate surveys would allow for a more granular assessment of how minimum wage policies and tax structures affect hiring decisions and earnings trajectories at the entry level. Second, econometric modelling could enable the estimation of causal relationships between the institutional dimensions examined in this paper, overcoming the descriptive limitations of the present approach. Third, comparative case studies involving transition economies with similar structural characteristics could help identify which institutional configurations are most effective in facilitating youth labor market integration. Addressing these directions would substantially advance the understanding of the education-employment nexus in emerging European economies.

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The Paradox of Green Security: how renewable transitions reshape global power dynamics

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Abstract. *The global shift towards renewables is believed to be necessary in terms of climate change, sustainability improvement, and reduction of reliance on oil and gas. At the same time, while decarbonization may help overcome the issues associated with the energy security of countries and regions, it poses several challenges related to geopolitical, economic, and infrastructural vulnerabilities. The paper presents a concept called the “Green Security Paradox” and defines it as the phenomenon in which a country's move towards renewables reduces some strategic threats but creates new vulnerabilities regarding the use of critical minerals, the establishment of specialized production chains, cybersecurity and digital infrastructure. With the help of qualitative conceptual analysis based on academic literature and international policy reports, the study focuses on analyzing the transition of the country's focus from traditional geopolitics of fossil fuel use to renewable geopolitics. As a result of the research, it can be concluded that energy security is not eliminated by the transition towards renewable energies but simply becomes redefined due to its new aspects such as digitalization.*

Keywords: energy, security, geopolitics, infrastructure, cybersecurity.

JEL Classification: Q42, F52, Q48, Q34.

Introduction

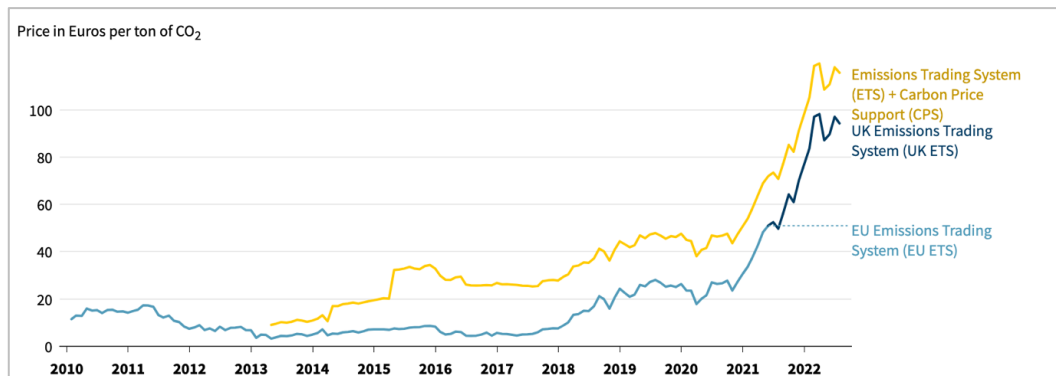
The shift from fossil fuel to renewable energy is one of the most important economic, technological and political changes of this century. Governments in all regions of the world are increasingly working with renewable technologies as a core element of their climate change mitigation strategies. Agreements, such as the Paris Agreement and additional climate commitments, have the same goal, namely the decarbonization of energy systems.

Renewable energy sources provide numerous environmental benefits such as reducing greenhouse gas emissions, ensuring better quality air, increasing long-term sustainability.

Conversely, the energy transition is changing the underlying principles of power all over the globe. The influence of nations in global affairs depended widely on their access to fossil fuel resources, transport corridors and hydrocarbon markets. How modern renewable energy systems operate relies on other types of resources and infrastructure including critical minerals, complex manufacturing capabilities, digital technology and global supply chains. As a result, the shift is giving rise to new forms of dependencies and vulnerabilities that move beyond traditional notions of energy security.

Earlier studies have examined, among other things, the geopolitical impacts of renewable energy, dependencies on critical minerals, and infrastructure resilience.

Figure 1. UK and EU carbon prices under the Emissions Trading System and Carbon Price Support mechanism, 2010–2022 (€ per tonne of CO₂).



Source: adapted from UK and EU emissions trading scheme price data.

