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**ОРИГИНАЛНИ НАУЧНИ ЧЛАНЦИ**  
**ORIGINAL SCIENTIFIC PAPERS**

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# EVALUATING THE PERCEIVED RISKS OF AI IN SOUTH AFRICAN FINANCIAL INSTITUTIONS: A MULTIDIMENSIONAL APPROACH<sup>1</sup>

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## ABSTRACT

Risk management procedures in financial institutions around the world have been significantly altered by artificial intelligence (AI). However, little is known about the perceived risks of implementing AI, especially in developing nations such as South Africa. The aim of this study is to assess, from a multidimensional perspective, the perceived risks of AI adoption by employees in South African financial institutions. This study employs a mixed-methods approach, using a purposive and snowball sample of 90 survey respondents and semi-structured interviewees from several South African financial institutions. The study revealed a broad spectrum of concerns ranging from AI-induced unemployment to cybercrime vulnerabilities. The analysis provides layered insights into how different departments, including Risk Management, IT, and Operations Management, uniquely perceive and manage AI-related challenges. This study underscores the need for personalised risk management strategies that meet unique departmental concerns, as well as the importance of strategic planning in the integration of AI technology by financial institutions to maximise potential while limiting associated risks. It adds to the growing body of knowledge on AI adoption in emerging markets by providing practical information to practitioners and policymakers.

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## 1. INTRODUCTION

The fourth industrial revolution (4IR), characterised by the fusion of digital, physical, and biological technologies, is transforming humanity and affects many aspects of life, the work environment and social interactions (Skilton and Hovsepian, 2018). To survive today, businesses such as financial institutions need detailed digital strategies. Artificial intelligence (AI) is an essential component of these strategies, acting as a fundamental tool for adapting to the digital environment. The financial sector in several countries experienced significant growth in the use of financial services due to the application of AI (Kshetri, 2021). Although the use of AI has been extensively researched in developed countries, African countries have limited research that focusses on the use of AI in the banking sector (Maouloud et al., 2022). Most studies on African financial institutions focus on the technological and organisational implications of technology (Mariemuthu, 2019; Coetzee, 2019; Akinwale and Kyari, 2022; Qwabaza, 2022). There is a lack of information on the attitudes of these financial institutions' staff regarding the application of AI. It is important to understand the attitudes, fears and sentiments of the workforce to successfully integrate and use AI in financial institutions. Therefore, the purpose of this study is to understand the perceptions of risk of the financial institution workforce about the use of AI in banking.

AI refers to the simulation of human cognitive processes (Qwabaza, 2022), encompassing technologies focussing on machine learning (ML) and natural language processing (IBM, 2024). The computer programmes that these machines use are designed to mimic human cognitive processes (Hind, 2019), including visual perception, speech recognition, decision-making and translation (Wogu et al., 2017).

Financial institutions use artificial intelligence (AI) to automate procedures, improve decision-making skills and provide data-driven insights (Owen-Hill, 2017; Hind, 2019), to increase operational efficiency, generate cost savings and facilitate significant business transformation initiatives (Fontaine McCarthy & Saleh, 2019). This transformation has led to a change in the way client engagement is primarily conducted, with a shift from traditional face-to-face interactions and product-centric strategies toward a stronger emphasis on providing seamless digital consumer experiences (Jeyalakshmi, 2020; Muregess, 2022).

The banking sector in Africa is also significantly impacted by AI. In Ghana (Domeher, Frimpong & Appiah, 2017), South Africa (Mamela and Mukwakungu, 2020) and Nigeria (Ononokpono, Osademe & Olasupo, 2023), AI has been shown to increase banking efficiency, customer satisfaction and improve risk and regulatory management, as well as security (Rahmani, 2023).

Despite the many advantages of AI, it is important to understand the inherent risks associated with its use. Among the primary disadvantages of AI is job displacement, which increases the unemployment rate (Bonorchis & Burkhard, 2016; Manyika et al., 2017; Darangwa, 2021; Fares, Butt & Lee, 2023; Kanupriya, 2024; Molla, 2024) and algorithm bias (Giudici, Centurelli, & Turchetta, 2023; Oğuz, 2024). Recent studies have highlighted ethical and operational challenges (Smith and Jones, 2023), and calls for robust governance are made (Doe, Roe & Poe, 2024). AI also has an impact on salaries. According to Ashta and Herrmann (2021), AI is expected to cause downward pressure on the remuneration of workers in developed nations.

Understanding employee perceptions of these risks is vital for effective AI integration (Klein et al., 2023). A study by McGee (2024) revealed that the perceived risks associated with AI in financial institutions are significant, and there is a varied understanding of AI risks between institutions. This varied perception is also confirmed by studies in Asia (Kaur & Ali, 2021; Boustani, 2022) and globally (Wittmann and Lutfiju, 2021; Sachdeva et al., 2024). Currently, little research is being done in South Africa (Mariemuthu, 2019; Huang and Rust, 2022; Fares Butt & Lee, 2023; Khan and Hagglund, 2025). By examining and documenting the concerns and perceptions of employees in South Africa's financial sector regarding the use of AI in the workplace, this study aims to address the existing knowledge gap.

## 2. MATERIALS AND METHODS

The study investigated the perceived risks of AI usage in financial institutions in South Africa, using a mixed-methods approach (El Hajj & Hammoud, 2023). A purposive and snowball sampling strategy was used to recruit participants with direct experience from the Risk Management, IT and Operations Management departments. The inclusion criteria require at least two years of departmental experience and familiarity with AI applications. Potential participants were identified through professional networks and industry associations.

The quantitative sample size was calculated using the Cochran (1977) formula, considering a confidence level of 95% and a margin of error of 5%, resulting in a sample of 385 professionals from the Risk Management, IT and Operations Management sectors. The adequacy of this sample size is supported by previous studies, such as Weller and Tikir (2011), who used a sample size of 233 participants, and Thielmann et al. (2016), who employed a sample size of 120 participants.

To obtain an impartial portrayal of the participants and to assess the degree of diversity among them, the study used stratified random sampling, grouping the initial 385 participants into three distinct strata, each representing a specific field of competence, namely Risk Management, IT and Operations Management. Subsequently, the purpose-sampling technique was used for each stratum to choose representatives who meet the inclusion criteria. The final sample size consisted of 90 experts from the three competencies, based on studies conducted by [Sekaran \(2003\)](#) and [Roscoe \(1975\)](#). Similar sample size was used in studies by [Weber, Blais & Betz \(2002\)](#), [Hanochm Johnson & Wilke \(2002\)](#), [Harris and Jenkins \(2006\)](#), and [Weller and Tikir \(2011\)](#).

Studies by [Sandelowski \(1995\)](#), [Creswell & Plano Clark \(2011\)](#), and [Van der Merwe and Nell \(2013\)](#) were used as a guide to determine the qualitative sample size. A final sample size of 18 specialists in three datasets was selected to warrant data saturation, as proposed by [Charmaz \(2006\)](#). The study adhered to all ethical guidelines by obtaining the necessary ethical clearance, and informed consent was obtained from all participants.

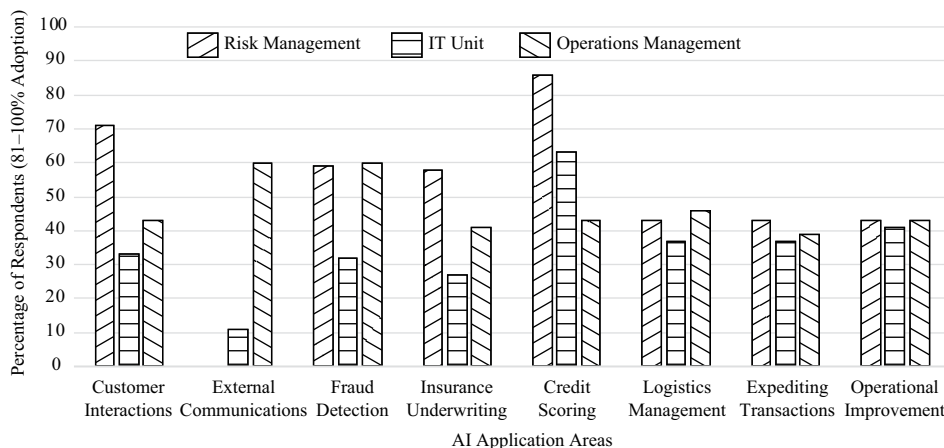
### **3. RESULTS AND DISCUSSIONS**

The survey (with an 84% response rate) prompted strong participation from key departments within South African financial institutions. With a response rate of 93.3%, the IT unit formed the largest response group, followed by Operations Management, with a response rate of 90%, and Risk Management, with a lower response rate of 70%. All participants in the Risk Management unit had previous AI exposure, followed by 85.7% with previous AI exposure in the Operations Management unit. Interestingly, only 71.4% of the IT unit reported previous exposure to AI. Most of the respondents had more than five years of experience (32.6%) and an average of 20% of the three subgroups had less than two years of experience.

Insurance companies dominated the responses (26.3%), with retail and commercial banks second with 23.3%, followed by investment banks (13.2%). Other sectors of the financial industry represented include central banks (11%), Internet banks (9.3%) and broking firms (4.1%), indicating different representations. Sectors such as mortgage companies and credit associations were represented less (5.5% or less), ensuring the inclusion of a variety of sectors within the financial industry.

The first set of questions aimed to determine the perceived adoption of AI in various organisational activities and the range of applications by the various subgroups. Activities include the use of AI for customer interaction, external

communication, fraud detection, insurance and underwriting, credit scoring, logistics management, and how claims are processed. Respondents were asked to indicate their perceived use of AI in various functions using a segmentation from 0 to 20% to 81 to 100%. The results are depicted in Figure 1 below.



**Figure 1:** Patterns of AI adoption in units  
Source: Authors’ calculations

The varied levels of adoption of AI between units in South African institutions, with a focus on high-level applications (81-100%) in domains, show that fraud detection, customer interactions and operational improvement are important. The considerable use of AI, especially in the areas of fraud detection (57.1%) and credit scoring (85.7%), demonstrates the strategic focus of the Risk Management unit on applying AI to improve compliance and financial security. These findings align with studies by [Press \(2019\)](#), which emphasised the value of AI in identifying anomalies and lowering the risk of fraud in financial institutions.

In the Operations Management unit, AI is also frequently used in logistics management (46.2%) and customer interactions (42.9%). Our customer-interaction results mirror those of [Muregess \(2022\)](#), who determined that chatbots are essential for improving customer experience by providing efficient and customised interactions. Furthermore, the IT unit exhibits strong AI integration in areas such as logistics (36.4%) and transaction acceleration (36.4%), which is consistent with research by [Manyika et al. \(2017\)](#) that highlighted supply chain optimisation and logistics as the main benefits of AI-powered ML applications.

Additionally, our findings revealed a broad perception of AI’s use in fleet management, transaction acceleration and external device monitoring,

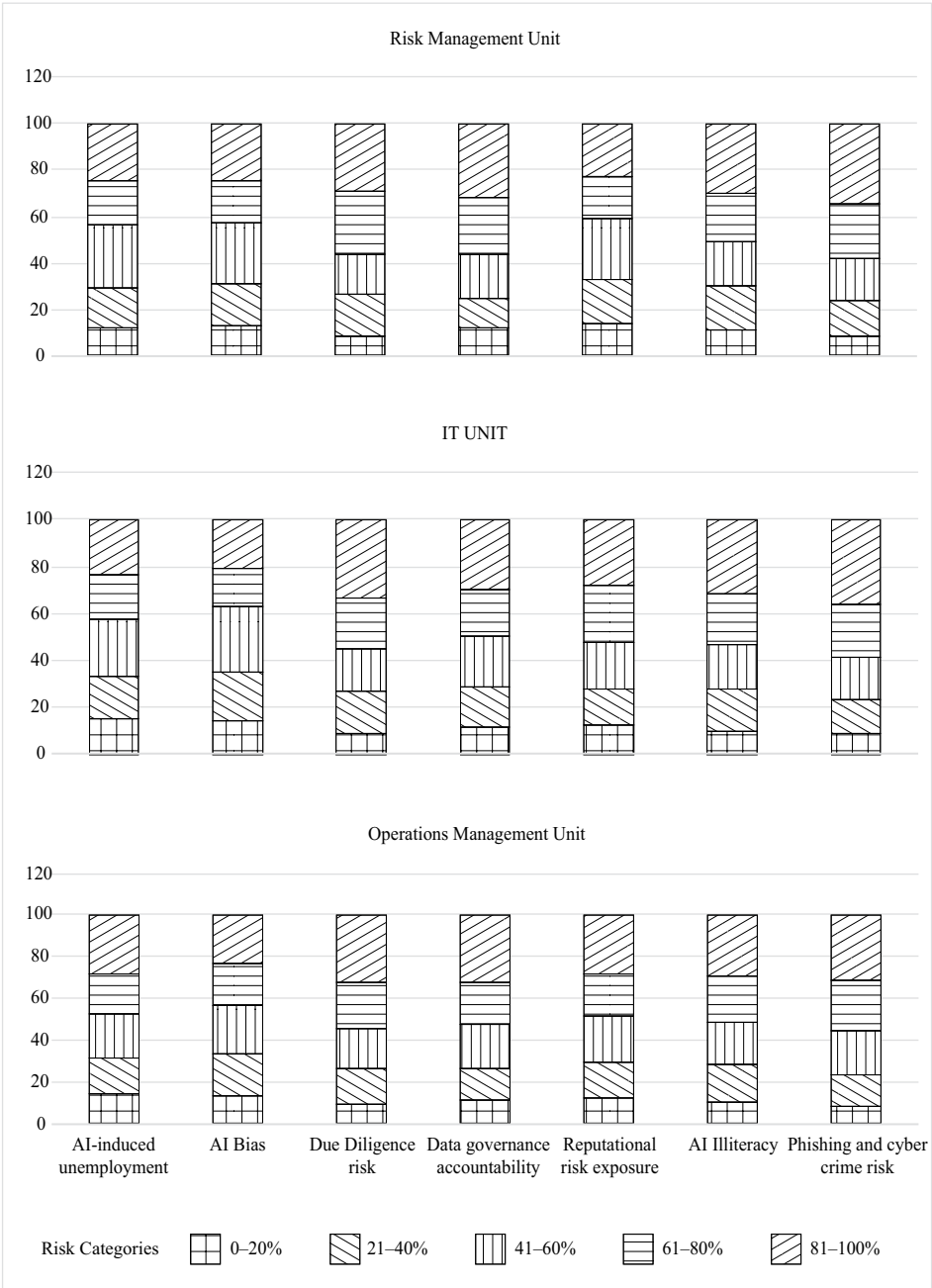
highlighting the various institutions' emphasis on the perceived use of AI for operational efficiency and management procedures. The three departments showed a high perceived use of AI in transaction speeding, external device and system monitoring, and fleet management. These results support the findings by [Huang and Rust \(2022\)](#) that AI can be used by delegating routine tasks to algorithms, freeing human resources for strategic responsibilities. They also underscore the need to take advantage of AI to streamline processes across departments within an organisation.

Despite these perceived adoptions mentioned above, the units show varying acceptance rates for the other variables tested. Only 11.8% of IT respondents reported a high use of AI in external communications, which is quite limited and reflects the reluctance to use AI in public-facing jobs due to algorithm biases and reputational risks. This result is consistent with that of [Fares Butt & Lee \(2023\)](#), who noted similar apprehension in businesses, especially in areas where AI affects the participation of external stakeholders.

The findings indicate that consistent departmental objectives influence the extent of perceived AI adoption. Technical efficiency is given greater importance by the IT unit; customer-facing and logistics procedures are the focus of Operations Management, and security and compliance are the primary focus of the Risk Management unit. These results are in line with research by [Boukherouaa et al. \(2021\)](#), who discovered that company culture and operational priorities have an impact on the adoption rates of AI across industries.

In general, the perceived use of AI by South African financial institutions demonstrates a diverse, yet well-balanced, integration in key operating areas. Although perceived adoption patterns are in line with global trends, the South African environment complicates the implementation of AI technologies due to factors such as labour readiness, departmental objectives, and regulatory challenges and brings complexity to the use of AI technologies. These results highlight the need for customised approaches that align AI integration with organisational goals to achieve optimal effectiveness and impact.

The next set of questions explored how various units within financial institutions, i.e., Risk Management, IT, and Operations Management, perceive risk with the adoption of AI. Our objective is to learn more about the various concerns and goals within the financial sector by examining their responses to questions about possible risks associated with the deployment of AI. Figure 2 highlights the importance of strategic risk management in navigating this transformative era and offers a brief overview of the prospects and difficulties related to the integration of AI in financial institutions.



**Figure 2:** Perceptions of risk associated with AI use per unit

Source: Authors' calculations

Several commonalities become evident when examining the perceived risk responses of the various units. While [Darangwa \(2021\)](#) and [Ashta and Herrman \(2021\)](#) predicted significant workforce reductions, our findings align with [Klein et al. \(2023\)](#), which show department-specific impacts. The anxiety of operations managers about role obsolescence (87% expressed concern) contrasts with the focus of IT on skill adaptation.

Another major perceived risk that we have identified is the risk of AI bias. Many respondents expressed concern about the lack of explainability in AI-driven decision making (for instance, credit scoring or fraud detection algorithms whose inner workings are not transparent). Several respondents from Operations and Risk Management expressed their concern that this can result in reputational risk, as these errors can go undetected until harm occurs. Both units indicated that AI bias is universal risk, categorising it as moderate risk (61-80% risk category). This aligns with the findings of [Fares Butt & Lee \(2023\)](#) who determined that there exists a critical need for fairness in AI systems to mitigate bias in decision-making.

Regarding due diligence risk, 57.1% of the respondents in the Risk Management unit rated it as moderate risk, while 38.5% of the respondents in the IT unit indicated it as high risk (81-100% risk category). These findings echo the recommendations of [Huang and Rust \(2022\)](#), who emphasise the importance of solid governance mechanisms to handle compliance and legal issues in AI implementation.

42.9% of the respondents in the Risk Management unit felt that data governance accountability is a significant risk, while 50% of the respondents in the IT unit felt that data governance accountability is a moderate risk. All units indicated that accountability for errors in nonrepresentative data is a critical concern. The IT unit also indicated that reputational risk is a moderate concern, as stated by 58.3% of the respondents.

A major issue was the lack of proper AI training, especially for the Risk Management unit, where 71.4% of the respondents indicated that the risk was severe (81-100%). Notable concerns were also expressed by the Operations Management unit, which saw AI illiteracy as a critical issue (42.9%). These results are consistent with those of [Boukherouaa et al. \(2021\)](#), who support employee training as a tool to facilitate the successful integration of AI.

The importance of cybersecurity measures was indicated as a concern between units, with 57.1% of the Risk Management respondents indicating it as a critical risk (81-100% risk category), supported by 25% of the IT unit and 30.8% of

the Operations Management unit respondents. These concerns are supported by Faures et al. (2023), who highlighted confidentiality and cybersecurity as key barriers to the widespread adoption of AI in the financial sector, and by Chen et al.'s (2022) model of AI vulnerability that surfaces in financial systems.

The unique priorities and operational challenges of each unit are reflected in the differences in perceived risks between the organisational units. The IT unit stresses cybersecurity and reputational risks, the Operations Management unit raises concerns about workforce-related challenges and fairness in AI systems, and the Risk Management unit concentrates on AI illiteracy, pirating, cybercrime risk and reputational risk exposure. Customised unit-specific risk mitigation strategies that complement the more general objectives of ethical and effective AI integration will be needed to ease these concerns. A blanket approach will not address the perceived risks related to AI in the various units.

The interviews conducted with professionals from South African financial institutions provided useful insights into the perceived risks and challenges associated with the implementation of AI. Data saturation was reached after six professionals were interviewed. They were an investment banker, a senior business analyst, an insurance commission manager, an IT systems administrator, a development manager who oversees system enhancements, and a project manager responsible for IT-related project execution.

The results of the interview reveal a terrain marked by both difficulties and possibilities. Participants unanimously raised concerns about the insufficient preparation for AI implementation, underscoring the need for comprehensive initiatives to address this preparedness gap. The importance of strong measures to protect sensitive information was highlighted, focussing on the primary issues of data security and privacy. The perception of a significant danger in job displacement and workforce changes has highlighted the need to prioritise the development of new skills and the acquisition of additional knowledge to facilitate the transition to a more automated work environment.

The findings suggest that South African financial institutions have both a positive view of the ability to bring about significant changes and a cautious attitude due to concerns about ethical considerations, regulatory compliance, and impact on the workforce. The results indicate that a well-balanced and careful strategy is necessary for the effective integration of AI in the financial sector. This approach should prioritise continuous education, cooperation between organisations and careful risk management.

The themes that emerged from the interviews highlight the complex issues surrounding the use of AI in financial institutions in South Africa. Institutions should adopt a holistic approach that considers increasing organisational readiness (Fountaine, McCarthy & Saleh, 2019), strengthening data governance (Press, 2019), training of the workforce (Manyika et al., 2017), and encouraging ethical AI practices (Fares, Butt & Lee, 2023).