Literature Review

The term “Green Paradox,” coined by Sinn (2008), describes a specific and counter-intuitive mechanism: when fossil-fuel owners anticipate that future climate policy will restrict their ability to sell carbon-intensive resources, they have an incentive to extract and sell those resources faster or monetize them, accelerating near-term emissions even as long-term policy intends to reduce them. Subsequent literature has used the term more loosely to describe a range of unintended consequences of climate policy (Svenn Jensen, 2015). This literature is the origin of the phrase, but it is not the subject of the present paper.

This paper elaborates on and explains the hypothesis of a Green Security Paradox: the idea that moving away from fossil fuels does not remove energy security risks but reshapes them into different forms. This expands upon, and is different from, an increasing body of work on renewable geopolitics, which argues that the transition from fossil fuels to renewables is altering the geographic and political foundations of energy dominance. Decentralized renewable generation lessens the strategic significance of oil and gas reserves and their transportation chokepoints, yet it heightens the strategic importance of nations that extract, process, and produce the materials essential for renewable systems. (Mañé-Estrada, 2023).

The International Energy Agency and the International Renewable Energy Agency have separately documented two of the mechanisms this paper draws together: the geographic concentration of critical-mineral mining and refining (IEA, 2025), and the rapid build-out of solar and wind capacity that is outpacing investment in the transmission and distribution infrastructure needed to integrate it (IRENA, 2024). A more recent strand of policy literature has documented the cybersecurity exposure generated by networked solar equipments like inverters, most of which are manufactured by a number of Chinese firms and remain remotely updateable after installation (ESMC, 2025; European Council on Foreign Relations, 2025). These three main pillars – critical minerals, grid infrastructure, and inverter or SCADA cybersecurity – are each well established individually. What remains underdeveloped in the literature is a single framework that connects them as expressions of the same underlying dynamic: that decentralising energy generation does not decentralise the supply chains and control systems generation depends on. This is the gap the present paper addresses.

Methodology

This paper adopts a conceptual, literature-based methodology rather than original empirical data collection. The approach follows established practice for conceptual contributions in the energy-policy and geopolitics literature, where the objective is to synthesise dispersed evidence into a coherent analytical framework rather than to test a hypothesis against new data.

Evidence was gathered from three types of sources: scholarly articles on the Green Paradox, energy transitions, and renewable geopolitics; reports and data from pertinent international organizations and industry groups, such as the International Energy Agency, the International Renewable Energy Agency, the European Solar Manufacturing Council, and the European Council on Foreign Relations; and recorded cybersecurity events impacting energy infrastructure, sourced from an independently maintained industry tracker. (KonBriefing Research, 2024).

The analysis follows the examination of each of the three reconfigured dependencies in turn, situating each within the historical shift from fossil-fuel to renewable geopolitics, before progressing to the policy dilemma raised by climate taxation design. This structure is intended to move the paper from description towards an explicit analytical framework, addressing a central limitation identified in peer review of the earlier draft, where the absence of a stated method made it unclear whether the paper was a conceptual contribution, a case study, or a narrative synthesis.

Analysis

A. Mature Infrastructure and the Limits of Renewable Build-Out

A significant portion of global electricity transmission systems was established many years ago to link a limited number of large, centralized fossil-fuel and nuclear power plants to demand hubs, focusing on creating fewer but larger production units. Renewable generation changes this trend: solar and wind power is installed at numerous scattered, frequently smaller locations, many of which are situated based on resource availability instead of closeness to current grid connections.

Government subsidies and favourable permitting regimes have accelerated the construction of new generation and storage capacity, but investment in the transmission and distribution networks needed to transport and distribute that electricity to demand centres has not kept pace. The consequence is that, in many countries, old transmission lines cannot reliably absorb the output of newly connected renewable facilities, producing connection delays, curtailment, and localised reliability problems. This is not a failure of renewable technology itself, but evidence that the security implications of the transition extend beyond generation capacity to the physical network that generation depends on – the first of the three reconfigured dependencies developed in this paper.

B. From Traditional Geopolitics to Renewable Geopolitics

Energy geopolitics in its modern form dates to the Industrial Revolution. Prior to large-scale coal use, energy endowments did not generate significant geopolitical disparities between territories (Wrigley, 2010; Malanima, 2014). The change to coal-fired generation changed this: territories with accessible coal reserves had obtained a durable competitive advantage over those without, and access to fossil energy became a source of state power in its own right.

The further shift from coal to oil in the twentieth century concentrated this advantage even more narrowly, in the hands of a small number of oil-exporting states and the corporations that controlled extraction and transport. This is the model of fossil-fuel geopolitics against which the present transition should be compared: a small number of resource holders exercising leverage over a much larger number of resource-dependent states.

The shift to renewable energy alters the ownership of this advantage instead of eliminating it. Power is transitioning from nations and companies that export oil and gas to those that oversee the extraction and processing of essential minerals, the production of renewable energy and grid technologies, and the technology that supports decentralized generation. This alteration decreases the likelihood of disputes particularly regarding oil reserves and transportation paths, which were central to energy geopolitics in the twentieth century, while creating new sources of friction related to essential mineral supply chains, hardware acquisition for grids, and the cybersecurity of more interconnected energy systems. The rest of this section analyzes each of these emerging tensions sequentially.

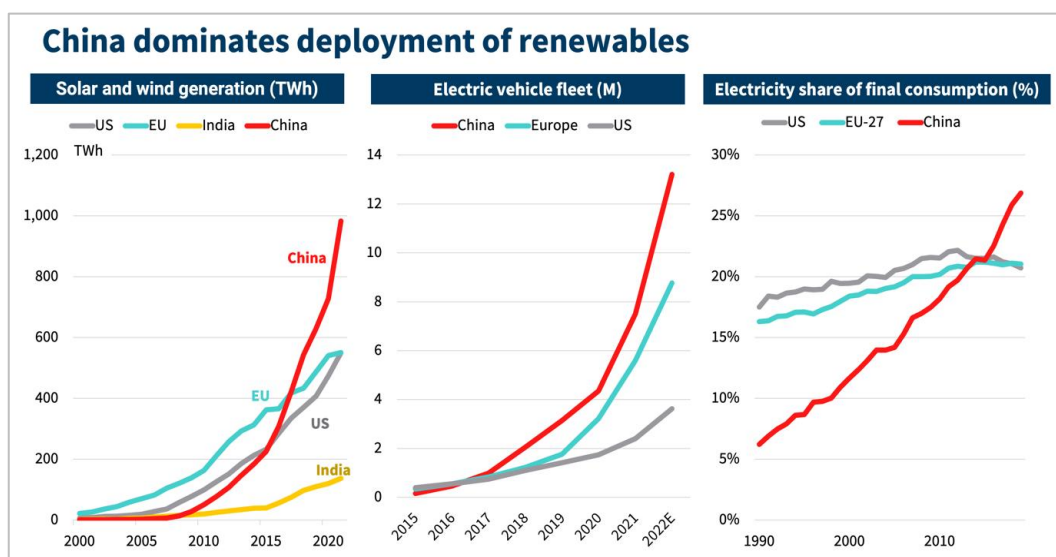
C. New Strategic Dependencies

The pace of the net-zero transition has been shaped less by a planned, orderly substitution of energy sources than rather by a series of deadline-driven political commitments. The

2021 Glasgow Climate Pact, for example, accelerated the carbon-reduction timeline agreed under the 2015 Paris Agreement (Roman Vakulchuk, 2020) who has presented weak results. The tight timeline this created has pushed demand for renewable-energy inputs to grow faster than supply chains could expand smoothly, intensifying the dependencies discussed below rather than allowing them to develop gradually.

This shortened timeline has led to heightened, unequal competition among producers for renewable-energy resources, where nations that dominate the extraction or production of essential components maintain a structural edge irrespective of the pace of demand increase in other areas. We can already recognize notable behavior; two instances demonstrate this. Initially, over 200 gigawatts of solar capacity in Europe is linked to inverters produced in China, mainly from Huawei and Sungrow, which represent a large portion of global inverter deliveries; since these devices can be updated remotely post-installation, EU regulators and industry groups have recognized this as both a supply-chain concern and a cybersecurity vulnerability (European Solar Manufacturing Council, 2025; European Council on Foreign Relations, 2025); the United States has held discussions multiple times regarding what kind of sanctions the government should impose for this risk. The Democratic Republic of the Congo is responsible for approximately seventy percent of the world's cobalt mining output, with Indonesia being the primary secondary producer, while China leads in the refining capacity for cobalt and nickel (International Energy Agency, 2025). This concentration implies that disturbances in a limited number of producing or refining nations – due to political unrest, export limitations, or intentional government actions – can exert significant impacts on global battery and renewable-equipment supply chains.