#### **4. LIMITATIONS AND FUTURE RESEARCH**

Although this study provided valuable information on perceived AI risks in South African financial institutions, it is important to recognise several limitations. First, the research is limited in scope and focusses geographically only on South African financial institutions, which may limit the generalisability of the findings. Cultural, economic (South Africa being a developing economy with a dualistic nature) and regulatory factors specific to South Africa could influence risk perceptions in ways that are not applicable to other regions. Future research should consider a larger and more varied sample, including financial institutions from other countries and at different levels of economic development. Stakeholder groups could also be expanded to include customers, regulators and fintech entrepreneurs, as these groups may perceive AI risks differently.

The use of self-reported perceptions, which are prone to bias based on optimism or fear, limits our analysis. While some subjectivity was mitigated by anonymity assurances and mixed-methods triangulation, objective indicators of AI adoption and performance should be included in future studies to supplement surveys and interviews. Some indicators to consider are deployment footprint, AI usage intensity, performance and efficiency metrics, risk and compliance data reports, customer-impact measures, human resources effects and financial outcomes. A more comprehensive assessment of AI adoption and its practical consequences will be possible through the collection and analysis of such system-generated metrics than by using perception data alone.

Our study also captured a snapshot in the time of AI perception during a period of rapid technological advancement. The significance of this study may be limited because our data had been collected before some of the most recent advances in AI, which may have excluded concerns such as hallucinations. To investigate the long-term impacts of AI adoption on risk perceptions and organisational outcomes, longitudinal studies are required.

A final limitation of our study was that its scope was based on perceptions rather than objective risk measures. We did not evaluate actual risk management

results or AI-related failures. Future research might integrate objective AI risk assessments (such as algorithm bias audits, security penetration testing results, or incident reports of AI failures) and examine their relationships with perceived risk. Correlating perceived risks with actual risk indicators can reveal where perceptions over- or underestimate real risks. This could help improve risk communication and training.

## **5. CONCLUSIONS**

The purpose of this research was to evaluate the perceived risk attitude in the adoption of AI in South African financial institutions. The study found that several factors influence the adoption of AI in South African financial institutions. These factors include the level of trust in AI technology, understanding its potential and limitations, the regulatory openness of compliance issues, and the ability of financial institutions to adopt modern technologies.

Surprising patterns emerged when perceived risk responses were examined in the various units. While Risk and Operations Management exhibit higher perceived risks, primarily falling within the 81 to 100% range, the IT unit mainly perceives risks in the 61 to 80% range. The level of focus and skill that each unit possesses could be a possible factor contributing to this inconsistency. Given its experience and confidence in handling cybersecurity threats and complex technology systems, the IT unit can identify risks in a range that corresponds to these challenges. However, the Risk Management and Operations Management units, which oversee operational continuity and comply with regulations, could prioritise and see risks differently, which could explain the higher concentration in the 81 to 100% range. The interviews confirmed this as AI literacy emerged as an important element in managing perceived risks.

Although South African financial institutions show increasing interest in implementing AI, the study found that their risk attitudes are still influenced by concerns about data security, ethical implications, and job losses and displacement. This study highlights how crucial it is to address these complex issues to help South African financial institutions implement AI. To effectively manage and reduce perceived risks associated with the adoption of AI technology, a complete approach that combines technological preparedness, regulatory frameworks and a proactive effort to develop trust in technology, is needed.

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An AI generator was used to translate the abstract into Serbian and an AI-powered editing application to refine the grammar of the text.

## Conflict of interest

The authors declare that there is no conflict of interest. Furthermore, the authors declare that no funding was received for the study and that the results presented are unbiased.

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## ПРОЦЈЕНА ПЕРЦЕПЦИЈЕ РИЗИКА ВЈЕШТАЧКЕ ИНТЕЛИГЕНЦИЈЕ У ФИНАНСИЈСКИМ ИНСТИТУЦИЈАМА ЈУЖНОАФРИЧКЕ РЕПУБЛИКЕ: МУЛТИДИМЕНЗИОНАЛНИ ПРИСТУП

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### САЖЕТАК

Процедуре управљања ризиком у финансијским институцијама широм свијета значајно је измјенила вештачка интелигенција (AI). Међутим, мало се зна о перципираним ризицима имплементације AI, посебно у земљама у развоју као што је Јужноафричка Република. Циљ ове студије јесте да, из мултидимензионалне перспективе, процијени перципиране ризике усвајања AI од стране запослених у финансијским институцијама Јужноафричке Републике. Ова студија користи приступ мјешовитих метода, примењујући сврсисходан и узорак сљежне грудве од 90 анкетираних испитаника и полуструктурираних интервјуисања из неколико финансијских институција Јужноафричке Републике. Студија је открила широк спектар забринутости, од отпуштања изазваног AI до рањивости на сајбер криминал. Анализа пружа слојевите увиде у то како различита одјељења, укључујући управљање ризиком, ИТ и управљање операцијама, на јединствен начин перципирају и управљају изазовима везаним за AI. Ова студија истиче потребу за персонализованим стратегијама управљања ризиком које одговарају специфичним потребама одјељења, као и важност стратешког планирања приликом интеграције AI технологије у финансијским институцијама како би се максимизирао потенцијал уз ограничење повезаних ризика. Она доприноси растућем тијелу знања о усвајању AI у земљама у развоју и пружа практичне информације за практичаре и доносиоце политика.

**Кључне ријечи:** *вештачка интелигенција, финансијске институције, перцепција ризика, управљање AI, организациони ризик, Јужноафричка Република.*

# ECONOMETRIC ASSESSMENT OF THE MACROECONOMIC CONTRIBUTIONS OF TOURISM IN REPUBLIC OF SRPSKA<sup>1</sup>

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## ABSTRACT

This paper provides an econometric assessment of the macroeconomic contributions of tourism in Republic of Srpska. The analysis is based on the Tourism-Led Economic Growth (TLEG) hypothesis and examines the elasticity of gross value added in the services and agriculture sectors in relation to tourist arrivals, as well as the long-term relationship between tourism and GDP growth. The results suggest that tourism positively influences economic development, particularly through its effects on service-oriented and agricultural activities. Despite the limitations in the availability and reliability of official data, the findings support the recognition of tourism as a strategic sector. The paper highlights the need for improved statistical infrastructure, greater investment and the strategic development of the tourism sector to enhance its growth and competitiveness potential.

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## 1. INTRODUCTION

Tourism in many countries plays a vital role in the economy. However, existing tourism statistics cannot show its full economic importance and impact. The lack of appropriate economic measurement of tourism often leads to an underestimation of the benefits of tourism, especially in comparison with other economic sectors. For this reason, it is of practical and political importance

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to determine the potential that tourism as a sector in the context of generators of economic growth and development has. It is necessary to determine the contribution of tourism sector to the key variables of economic growth and development using scientifically accepted methods to raise awareness of the possibilities that tourism brings with it. Only based on the included and measured contributions of tourism to economic growth and development, it can become a pillar of economic growth by itself. In the scientific sense, the hypothesis based on the assumption that economic growth in a particular country is determined by tourism is called the Tourism Leading Growth Hypothesis. Confirmation of the validity of this hypothesis is carried out by econometric methods that, based on the available data, provide an answer to the question of whether the growth of the tourism sector leads to economic growth or whether economic growth is the driving force of tourism development. If empirical evidence demonstrates that tourism is the primary driver of economic growth due to its multiplying effects, it can be stated that tourism receives the status of a key development factor. In the practical economic policy, this would mean that at an empirically confirmed level, tourism must be declared a sectoral priority. Based on that, to support economic growth and economic convergence, governments are obliged to pay special attention and provide operational and financial support to promote tourism as a driving force of economic growth. Based on the above, it is evident that tourism as an economic branch can acquire such status only from its overall macroeconomic contributions.

In this paper, we apply the concept of Tourism-Led Economic Growth (TLEG), which posits that tourism can serve as a generator of economic growth, particularly in developing and transition economies. TLEG is a widely recognised theoretical framework in empirical research, focusing on the causal relationship between tourism activity and macroeconomic aggregates such as GDP and gross value added. Our approach uses this theoretical basis to assess the macroeconomic significance of tourism in Republic of Srpska.

The objective of this analysis is to measure the economic contribution of the tourism sector of Republic of Srpska using a scientifically accepted methodology. To the best of the authors' knowledge, and following a comprehensive review of the available literature, this represents the first study of its kind specifically focused on this region. The study also aims to determine the interdependence between economic growth and tourism in order to assess the sector's potential as a driver of economic development in the country. Along with the measurements, we will also explain the channels through which tourism positively influences other sectors, thus satisfying the criteria for recognising tourism as a potential engine of economic growth. It should be emphasised here that the limited availability and

statistical coverage of certain data on the positive impact of tourism on overall economic growth affect the fact that the results obtained are a more conservative assessment of the macroeconomic contribution of the tourism sector. One of the most important limitations of this type of macroeconomic evaluation in Republika Srpska lies in the insufficient reliability and comprehensiveness of the available data. The absence of a fully developed tourism satellite account (TSA), the lack of disaggregated tourist expenditure data and the limited capacity of national statistics to capture indirect and induced effects, constrain the precision of the econometric estimates. These constraints are not unique to this study, but rather reflect a broader issue common in many developing or transitional economies, where statistical systems lag behind the growing economic complexity of the tourism sector (UNWTO, 2019). Acknowledging this limitation is essential for interpreting the study's findings appropriately and sets the basis for further institutional efforts aimed at improving tourism-related economic measurement in the country. In other words, the barriers of the statistical availability of data affect the fact that the positive results determined are less than the maximum contribution which tourism makes to economic growth.

Quantitative methods ranging from stochastic to deterministic are used almost exclusively in the assessment of the economic contribution of tourism to the economy and economic growth. Of the stochastic methods, econometric methods based on the analysis of time series, cross-sectional and panel data, are most often used. Deterministic methods are gravity models, input-output analysis (IO), matrices of national accounts (Social Accounting Matrix, SAM), satellite accounts of tourism (Tourism Satellite Accounts, TSA) and model of general equilibrium (Computable General Equilibrium, CGE).

The main objective of this study is to empirically test the TLEG hypothesis using time-series econometric techniques, applying the number of tourist arrivals as a proxy for tourism activity. Given the lack of disaggregated data on tourism expenditures, this proxy has been adopted following international empirical practices. The research aims to determine whether there exists a long-term equilibrium relationship between tourism development and economic growth indicators in Republic of Srpska.

## 2. LITERATURE REVIEW

Tourism-Led Economic Growth (TLEG) concept has been extensively studied, particularly its impact on GDP, employment and foreign exchange earnings. Early studies, such as Ghali (1976), highlighted the direct contributions of tourism to economic expansion by fostering investment in infrastructure and increasing

consumer spending. Tourism is widely recognised as a catalyst for economic growth, particularly in developing economies, where it can stimulate various sectors through increased demand for goods and services. The concept of Tourism-Led Economic Growth (TLEG) suggests that tourism activities play a crucial role in the overall growth of an economy, functioning as both a direct contributor to GDP and an indirect driver through related industries (Brida, Cortes-Jimenez & Pulina, 2016). Tourism stimulates investment in infrastructure, enhances the productivity of labour and encourages greater participation in global trade, all of which contribute to macroeconomic expansion (Balaguer & Cantavella-Jordá, 2002). Balaguer and Cantavella-Jordá (2002) extended this analysis by showing that tourism was a long-term growth driver in Spain, demonstrating a positive correlation between tourism receipts and GDP. Further research has confirmed similar effects in developing and small economies, where tourism represents a significant portion of national income (Fayissa, Nsiah & Tadasse, 2008).

The employment-creating potential of tourism is another well-documented aspect, with tourism sectors often linked to broader job creation and poverty alleviation (Brida, Cortes-Jimenez & Pulina, 2016). Tourism spending has been shown to produce multiplier effects across various industries, further stimulating economic growth (Nowak, Sahli & Sgro, 2007). Nevertheless, the dependency on tourism can also expose economies to risks associated with external shocks, including financial crises and natural disasters, which challenge the sustainability of TLEG (Sequeira & Nunes, 2008). Therefore, while tourism is a critical growth driver, its effectiveness depends on the resilience and diversification of the broader economy.

One significant benefit of tourism is its ability to generate foreign exchange earnings, which can alleviate balance of payments constraints. This inflow of foreign currency strengthens the national economy, promoting development through enhanced purchasing power and investment capabilities (Fayissa, Nsiah & Tadasse, 2008). Additionally, the tourism sector creates employment opportunities across various skill levels, which can reduce poverty rates and promote inclusive growth. The multiplier effects of tourism spending amplify these benefits as income circulates through the economy, affecting industries such as transportation, hospitality and retail (Ghali, 1976).

Empirical studies often highlight the positive correlation between tourism receipts and economic growth, especially in small, open economies heavily reliant on tourism. For example, in Caribbean and Mediterranean countries, tourism has been shown to significantly impact long-term GDP growth, as the sector often represents a substantial portion of their national income (Nowak, Sahli & Sgro, 2007). Moreover, TLEG theory posits that tourism enhances human capital

development through skill acquisition and international exposure, fostering innovation and higher productivity (Sequeira & Nunes, 2008). Consequently, these effects can increase the competitiveness of other sectors, leading to broader economic benefits beyond tourism.

Nevertheless, the impact of tourism on economic growth is not uniformly positive. There are concerns about dependence on tourism, particularly in countries where over-reliance may lead to economic vulnerability due to external shocks, such as global financial crises or pandemics. The volatility of international tourist arrivals can expose economies to risks associated with fluctuating demand, exchange rate volatility and seasonality (Brida, Cortes-Jimenez & Pulina, 2016). Therefore, while tourism can drive growth, its long-term sustainability requires diversified economic strategies and investments in resilience.

In conclusion, the tourism sector has significant potential to drive economic growth, especially in developing and small economies, by generating foreign exchange, creating jobs and enhancing infrastructure. However, the benefits of tourism-led growth must be balanced with efforts to mitigate risks related to over-dependence and vulnerability to external shocks. For tourism to serve as a sustainable driver of growth, it must be integrated into a comprehensive economic strategy that includes diversification and the development of complementary sectors.

In addition to the cited literature, it is important to acknowledge the theoretical contributions of Wall (2006), Veal (2011), Hall (2008), Tribe (2004) and Butler (1980), whose work has greatly influenced tourism economics. These authors explore various dimensions such as the role of tourism in sustainable development, socio-economic multipliers and destination lifecycle theory. Their contributions support the view of tourism as a multidimensional economic force capable of stimulating structural transformation.

### **3. ECONOMETRIC ANALYSIS OF MACROECONOMIC EFFECTS OF TOURISM IN REPUBLIKA SRPSKA**

In the first part of the analysis, the goal was to determine the elasticity of the gross added value of the service sector and the agriculture sector in relation to tourism. To cover the credibility of the impact of tourism on the service sector, service sectors related to tourism are included. First of all, this refers to the following sectors: transport and storage; activities of providing accommodation, preparing and serving food; hotel and catering industry; real estate business; administrative and auxiliary service activities; and arts, entertainment and recreation. Due to

the lack of data on tourist consumption, the total number of tourist arrivals (both foreign and domestic tourists) was taken as a variable that measures the effects of tourism. Annual data were collected for the gross added value of the analysed sectors and total tourist arrivals in the period from 2000-2020. The data source is the Republic of Srpska Institute of Statistics. Due to limitations in the availability of consistent data on tourism consumption in Republic of Srpska, we employ the total number of tourist arrivals—both domestic and international—as a proxy variable to measure tourism activity. This approach aligns with prior studies conducted in similar data-constrained contexts (e.g., [Fayissa, Nsiah & Tadasse, 2008](#); [Nowak, Sahli & Sgro, 2007](#)). While not exhaustive, this proxy captures the scale and dynamic of tourism flows, providing a reasonable approximation for assessing its macroeconomic effects.

To obtain elasticity coefficients, all data were transformed into their logarithmic form, and regression models were subsequently estimated using the ordinary least squares (OLS) method. The estimated elasticity parameter is statistically significant at the 1% risk level and amounts to 0.536. The coefficient of determination is high considering that only one variable is included in the model. The results indicate that 55% of the variation in the dependent variable - the gross added value of services - is explained by variations in total tourist arrivals. To verify the validity of the model, diagnostic tests were conducted to assess the fulfilment of the key assumptions underlying the ordinary least squares method. These are the Jarque–Bera test of normality of the residuals, the Breuche-Pagan autocorrelation test and the White heteroskedasticity test. Based on the p-value of the obtained statistics, all assumptions were found to be satisfied, confirming the model's validity for inference.

**Table 1:** The elasticity of the gross added value of services in relation to tourism

Variables	Coefficients	Standard error	p - value
Constant	7.757731	1.490398	0.0001
Log (total arrivals)	0.536879	0.119901	0.0004
R2	0.556170		
Custom R2	0.528431		
F statistic	20,04984		0.000381
LM test of serial correlation	1.539183		0,4632
Jarque-Bera test	2.095353		0.350752
White heteroskedasticity test	2.881165		0.2368

Source: Authors' calculation

The statistically significant positive coefficient of elasticity of VAT services concerning the tourism sector indicates a great potential of the tourism sector in the context of contributing to a significant increase in earnings. Namely, the growth of gross added value is a key variable for ensuring sustainable wage growth. On the other hand, the entire tourism sector, based on the research of trends in the labour market, faces the problem of a deficit of sensitive basic labour force, which is primarily determined by the migration of the same to other countries in the surrounding area due to significant differences in earnings. Another conclusion that emerges from these results is the necessity of increasing the competitiveness of the tourism offer of Republic of Srpska in terms of improving its content, which, taking into account the specificity of tourism as a sector, represents a direct channel of transmission to the level of added value. In circumstances where the quality and diversity of the tourism offer were enhanced, the level of added value would increase significantly, thereby creating sustainable and realistic conditions for ensuring competitive wages for employees in the tourism sector, as well as, as the research shows, in other related service sectors. This becomes particularly significant when considering that, within the analysis of the gross value added of the service sector, financial activities are excluded. Consequently, the impact of tourism on the added value of the service sector becomes even more pronounced.

In support of the previously stated claim about the relationship between earnings and added value, the elasticity of gross added value on earnings, including earnings concerning tourist arrivals, was evaluated.

**Table 2:** Elasticity of VAT Services in relation to wages

<b>Variables</b>	<b>Coefficients</b>	<b>Standard error</b>	<b>p - value</b>
Constant	5.953234	0.451961	0.0000
Log (total arrivals)	1.339491	0.04006	0.0000
R2	0.951697		
Custom R2	0.949013		
F statistic	354.6499		0.0000
LM test of serial correlation	10.03040		0.0066
Jarque-Bera test	2.897362		0.235586
White heteroskedasticity test	3.274773		0.1945

Source: Authors' calculation

As the value of the LM test indicated the existence of autocorrelation of residuals, the model with standard error correction (Newey-West) was evaluated without affecting the statistical significance of the evaluated parameters. The high statistical significance of the elasticity parameter and the overall model confirm the above statements. The gross added value in the service sector is highly elastic to wages in this sector because, according to the obtained results of the evaluated model, a 1% increase in wages leads to an increase in the gross added value of the service sector by 1.34%.

**Table 3:** Elasticity of GVA of agriculture in relation to tourist arrivals

Variables	Coefficients	Standard error	p - value
Constant	10.62809	1.018425	0.0000
Log (total arrivals)	0.244465	0.081931	0.0000
R2	0.357508		
Custom R2	0.317352		
F statistic	8.9030202		0.00871
LM test of serial correlation	0.750153		0.6872
Jarque-Bera test	4.637882		0.098378
White heteroskedasticity test	4.600880		0.1002

Source: Authors' calculation

The analysis of the impact of tourism on the gross added value of agriculture provides very instructive insights regarding the need to connect agriculture and tourism itself. Namely, the major problems in agricultural production are related to the high level of uncertainty regarding the security of placement and the price level of agricultural products. Among other things, these are the main reasons for the reduced level of investment in raising agricultural production, because these investments are accompanied by a high degree of risk. To reverse trends and transform agriculture into an activity with a higher level of added value, it is necessary to connect it to the value chains of sectors whose growth trend of added value is high. Given the previously statistically confirmed positive elasticity of the gross added value in this sector with respect to tourist arrivals, it becomes clear that agriculture, in the context of overcoming the perceived barriers, should be integrated with the tourism sector. This integration can be achieved in a direct sense by developing rural tourism as a specific form of tourism, which is carried out by agricultural holdings. In addition to accommodation services and certain tourist facilities, the mentioned farms also provide short supply chains in

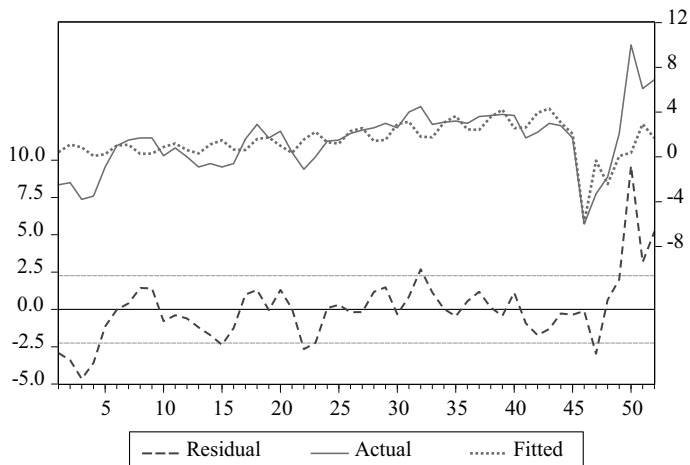
agricultural production and nutrition. In this way, agricultural products would be exported through tourist services that provide much higher prices compared to sales on the markets of primary agricultural products. Another channel through which it is possible to provide a market for a more profitable placement of agricultural products is the segment of the hotel industry. The development of domestic protected tourist products from the gastronomic sector, along with domestic agricultural products, enables a significant part of the invisible export of agricultural products at significantly higher prices to be secured through the hotel industry.

#### 4. THE IMPACT OF TOURISM ON ECONOMIC GROWTH

An error-corrected model was used to determine the effects of tourism on economic growth. For this analysis, the available data from the Republic of Srpska Institute of Statistics are quarterly data for GDP growth rate (this variable is commonly used as a determinant of economic growth), as well as quarterly data for tourist arrivals. This data is available from the first quarter of 2009 to the last quarter of 2021. The equilibrium error correction model makes it possible to determine the rate of adjustment of these variables to the long-term equilibrium in response to short-term disturbances due to the impact of tourism on GDP. Initially, the stationarity of the observed series was examined, referring to the constancy of both the mean and variance of the time series over time. The ADF unit root test was applied, and it was determined that the series were stationary at the first difference. Based on this, the evaluation of the regression model with variables at the level can cast doubt on the meaning of the results of the regression analysis, more precisely to the so-called false regressions, so the model with equilibrium error correction was used to determine the long-term and short-term relationship between the observed variables. This model requires a preliminary test for the cointegration of non-stationary time series, which is conducted by analysing the stationarity of the residuals from the regression equation at the level. As the results of the ADF test rejected the null hypothesis of non-stationarity of the residuals at the significance level of 1%, and the long-term relationship between tourism and economic growth is confirmed. In other words, these two variables follow each other over time. The cointegration equation and ADF test results are below:

$$sbdp = -34,037 + 3,445 \log(ud)$$

The ADF test of the unit root of the residual from the previous equation is -3.199303, and the p-value of the statistic is 0.0258, so it is concluded that the observed series are cointegrated.



**Graph 1** Residuals from the estimated relationship between the growth rate and tourist arrivals

Source: Authors' calculation

This graph presents the actual movement of the growth rate, the model-estimated growth rate movement and the movement of the series of residuals. This visual inspection of the residuals confirms the long-term consistency of the observed variables.

The model with equilibrium error correction reads:

$$\Delta sbdp_t = \theta_0 + \theta_1 \hat{e}_{t-1} + \lambda_1 \Delta \log(ud)_t,$$

where  $\hat{e}_{t-1}^* = sbdp_{t-1} - \beta_0 - \beta_1 ud_{t-1}$

The evaluated model is:

$$\Delta sbdp_t = -0.155 - 0.454 \hat{e}_{t-1} + 2.975 \Delta \log(ud)_t,$$

The table below shows the results of the evaluation model in the EVIEWS software package.

**Table 4:** Model with correction of equilibrium errorDependent Variable:  $\Delta(\text{sbdp})$ 

Method: Least Squares

Date: 03/09/22 Time: 08:59

Sample (adjusted): 2 47

Included observations: 46 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.155392	0.251088	-0.618875	0.5393
$\hat{\epsilon}_{t-1}$	-0.454960	0.142959	-3.182447	0.0027
$\Delta \log(\text{ud})$	2.975558	0.528778	5.627231	0.0000
R-squared	0.494973	Mean dependent var		-0.232609
Adjusted R-squared	0.471484	S.D. dependent var		2.335060
S.E. of regression	1.697568	Akaike info criterion		3.959264
Sum squared resid	123.9147	Schwarz criterion		4.078523
Log likelihood	-88.06307	Hannan-Quinn criteria.		4.003939
F-statistic	21.07200	Durbin-Watson stat		1.811165
Prob(F-statistic)	0.000000			

Source: Authors' calculation in EViews

The parameter's negative and statistically significant value supports the long-term equilibrium relationship between the variables. It shows us that the current value of the growth rate is above the long-term equilibrium link, indicating that the current value of the growth rate adjusts to the estimated long-term equilibrium link at a rate of 0.683 multiplied by the deviations from the previous period if there is any short-term deviation. The basic conclusion is that tourism, measured by the number of total tourist arrivals, can be used as a channel for increasing economic growth in Republic of Srpska.

A positive and statistically significant short-term parameter suggests that short-term fluctuations in the GDP growth rate are influenced by contemporaneous changes in the number of tourist arrivals, with this effect being reflected in the observed trend of economic growth.

It can be concluded that the results obtained indicate a progressive and significant influence of the number of tourist arrivals on the movement of the GDP growth rate in both the short and long term, demonstrating that tourism constitutes a key driving force of economic growth in Republic of Srpska.

The results of the study imply an important role of tourism in the economic growth of the country. The main contribution of this study is identifying the

role of tourism in the economic growth of Republic of Srpska. Understanding the relationship between tourism and economic growth can help researchers and planners assess future tourism planning. This understanding is important for policymakers in developing policies that best suit economic objectives.

## **5. CONCLUSIONS**

Determining the macroeconomic effects of tourism as an economic sector holds a dual significance. On one hand, identifying the direct and indirect effects that tourism generates in the context of its contribution to economic growth and employment is crucial for recognising the transmission mechanisms, as well as the channels through which tourism stimulates growth and employment. By determining the intensity of the impact of tourism on other sectors and the economy as a whole, measurements of the macroeconomic contribution of tourism enable the development of awareness of the potential that the tourism sector carries within it as a possible driver of economic growth. In line with these goals, this paper measured the macroeconomic contributions of tourism in Republic of Srpska for the first time. The results of econometric measurements showed that tourism as a sector is a factor in the development of Republic of Srpska. Despite the rigorous application of econometric methods, it must be acknowledged that the results of this study are conditioned by the quality and granularity of the available data. In particular, the absence of consistent series on tourism expenditures, value chain linkages and sectoral spillovers introduces uncertainty regarding the full magnitude of the role of tourism in economy. While this challenge is common in economies lacking integrated statistical systems such as TSA, it underscores the urgent need for institutional reforms and investments in the tourism statistics framework in Republic of Srpska. Future research would benefit substantially from the development of dedicated measurement instruments that capture the direct, indirect and induced effects of tourism, which would in turn allow for more robust policy conclusions. Its influence on other branches, such as agriculture and service activities, is a relevant argument for the determination of more significant investment funds directed to the tourism of Republic of Srpska. It is essential to emphasise that the results presented in this study represent a conservative assessment of the macroeconomic contribution of tourism due to limitations in the statistical system. Future research could benefit from the inclusion of more granular data such as tourism spending patterns, seasonal variability and the segmentation of tourist demand. Nevertheless, the findings confirm the significant and progressive impact of tourism on key sectors and overall economic growth in Republic of Srpska. Through this economic justification, tourism should finally be the focus

of operational economic policies as a branch whose growth would accelerate the development transition of Republic of Srpska. The identified transmission mechanism of the impact of tourism on growth, which is contained in this study, maps the roadmap of measures for active economic and political support for the development of tourism and thus the economy.

### Conflict of interests

The authors declare there is no conflict of interest.

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## ЕКОНОМЕТРИЈСКА ПРОЦЈЕНА МАКРОЕКОНОМСКИХ ДОПРИНОСА ТУРИЗМА У РЕПУБЛИЦИ СРПСКОЈ

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### САЖЕТАК

Овај рад представља економетријску процјену макроекономских доприноса туризма у Републици Српској. Анализа се заснива на хипотези о туризмом вођеном економском расту (TLEG) и обухвата испитивање еластичности бруто додате вриједности у секторима услуга и пољопривреде у односу на број туристичких долазака, као и дугорочне везе између туризма и раста БДП-а. Резултати указују на позитиван утицај туризма на економски развој, посебно кроз ефекте на услужне и пољопривредне дјелатности. Упркос ограничењима у погледу доступности и поузданости званичних података, налази истраживања подржавају потребу да се туризам препозна као стратешки сектор. Рад наглашава важност унапређења статистичке инфраструктуре, већих инвестиција и стратешког развоја туристичке понуде у циљу јачања њеног развојног и конкурентског потенцијала.

**Кључне ријечи:** *туризам, туризмом вођени економски раст, макроекономски доприноси, Република Српска.*

# THE EFFECTS OF AGRICULTURAL FINANCE AND FINANCIAL DEVELOPMENT ON THE ECONOMIC GROWTH OF THE SSA COUNTRIES<sup>1</sup>

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## ABSTRACT

This study examined the effects of agricultural finance and financial development on the economic growth of the SSA from 2000 to 2021. The study employed the panel ARDL regression models and the panel VAR-based Granger causality test as tools for data analysis. The study revealed that capital accumulation impacts agricultural performance negatively in the long run; the effect on economic growth is negative in the short run but positive in the long run. Also, there is no evidence for the short-run impact of labour on both agricultural performance and economic growth; however, the long-run effect is positive and significant. There is a piece of strong evidence supporting financial development as an agricultural performance and economic growth drivers both in the short and long run. Per capita income which reflects the individual purchasing power impacted agricultural performance only in the long run whereas its impact on economic growth which is only significant in the long run is negative. Further, it is revealed in the study that the role played by agricultural performance in driving economic growth cannot be overemphasised both in the short run and long run. Therefore, this study recommends strengthening institutional capacity for financial sector monitoring through legislation and countercyclical buffers, promoting R&D and policies to enhance industrial and agricultural performance, and advancing financial institutions to optimise agriculture-linked industrialisation. Also, governments should encourage affordable agricultural credit, supported by awareness campaigns, and prioritise apprenticeship programs, reskilling and technology-driven R&D to boost labour productivity and sustain economic growth in Sub-Saharan Africa.

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## 1. INTRODUCTION

Across the globe agriculture remains one of the important activities in the real sector with huge contributions to economic growth. Apart from this, the sector is the engineroom of many economies for solving chronic economic development problems such as unemployment, low and narrow-based output, and poverty among others (Ho, Pham & Nguyen, 2021). One of the major challenges confronting the sector over the years, especially in the SSA where the real sector is largely underdeveloped, is inadequate funding. The responsibility of funding the real sector of any economy falls mainly on the financial sector; hence in most developed countries the level of financial development is such that provides easy access to funds at an affordable cost to the agricultural sector so that the sector can contribute as expected to the economy growth (AfDB, 2020). However, in the SSA the situation appears to be different. Although most of the SSA countries have banks, capital markets and other financial intermediaries with high rankings among their contemporary in the World, the agricultural sector of most of the SSA countries is grossly underdeveloped due to inadequate funding and this is limiting the contributions of the sector to the economic growth of many SSA countries.

Normally, a virile and strong financial sector where banks both at the sub-regional and country level in the SSA are achieving outstanding ratings. From international agencies such as the FITCH rating it is expected to bring about a high level of financial development that will have a significant impact on the agricultural sector. For instance, within the last five years, Africa Development Bank AfDB which is the most dominant Sub Regional financial institution in SSA has continued to maintain AAA ratings for five years consecutively (IMF, 2021). At the country level, the five big banks in South Africa and the five-tier money lenders in Nigeria have continued to maintain impressive rankings among their contemporaries across the globe (World Bank, 2020). In addition, the SSA capital markets which include the JSE (Johannesburg Stock Exchange), NSE (Nigeria Stock Exchange) and the KSE (Kenya Stock Exchange) have all been recording impressive performances among their contemporaries, especially within the last decade despite the COVID-19 pandemic (IMF, 2020). These outstanding track records in the financial sector of most of the SSA countries are expected to procreate a kind of financial development that will have significant positive contributions to the growth of the real sector by providing a broad-based finance structure that makes funding available and affordable to the agricultural sector which is an important sub-sector of the real sector.

According to [Aluko and Ajayi \(2018\)](#), promoting the synergy between agricultural finance and financial development is very important to the economic growth of any country. Realising this fact prompted many SSA countries to embark on different programs as well as the establishment of agencies that will aid this synergy in a bid to make accessible and affordable funds available for the agricultural sector. One of these programs is the mobile banking strategy which is one of the efforts to improve financial inclusion. In the last ten years many SSA countries have intensified efforts to have a broad-base financial development that will have a spread effect on the rural communities where many subsistence farmers that dominate the agricultural sector in the SSA reside. Countries like Nigeria, South Africa, Rwanda, Kenya and Uganda among others have made tremendous achievements in this regard ([Asratie, 2021](#)). The financial inclusion strategy followed a series of efforts such as microcredit schemes leading to the increase in the numbers of microfinance banks and other specialised microfinance agencies that are saddled with the main responsibilities of making loans and other credit facilities with less stringent conditions available to the agricultural and other sectors of many SSA countries. Many schemes like these are prominent in countries such as South Africa, Nigeria, Zambia, Rwanda, Tanzania, Uganda and Kenya among others ([Mbulawa, 2015](#)). Apart from this, some countries in the SSA have established specialised development banks for the real sector. Examples are the Bank of Agriculture (BOA) and Bank of Industry (BOI) in Nigeria, the Development Bank of Southern Africa (DBSA) in South Africa, the Development Bank of Rwanda (PLC) in Rwanda, the Land and Agricultural Development Bank (LANDBANK) in South Africa, East African Development Bank in Uganda among others. All these banks have a specialised mandate to make more funding to the real sector, especially the Agricultural sector more than other sectors of the economy. All these efforts have been taken by these countries to promote the synergy between financial development and agricultural finance to aid the contributions of the agricultural sector's economic growth in the SSA.

Despite all these efforts, the performance of the agricultural sector is still far below expectations in the SSA sub-region. For instance, in Nigeria, the contribution of the sector to the GDP fell from 29.25% in 2019 to 24.65% in 2020 and it fell further to 22.35% in 2021 ([World Bank, 2021](#)). The same trend has been recorded recently in South Africa where the sector only contributed 2.4% to the GDP compared to sectors like industry and services which contributed 25.2% and 65.45% in 2020 ([World Bank, 2021](#)). In Kenya, although there was a rise in the share of the agricultural sector in the GDP between 2019 and 2020, recently the contribution has been falling. For instance, the growth rate of the sector fell

from 7.3% in 2020 to 6.3% in the 2021 second quarter. In Rwanda, the story is the same as the contribution of the sector to GDP fell from 26.35% in 2017 to 23.54% in 2019 (World Bank, 2021). The data shown here is an indication that all the efforts discussed above have yielded little or no effect. But the question is: could agricultural finance with the level of financial development be held responsible for the fall in contributions of the agricultural sector to economic growth despite the impressive rankings of many financial institutions in the SSA? This question among others remains one of the tasks in this study. In addition, the financial development synergy with the agricultural sector should manifest via agricultural finance. Some issues on this have been discussed under the background of the study. These issues—such as financial inclusion and the specialised nature of the agricultural sector—are critical challenges that must be addressed for financial development to have a meaningful impact on agricultural finance. These issues have continued to resonate in the finance literature to date without any consensus on the extent of the influence of financial development on agricultural finance (Onyishi, Arene & Ifiorah, 2015).

Furthermore, the effectiveness of financial development in addressing agricultural finance challenges depends on several widely recognised factors (Zakaria, Jun & Khan, 2019). It is believed that the identification of these factors affecting SSA can go a long way in providing policy options that will improve the allocation of funds to the agricultural sector in a more accessible and affordable manner (Onyishi, Arene & Ifiorah, 2015). Consequently, apart from investigating the impacts of both agricultural finance and financial development on economic growth in the SSA, the study will also assess the level of the influence of financial development on agricultural finance as well as identify these factors that determine the level of financial development in the SSA.

## 2. EMPIRICAL LITERATURE

The empirical literature on the relationship between financial development and agricultural finance is relatively scarce. What is common in the literature is the impact of financial development on agricultural output. However, some authors also used agricultural output to proxy agricultural finance since it is believed that the level of finance put into a sector dictates the performance of the sector (Chandio, Yuansheng & Magsi, 2016). The reason behind this is the fact that there has been no data on the finance of agriculture for many countries. Few studies using expenditure or funding proxies for agricultural finance focus on sub-Saharan Africa, as most are based on industrialised countries. However, studies using agricultural output as a proxy for agricultural finance are reviewed below.

One of the few studies on factors affecting agricultural finance is that of [Veselinović and Drobnjaković \(2014\)](#). The study investigated both macro and micro determinants of agricultural finance in Serbia. The role played by the financial sector was put into perspective in the study and both qualitative and quantitative approaches were applied in the methodology. The result of the study suggests that the financial sector in Serbia offered a very poor loan facility to the agricultural sector in the country and this inhibits the growth of the agricultural sector. It was discovered that access to finance remains a great challenge to the sector in the country and the financial sector has not played the required role in resolving these challenges. [Dhrifi \(2014\)](#) investigated the impact of financial development on agricultural productivity. A panel of 44 African countries from 1990 to 2012 was analysed using the generalised method of moments. The results indicate that financial development alone does not positively impact agricultural productivity without the presence of strong institutional quality. The study also found that a particular threshold exists before institutional quality can have a significant impact on agricultural productivity. [Chisasa and Makina \(2015\)](#) used South Africa as a case study and examined the effect of bank credit on the output of the agricultural sector. The study spanned from 1970 to 2011, whereas Johansen cointegration analysis was applied and the Granger causality test was carried out. The study discovered that both bank credit and capital formation have a significant impact on agricultural output in the country. Furthermore, the study found that there exists a bidirectional causality between capital formation and agricultural output during the period under review.

[Ismail and Kabuga \(2016\)](#) examined the effect of agricultural output on the economic growth of Nigeria. The ARDL cointegration approach was used and the study found a significant long-run relationship between agricultural output and Nigeria's economic growth. The study concluded that agricultural output is an important determinant of the economic growth of Nigeria, hence the need to take the sector seriously. [Chandio, Yuansheng and Magsi \(2016\)](#) determined the impact of government expenditure on the agricultural sector and its implication on the economic growth in Pakistan. The study applied Johansen cointegration and error correction model. The result established a significant causal relationship between government finance and agricultural output. Furthermore, it was discovered that both agricultural output and government expenditure have a significant impact on the economic growth of the country. Notwithstanding, the study identified paucity of funds as the main challenge facing the agricultural sector in Pakistan. [Onoja \(2017\)](#) used agricultural sector productivity and investigated the impact of financial development on it in a group of 75 developing countries. Panel data analysis was employed, along with several multivariate analyses incorporating

both fixed and random effects models. The results from the panel data indicated that economic size, institutional quality, agricultural environment factors, infrastructure and human capital all have significant impacts on the agricultural productivity in the countries investigated.

Using a West African country, [Karimou \(2018\)](#) investigated the impact of agricultural output on the economic growth of the Benin Republic. Other variables that were used in the study are industrial output and capital formation. The study applied the vector error correction model and found a significant co-movement between agricultural output, capital formation, industrial output and the GDP of the Benin Republic. The study also found that capital formation is very germane to the growth of the agricultural sector in the Benin Republic. [Ibrahim and Alagidede \(2018\)](#) applied GMM to 29 SSA countries and found that financial development has a stronger impact on economic growth under balanced sectoral growth. However, the transmission of finance to growth was primarily through investment, particularly in the real sector of the SSA economy.

[Olayungbo and Quadri \(2019\)](#) examined the effect of financial development on economic growth in Sub-Saharan Africa, this time incorporating the role of remittances into their analysis. Twenty SSA countries were selected for the study, and after the application of ARDL estimating techniques, the pooled mean group result shows that there exists a significant long-run relationship between remittances, financial development and economic growth in the SSA. Particularly it was established that financial development has a significant impact on economic growth in the SSA in both long and short-run periods. [Ibidunni et al \(2019\)](#) examined the impact of labour productivity on the SSA economy. The study focused on 43 SSA countries and applied panel data regression analysis. It revealed that labour productivity and the contribution to the growth of the SSA economy is very low during the period under review, naimly 2010-2017. The study concluded that SSA countries will need to invest more in agriculture to engage more labour which will contribute meaningfully to the growth of the sector. Still, regarding financial development and agricultural productivity, [Zakaria Jun and Khan \(2019\)](#) used South Asian countries as a case study. In the panel analysis variables such as human and physical capital, income and trade openness were used to proxy financial development. Panel cointegration results indicate that these variables have a long-run relationship with agricultural productivity and that financial development improves agricultural productivity. Financial development was also found to have an inverted U Shape whereas trade openness is negatively related to agricultural productivity in the sub-region.

In a similar study, [Florence and Nathan \(2020\)](#) assessed the impact of the commercial banks' credit to the agricultural sector as a financial development proxy on agricultural sector performance in Uganda. The ARDL bound test was applied and the study found that there is a significant long-run relationship between the commercial bank credit and agricultural output in the economy. The study further found out that agricultural credit by the commercial banks failed to have a short-run impact; however, in the long run, the impact became significant. The study concluded that credit to the agricultural sector should be prioritised by the Ugandan government if the sector is to have sustainable improved performance. Furthermore, [Raifu and Aminu \(2020\)](#) determined the impact of financial development on agricultural performance, and the role of institutions was also put into perspective in the study. The study computed the financial development index from some sets of indicators and used some institution variables as independent variables in the study. Data from 1990 to 2016 were used and with the application of the ARDL, it was established by the study that there is a positive and significant relationship in the long run between financial development and agricultural performance in Nigeria. [Mohammed, Damba and Amikuzuno \(2020\)](#) examined the impact of agricultural output on the economic growth of Ghana. The study used capital formation and inflation rate as other variables in the model apart from the agricultural output. The application of the Johansen cointegration analysis showed that there exists a long-run relationship between agricultural output and the Ghanaian economic growth but the effect of the agricultural output on the economic growth of the country is not significant. [Ho, Pham and Nguyen \(2021\)](#) investigated the impact of financial development on the economic growth of the ASEAN countries. Linear panel data of both fixed and random effects were used for about 120 countries and the result suggests that the role of trade openness in promoting the economic growth of these countries was more than that of financial development. The study established that financial development will influence the economic growth of these countries significantly if trade openness plays its expected role. Also, [Zhao and Gong \(2021\)](#) investigated the impact of financial development on the economic growth of some cities in China. The GMM was applied and the result showed that financial development failed to affect the economic growth of the selected Chinese cities during the period under investigation. The study concluded that China can only achieve effective financial development that is growth-promoting if the entire financial sector of the country is reformed.