Figure 2. China's dominance in the deployment of solar and wind generation, electric vehicle fleets, and electricity's share of final consumption, compared with the United States, the European Union and India.



Source: adapted from International Energy Agency data.

Infrastructure Vulnerabilities

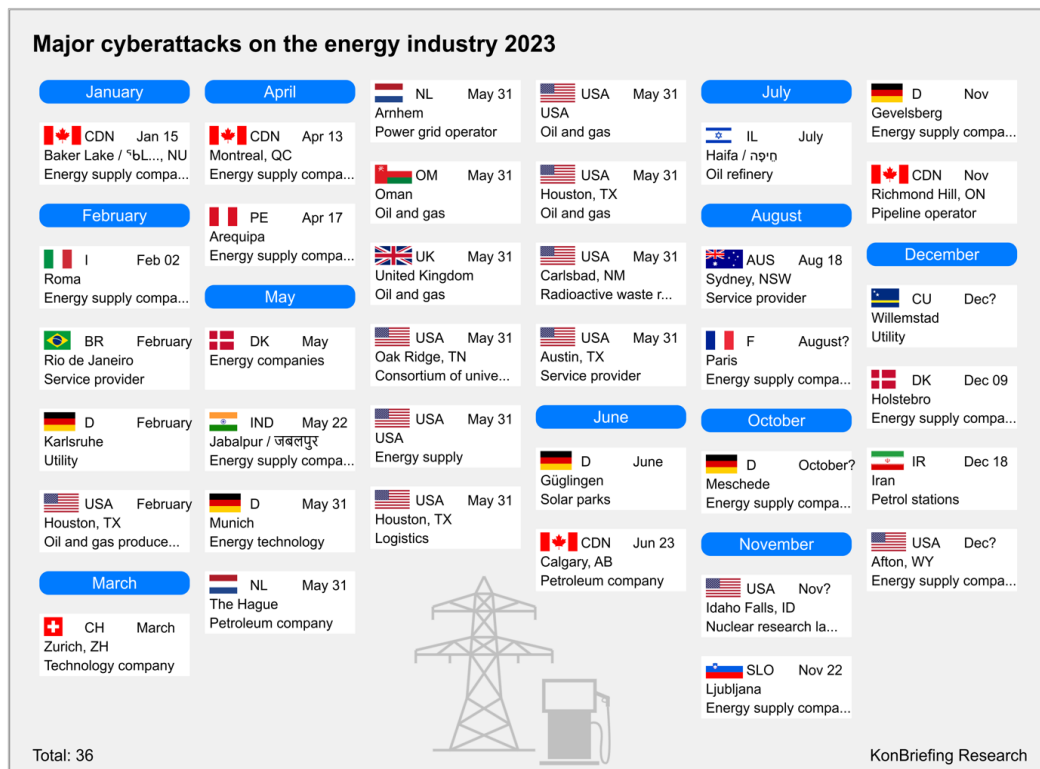
The digitization of energy infrastructure is typically depicted as an advantage of the transition: it allows renewable generation to be monitored, balanced, and integrated into the grid with much greater accuracy than was possible with older, analog systems. Nevertheless, without equivalent investment in cybersecurity and physical resilience, this same digitalisation brings about new attack vectors and generates additional vulnerabilities. Below are four vulnerabilities discussed (JungMin Lee, 2026).

The first vulnerability concerns the solar and renewable supply chain itself. The European Union's installed solar capacity reached approximately 406 gigawatts in 2025, and combined European wind and solar capacity has been approaching 850 gigawatts (IRENA, 2024; SolarPower Europe, 2025). Within this installed power, more than 200 gigawatts of European solar capacity is connected to inverters from Chinese manufacturers, with assessments by the European Solar Manufacturing Council and the European Council on Foreign Relations identifying the risk that a coordinated remote interference with these networked devices could destabilise sections of the grid (European Solar Manufacturing Council, 2025; European Council on Foreign Relations, 2025). This risk is best understood as a plausible vulnerability rather than a demonstrated attack: no confirmed large-scale manipulation of European inverters has occurred to date, but the technical capability for remote interference exists and has already prompted EU restrictions on the use of high-risk vendors in publicly funded solar projects.