The empirical literature clearly shows a greater focus on financial development and economic growth than on agricultural finance and economic growth. Few studies explicitly link agricultural finance to financial development and

economic growth, and to the best of the author’s knowledge, none exist for SSA. This highlights the originality of the present study. Additionally, most studies treat agricultural finance as a subset of financial development, as previously noted in the literature gaps. This study addresses this by using agricultural output as a proxy for agricultural finance—reflecting its tangible outcomes—and incorporates it alongside a financial development index as the independent variable, with economic growth as the dependent variable.

### 3. MATERIALS AND METHODS

The model adopted to investigate the impact of financial development on agricultural finance follows the empirical studies of [Zakaria, Jun and Khan \(2019\)](#), and [Onyishi, Arene and Ifiorah \(2015\)](#), where the output in the agricultural sector was used to proxy the extent of finance deployed to the sector at a particular period. The generic model can be expressed functionally as:

$$A = f(K, L, FD) \dots\dots\dots(1)$$

Where in equation (1), A is the agricultural output, K is the capital, L is the labour, and FD is the financial development. However, [Zakaria, Jun and Khan \(2019\)](#) emphasised per capita income as a key determinant of agricultural finance, noting that in developing countries, where agriculture is largely subsistence-based, household income significantly influences the level of financing in the sector. It is important to note that the computation of financial development (FD) already incorporates several variables, including trade openness and key macroeconomic indicators like inflation and exchange rates. Therefore, the new model can be functionally specified as follows:

$$A = f(K, L, FD, PCI) \dots\dots\dots(2)$$

To estimate equation (2) parametrically, it is expressed in a dynamic regression model (ignoring the constant term) as equation (3) below:

$$\Delta \log A_{it} = \sum_{j=1}^{p-1} \alpha_{ij} \Delta \log A_{i,t-j} + \sum_{j=1}^{q-1} \delta'_{ij} \Delta \log X_{i,t-j} + \theta_i (\log Y_{i,t-1} - \beta'_{ij} \log X_{i,t}) + \varepsilon_{it} \dots\dots(3)$$

Where in equation (3), X is the vector of the explanatory variables (capital, labour, financial development and per capita income). Also, the adjustment parameter is expected to be significantly negative and have an absolute value of less than one.

The parameter  $\lambda$  is the long-run impact estimate of the explanatory variables on the dependent variable (agricultural output). The parameter  $\alpha$  captures the short-run impact of the regressors on the regressand while the parameter  $\beta$  captures the short-run dynamic of the dependent variable. The parameters  $p$  and  $q$  are the lag parameters which can be optimally selected using statistical criteria or independently fixed.

Adapting the endogenous growth model employed by Onyishi, Arene and Ifiorah (2015), a model that described the relationship between financial development, agricultural finance and economic growth of the SSA is specified in this study. In contrast to Onyishi, Arene and Ifiorah (2015), this study replaces financial intermediation with a financial development index and substitutes intermediate inputs with agricultural finance (proxied by agricultural value added). The model, therefore, is expressed functionally as:

$$Y = f(K, L, FD, AF, PCI) \dots \dots \dots (4)$$

Where  $Y$  is the economic growth,  $K$  is the capital,  $L$  is the labour force,  $FD$  is the financial development,  $AF$  is the agricultural finance, and  $PCI$  is the per capita income

$$\Delta \log Y_{it} = \sum_{j=1}^{p-1} \gamma_{ij} \Delta \log Y_{i,t-j} + \sum_{j=1}^{q-1} \vartheta'_{ij} \Delta \log X_{i,t-j} + \varphi_i (\log Y_{i,t-1} - \lambda'_{ij} \log Z_{i,t}) + \varepsilon_{it} \dots \dots \dots (5)$$

Where in equation (5),  $Z$  is the vector of the explanatory variables (capital, labour, financial development, agricultural finance and per capita income). Also, the parameter  $\lambda$  is the speed of adjustment which is expected to be significantly negative and less than one. The parameter  $\alpha$  is the long-run impact estimate of the explanatory variables on the dependent variable (agricultural output). The parameter  $\beta$  captures the short-run impact of the regressors on the regressand while the parameter  $\beta$  captures the short-run dynamic of the dependent variable. The parameters  $p$  and  $q$  are the lag parameters which can be optimally selected using statistical criteria or independently fixed.

The Panel VAR (PVAR) based Granger causality is adopted to examine the causal relationship between agricultural finance, financial development and economic growth in the SSA in this study. The PVAR(p) equations are presented below:

$$\Delta \log A_{it} = \sum_{i=1}^p B_{11,j} \Delta \log A_{i,t-j} + \sum_{i=1}^p B_{12,j} \Delta \log FD_{i,t-j} + \sum_{i=1}^p B_{13,j} \Delta \log Y_{i,t-j} + D_{11} + v_{1t} \dots (6)$$

$$\Delta \log FD_{it} = \sum_{i=1}^p B_{21,i} \Delta \log A_{i,t-i} + \sum_{i=1}^p B_{22,i} \Delta \log FD_{i,t-i} + \sum_{i=1}^p B_{23,i} \Delta \log Y_{i,t-i} + D_{21} + v_{2t} \quad (7)$$

$$\Delta \log Y_{it} = \sum_{i=1}^p B_{31,i} \Delta \log A_{i,t-i} + \sum_{i=1}^p B_{32,i} \Delta \log FD_{i,t-i} + \sum_{i=1}^p B_{33,i} \Delta \log Y_{i,t-i} + D_{31} + v_{3t} \quad (8)$$

The hypothesis of non-granger causality is tested for each of the variables. A variable does not Granger-cause another if the joint coefficients of its lagged values in the equation of interest are statistically zero. Otherwise, the variable Granger causes the dependent variable. The test typically follows a chi-square distribution, although a Fisher (F) version also exists. A significant result indicates that the lagged values of the tested variable provide explanatory power for predicting the dependent variable in the equation.

**Table 1:** Measurement and source of data

Variable	Measurement	Sources of data
A	Agricultural value added.	World Bank Development Indicators
FD	Domestic to the private sector	World Bank Development Indicators
K	Gross fixed capital formation (Constant)	World Bank Development Indicators
L	Total labour force	World Bank Development Indicators
PCI	GNI per capita	World Bank Development Indicators
Y	Gross Domestic Product (Constant)	World Bank Development Indicators

Source: World Bank Indicators

Table 1 depicts the variables employed in this study and their respective sources. This study employed data on 27 sub-Saharan African countries from 2000 to 2021.

### 4. RESULTS AND DISCUSSION

Table 2 shows the descriptive statistics for agricultural finance (A), real gross domestic product (Y), gross fixed capital formation (K), labour force (LF), financial development index (FD) and per capita income (PCI) in the SSA from 2000 to 2021. It can be observed that the mean for all the variables is positive. The coefficient of variation (C.V.) is used to measure the relative dispersion in data and is calculated as the standard deviation divided by the mean. A variable with a larger coefficient of variation shows it has much more variation than the other.

**Table 2:** Descriptive statistics

Variable	Mean	Std. Dev.	C.V.	Max.	Min.	J-B	Obs
A	1671.526	1779.483	1.065	9470.672	265.089	636.418***	594
Y	3.97E+10	9.06E+10	2.282	5.20E+11	6.90E+08	4847.946***	594
K	25.751	13.466	0.523	74.117	2.857	263.068***	594
LF	18.288	22.728	1.243	142.422	0.002	5792.498***	594
FD	7.75E+09	1.54E+10	1.987	8.02E+10	36402660	2675.954***	594
PCI	15.947	13.483	0.846	70.382	0.002	793.308***	594

\*\*\*p<1%; \*\*p< 5%; \*<10%

Source: Author's analysis

It can be deduced from the table that the gross fixed capital formation has the lowest degree of variation while the real gross domestic product has the highest level of variation among the variables. The high degree of variation in the gross domestic product reflects the frequent degree of the business cycle in the SSA economies. The lower degree of variation in the gross fixed capital formation implies that the capital formation in the SSA countries has not been faring well over the decades, despite the seemingly high rate of output formation in the economies. The limited fluctuation in gross fixed capital formation indicates a persistent challenge: capital investment in SSA countries has remained relatively stagnant over the past decades, even with periods of high output growth. This suggests a potential disconnect between output and investment. The probability value of the Jarque-Bera (J-B) normality test is statistically significant for all the variables and this implies that they are not normally distributed. However, since we are using a fairly large sample size, the issue of normality in data will not pose a problem due to the law of large sample size; the parameter estimates based on the data will converge to their true value asymptotically.

Table 3 depicts the panel unit root test results for the variables. The tests are categorised into two groups: those assuming a common unit root process across all panels (Levin-Lin-Chu and Breitung tests) and those allowing for individual unit root processes across panels (Im-Pesaran-Shin, ADF Fisher Chi-square, and PP Fisher Chi-square tests). The result shows that there is no consensus on the stationarity of the variables under the homogeneity assumption; however, capital, labour and per capita income are shown to be stationary under the heterogeneity assumption. The results suggest that the variables may have a mixed order of integration, with strong evidence that agricultural finance and real GDP are integrated of order one,  $I(1)$ . The employment of the panel ARDL model suffices in carrying out such analysis by accommodating integrated and stationary regressors and this aids in achieving the objectives of this study.

**Table 3:** Unit root test results summary

Variable	Common unit root		Individual unit root		
	LLC	BRG	IPS	ADF	PP
A	2.075	1.060	3.786	33.174	31.280
Δ(A)	-12.788***	-5.288***	-15.706***	286.594***	453.680***
Y	-3.431***	3.921	0.269	76.134**	71.738*
Δ(Y)	-15.847***	-9.794***	-16.384***	303.811***	611.649***
K	-2.284**	-1.072	-2.140**	72.751**	71.958*
Δ(K)	-13.963***	-7.508***	-12.831***	251.017***	422.176***
Lab	0.842	-6.760***	-1.815**	82.569***	143.494***
Δ(Lab)	-39.722***	-4.936***	-23.558***	576.231***	833.299***
PCI	1.130	0.468	-2.803***	85.124***	133.582***
Δ(PCI)	-38.571***	-4.702***	-22.556***	558.018***	1082.540***
FD	0.147	4.881	2.063	48.882	202.547***
Δ(FD)	-15.421***	-4.848***	-13.849***	249.333***	398.029***

Note: variables with Δ implies first difference; \*\*\*p<1%; \*\*p< 5%; \*< 10%  
 Source: Author’s analysis

**Table 4:** Panel cointegration test results summary

Test Type	Dependent variable			
	Agric Finance (A)		Economic growth (Y)	
	ADF	PP	ADF	PP
Kao	-3.42***		-5.58***	
Pedroni (Common AR)	-9.84***	-9.76***	-2.25**	-11.3***
Pedroni (Individual AR)	-5.58***	-4.14***	-3.61***	-13.7

Note: ADF and PP are the augmented Dickey-Fuller and the Phillips-Perron test statistics.  
 \*\*\*p<1%; \*\*p< 5%; \*< 10%  
 Source: Author’s analysis

The panel cointegration test results for the agricultural finance and economic growth models are presented in Table 4. The null hypothesis tests the absence of a cointegration relationship among the variables (given the dependent variable). A statistically significant result, or a very low p-value, indicates the rejection of the null hypothesis and the acceptance of the alternative hypothesis, which posits the existence of a cointegration relationship among the variables (between each independent variable and the dependent variable). The Kao cointegration test result shows that the test statistics are significant at a 1% level and thus implies accepting the hypothesis of cointegration. Also, in the Pedroni test result, there is evidence of cointegration by the PP and the ADF tests in the first panel, as well as in the second panel.

Table 5 shows the regression model estimate of the impact of financial development on agricultural finance. The coefficient of capital is found to be significant in the PMG model and only in the long run and is negative. All things being equal, a percentage increase in capital is shown to reduce agricultural finance by about 0.21% in the long run. Moreover, the coefficient of labor is found to be significant and positive in the PMG model, but only in the long run, unlike the case of capital.

The result shows that a percent rise in the labour force will increase agricultural finance by about 0.19% on average in the long run. There is a shred of strong evidence for the positive impact of financial development on agricultural finance by the three models. The result shows that a percent rise in the financial development level will bring about a 0.087% to 0.13% increase in agricultural finance in the short run and a 0.23% to 0.32% increase in the long run on average. Lastly, the coefficient of per capita income is found to be significant and positive in the PMG model, but only in the long run. All things being equal, the result shows that if the per capita income increases by one percent, agricultural finance will increase by about 0.22% in the long run. The error correction term is significant in the three models and it can be deduced that if an unexpected shock hits the economy, the agricultural finance will adjust back to its initial steady state correcting at most about 14% of the shock effect or at least about 47% of it.

It can be inferred from the result in Table 5 that capital insignificantly impacted agricultural finance in the short run but negatively in the long run. This is contrary to theory as capital is expected to drive output, as well as to the studies of [Karimou \(2018\)](#) and [Zakaria, Jun and Khan \(2019\)](#). The insignificance of capital in contributing to agricultural finance in the short run is likely due to the continued reliance on crude implements in agricultural practices across many SSA countries. Most farming operations remain subsistence-based, primarily supporting hand-to-mouth consumption, which limits the scale and productivity needed to attract or utilise capital effectively. Moreover, the high cost of modern farming equipment—combined with unfavourable exchange rates—makes mechanisation largely inaccessible. Other potential explanations include poor rural infrastructure, which hampers distribution and market access, limited access to affordable credit facilities for smallholder farmers, weak institutional support, and inadequate extension services. Also, there are not enough savings to encourage capital accumulation in the SSA and the available ones are not properly channelled to the right source. All these factors contribute to the insignificant impact of capital on agricultural financem the accumulation of which over a long period leads to the noticeable negative effect in the long run. Although labour impact on agricultural finance is expected to be positive,

the effect is found to be significant only in the long run. Similar to the case of capital, much of the labour force engaged in agriculture across SSA remains largely unskilled. Unlike advanced economies such as France, where scientific methods are integrated into agricultural practices to boost productivity, farming in SSA is still predominantly manual. A significant proportion of farmers are not literate and are often resistant to adopting modern farming techniques. Agricultural extension workers frequently face challenges in promoting labour-saving innovations, many of which are perceived as foreign or even inappropriate by older farmers. Consequently, the adoption of modern practices is slow and limited mostly to the small group of educated farmers. This low adoption rate contributes to the insignificant impact of labour on agricultural output and, by extension, on agricultural finance in the short run. However, in the long run, the cumulative effect of the few skilled and innovative labourers becomes more pronounced, significantly enhancing agricultural finance.

**Table 5:** Panel ARDL regression estimates for agricultural finance

Variable	DFE	MG	PMG
log(K)	0.019 (0.121)	0.126 (0.412)	-0.209*** (0.026)
log(L)	-0.179 (0.312)	-6.935 (19.368)	0.185*** (0.038)
log(FD)	0.251*** (0.043)	0.317* (0.173)	0.225*** (0.017)
log(PCI)	0.118 (0.305)	6.955 (19.302)	0.217*** (0.034)
$\Delta$ log(K)	0.040 (0.037)	-0.052 (0.035)	-0.032 (0.026)
$\Delta$ log(L)	-0.025 (0.111)	5.527 (10.873)	6.640 (5.469)
$\Delta$ log(FD)	0.132*** (0.021)	0.048 (0.038)	0.087*** (0.029)
$\Delta$ log(PCI)	0.019 (0.111)	-5.517 (10.845)	-6.640 (5.457)
ECM(-1)	-0.229*** (0.027)	-0.470*** (0.057)	-0.139*** (0.047)
Constant	0.393** (0.187)	1.265* (0.736)	0.303*** (0.109)
Hausman test	131.850***	84.928***	

*Note:* variables with  $\Delta$  implies their short-run. Also, DFE, MG, and PMG are the dynamic fixed-effect, mean group, and pooled mean group panel ARDL estimators.

\*\*\*p<0.001; \*\*p< 0.01; \*<0.05

Source: Author's analysis

In confirmation to theory, the study shows evidence for the significant positive impact of financial development on agricultural finance both in the short run and long run. This supports the claims of [Onoja \(2017\)](#), [Florence & Nathan \(2020\)](#) and [Raifu and Aminu \(2020\)](#) but is contrary to the studies of [Veselinović and Drobnjaković \(2014\)](#) and [Dhrifi \(2014\)](#). The significant impact of financial development reflects the recent forms of transaction aided by global technological advancement. For instance, it is becoming easier nowadays to order agricultural products or items from China using different forms of electronic payments such as Bitcoin or any other kind of cryptocurrency. Moreover, interbank transfer is becoming prominent in transactions among SSA countries these days. On per capita income, the study only proves evidence of its positive impact on agricultural finance in the long run. The insignificant short-run impact of per capita income on agricultural finance reflects the lower level of purchasing power of an average person in the SSA countries. However, the accumulative effect is observable over time. In the modern monetised economy, unlike in a barter system, effective demand—that is, demand that translates into actual purchases—is largely determined by purchasing power. However, this ability is found to be very limited, especially among the masses in developing countries such as SSA countries. As a result, it is anticipated that the effects of individual demand-driven decision-making will be felt in every area of economic activity.

Table 6 shows the regression model estimate of the impact of financial development and agricultural finance on economic growth in the SSA countries. There is a piece of strong evidence from the result presented that capital negatively impacts economic growth in the short run but positively in the long run. The result shows that if capital increases by a percent, real GDP will reduce by 0.06%–0.08% on the impact in the short run but will eventually grow by about 0.21% in the long run.

The coefficient of labour is found to be relatively significant only in the long run and is positive. All things being equal, a percentage increase in labour is shown to bring about a 0.77%–26.1% increase in real GDP growth on average in the long run. The significant impact of financial development on real GDP growth is found more evidently in the long run than in the short run. It can be deduced from the result that a percent rise in the financial development level will bring about a 0.04% increase in the real GDP growth in the short run and about a 0.13% to 0.49% increase in the long run on average. On the impact of agricultural finance on real GDP growth, the short-run and the long-run results consistently show that agricultural finance positively impacts real GDP growth. It can be deduced that if agricultural finance increases by one percent, real GDP

will rise on the impact by 0.06%–0.44% in the short run and will eventually grow by about 0.38%–1.06% on average in the long run. Lastly, the coefficient of per capita income is found to be significant in both the MG and PMG models, but only in the long run, and it is negative. All things being equal, the result shows that if the per capita income increases by one percent, real GDP growth will decline by about 0.74%–25.8% in the long run. The error correction term is statistically significant across all three models, indicating the speed at which real GDP adjusts to restore equilibrium following a shock. Specifically, the speed of adjustment is 12% in the DFE model, 46% in the MG model and 16% in the PMG model.

**Table 6:** Panel ARDL regression estimates for economic growth

Variable	DFE	MG	PMG
log(K)	0.211* (0.109)	0.802 (2.573)	0.206*** (0.003)
log(L)	-0.049 (0.284)	26.060* (13.516)	0.769*** (0.223)
log(FD)	0.486*** (0.059)	-2.460 (3.828)	0.133*** (0.020)
log(A)	0.376** (0.158)	6.622 (11.477)	1.063*** (0.054)
log(PCI)	-0.069 (0.276)	-25.782* (13.175)	-0.741*** (0.219)
$\Delta$ log(K)	-0.075*** (0.018)	-0.076** (0.034)	-0.057*** (0.018)
$\Delta$ log(L)	-0.018 (0.053)	-3.982 (3.539)	0.414 (1.670)
$\Delta$ log(FD)	-0.011 (0.011)	0.020 (0.023)	0.038*** (0.014)
$\Delta$ log(A)	0.060*** (0.021)	0.143 (0.088)	0.435*** (0.080)
$\Delta$ log(PCI)	0.037 (0.053)	3.920 (3.541)	-0.435 (1.678)
ECM(-1)	-0.121*** (0.015)	-0.462*** (0.069)	-0.160*** (0.025)
Constant	1.849*** (0.227)	6.259*** (1.032)	1.959*** (0.109)
Hausman test	110.803***	6.406	

Note: variables with  $\Delta$  implies their short-run; \*\*\*p<1%; \*\*p< 5%; \* < 10%

Source: Author's analysis

By implication, the results in Table 6 reveal that capital has a negative impact on economic growth in the short run but a positive effect in the long run. This is inconsistent with the standard theory of production and economic growth, particularly Inada's conditions, which suggests that positive additions to capital should yield marginal increases in output. One plausible explanation for the observed short-run negativity is the underutilisation or misallocation of capital resources in SSA countries. In the short term, firms may face difficulties adopting or integrating new technologies due to structural and institutional lags. However, in the long run, as firms adjust and optimise capital usage, their contribution becomes positive, aligning with theoretical expectations.

Similarly, labour shows a statistically significant positive effect on economic growth only in the long run. This result aligns with *Ibidunni et al. (2019)*, who found labour to be insignificant in the short run. In the SSA region, much of the labour force engaged in economic activities is unskilled, which likely diminishes productivity gains in the short term. However, over time, labour-augmenting factors such as vocational training, knowledge spillovers and sensitisation programs may enhance labour productivity. Nonetheless, while several higher institutions exist, access remains limited for many, and such assumptions should be treated cautiously without further empirical verification.

Regarding financial development, the study finds a robust and significant positive effect on economic growth in both the short and long run. This supports the findings of *Ibrahim and Alagidede (2018)*, *Olayungbo and Quadri (2019)*, and *Ho, Pham and Nguyen (2021)*, affirming the growth-enhancing role of financial systems. With the recent expansion of digital banking and mobile money across SSA, financial services have become more accessible, enabling more efficient resource allocation and intermediation. However, this finding contrasts with *Zhao and Gong (2021)*, who found financial development to be insignificant, underscoring the need to consider country-specific financial structures and institutional quality.

Agricultural finance is also found to positively influence economic growth in both the short and long term, in line with theoretical expectations and supported by studies such as *Ismail and Kabuga (2016)* and *Chandio, Yuansheng and Magsi (2016)*. This suggests that improved funding for agriculture can stimulate broader economic activity, given agriculture's central role in many SSA economies. However, contrary findings by *Okunlola, Osuma & Omankhanlen (2019)* and *Mohammed, Damba and Amikuzuno (2020)* suggest that the effectiveness of agricultural finance may depend on how funds are allocated and absorbed within the sector. Potential limitations such as inefficient credit delivery systems and poor infrastructure may undermine the full impact of agricultural finance.

Interestingly, per capita income is found to exert a negative effect on economic growth in the long run, which deviates from theoretical expectations. This result may reflect income inequality or consumption patterns that do not favour productive investment. In economies where rising per capita income is concentrated among a few, the broader economy may not experience inclusive growth. Policymakers could address this issue by implementing redistributive policies, increasing investment in human capital, and improving access to credit for economically marginalized groups, thereby ensuring that income gains translate into sustainable economic growth.

**Table 7:** PVAR(1) granger causality test result summary

<b>Null Hypothesis:</b>	<b>Chi-square</b>
FD does not Granger Cause A	7.698***
A does not Granger Cause FD	4.453**
Y does not Granger Cause A	10.697***
A does not Granger Cause Y	22.378***
Y does not Granger Cause FD	16.963***
FD does not Granger Cause Y	10.590***

\*\*\*p<1%; \*\*p< 5%; \*< 10%

Source: Author's analysis

It has to be understood that Granger causality simply implies precedence. In a statistical sense, it means that a variable could help in predicting the future of other variables if its occurrence precedes the variable, and therefore Granger caused it. Table 7 depicts the panel VAR model-based Granger causality test result. The values in the table represent the chi-square value for the test and the asterisks denote the level of their respective significance. From the results, there is evidence of bidirectional causality running from each of the variables (financial development, agricultural finance and real GDP growth) to the other thus implying that they could all help predict one another. Therefore, the development in the financial sector is a panacea for economic growth in SSA countries. This for instance can be seen in the case of China which has turned the development of the cryptocurrency market into economic growth. Also, when the economy is growing, there will be a need to expand the financial sector which in turn brings about economic growth. A rise in financial development will aid in financing the agricultural sector in return.

## 5. CONCLUSIONS

This study investigated the impact of agricultural finance and financial development on economic growth in Sub-Saharan Africa. The results indicate that capital negatively affects agricultural performance in the long run and exerts a negative short-run, but positive long-run, impact on economic growth. Labour has no short-run effect but contributes positively in the long run. Financial development significantly drives both agricultural performance and economic growth in the short and long run. Per capita income positively affects agriculture only in the long run but reduces economic growth over time. Agricultural performance also significantly supports growth in both periods. Policy efforts should focus on strengthening financial regulation, expanding R&D, and supporting agricultural and industrial alignment. Affordable agricultural credit and awareness campaigns should be promoted. Enhancing labour productivity through training and technology is also crucial. This study contributes uniquely by linking agricultural finance to financial development and growth in SSA, a rarely explored area. However, limitations include data constraints and potential country-level heterogeneity. Future research should consider more granular data and country-specific analyses.

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## Conflict of interests

The authors declare there is no conflict of interest.

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## ЕФЕКТИ ПОЉОПРИВРЕДНОГ ФИНАНСИРАЊА И ФИНАНСИЈСКОГ РАЗВОЈА НА ЕКОНОМСКИ РАСТ ЗЕМАЉА ПОДСАХАРСКЕ АФРИКЕ

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### САЖЕТАК

Ово истраживање је испитивало утицај пољопривредних финансија и финансијског развоја на економски раст подсахарске Африке (SSA) у

периоду од 2000. до 2021. године. У студији су коришћени панел ARDL регресиони модели и панел VAR тест Грејнцерове узрочности као алати за анализу података. Истраживање је показало да акумулација капитала дугорочно негативно утиче на пољопривредне перформансе; ефекат на економски раст је негативан краткорочно, али позитиван дугорочно. Такође, нема доказа о краткорочном утицају рада ни на пољопривредне перформансе, нити на економски раст. Међутим, дугорочни ефекат је позитиван и значајан. Постоје снажни докази који подржавају финансијски развој као покретач пољопривредних перформанси и економског раста, и краткорочно и дугорочно. Доходак по становнику, који одражава индивидуалну куповну моћ, утиче на пољопривредне перформансе само дугорочно, док је његов утицај на економски раст, који је значајан само дугорочно, негативан. Даље, студија открива да се улога пољопривредних перформанси у подстицању економског раста не може пренагласити — и у кратком и у дугом року. Стога, ова студија препоручује јачање институционалних капацитета за надзор финансијског сектора кроз законодавство и контрацикличне резерве, унапређење истраживања и развоја (R&D) и политика за побољшање индустријских и пољопривредних перформанси, као и развој финансијских институција ради оптимизације индустријализације повезане са пољопривредом. Такође, владе треба да подстичу приступачне пољопривредне кредите, уз подршку кампања за подизање свести, те да дају приоритет програмима приправништва, преквалификације и технолошки вођеном истраживању и развоју како би се повећала продуктивност рада и одржао економски раст у подсахарској Африци.

**Кључне ријечи:** *пољопривреда, финансије, раст, ARDL - ауторегресивни модел са распоређеним закашњењима, PMG – комбинована групна средина.*



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**ПРЕГЛЕДНИ НАУЧНИ ЧЛАНЦИ**  
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# CHALLENGES OF LOW-CODE/NO-CODE PLATFORMS IN SUPPORTING ORGANISATIONAL INFORMATION PROCESSES: A LITERATURE REVIEW AND CASE STUDY EVIDENCE<sup>1</sup>

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## ABSTRACT

Digital transformation increasingly positions business informatics at the core of organisational competitiveness, driving companies to digitalise and automate their business processes. In this context, low-code/no-code (LCNC) platforms have emerged as a promising solution within business information systems, enabling rapid development of process-oriented applications with minimal or no programming. By empowering employees without formal IT backgrounds to participate in system development, LCNC platforms address the shortage of IT professionals and help bridge the gap between technical and domain-specific business knowledge. Although vendors emphasise advantages such as ease of use, accelerated development cycles, reduced costs, lower IT dependency and enhanced process innovation, they often overlook the organisational, technological and governance challenges associated with LCNC adoption. This paper systematically identifies key inhibitors and LCNC implementation through a comprehensive literature review, followed by an assessment of their significance across multiple case studies with LCNC users. Seven

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major inhibitors are identified: vendor lock-in, security and compliance risks, integration challenges, limited scalability, insufficient documentation, limited testing support, and lack of flexibility. Case study findings indicate that lack of flexibility and customisation, vendor lock-in and insufficient testing support represent the most critical barriers. The paper presents preliminary insights from an ongoing investigation into LCNC development.

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## 1. INTRODUCTION

Digital transformation represents a process that has affected many organisations. The workplace has become increasingly digital, with numerous applications accessed by employees daily. An increasing number of business processes are being partially or fully automated. To enable this, it is necessary to develop applications that will automate these business processes. Given that the number of professional programmers is insufficient to meet the ever-growing demand, one of the driving forces behind digital transformation (Viljoen, Radić, et al., 2024), large number of software vendors are turning to the development of tools that allow end-users to create their own applications, automate business processes and build customised business solutions tailored to specific organisational needs (Kok et al., 2024). These end-users are often referred to as citizen developers or end-user developers, while the tools they use are known as low-code and no-code tools/platforms, and the development approach itself as low-code and no-code development (LCNC). It is important to emphasise the observation by Viljoen et al. (2024) that citizen developers do not create complex software, but rather smaller applications aimed at solving specific problems within their business units, thus extending development beyond the boundaries of traditional IT departments (Matook Wang & Axelsen, 2025). Viljoen et al. (2025) emphasise that LCNC platforms are increasingly recognised as essential for advancing digital transformation. When referring to LCNC platforms, the most mentioned examples include ServiceNow, Microsoft Power Platform, Mendix, Google AutoML, Amazon SageMaker and similar solutions (Kok et al., 2024). These platforms may play a pivotal role in accelerating digital transformation by democratising software development (Viljoen, Radić, et al., 2024).

The terms low-code and no-code are frequently used interchangeably (Elshan et al., 2024). However, it is important to distinguish between them. No-code tools enable application development without any need for coding, whereas low-code

tools require some degree of code customisation or manual code integration. As noted by Elshan et al. (2024), the low-code paradigm is broader in scope, with no-code representing a subset within it.

Numerous benefits are often associated with LCNC tools, such as rapid, simple and cost-effective development of business applications (Raković, Djordjevic Milutinovic, et al., 2025; Raković, Đorđević, et al., 2025). Four out of five organisations believe that LCNC accelerates digital transformation (Gonçalves et al., as cited in Viljoen et al., 2025). Furthermore, Hurlburt et al. (2025) report forecasts suggesting that LCNC will account for as much as 65% of application development, with development time potentially reduced by up to 90%. Viljoen et al. (2024) also cite Gartner research predicting that, in the future, as many as 80% of applications will be developed by individuals without traditional IT roles. However, what LCNC platform vendors often fail to disclose are the numerous challenges or inhibitors that accompany LCNC development. Viljoen et al. (2025) emphasise the need to balance the flexibility and risk associated with LCNC platforms, warning that efforts to reduce risk through excessive standardisation may compromise the fundamental purpose of LCNC tools, to empower users through autonomy and flexibility.

As the inhibitors of LCNC platforms and LCNC development are often insufficiently explored and largely overlooked, the following research questions have been formulated:

RQ1: What are the inhibitors of LCNC development?

RQ2: How important are the identified inhibitors of LCNC development?

To address the first research question, a systematic literature review was conducted. Subsequently, a multiple case study, based on interviews with users of LCNC platforms, was carried out to evaluate the importance of the previously identified inhibitors of LCNC development.

Chapter two presents the phases of the systematic literature review. The same chapter also presents the inhibitors of low-code/no-code development. The third chapter is reserved for the design and results of the conducted empirical research. The paper concludes with final considerations.

## 2. LITERATURE REVIEW

The systematic literature review was conducted following the methodology proposed by Xiao and Watson (2019), with additional guidance from the works of Kitchenham et al. (Brereton et al., 2007; Kitchenham, 2004; Kitchenham et al., 2010, 2013; Turner et al., 2008). To identify relevant inhibitors, two major

citation databases SCOPUS and Web of Science (WoS) were searched using the keywords “Low Code” and “No Code”. The database search was carried out in May 2025. Table 1 presents the number of hits retrieved from each database. In the first iteration, titles, keywords and abstracts were screened. The inclusion criterion for proceeding to the next phase was the potential relevance of a study to the identification of LCNC development inhibitors. The third column of Table 1 shows the number of studies that met this criterion and were included in the subsequent analysis. Next, the results from WoS and Scopus were merged, and duplicates were removed, resulting in 641 unique records. These remaining studies were then analysed in detail. Ultimately, 25 studies were selected for the final analysis focused on identifying inhibitors of LCNC development. The full list of included studies is provided in Table 2.

**Table 1:** Searched databases

Citation Database	Number of Hits in Initial Search	Number of Studies Included in the Next Phase
Scopus	2146	537
WoS	1236	329

Source: Authors' calculation

**Table 2:** Identified studies

Authors and Year	Title	Type of Source
<a href="#">Ajimati, Carroll &amp; Maher (2025)</a>	Adoption of low-code and no-code development: A systematic literature review and future research agenda	Journal
<a href="#">Beranic, Rek &amp; Hericko (2020)</a>	Adoption and Usability of Low-Code/ No-Code Development Tools	Conference proceedings
<a href="#">Biedova et al. (2024)</a>	Strategies for Managing Citizen Developers and No-Code Tools	Journal
<a href="#">Binzer &amp; Winkler (2024)</a>	‘To Code, or Not to Code’, Unpacking the Understanding and Difficulties of Citizen Development Programs	Conference proceedings
<a href="#">Binzer et al. (2024)</a>	Establishing a Low-Code/No-Code-Enabled Citizen Development Strategy	Journal
<a href="#">De Silva, Shangavie &amp; Ranathunga (2024)</a>	Role of Quality Assurance in Low-Code/No-Code Projects	Conference proceedings
<a href="#">Di Ruscio et al. (2022)</a>	Low-code development and model-driven engineering: Two sides of the same coin?	Journal

Authors and Year	Title	Type of Source
Elshan et al. (2024)	Unveiling Challenges and Opportunities in Low Code Development Platforms: A StackOverflow Analysis	Conference proceedings
Gomes & Brito (2022)	Low-Code Development Platforms: A Descriptive Study	Conference proceedings
Hintsch et al. (2021)	Low-code development platform usage: Towards bringing citizen development and enterprise IT into harmony	Conference proceedings
Kaess (2022)	Low Code Development Platform Adoption: A Research Model	Conference proceedings
Käss et al. (2023a)	A Multiple Mini Case Study on the Adoption of Low Code Development Platforms in Work Systems	Journal
Käss et al. (2023b)	Practitioners’ Perceptions on the Adoption of Low Code Development Platforms	Journal
Kass et al. (2022)	Drivers and Inhibitors of Low Code Development Platform Adoption	Conference proceedings
Luo et al. (2021)	Characteristics and Challenges of Low-Code Development	Conference proceedings
Martinez, Pfister& Stauch (2024)	Developing a novel application to digitalize and optimize construction operations using low-code technology	Conference proceedings
Martins, Branco & Mamede (2023)	Combining low-code development with ChatGPT to novel no-code approaches: A focus-group study	Journal
Mottu & Sunyé (2024)	Emerging New Roles for Low-Code Software Development Platforms	Conference proceedings
Pańkowska (2024)	Low Code Development Cycle Investigation	Conference proceedings
Pinho, Aguiar & Amaral (2023)	What about the usability in low-code platforms? A systematic literature review	Journal
Rokis & Kirikova (2023)	Exploring Low-Code Development: A Comprehensive Literature Review	Journal
Rokis & Kirikova (2022)	Challenges of Low-Code/No-Code Software Development: A Literature Review	Conference proceedings
Sahay et al. (2020)	Supporting the understanding and comparison of low-code development platforms	Conference proceedings
Viljoen, Radić, et al. (2024)	Governing Citizen Development to Address Low-Code Platform Challenges	Journal
Viljoen et al. (2025)	Navigating Flexibility and Standardisation in Low-Code/ No-Code Development	Journal

Source: Authors’ calculation

## 2.1 Low code/No code inhibitors

Viljoen et al. (2024) identify the primary risks of LCNC platforms as the quality of the software produced, the emergence of shadow IT, which poses a significant threat, and the accumulation of so-called technical debt. Similarly, Zaheri et al. (2024) emphasise that, despite the advantages of rapid development, LCNC developed applications that frequently exhibit inconsistencies in functionality, often resulting in data loss. Dependence on platform vendors for software updates, security and long-term support is cited as one of the main inhibitors of LCNC platforms. Ajimati, Carroll & Maher (2025) argue that such dependency may lead to increased costs in cases requiring maintenance or platform replacement. These authors further recommend that organisations carefully select their LCNC platforms to minimise this inhibitor.

Additionally, Gomes and Brito (2022) highlight the lack of freedom and choice available to users of LCNC platforms compared to those who have access to source code. Increased risks related to security, compliance and privacy, such as data breaches, cyberattacks, shadow IT and non-compliance issues, are noted by Viljoen et al. (2024) as stemming from a lack of consistency in corporate identity across applications. According to Ajimati Carroll & Maher (2025), security risks also arise from the creation of unauthorised shadow IT applications by users who often lack awareness of cybersecurity threats and network security.

Integration and interoperability challenges, such as the difficulty in integrating LCNC tools with other enterprise systems, are cited as significant barriers to the adoption of LCNC platforms (Kass et al., 2022). Naqvi et al. (2025) mention “challenges integrating with digital ecosystems and difficulties migrating between platforms”.

Kass et al. (2022) emphasise that although LCNC platforms are frequently associated with easy scalability in the literature, research indicates that developing scalable LCNC software requires advanced knowledge, which often lacks among citizen developers. Limited scalability is also associated with restricted support for large-scale computations or flexible cloud deployment. Insufficient documentation is linked, on one hand, to the lack of clear guidelines, user manuals, or best practices (Beranic, Rek & Hericko, 2020), and on the other, to the fact that citizen developers do not document the applications they develop. Documentation of the developed software is essential both for its usage and maintenance, and the absence of such documentation hinders subsequent maintenance of LCNC software (Hintsch et al., 2021).

Another commonly cited inhibitor is the inadequate support for testing and analytics. To ensure software quality, testing must be properly conducted;

however, citizen developers often lack training in testing, debugging or performance analysis (Hintsch et al., 2021). The lack of testing may result in reliability issues with LCNC developed software (Viljoen et al., 2025). Although LCNC platforms are associated with the flexibility of citizen developers to create their own applications (Viljoen et al., 2025), it is often pointed out that LCNC platforms have a restricted ability to implement complex or highly tailored functionalities, representing the inhibitor of lack of flexibility and customisation. Table 3 presents the most significant inhibitors of LCNC platforms.

**Table 3:** Low Code/No Code inhibitors

Inhibitors	Sources
Vendor or third-party lock-in	Ajimati, Carroll & Maher 2025; Biedova et al., 2024; Binzer et al., 2024; Binzer & Winkler, 2024; Di Ruscio et al., 2022; Kaess, 2022; Kass et al., 2022; Käss et al., 2023a, 2023b; Luo et al., 2021; Rokis & Kirikova, 2022, 2023; Sahay et al., 2020
Increased risks related to security, compliance and privacy	Ajimati, Carroll & Maher, 2025; Biedova et al., 2024; Hintsch et al., 2021; Kaess, 2022; Naqvi et al., 2025; Viljoen, Altm, et al., 2024; Viljoen et al., 2025; Viljoen, Radić, et al., 2024; Zaheri, Famelis & Syriani, 2024
Integration and interoperability challenges	Elshan et al., 2024; Kass et al., 2022; Naqvi et al., 2025; Rokis & Kirikova, 2022; Sahay et al., 2020
Limited scalability	Ajimati, Carroll & Maher, 2025; Käss et al., 2023b; Rokis & Kirikova, 2022, 2023; Sahay et al., 2020
Insufficient documentation	Biedova et al., 2024; Hintsch et al., 2021; Kass et al., 2022; Käss et al., 2023b; Martins, Branco & Mamede, 2023
Limited testing and analytics support	De Silva, Shangavie & Ranathunga, 2024; Hintsch et al., 2021; Rokis & Kirikova, 2022, 2023
Lack of flexibility and customisation	(De Silva, Shangavie & Ranathunga, 2024., 2024; Kass et al., 2022; Käss et al., 2023b; Luo et al., 2021; Mottu & Sunyé, 2024; Naqvi et al., 2025; Rokis & Kirikova, 2022; Viljoen, Radić, et al., 2024)

Source: Authors' calculation.

### 3. RESEARCH DESIGN

To address the second research question, a qualitative study was conducted, using the multiple case study methodology (Runeson & Höst, 2009; Yin, 2009). Organisations utilising LCNC tools were selected, and the participants were users who employ LCNC platforms daily. A semi-structured interview was conducted with the participants via the MS Teams online platform. Following the

initial questions, participants were asked to evaluate the relevance of previously identified inhibitors. The semi-structured interview was conducted in accordance with the guidelines provided by Ristić (2016) and Runeson & Höst (2009). The research was carried out during June and July of 2025 in organisations from Bosnia and Herzegovina. The inclusion criterion for participants was familiarity with LCNC tools and active use of them in their professional duties.

The case study was conducted in nine organisations, with one participant from each. Table 4 presents the structure of the participants according to the size and type of organisation, the department in which they are employed, their current position and years of experience. The majority of participants work in organisations with up to or over one thousand employees, primarily within the banking and private sectors. Furthermore, most participants are employed in IT departments and possess more than twenty years of experience.