The second vulnerability concerns Supervisory Control and Data Acquisition (SCADA) systems, which are used to monitor and control production facilities remotely. Connecting these systems to the internet, in order to allow remote management and integration with broader grid operations, has been a core part of the digitalisation of energy infrastructure described above. The same connectivity, means that a cyberattack on a SCADA system can translate directly into physical disruption of the equipment it controls, a mechanism distinct from conventional data breaches and one for which the consequences are physical rather than purely informational.

The third vulnerability concerns dependence on critical raw materials, particularly rare earth elements and battery metals such as cobalt and nickel. Export restrictions, mining bans, or transport disruptions in any of these countries can automatically generate volatility that propagates through global renewable-equipment supply chains and ultimately affects infrastructure costs and project timelines well beyond the country in which the disruption originates, therefore creating mass delays in project development and logistics.

The fourth vulnerability is rather physical than digital. Renewable installations, particularly utility-scale solar and wind farms, typically require large areas of land and are frequently sited in remote locations chosen for resource availability rather than security considerations. This makes them comparatively exposed to physical tampering relative to traditional power plants, which are smaller in footprint and have historically been built with dedicated physical security measures from the outset.

Figure 3. Documented major cyberattacks on the energy industry worldwide, 2023.

Source: KonBriefing Research (2024).

The Policy Dilemma

This is the point at which the classical Green Paradox, connects directly to the security reconfiguration that is the focus of this paper. When producers anticipate that future climate regulation will restrict their ability to sell fossil-fuel reserves, they have an incentive to accelerate extraction in the present, maximising revenue before the restriction takes effect. A carbon tax introduced abruptly, rather than announced and phased in gradually, sharpens this incentive, since it gives producers a clear and immediate deadline against which to race; the same outcome that motivates the EU's practice of phasing in carbon prices gradually, illustrated in Figure 1.

Another design decision relates to the point in the supply chain where a carbon tax is applied. Directly taxing extraction, instead of only taxing consumption later in the supply chain, more effectively discourages ongoing exploitation of fossil reserves, as it increases producers' costs at the decision point rather than merely impacting the price for end consumers. This also influences and alters the development potential of both small and large producers, enabling entities with specific resources to stay competitive. (Daniel Nachtigall, 2016).

The security aspect this paper contributes to the discussion is that policies focused exclusively on reducing anticipatory extraction may neglect the new vulnerabilities arising on the renewable side of the transition. A combination of incremental, upstream carbon taxes with incentives for renewable energy deployment could effectively diminish the attractiveness of fossil fuel extraction, while at the same time, and without further protections, increasing reliance on concentrated mineral, manufacturing, and digital supply chains. Effective policy design should regard supply-chain diversification and cybersecurity investment as intentional enhancements to carbon taxation, rather than as a separate policy path to be considered later.

Conclusion – Security is not Eliminated – It is Reconfigured

This paper has argued that the transition away from fossil fuels reduces some forms of energy security risk while simultaneously creating new ones, and that these two effects should not be allowed to obscure one another. The clearest expression of this paradox is that renewable energy systems are becoming more decentralised at the point of generation, while becoming more centralised, and more concentrated in a small number of countries, at the level of mineral supply, component manufacturing and digital control infrastructure.

Renewable technologies rely on materials and parts that are often sourced from a small number of producing nations or regions. Consequently, the domestic portrayal of advancing energy independence often relies on transnational dynamics that are more obscured than the fossil-fuel dependencies they supplant, particularly since they are spread across mineral resources, production, and digital systems instead of being centralized in a singular, easily observable category like oil imports.

The renewable transition should thus not be seen as a path to reduced energy security issues, but rather as a move towards a more integrated and technology-driven energy system, which has its own unique security characteristics. The paradox highlighted in this paper is that the same transition can lead to a cleaner environment while simultaneously increasing geopolitical tensions in significant ways. This suggests to policymakers that diversification of supply chains, modernization of grids, and cybersecurity of infrastructure must be regarded as essential rather than ancillary elements of climate and energy policy. Upcoming research will focus on empirically assessing if mineral concentration, grid age, and diversity of control-system vendors collectively forecast the security vulnerabilities of national or regional energy systems, advancing the theoretical framework created here into a verifiable analytical instrument.

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