**Table 4:** Case study organisations

Participant code	Size of organisation	Type of organisation	Department	Current position	Years of experience
Rsp. 1	201–1000	Financial services / Banking / Insurance	Information Technology (IT)	Manager / Team leader	20+
Rsp. 2	1000+	International organisation	Administration / General Management	Manager / Team leader	20+
Rsp. 3	1000+	Private company (for-profit)	Information Technology (IT)	Software developer / IT specialist	6-10
Rsp. 4	201–1000	Financial services / Banking / Insurance	Research & Development (R&D)	Manager / Team leader	20+
Rsp. 5	1000+	Telco company	Information Technology (IT)	Manager / Team leader	20+
Rsp. 6	201–1000	Financial services / Banking / Insurance	Information Technology (IT)	Business analyst	11-20
Rsp. 7	1–10	IT/Software services provider	Information Technology (IT)	Software developer / IT specialist	3-5
Rsp. 8	1000+	Financial services / Banking / Insurance	Information Technology (IT)	Vice president	20+
Rsp. 9	201–1000	Private company (for-profit)	Information Technology (IT)	Software developer / IT specialist	11-20

Source: Authors' calculation.

### 3.1 Results

Participants evaluated the impact of each inhibitor on LCNC software development using a scale from 0 to 5 (0 – no impact, 5 – strong impact). Table 5 presents the average scores assigned by the participants for each identified inhibitor. Based on the data, it can be concluded that participants consider the most significant inhibitor of LCNC development to be the lack of flexibility and customisation, followed by vendor or third-party lock-in and limited testing and analytics support. The least significant inhibitor identified by participants is insufficient documentation.

**Table 5:** Low Code/No Code inhibitors – Average scores

Inhibitors	Average score
Vendor or third-party lock-in	4.4
Increased risks related to security, compliance and privacy	4
Integration and interoperability challenges	4
Limited scalability	3.4
Insufficient documentation	3.3
Limited testing and analytics support	4.4
Lack of flexibility and customisation	4.6

Source: Authors’ calculation.

The results of the conducted research indicate that users of LCNC tools express the greatest concern regarding the limited adaptability of the systems and dependence on external platforms or vendors. This may suggest a need for greater modularity and the adoption of open standards within LCNC solutions. High ratings for inhibitors related to testing, analytics, security and interoperability suggest that, although LCNC platforms offer rapid development and accessibility, their technical maturity and ability to integrate into complex IT environments still raises skepticism among users. On the other hand, the relatively low rating for “insufficient documentation” may indicate that users, while recognising shortcomings in this area, do not consider it a significant limitation to tool usage, or that they rely on alternative sources of knowledge (e.g., communities, tutorials, support).

## 4. CONCLUSIONS

LCNC platforms enable rapid development of business applications and the automation of numerous business processes. End-users who utilise LCNC

platforms and develop their own applications are referred to as citizen developers or end-user developers. LCNC development remains a relatively new phenomenon, and according to [Viljoen et al. \(2024\)](#), it is still unclear what organisations should do to strike a balance between speed and decentralisation and high software quality. The same authors emphasise the need for governance of LCNC development, stating that without proper management, issues such as poor software quality, shadow IT and technical debt will only escalate.

Furthermore, [Matook Wang & Axelsen, I. \(2025\)](#) argue that the training of new generations of developers (citizen developers) is the responsibility of higher education institutions, while [Naqvi et al. \(2025\)](#) highlight that organisations must develop comprehensive programs that demonstrate both the capabilities and limitations of LCNC platforms. A similar claim is made by [Takahashi et al. \(2024\)](#), who state that merely introducing LCNC platforms is insufficient; management must provide support for their use by fostering a cooperative environment through workshops and other forms of assistance.

This study aimed to identify the key inhibitors of LCNC solution development and to assess their significance from the perspective of end-users. To answer the first research question, a systematic literature review was conducted, through which a range of inhibitors to LCNC software development was identified. These inhibitors were derived from an analysis of 25 relevant papers sourced from the SCOPUS and Web of Science databases.

The answer to the second research question was established based on a multiple case study involving end-users of LCNC tools. Based on the collected data, users highlighted lack of flexibility and customisation, vendor lock-in, and limited support for testing and analytics as the most significant inhibitors. In contrast, insufficient documentation was rated as the least restrictive factor. The results indicate that users perceive technical and infrastructural limitations as the primary barriers to broader and more effective use of LCNC platforms.

The research conducted confirms that the inhibitors to LCNC solution development are real and multifaceted, and that ignoring them may significantly diminish the benefits that the LCNC approach can offer to users. Future research should focus on developing concrete guidelines and strategies for overcoming the identified obstacles, as well as on longitudinal studies that track changes in user perception and the maturity of LCNC technologies over time.

This paper presents only preliminary findings from ongoing research aimed at examining the drivers and inhibitors of LCNC software development. Current results indicate that the most significant inhibitors to LCNC development are the

lack of flexibility and customisation, vendor or third-party lock-in, and limited testing and analytics support. Full findings will be presented in future publication.

### Conflict of interests

The authors declare there is no conflict of interest.

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## ИЗАЗОВИ ПЛАТФОРМИ СА МАЛО КОДИРАЊА ИЛИ БЕЗ КОДИРАЊА У ПОДРШЦИ ОРГАНИЗАЦИОНИМ ИНФОРМАЦИОНИМ ПРОЦЕСИМА: ПРЕГЛЕД ЛИТЕРАТУРЕ И ДОКАЗИ ИЗ СТУДИЈЕ СЛУЧАЈА

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### САЖЕТАК

Дигитална трансформација све више позиционира пословну информатику у средиште организационе конкурентности, подстичући компаније да дигитализују и аутоматизују своје пословне процесе. У овом контексту, low-code/no-code (LCNC) платформе су се појавиле као обећавајуће рјешење у оквиру пословних информационих система, омогућавајући брз развој

процесно оријентисаних апликација уз минимално програмирање или без њега. Оснаживањем запослених без формалног ИТ образовања да учествују у развоју система, LCNC платформе рјешавају проблем недостатка ИТ стручњака и помажу у премошћавању јаза између техничког и пословног знања из одређене области. Иако креатори LCNC платформи наглашавају предности као што су једноставност употребе, убрзани развојни циклуси, смањени трошкови, нижа зависност од ИТ-а и унапређена иновативност процеса, они често занемарују организационе, технолошке и управљачке изазове повезане са усвајањем LCNC-а. Овај рад систематски идентификује кључне инхибиторе и имплементацију LCNC-а кроз свеобухватан преглед литературе, након чега слиједи процјена њиховог значаја кроз вишеструке студије случаја са LCNC корисницима. Идентификовано је седам главних инхибитора: везаност за добављача, ризици безбједности и усаглашености, изазови интеграције, ограничена скалабилност, недовољна документација, ограничена подршка тестирању и недостатак флексибилности. Налази из студија случаја указују да недостатак флексибилности и прилагођавања, везаност за добављача и недовољна подршка тестирању представљају најкритичније баријере. Рад представља прелиминарне увиде из истраживања LCNC развоја које је у току.

**Кључне речи:** *развој са мало кодирања или без кодирања; развој од стране крајњих корисника; инхибитори.*



# MODELLING THE EMISSIONS-INCOME RELATIONSHIP IN EAST AFRICAN COMMUNITY (EAC) COUNTRIES: A PANEL COINTEGRATION APPROACH<sup>1</sup>

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## ABSTRACT

This study examines the nexus between economic growth and carbon dioxide (CO<sub>2</sub>) emissions in East African Community (EAC) countries, with a focus on the role of renewable energy consumption. As EAC countries undergo rapid industrialisation and urbanisation, understanding the impact of economic growth on emissions is critical for shaping sustainable development policies. Using a panel cointegration approach, the study applies the environmental Kuznets curve (EKC) hypothesis to data from six EAC countries, namely, the Democratic Republic of the Congo, Burundi, Rwanda, Kenya, Uganda and Tanzania, for the period from 1990 to 2022. The panel autoregressive distributed lag (ARDL) model is employed, with the pooled mean group (PMG) estimator used to analyse both long-run and short-run dynamics. The results reveal a U-shaped relationship between economic growth and CO<sub>2</sub> emissions, challenging the traditional inverted U-shaped EKC hypothesis. The findings suggest that while the early stages of economic growth reduce emissions, emissions begin to rise again beyond a certain income threshold, indicating a potential overdevelopment phase. Renewable energy consumption is found to significantly reduce CO<sub>2</sub> emissions; however, its economic benefits are constrained by infrastructural and policy challenges. This study contributes to existing literature by integrating renewable energy into the EKC framework and offers valuable insights for policymakers seeking to balance economic growth with environmental sustainability. The findings emphasise the need for targeted policies to promote clean energy adoption, low-carbon industrialisation and stronger environmental governance across EAC countries.

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## 1. INTRODUCTION

The nexus between economic growth and environmental degradation, particularly carbon dioxide (CO<sub>2</sub>) emissions, remains a central concern in global sustainability discussions. As economies expand, greenhouse gas (GHG) emissions have surged, exacerbating climate change and posing significant threats to economic stability, public health and ecosystems. The growing frequency and intensity of extreme weather events, such as floods, droughts and heat waves, reflect the tangible consequences of these emissions. These climate-induced disruptions reduce agricultural productivity, threaten livelihoods and accelerate biodiversity loss. According to the World Economic Forum's Global Risks Report ([World Economic Forum, 2024](#)), climate change, extreme weather and ecosystem collapse rank among the most pressing global risks, emphasising the need for coordinated international action. This aligns with the 2015 Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC), which advocates for global collaboration to limit temperature increases and reduce emissions.

These environmental challenges are particularly pronounced in the East African Community (EAC), where rapid urbanisation, industrialisation and increasing energy demands have intensified pollution and environmental degradation. According to [Sun et al. \(2022\)](#), economic growth in EAC countries is largely driven by carbon-intensive sectors such as agriculture, manufacturing and energy production. Unlike many developed economies that have begun to decouple economic expansion from environmental degradation, growth within the EAC remains closely tied to rising CO<sub>2</sub> emissions. This interdependence presents a significant development dilemma: how to pursue sustained economic progress without exacerbating ecological damage. Addressing this challenge requires acknowledging the region's continued reliance on traditional fossil fuels, which underscores the urgent need for a strategic transition toward cleaner, renewable energy sources. Embracing renewables and adopting low-carbon development strategies will be essential to align the region's economic aspirations with environmental sustainability.

Given these regional challenges, it becomes essential to apply robust theoretical frameworks to understand the interaction between economic activity and emissions. One such framework is the environmental Kuznets curve (EKC), which posits an inverted U-shaped relationship between income and environmental degradation. According to this hypothesis, environmental degradation tends to increase in the early stages of economic growth but may decline as income rises and cleaner technologies are adopted. However, its applicability in developing

regions, particularly East Africa, remains inconclusive, as early stages of economic growth often coincide with rising emissions before any potential decoupling occurs (Baidoo, 2023). Renewable energy consumption emerges as a promising pathway to reduce CO<sub>2</sub> emissions while sustaining growth. Although the broader role of renewables in addressing climate change is well established, their specific impact on emissions within EAC countries remains underexplored. As investment in clean energy accelerates across the region, understanding its implications for both environmental and economic outcomes has become increasingly vital.

To address these gaps, this study aims to investigate the long-term and short-term relationship between economic growth and CO<sub>2</sub> emissions in East African Community countries, with a focus on the role of renewable energy consumption. The objectives are twofold: first, to assess the validity of the EKC hypothesis in the EAC countries; and second, to evaluate the impact of renewable energy consumption on the emissions-income relationship. The study utilises data from six EAC countries: the Democratic Republic of the Congo, Burundi, Rwanda, Kenya, Uganda and Tanzania, spanning the period from 1990 to 2022, marked by early industrialisation and a surge in clean energy investments. The study applies the EKC framework using the pooled mean group (PMG) estimator within a panel autoregressive distributed lag (ARDL) model to analyse both long-run and short-run dynamics.

By examining the emissions-growth nexus, this study provides key insights into the sustainability challenges facing East African Community countries and highlights the transformative potential of renewable energy. Moreover, it contributes to the broader discourse by shedding light on a region that is often underrepresented in global discussions on environmental sustainability. The rest of the paper is structured as follows: Section 2 reviews the relevant literature; Section 3 details the data and methodology; Section 4 presents the empirical results; Section 5 discusses the key findings; and Section 6 concludes with policy recommendations.

## 2. EMPIRICAL LITERATURE

The relationship between income and carbon emissions has been widely examined, yielding mixed evidence regarding the validity of the environmental Kuznets curve (EKC) hypothesis. As previously described, the EKC hypothesis suggests that CO<sub>2</sub> emissions initially rise with income but may decline after a certain threshold is reached. However, empirical findings remain inconclusive.

While some studies support the EKC hypothesis, others reveal alternative patterns, including monotonic increases, N-shaped curves, or even no clear relationship. These inconsistencies often stem from differences in a country's economic and structural conditions, income levels, methodological approaches and the specific pollutants or indicators under study.

Recent empirical studies offer robust support for the applicability of the EKC hypothesis, particularly within developing countries. [Ganda \(2023\)](#), employing the autoregressive distributed lag (ARDL) model, confirmed the existence of an inverted U-shaped relationship between income and CO<sub>2</sub> emissions in South Africa, consistent with the EKC framework. Similarly, [Boga and Boga \(2024\)](#) provided evidence that renewable energy consumption and financial development play a critical role in mitigating emissions, thereby reinforcing the EKC hypothesis across leading renewable energy-consuming countries. Complementing these findings, [Hlongwane and Daw \(2022\)](#) applied a vector error correction model (VECM) and found a statistically significant negative long-run relationship between economic growth and carbon emissions in South Africa, further validating the EKC trajectory in Sub-Saharan Africa.

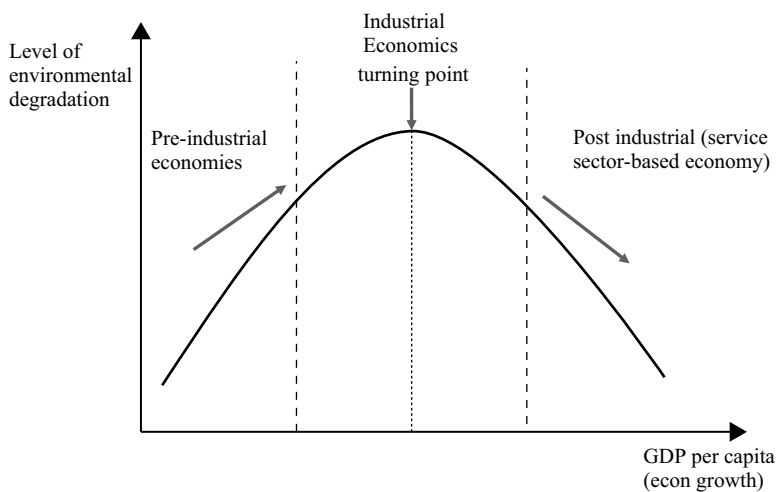
[Adeleye, Adedipe, and Okunlola \(2021\)](#) revealed significant variation in the income-emissions nexus across 28 African countries, emphasising the importance of regional variation in shaping this relationship. Their study found that per capita income moderates the effect of energy consumption on carbon emissions, with marked regional contrasts. Southern Africa exhibited the highest energy-driven emissions, whereas West Africa demonstrated the strongest moderating effect of income. While regional heterogeneity is central to understanding the EKC within Africa, global patterns also provide critical insight into the complex relationship between income and emissions. [Almeida, Duarte, and Pinheiro \(2024\)](#) found that high-income countries are increasingly successful at decoupling economic growth from emissions, while low-income countries continue to experience a positive and often linear relationship between the two.

While the EKC hypothesis offers a valuable lens for examining the relationship between income and emissions, empirical evidence indicates that it is not universally applicable. Emissions outcomes are shaped by a complex interplay of factors, including the energy mix, income inequality and distinct regional dynamics. [Shivani \(2024\)](#) highlights the moderating role of renewable energy, suggesting that its integration into the energy system can significantly reduce the environmental impact of economic growth. Similarly, [Boga and Boga \(2024\)](#) emphasise that income inequality, along with globalisation drivers such as international trade and foreign direct investment, influences emissions patterns,

thereby highlighting the need for multidimensional and country-specific policy approaches. While economic expansion tends to drive emissions upward, studies by Teklie and Dogan (2024) affirm that technological innovation and increased adoption of renewable energy can counterbalance these effects. Collectively, these findings reinforce the importance of designing strategic, evidence-based policies that align economic development goals with environmental sustainability.

The diversity of empirical findings on the EKC highlights that a uniform policy approach is unlikely to yield effective results across different regions. Instead, strategies should be tailored to reflect the unique energy structures, socio-economic conditions and institutional capacities of each country. In the case of the EAC countries, examining the income-emissions relationship within a localised framework is essential for uncovering relevant patterns and designing policies that support both economic development and environmental sustainability.

Figure 1 visually represents the EKC hypothesis, describing an inverted U-shaped relationship between income and environmental degradation



**Figure 1:** Environmental Kuznets Curve

Source: Pettinger, 2019.

This transition, as shown in the EKC, reflects how countries may shift toward sustainability as incomes grow. In the early stages of economic growth, environmental quality deteriorates. However, as countries grow wealthier, they tend to adopt more sustainable practices. In the early stages of economic development, pollution tends to rise due to industrialisation, urban expansion

and increased consumption. During this phase, economic growth is often prioritised over environmental concerns, leading to heavy reliance on fossil fuels, deforestation and resource-intensive manufacturing. However, as income levels increase and economies mature, structural changes begin to take hold. Technological innovations facilitate the adoption of cleaner and more efficient production methods, while stronger regulatory frameworks and rising public awareness drive demand for environmental accountability. Simultaneously, increased investment in sustainable infrastructure, such as renewable energy, waste management and green transportation, further supports this transition. These combined efforts gradually decouple economic growth from environmental degradation, resulting in reduced emissions and improved environmental outcomes.

Wealthier societies are more likely to enforce stringent environmental regulations, such as the European Union's Carbon Border Adjustment Mechanism (CBAM) and Deforestation Regulation (EUDR), which promote sustainable practices across industries and global supply chains. These regulatory efforts are often accompanied by increased investment in sustainable infrastructure and renewable energy, as evidenced by the growing participation of institutional investors in green energy projects and climate finance initiatives (UNCTAD, 2023). In addition, structural economic transformations contribute to environmental improvements, including shifts in the labour market toward green jobs, facilitated by training programmes and the adoption of carbon taxes aimed at discouraging pollution-intensive production. Simultaneously, rising public awareness and enhanced institutional capacity reinforce sustainability efforts. Universities and corporations are progressively integrating green operational models, while development agencies champion coherent environmental, social and governance (ESG) frameworks and innovative financing mechanisms to align international trade with climate objectives (DCED, 2025). As living standards improve, so do public expectations for environmental accountability, generating political momentum for policies such as wealth taxes to fund climate resilience and ensure that high-emission industries are held responsible.

However, while these mechanisms have proven effective in wealthier countries, the extent to which developing countries can replicate such transitions remains uncertain. Despite the EKC's theoretical appeal, its applicability is still debated, particularly across varying country conditions and environmental indicators. According to Wang, Li, and Li (2024), although empirical studies often confirm the EKC in developed economies, many developing countries continue to face persistent environmental degradation even as incomes rise. This divergence is largely attributed to factors such as weak governance structures, limited access

to clean technologies, reliance on resource-intensive industries and ineffective environmental regulation, all of which hinder progress toward the EKC’s turning point. Moreover, not all pollutants adhere to the EKC trajectory; for example, CO<sub>2</sub> emissions frequently continue to increase with economic growth, reflecting an enduring dependence on fossil fuels for energy and transport.

### 3. DATA & METHODOLOGY

#### 3.1 Data

To examine the dynamic causal relationship between environmental degradation and economic growth, this study uses carbon dioxide (CO<sub>2</sub>) emissions per capita and renewable energy consumption as measures of environmental impact. Gross domestic product (GDP) per capita serves as the primary indicator of economic growth. The variables are denoted as follows: GDP for GDP per capita, CO<sub>2</sub> for carbon dioxide emissions per capita and REN for renewable energy consumption.

The analysis focuses on a panel of six East African Community countries: the Democratic Republic of Congo (DR Congo), Burundi, Rwanda, Kenya, Uganda and Tanzania. Annual data from 1990 to 2022 were obtained from the World Bank Indicators database. The dataset includes GDP per capita (in US dollars), CO<sub>2</sub> emissions per capita (in metric tons) and REN (measured as the percentage of total energy consumption derived from renewable sources).

Table 1 below presents the descriptive statistics for GDP per capita (lnGDP), CO<sub>2</sub> emissions per capita (lnCO<sub>2</sub>) and renewable energy consumption (lnREN) across six EAC countries from 1990 to 2022.

**Table 1:** Descriptive statistics

Variable		Mean	Sd	Min	Max	No. of observation
lnGDP	Overall	6.354	0.5139	5.249	7.411	186
	Within group		0.1602	6.128	6.626	31
	Between-group		0.4886	5.766	7.184	6
lnCO <sub>2</sub>	Overall	-2.5021	0.7626	-3.8263	-0.8902	186
	Within group		0.2011	-2.767	-2.119	31
	Between-group		0.7625	-3.350	-1.257	6
lnREN	Overall	4.493	0.0805	4.263	4.588	186
	Within group		0.0251	4.437	4.519	31
	Between-group		0.0795	4.349	4.569	6

Source: Author’s computation

GDP per capita (lnGDP) has the highest mean value of 6.354 among the variables. The between-group standard deviation (0.4886) is significantly larger than the within-group standard deviation (0.1602), indicating that the variation in GDP per capita is primarily driven by differences across countries rather than changes over time within each country.

CO<sub>2</sub> emissions per capita (lnCO<sub>2</sub>) have a mean of -2.5021, reflecting the overall low levels of per capita emissions for the countries. This variable exhibits the highest overall standard deviation (0.7626) among the three indicators, suggesting substantial variation in emissions levels across the sample. The between-group standard deviation (0.7625) is much higher than the within-group standard deviation (0.2011), implying that cross-country differences in CO<sub>2</sub> emissions are more pronounced than within-country variations over time. This suggests that some EAC countries have significantly higher per capita emissions than others, but the rate of change within individual countries is relatively small.

Renewable energy consumption (lnREN) has a mean of 4.493 and exhibits the lowest variation among the three variables. The between-group standard deviation (0.0795) is slightly larger than the within-group standard deviation (0.0251), indicating that differences in renewable energy consumption across countries are slightly greater than variations over time. This suggests that EAC countries have relatively stable renewable energy consumption patterns over time, with only minor cross-country differences.

### 3.2 Methodology

This study adopts a quadratic functional form, allowing for non-linear relationships between income levels and environmental degradation. The baseline specification follows the conventional EKC model (Shafik, 1994; Primer, 2002), where the natural logarithm of CO<sub>2</sub> emissions *i* is regressed on the natural logarithm of GDP per capita and its squared term:

$$\ln(CO2_t) = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln(GDP_t)^2 + \varepsilon_t \dots\dots\dots(1)$$

To account for country-specific effects and incorporate the role of renewable energy consumption, the study extends to a panel data model, applying a fixed-effects framework as shown below (Farhani et al., 2014):

$$\ln(CO2_{i,t}) = \alpha_i + \beta_1 \ln GDP_{i,t} + \beta_2 \ln(GDP_{i,t})^2 + \beta_3 \ln REN_{i,t} + \varepsilon_{i,t} \dots\dots\dots(2)$$

Here,  $\alpha_i$  captures unobserved country-specific heterogeneity, while  $i$  and  $t$  denote country and time, respectively. The coefficients  $\beta_1$  and  $\beta_2$  represent the elasticity of emissions for GDP and GDP squared, and  $\beta_3$  captures the effect of renewable energy consumption on emissions,  $\varepsilon_{it}$  is the stochastic disturbance error term.

For the EKC hypothesis to hold,  $\beta_1 > 0$  and  $\beta_2 < 0$ , implying an inverted U-shaped relationship between economic growth and environmental degradation. A linear relationship would be indicated by  $\beta_2 = 0$  while a U-shaped curve, reflecting an initial decline in emissions followed by a rise, would be supported if  $\beta_1 < 0$  and  $\beta_2 > 0$ .

According to [Arshed, Munir and Iqbal \(2021\)](#), the inverted U-curve is interpreted through two stages: the deterioration stage, where emissions rise with growth, and the maturity stage, where emissions begin to decline. Conversely, the U-shaped path follows a balanced growth phase, characterised by reduced emissions during initial development, followed by an overdevelopment phase where emissions rise again.

### 3.2.1 Cointegration and Stationary Tests

To determine the stationarity properties of the variables, panel unit root tests were applied under the assumption of a first-order autoregressive process. Each time series for cross-sectional unit  $i$  was modelled to assess integration order. Given the presence of a mix of I(0) and I(1) variables, the panel ARDL cointegration framework was selected for its flexibility in handling such series. Upon confirming cointegration, the pooled mean group (PMG) estimator was employed, constraining long-run parameters to be homogeneous across countries while allowing for short-run heterogeneity, thus ensuring consistent and efficient estimates within a panel data framework.

Assuming a first-order autoregressive process for the panel data, the time series for each cross-sectional unit  $i$  is represented as:

$$Y_{it} = (1 - \alpha_i)\mu_i + \alpha_i Y_{i,t-1} + \varepsilon_{it} \dots\dots\dots (3)$$

Rewriting in first differences yields:

$$\Delta Y_{it} = -\varphi_i \mu_i + \varphi_i Y_{i,t-1} + \varepsilon_{it} \dots\dots\dots (4)$$

where  $\Delta Y_{it} = Y_{it} - Y_{i,t-1}$  and  $\varphi_i = \alpha_i - 1$

Incorporating mean deviations,  $\hat{Y}_{it} = \alpha_i Y_{i,t-1} + \varepsilon_{it}$  and  $\hat{Y}_{it} = Y_{it} + \mu_i$ , the panel unit root model becomes:

$$\Delta \hat{Y}_{it} = \phi_i Y_{i,t-1} + \varepsilon_{it} \dots\dots\dots(5)$$

The null hypothesis tests for the presence of a unit root across all panels:

$$H_0: \phi_1 = \phi_2 = \dots = \phi_N = 0$$

The alternative hypothesis has two possible outcomes. The homogeneous alternative, where the stationary panel unit has identical autoregressive coefficients, and the heterogeneous alternative, where there are stationary panels with specific individual autoregressive coefficients.

Homogeneous alternative:  $H_{1a}: \phi_1 = \phi_2 = \dots = \phi_N = \phi$

Heterogeneous alternative:  $H_{1a}: \phi_1 < 0, \phi_2 < 0, \dots, \phi_N < 0$

Panel data stationarity testing is often constrained by challenges such as unobserved heterogeneity, cross-sectional dependence, and asymptotic limitations. To address these, both first-generation and second-generation unit root tests are employed. First-generation tests (e.g., Levin-Lin-Chu, Im-Pesaran-Shin) assume cross-sectional independence, whereas second-generation tests account for cross-sectional dependence due to common shocks or spatial effects. In the second-generation framework, a cross-sectional error component is introduced:

$$\Delta \hat{Y}_{it} = \mu_i \phi_i + \phi_i Y_{i,t-1} + \varepsilon_{it} \dots\dots\dots(6)$$

**3.2.2 Panel Cointegration**

To test for long-run relationships among CO<sub>2</sub> emissions, GDP per capita, and renewable energy consumption, Pedroni’s (2001, 2004) residual-based panel cointegration tests were applied. All seven test statistics were computed, including four-panel statistics (v-statistic, rho-statistic, PP-statistic, ADF-statistic) and three group statistics. Emphasis was placed on the panel v-statistic, panel ADF-statistic and group ADF-statistic due to their higher reliability for medium-sized

panels. The null hypothesis of no cointegration was rejected, confirming a stable long-run relationship across countries.

Cointegration implies the existence of a stationary linear combination of the variables:

$$\beta'_i X_{it} = \varepsilon_{it}, \quad \varepsilon_{it} \sim I(0) \dots\dots\dots (7)$$

Where  $\beta_i$  is a  $k \times r$  matrix,  $X_{it}$  is a  $k \times 1$  vector of the observed time series,  $\varepsilon_{it}$  is an  $r \times 1$  vector of the error term, and  $r$  ( $r \geq 1$ ) is the number of cointegration relations.

Following the confirmation of cointegration, the study estimates the short-run and long-run dynamics using the pooled mean group (PMG) estimator within a panel ARDL ( $p, q_1, q_2, \dots, q_k$ ) framework.

$$Y_{it} = \sum_{j=1}^p \alpha_{ij} Y_{i,t-j} + \sum_{j=0}^q \hat{\delta}_{ij} X_{i,t-j} + \mu_i + \varepsilon_{it} \dots\dots\dots (8)$$

where  $\mu_i$  is the fixed effect parameter,  $\delta_{ij}$  is a  $k \times 1$  vector for the explanatory coefficient vector.

Equation (8) is re-parameterised into the error correction model (ECM) form (Pesaran, Shin and Smith, 1999; Njenga, 2024):

$$\Delta Y_{it} = \phi_i Y_{i,t-1} + \beta'_i X_{it} + \sum_{j=1}^{p-1} \eta_{ij} \Delta Y_{i,t-j} + \sum_{j=0}^{q-1} \omega_{ij} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \dots\dots\dots (9)$$

Where

$$\phi_i = -\left(1 - \sum_{j=1}^p \alpha_{ij}\right), \quad \beta_i = -\sum_{j=0}^q \delta_{ij}, \quad \eta_{ij} = -\sum_{m=j+1}^p \alpha_{im}, \quad \omega_{ij} = -\sum_{m=j+1}^q \delta_{im}$$

Where  $j=1, 2, \dots, q-1$

Stacking the model across time for country  $i$  gives the compact short-run form:

$$\Delta Y_i = \phi_i Y_{i,-1} + X_{it} \beta_i + \sum_{j=1}^{p-1} \eta_{ij} \Delta Y_{i,-j} + \sum_{j=0}^{q-1} \Delta X_{i,-j} \omega'_{ij} + \mu_i + \varepsilon_i \dots\dots\dots (10)$$

where  $l$  is a  $T \times 1$  vector of ones and  $-j$  implies the lagged values of the respective variable. The implied long-run relationship is expressed as:

$$Y_{it} = - \left( \frac{\beta_i}{\phi_i} \right) X_{it} + \xi_{it} \dots\dots\dots(11)$$

Where the term  $\xi_{it}$  is a stationary process. This represents the equilibrium linkage between CO<sub>2</sub> emissions, income and renewable energy use in the panel.

The PMG model was estimated using maximum likelihood in R, employing the back-substitution algorithm. The short-run coefficients were allowed to vary across countries, while the long-run coefficients were constrained to be homogeneous. The error correction terms (ECTs) were negative and statistically significant, validating the long-run relationship and confirming convergence toward equilibrium after short-run shocks. These findings align with the earlier cointegration results and confirm the suitability of the panel ARDL-PMG approach for this study.

**3.2.3 Granger Causality**

To examine directional relationships among variables, the study applied the Dumitrescu-Hurlin (2012) panel Granger causality test, an extension of Granger’s (1969) causality framework. The test was implemented based on the following model (Lopez & Weber, 2017):

$$Y_{it} = \pi_i + \sum_{k=1}^k \rho_{ik} Y_{i,t-k} + \sum_{k=1}^k \tau_{ik} X_{i,t-k} + \varepsilon_{it} \dots\dots\dots(12)$$

The null hypothesis of non-causality is defined as:

$$H_0: \tau_{i1} = \tau_{i2} = \dots = \tau_{ik} = 0 \quad \forall i$$

The alternative hypothesis allows for causality in at least a subset of the cross-sectional units:

$$H_1: \tau_{ik} \neq 0 \quad \text{for some } i$$

The test statistic follows a standard normal distribution. Granger causality from ( $X_{it} \rightarrow Y_{it}$ ) is inferred when the Wald statistic exceeds the critical value or when the p-value falls below the 5% significance level.

### 4. RESULTS AND DISCUSSIONS

The environmental Kuznets curve (EKC) model results in Table 2 indicate that the relationship between economic growth and CO<sub>2</sub> emissions in EAC countries follows a U-shaped pattern rather than the traditional inverted U-shaped EKC hypothesis. The model explains approximately 73% of the variation in CO<sub>2</sub> emissions ( $R^2 = 0.73383$ ), suggesting a strong explanatory power. The F-statistic (162.663) and p-value (0.0001) confirm the overall statistical significance of the model at the 5% level.

**Table 2:** Fixed effect model results

Parameters		
Variable	Coefficient	Pvalue
$\ln GDP_{i,t}$	-3.3806	0.0200
$\ln(GDP_{i,t})^2$	0.3207	0.0063
$\ln RE_{i,t}$	-3.7071	0.0001
<b>Overall model</b>		
Total Sum of Squares	17.483	
Residual Sum of Squares	4.6534	
R-Squared	0.73383	
Adj. R-Squared	0.7218	
F-statistic	162.663	
Degree of Freedom	(3,177)	
p-value	0.0001	

Source: Author’s computation

Examining the coefficients of GDP and its squared term, the coefficient of  $\ln GDP$  ( $\beta_1$ ) is -3.3806 (negative and statistically significant at  $p = 0.0200$ ), while the coefficient of  $\ln GDP^2$  ( $\beta_2$ ) is 0.3207 (positive and highly significant at  $p = 0.0063$ ). This coefficient structure indicates a U-shaped relationship between economic growth and CO<sub>2</sub> emissions, which deviates from the standard inverted U-shaped EKC hypothesis. In this case, EAC countries initially experience a decline in CO<sub>2</sub> emissions as GDP increases. However, beyond a certain income threshold, further economic growth leads to a reversal, where CO<sub>2</sub> emissions start rising again, implying a shift toward higher environmental degradation. The coefficient of  $\ln RE$  (renewable energy consumption) is -3.7071 ( $p = 0.0001$ ), indicating a strong and significant negative effect on CO<sub>2</sub> emissions. This suggests that increased reliance on renewable energy sources effectively reduces environmental pollution, supporting the argument for policy interventions that promote clean energy adoption in EAC countries.

To determine the appropriate panel unit root test, this study first assessed cross-sectional dependence using the Pesaran (2004, 2015) cross-sectional dependence test.

**Table 3:** Cross-sectional dependency test results

Variable	Statistics	P-value
$\ln GDP_{i,t}$	44.141	0.0001
$\ln CO2_{i,t}$	47.783	0.0001
$\ln REN_{i,t}$	48.756	0.0001

Source: Author’s computation

The p-values for all variables are below the critical threshold, as shown in Table 3, indicating the presence of cross-sectional dependence among the observed variables. Given this result, the study applies second-generation panel unit root tests, specifically, the Choi (2001) Z-test and the modified Fisher statistic test, to account for cross-sectional dependence when assessing stationarity in the panel dataset.

The panel unit root tests presented in Table 4 examine the stationarity properties of the variables at levels and after first differencing. The results indicate a mixed order of integration, confirming that the variables are either I(0) (stationary at level) or I(1) (stationary after first differencing), which supports the use of panel ARDL cointegration techniques to analyse long-run relationships.

At level, GDP per capita ( $\ln GDP$ ) is trend stationary at conventional significance levels ( $p = 0.0234$  for Choi Z-statistic in the trend model). However, for the intercept model, it is of integrated order one (I(1)), requiring first differencing to achieve stationarity ( $p = 0.0001$  after first differencing).  $CO_2$  emissions ( $\ln CO_2$ ) show mixed results; while the trend component model is stationary at the 10% significance level ( $p = 0.0769$ ), the intercept model becomes stationary only after first differencing ( $p = 0.0001$  for Choi Z-statistic). This suggests that  $CO_2$  emissions follow a weak stationarity pattern in trend models but require first differencing for robust stationarity.

Renewable energy consumption ( $\ln REN$ ) is found to be non-stationary in both trend and intercept models at level ( $p$ -values  $> 0.05$  for all tests), confirming that it is integrated of order one (I (1)). However, after first differencing,  $\ln REN$  becomes stationary in both trend and intercept models ( $p = 0.0001$  for Choi Z-statistic and Fisher tests), indicating that it is an I(1) variable.

**Table 4:** Panel unit root test results

In level

Variable	Test	Intercept	P-value	Trend	P-value
lnGDP <sub><i>i,t</i></sub>	Choi Z-statistic	1.4886	0.9317	-1.9888	0.0234
	Choi Fisher	-0.5150	0.6967	5.4816	0.0001
lnCO <sub>2</sub> <sub><i>i,t</i></sub>	Choi Z-statistic	0.8447	0.8009	-1.4262	0.0769
	Choi Fisher	0.8746	0.1909	2.0407	0.0206
lnREN <sub><i>i,t</i></sub>	Choi Z-statistic	2.5987	0.9953	0.3563	0.6392
	Choi Fisher	-0.8411	0.7999	0.67044	0.2513

1st difference

Variable	Test	Intercept	P-value	Trend	P-value
lnGDP <sub><i>i,t</i></sub>	Choi Z-statistic	-5.6523	0.0001	-	-
	Choi Fisher	10.716	0.0001	-	-
lnCO <sub>2</sub> <sub><i>i,t</i></sub>	Choi Z-statistic	-10.946	0.0001	-9.9371	0.0001
	Choi Fisher	28.415	0.0001	-	-
lnREN <sub><i>i,t</i></sub>	Choi Z-statistic	-7.9048	0.0001	-9.4855	0.0001
	Choi Fisher	19.569	0.0001	27.289	0.0001

Source: Author’s computation

The findings confirm that the observed variables exhibit a mixed order of integration, with some variables stationary at level (I(0)) and others requiring first differencing (I(1)). This validates the suitability of panel ARDL cointegration techniques, complemented by the pooled mean group (PMG) estimator, to analyse both long-run and short-run relationships among GDP per capita, CO<sub>2</sub> emissions and renewable energy consumption across the six EAC countries studied. The panel ARDL approach is appropriate for this case, as it accommodates heterogeneous integration orders and allows for dynamic adjustments over time in response to economic and environmental changes.

Table 5 presents the results of Pedroni’s panel cointegration test, providing strong statistical evidence of a long-run equilibrium relationship among GDP per capita, CO<sub>2</sub> emissions per capita and renewable energy consumption in the panel of six EAC countries. The test evaluates both panel-based and group-based statistics, determining whether the variables exhibit cointegration across the sample.

**Table 5:** Pedroni's cointegration test results

Test Statistic	Empirical	Standardised
Panel v-statistic	$4.7144 \times 10^{34}$	-4.4398
Panel rho-statistic	7.9718	5.8974
Panel PP-statistic	1.8206	11.8280
Panel ADF-statistic	$-9.104 \times 10^{33}$	$-1.0976 \times 10^{34}$
Group rho-statistic	10.0867	7.21099
Group PP-statistic	2.4373	14.8222
Group ADF-statistic	-0.2082	11.2321

Source: Author's computation

The panel rho-statistic (7.9718) is significantly positive, suggesting strong evidence of cointegration among the variables in the panel. Additionally, the highly negative panel ADF-statistic ( $-9.104 \times 10^{33}$  empirically and  $-1.0976 \times 10^{34}$  standardised) further supports this conclusion, indicating that deviations from equilibrium are corrected over time, confirming the presence of a long-run relationship. The group rho-statistic (10.0867) and group ADF-statistic (-0.2082) provide further insights into cointegration within specific subgroups of the panel, supporting the presence of co-movements among the studied variables.

These results confirm that GDP per capita, CO<sub>2</sub> emissions per capita and renewable energy consumption move together over the long run, justifying the application of panel cointegration techniques for further analysis. Given this evidence, the study applies the pooled mean group (PMG) estimator, which is suitable for estimating long-run and short-run relationships while considering cross-country heterogeneity. The PMG approach enables the differentiation between country-specific short-run dynamics and shared long-run equilibrium relationships among economic growth, environmental degradation and renewable energy consumption. This method ensures that the long-run coefficients remain homogeneous across countries, while short-run adjustments can vary, capturing the diverse economic and environmental responses within the EAC countries.

Table 6 presents the pooled mean group (PMG) estimation model diagnostics, examining the overall model, JB normality test, Breusch-Godfrey autocorrelation test and JQ *heteroscedasticity* test in six EAC countries. The log-likelihood statistic (410.310) confirms the model's statistical significance at the 5% level, as it exceeds the critical value of 3.84, validating the model's suitability for analysing the economic-environmental nexus in EAC countries.

**Table 6:** PMG model diagnostics results

log-likelihood statistic = 410.310

ECM

Country	Breusch-Godfrey test		Breusch-Godfrey test		Goldfeld–Quandt test		Jarque–Bera test	
	Statistics (F)	p-value	Statistics (Chi-Squared)	p-value	statistics	p-value	Statistics	p-value
D.R Congo	0.0117	0.9997	0.0469	0.9997	3.0624	0.0698	1.2674	0.5306
Burundi	0.5856	0.6813	2.3425	0.6730	4.4149	0.0268	21.3564	0.0001
Kenya	0.3237	0.8553	1.2947	0.8623	1.2010	0.3978	1.9772	0.3721
Rwanda	1.1357	0.3990	4.5428	0.3373	3.5020	0.0500	7.4270	0.0244
Uganda	0.4868	0.7458	1.9471	0.7455	1.3049	0.3561	0.8385	0.6575
Tanzania	0.4565	0.7660	1.8259	0.7677	2.0645	0.1776	4.1472	0.1257

Source: Author’s computation

Both the Chi-squared and F-statistic results from the Breusch-Godfrey autocorrelation tests indicate no significant autocorrelation in the error terms across the individual country models, as the tests fail to reject the null hypothesis in any case. The Goldfeld–Quandt test reveals evidence of heteroscedasticity in the Burundi model, while the models for Kenya, DR Congo, Uganda and Tanzania exhibit homoscedastic error terms. Rwanda’s p-value for heteroscedasticity lies exactly at the 5% significance level, suggesting a borderline result. The Jarque–Bera test indicates that the residuals are normally distributed in DR Congo, Kenya, Uganda and Tanzania, while the data for Burundi and Rwanda show signs of skewness, violating the normality assumption. The PMG regression results are deemed efficient and reliable for DR Congo, Kenya, Uganda and Tanzania. However, the accuracy and performance of the Burundi and Rwanda models may be compromised due to the violation of the normality assumption.

Table 7 presents the pooled mean group (PMG) estimation results, examining long-run and short-run relationships between GDP per capita, CO<sub>2</sub> emissions per capita and renewable energy consumption in six EAC countries.

**Table 7:** PMG model results

<b>Long-run relationship</b>						
<b>Variable</b>			<b>Coefficient</b>		<b>p-value</b>	
$\ln CO_{2,t}$			0.1833		0.3155	
$\ln REN_t$			-13.3273		0.0022	
<b>Short-term dynamics</b>						
<b>DR Congo</b>			<b>Burundi</b>		<b>Kenya</b>	
Parameter	Estimate	p-value	estimate	p-value	estimate	p-value
Intercept	-1.6571		0.0344		0.0225	
<i>ECT</i>	0.0245	0.6136	-0.0003	0.9875	-0.0004	0.9628
$\Delta \ln GDP_{t-1}$	0.7796	0.0001	0.3996	0.0183	0.2685	0.121
$\Delta \ln CO_{2,t}$	0.0246	0.6671	0.1084	0.3714	-0.1041	0.3795
$\Delta \ln CO_{2,t-1}$	0.1236	0.0294	-0.0901	0.4794	0.0709	0.5724
$\Delta \ln REN_t$	-0.8276	0.4864	0.9003	0.654	-0.8543	0.1304
$\Delta \ln REN_{t-1}$	1.8231	0.1966	-1.2953	0.526	-0.0734	0.9062
<b>Rwanda</b>			<b>Uganda</b>		<b>Tanzania</b>	
Parameter	Estimate	p-value	estimate	p-value	Estimate	p-value
Intercept	6.9477		10.6866		0.6592	
	-0.1053	0.0022	-0.1588	0.0016	-0.0098	0.2727
	0.0717	0.7831	-0.4602	0.0073	0.8011	0.0001
	0.4156	0.0291	0.1887	0.1665	0.052	0.214
	0.0678	0.7101	0.1423	0.0009	-0.0008	0.9851
	3.4105	0.0008	-0.3611	0.5639	-0.0724	0.8835
	-0.467	0.6136	0.3113	0.6603	-0.2136	0.6787

Source: Author’s computation

**i. Short-Run Dynamics**

The short-run results from the PMG model highlight considerable heterogeneity in the relationship between GDP, CO<sub>2</sub> emissions and renewable energy consumption across the six EAC countries.

Rwanda and Uganda exhibit notable short-term adjustments toward equilibrium, as indicated by the significant error correction terms (ECTs) (p = 0.0022 for Rwanda, p = 0.0016 for Uganda). This suggests that GDP in these countries responds quickly to deviations from its long-run equilibrium, with CO<sub>2</sub> emissions and renewable energy consumption playing an active role in short-term GDP fluctuations. On the other hand, Kenya, Tanzania and Burundi experience a slow rate (less than 1%) of adjustment to equilibrium status. The rate of adjustment in these countries takes a longer time compared to Rwanda and Uganda. In Kenya, Tanzania and Burundi, changes in renewable energy or CO<sub>2</sub> emissions

do not significantly affect GDP in the short run, implying that these factors are not the immediate drivers of economic fluctuations. In DR Congo, there is no convergence to a long-run equilibrium. This scenario is attributed to either a significant change over time in the nexus that exists among the observed variables or errors in the data set for the country. This calls for a need to re-examine the nexus using alternative model for DR Congo.

DR Congo, Burundi and Tanzania demonstrate strong GDP persistence, where past GDP significantly influences current GDP growth at 5% significant level. This implies that historical economic performance strongly determines present economic outcomes, possibly due to structural economic factors, institutional inertia or investment patterns. In Uganda, past GDP performance leads to a significant decline in current GDP in the short term. Kenya and Rwanda past GDPs do not influence current GDP growth.

Kenya and Burundi show limited short-term dynamics, as CO<sub>2</sub> emissions and renewable energy consumption exhibit insignificant effects on GDP growth (p-values > 0.10 for most short-term coefficients). This suggests that other macroeconomic factors, beyond energy and environmental variables, may be more influential in shaping short-run economic performance in these countries.

These results highlight the heterogeneous nature of economic growth determinants in the countries. Countries exhibit varying responses to changes in CO<sub>2</sub> emissions and renewable energy consumption, indicating that a one-size-fits-all policy approach may not be effective.

**ii. Long-Run Relationship**

The long-run relationship between economic growth (GDP) and CO<sub>2</sub> emissions, while controlling for renewable energy consumption (REN) is expressed as follows:

$$\ln GDP_t = 0.1833 \ln CO2_t - 13.3273 \ln REN_t \dots\dots\dots(13)$$

The coefficient of CO<sub>2</sub> emissions (0.1833) is positive but statistically insignificant (p = 0.3155), indicating that although higher CO<sub>2</sub> emissions are associated with higher GDP, the relationship lacks robustness in the long run. This suggests that economic growth in EAC countries is linked to pollution, but the impact is not strong enough to be conclusive.

Conversely, the coefficient of renewable energy consumption (-13.3273) is negative and statistically significant (p = 0.0022). This implies that an increase

in the share of renewable energy in the energy mix is associated with a decline in GDP. A possible explanation is that at the current stage of economic development, the reliance on renewable energy may be associated with higher costs, lower efficiency and limited infrastructure, making it less economically competitive compared to traditional fossil fuels. These findings suggest that while renewable energy is crucial for sustainability, its economic benefits may not yet be fully realised in these countries due to structural challenges. This long-run analysis reveals a complex economic-environmental dynamic in EAC countries. While CO<sub>2</sub> emissions exhibit a weak positive relationship with GDP, renewable energy consumption appears to hinder economic growth in the current development phase.

**Table 8:** Causality test results

Causality directions	Statistic	p-value
$\ln GDP_t \rightarrow \ln CO2_t$	2.3651	0.0180
$\ln CO2_t \rightarrow \ln GDP_t$	2.2282	0.0259
$\ln CO2_t \rightarrow \ln REN_t$	0.7198	0.4716
$\ln REN_t \rightarrow \ln CO2_t$	3.4471	0.0006
$\ln REN_t \rightarrow \ln GDP_t$	5.4232	0.0001
$\ln GDP_t \rightarrow \ln REN_t$	2.2084	0.0272

Source: Author’s computation

Table 8 presents the results of the panel causality test, examining the directional relationships between GDP per capita, CO<sub>2</sub> emissions per capita and renewable energy consumption in the panel of six EAC countries. The findings reveal a complex interplay among economic growth, environmental pollution and renewable energy adoption.

The results indicate a significant bidirectional causality between GDP and CO<sub>2</sub> emissions ( $p = 0.0180$  for  $GDP \rightarrow CO_2$  and  $p = 0.0259$  for  $CO_2 \rightarrow GDP$ ). This suggests that economic growth leads to an increase in CO<sub>2</sub> emissions, likely due to higher industrial activity, energy consumption and fossil fuel reliance. Conversely, higher CO<sub>2</sub> emissions also contribute to GDP growth, implying that pollution-intensive industries, such as manufacturing and energy production, play a substantial role in driving economic activity. This reinforcing relationship highlights the environmental costs of economic expansion, as growth-driven emissions could further accelerate climate-related challenges in these countries.

The causal relationship between CO<sub>2</sub> emissions and renewable energy consumption is insignificant ( $p = 0.4716$  for  $CO_2 \rightarrow REN$ ). This implies

that changes in CO<sub>2</sub> emissions do not significantly influence the adoption or consumption of renewable energy in the short term. However, renewable energy consumption does exhibit a significant causal impact on CO<sub>2</sub> emissions ( $p = 0.0006$  for  $REN \rightarrow CO_2$ ), suggesting that increasing the share of renewables effectively reduces emissions. This reinforces the importance of transitioning to cleaner energy sources to mitigate environmental degradation.

A strong causal relationship is observed between renewable energy consumption and GDP, where increasing renewable energy usage positively impacts economic growth ( $p = 0.0001$  for  $REN \rightarrow GDP$ ). This could be attributed to factors such as job creation in the renewable energy sector, infrastructure investments and enhanced energy security, which collectively contribute to economic expansion. In addition, the causality from GDP to renewable energy consumption is also significant ( $p = 0.0272$  for  $GDP \rightarrow REN$ ), suggesting that economic growth facilitates greater investment in renewable energy technologies. As economies expand, they generate more financial resources, policy incentives and institutional capacity to support the transition to clean energy.

## 5. DISCUSSIONS

This study reveals a U-shaped relationship between economic growth and CO<sub>2</sub> emissions in EAC countries, deviating from the traditional inverted U-shaped environmental Kuznets curve (EKC) hypothesis. Initially, economic growth leads to a decrease in emissions; however, once a certain income threshold is surpassed, emissions begin to rise again. This U-shaped pattern contrasts with the typical inverted U-shaped curve, where environmental degradation worsens with initial growth but improves as economies advance. These results are consistent with the findings of [Simbi et al. \(2024\)](#), who found that in low-income countries, early stages of economic growth might reduce emissions, but sustained development could eventually lead to greater environmental pressure. This deviation observed in EAC countries can likely be attributed to their early-stage industrialisation, high dependence on carbon-intensive energy sources and challenges in adopting renewable energy.

The findings indicate a mutually reinforcing relationship between economic growth and CO<sub>2</sub> emissions, driven by pollution-intensive industries that fuel expansion. Without targeted interventions, this cycle is positioned to intensify environmental degradation. Although renewable energy positively influences GDP growth and can drive investment in clean energy technologies, the countries' underdeveloped renewable energy infrastructure limits its full

economic potential. The findings agree with the [United Nations' \(2022\)](#) Regional Collaborative Platform Report for Africa, which emphasises the need for country-specific policies that align economic growth with environmental sustainability. Prioritising low-carbon industrialisation, renewable energy investments and stronger governance can help EAC countries transition toward a sustainable future while fulfilling developmental and climate commitments.

A critical outcome of the study is the strong negative correlation between renewable energy consumption and CO<sub>2</sub> emissions, which aligns with global evidence suggesting that an increased share of renewable energy sources reduces environmental degradation. However, the results also reveal a counterintuitive finding: renewable energy consumption negatively affects GDP per capita. This suggests that renewable energy adoption in EAC countries may not yield the expected economic benefits yet. Several plausible explanations emerge for this: First, renewable energy technologies may still be in a nascent stage, characterised by high capital costs, low efficiency and limited grid integration. Second, inadequate infrastructure for the storage and distribution of renewable energy may hinder its economic viability, constraining industrial productivity. Third, the current policy landscape may not sufficiently support renewable energy investments, limiting their capacity to drive economic growth.

The study also reveals significant heterogeneity in short-run economic and environmental dynamics across the six countries. Rwanda and Uganda exhibit rapid adjustments to economic and environmental shocks, as indicated by significant error correction terms (ECTs). In contrast, DR Congo and Tanzania demonstrate a high degree of GDP persistence, suggesting that past economic conditions heavily influence current economic trajectories. Kenya and Burundi display weak short-run linkages between CO<sub>2</sub> emissions, renewable energy consumption and GDP, implying that other macroeconomic variables may exert stronger influences on their growth.

The bidirectional Granger causality between economic growth and CO<sub>2</sub> emissions observed in EAC countries mirrors findings from Western and Central Africa, where a 2023 VECM analysis (1970-2020) demonstrated that both variables adjust to restore long-run equilibrium. This interdependence suggests that economic growth drives higher emissions, aligning with the notion that industrialisation, urbanisation and rising energy demand contribute to environmental degradation. Conversely, the reverse causality, where increased CO<sub>2</sub> emissions also fuel GDP growth, reinforces the reliance of these economies on pollution-intensive sectors such as mining, manufacturing and transportation. This cycle presents a challenge, as continued dependence on carbon-intensive industries

risks exacerbating environmental degradation and jeopardizing long-term sustainability (Yu et al., 2024). Without proactive interventions, the EAC countries may struggle to transition toward a low-carbon growth trajectory.

The study also finds a positive causal relationship between renewable energy consumption and GDP growth. This suggests that investment in renewable energy can stimulate economic expansion by generating employment, improving energy security, and fostering technological innovation. Moreover, the bidirectional causality between GDP and renewable energy implies that economic growth facilitates greater investment in clean energy technologies, further supporting sustainability transitions. However, as earlier results indicated, the current renewable energy framework in EAC countries has not yet yielded optimal economic benefits. The potential of renewables as an economic driver can only be realized if challenges related to energy infrastructure, policy support, and financial accessibility are addressed.

## 6. CONCLUSIONS AND POLICY RECOMMENDATIONS

This study examines the relationship between economic growth, CO<sub>2</sub> emissions and renewable energy consumption in six EAC countries from 1990 to 2022. The findings reveal a U-shaped relationship between GDP per capita and CO<sub>2</sub> emissions, which deviates from the conventional environmental Kuznets curve (EKC) hypothesis. This suggests that while economic growth initially improves environmental quality, it eventually leads to increased CO<sub>2</sub> emissions beyond a certain threshold, highlighting the risk of environmental degradation without effective policies. The study confirms the presence of a long-run relationship between economic growth, CO<sub>2</sub> emissions and renewable energy consumption, with significant long-term dynamics observed in Rwanda and Uganda. Granger causality tests show bidirectional causality between GDP and CO<sub>2</sub> emissions, reinforcing a cycle of growth-driven emissions, while renewable energy consumption positively impacts GDP. However, the study also finds that some renewable energy sources may still contribute to CO<sub>2</sub> emissions due to inefficiencies and infrastructure limitations.

To ensure sustainable growth across East African Community (EAC) countries, it is imperative to adopt tailored policy frameworks that reflect each country's unique economic structure, energy profile and responsiveness to environmental and growth-related shocks. The study reveals significant heterogeneity in short-run dynamics; Rwanda and Uganda exhibit faster adjustments to shocks, suggesting a high potential for responsive policy interventions. These could include rapid-response green stimulus programs or pilot renewable projects with

measurable outcomes. Conversely, DR Congo and Tanzania show persistent GDP patterns, indicating a need for long-term structural reforms that decouple growth from emissions, such as investing in greener value chains and energy transition infrastructure. Kenya and Burundi, which exhibit weaker short-run linkages between GDP, emissions and renewable energy, need to pursue comprehensive macroeconomic diagnostics to identify alternative drivers of growth and environmental change before designing integrated sustainability policies.

A key policy priority is to disrupt the feedback loop between economic growth and CO<sub>2</sub> emissions, as revealed by the bidirectional Granger causality in the study. This finding suggests that growth is both a cause and a consequence of emissions, largely driven by pollution-intensive sectors such as manufacturing, mining and transport. To address this, EAC countries need to embrace green industrialisation, transforming production processes and value chains toward cleaner technologies. Fiscal instruments such as green tax incentives, technology adoption subsidies and accelerated depreciation allowances for low-emission equipment would create incentives for firms to adopt environmentally friendly practices. These interventions reduce emissions and support industrial competitiveness and technological upgrading, especially in emerging green sectors.

The study highlights that renewable energy consumption causally reduces CO<sub>2</sub> emissions and has a positive effect on GDP, supporting the case for scaling up renewable energy investments. However, the evidence also points to underutilisation of this potential due to infrastructure and integration challenges. Therefore, a focused policy effort is needed to expand energy infrastructure, particularly grid and off-grid renewable systems, which can serve both urban industries and rural communities. This includes investing in storage, smart grids and distribution networks that can handle the intermittency of renewables and integrate them into national energy mixes. Establishing dedicated green infrastructure funds, either nationally or at the EAC level, can help crowd in private investment and leverage concessional finance from international climate funds.

Moreover, the bidirectional causality between GDP and renewable energy consumption found in the study reveals that economic growth and clean energy uptake reinforce each other. As such, policy coherence between growth planning and energy strategies is vital. National development plans need to embed clear renewable energy targets, while energy policies need to be aligned with broader macroeconomic objectives to ensure coherence between environmental sustainability and economic growth. Economic expansion can generate fiscal

space and stimulate demand for clean energy, while well-developed renewable energy infrastructure enhances productivity, improves energy security and strengthens long-term economic resilience.

A counterintuitive finding of the study, that renewable energy adoption may negatively affect GDP per capita in the short run, points to important transitional challenges. This suggests that while renewables reduce emissions, current systems may be plagued by high capital costs, low energy output and weak grid connectivity. Policymakers need to focus on improving the quality and efficiency of renewable technologies in the region. This includes supporting local innovation ecosystems around renewables (e.g., solar panel assembly, battery research) and offering capacity-building programs for technicians, engineers and entrepreneurs working in the clean energy space.

Given the study's emphasis on the long-run equilibrium among GDP, emissions and renewable energy, enhancing environmental governance is essential to ensure that growth remains within ecological limits. Governments need to strengthen emission standards, environmental audits and carbon pricing mechanisms such as carbon taxes or emissions trading systems. These tools not only internalise environmental costs but also incentivise firms and households to switch to cleaner alternatives. Revenues from carbon pricing can be reinvested in climate resilience programs and energy access initiatives, creating a virtuous cycle of sustainable development. Additionally, regional collaboration under the EAC framework can amplify these outcomes. The establishment of a regional clean energy investment platform, co-financed by member states and development partners, would facilitate cross-border energy trade, optimise renewable resource distribution (e.g., hydro in Uganda, geothermal in Kenya) and promote policy harmonisation. Such collaboration would help overcome the scale and capital limitations that individual countries face.

To further support effective implementation, EAC countries need to strengthen data systems and policy evaluation mechanisms. The observed variability in country responses to growth and environmental dynamics suggests a need for evidence-based policymaking supported by timely, disaggregated and accurate data. National statistical offices should receive technical and financial support to build robust monitoring, evaluation and learning (MEL) frameworks, enabling adaptive policy adjustments in response to real-world performance.

This study reinforces that EAC countries are managing the trade-off between accelerating economic growth and safeguarding the environment. By adopting country-specific, evidence-based and future-focused policy strategies, the region can shift toward a low-carbon development pathway, one that safeguards

livelihoods, strengthens energy resilience and positions the region as a proactive contributor to global climate action.

### Conflict of interest

The authors declare there is no conflict of interest

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## МОДЕЛОВАЊЕ ОДНОСА ИЗМЕЂУ ЕМИСИЈА И ДОХОДКА У ЗЕМЉАМА ИСТОЧНОАФРИЧКЕ ЗАЈЕДНИЦЕ: ПРИСТУП ПАНЕЛ КОИНТЕГРАЦИЈЕ

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### САЖЕТАК

Ова студија испитује везу између економског раста и емисије угљен-диоксида (CO<sub>2</sub>) у земљама Источноафричке заједнице (ЕАС), са фокусом на улогу потрошње обновљиве енергије. Како земље ЕАС пролазе кроз брзу индустријализацију и урбанизацију, разумијевање утицаја економског раста на емисије од кључног је значаја за обликовање политика одрживог развоја. Користећи приступ панел коинтеграције, студија примјењује хипотезу еколошке Кузнецове криве (ЕКК) на податке из шест земаља ЕАС, и то: Демократске Републике Конго, Бурундија, Руанде, Кеније, Уганде и

Танзаније, за период од 1990. до 2022. године. Примичењен је панел модел ауторегресивног распоређеног закашњења (ARDL), при чему је коришћен процјењивач комбиноване групне средине (PMG) за анализу дугорочне и краткорочне динамике. Резултати откривају U-обликован однос између економског раста и емисија CO<sub>2</sub>, што доводи у питање традиционалну обрнуту U-обликовану ЕКС хипотезу. Налази сугеришу да, иако ране фазе економског раста смањују емисије, оне почињу поново да расту након одређеног прага дохотка, што указује на могућу фазу „преразвијености“. Утврђено је да потрошња обновљиве енергије значајно смањује емисију CO<sub>2</sub>; међутим, њене економске користи су ограничене инфраструктурним и политичким изазовима. Ова студија доприноси постојећој литератури интегрисањем обновљиве енергије у оквир ЕКС и нуди вриједне увиде доносиоцима политика који настоје да уравнотеже економски раст и еколошку одрживост. Налази наглашавају потребу за циљаним политикама ради подстицања усвајања чисте енергије, нискоугљеничне индустријализације и јачања еколошког управљања у земљама ЕАС.

**Кључне ријечи:** *еколошка Кузнецова крива (ЕКС), панел коинтеграција, комбинована групна средина (PMG), економски раст, емисије гасова са ефектом стаклене баште, климатске промјене.*



# BANKING INSTABILITY AND CONSEQUENCES IN THE SOVEREIGN RISK CONTEXT - EUROPEAN ECONOMIES<sup>1</sup>

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## ABSTRACT

Banking instability, as a result of the sovereign risk emergence, triggered, over time, the need for a detailed diagnosis by decision-makers from the monetary authorities, being a theme of permanent relevance and complexity among economic policies. The main issue is related to the existence of a very close, dependent link between the probability of banking instability and sovereign risk. The rigor of the issue requires an in-depth analysis; therefore, this paper aims to capture aspects of micro and macroprudential, based on a panel data set for European Union countries, starting from 2005. In this context, the research identifies liquidity and solvency as the main vulnerabilities to macroeconomic stability, based on its objectives. This is achieved through a micro-level analysis of credit institutions and the use of macroprudential assessment tools, applying multivariate regression and vector autoregressive models, and complemented by unifactorial and multifactorial resilience scenarios to extreme but plausible events. Another objective is to develop a diagnostic framework that enables the assessment of banking performance sensitivity to government bond yield dynamics through both market and credit risk channels. The importance of this research and the estimated results lie in identifying the negative impact of rising government bond yields on banking profitability, particularly on capital adequacy. On the other hand, the originality of this research lies in the estimates that contribute to shaping a set of policy options within the economic policy mix and to formulating proposals for preventive measures aimed at mitigating systemic risks arising from the interaction between sovereign risk and the likelihood of banking instability.

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## 1. INTRODUCTION

The last decades have been characterised by financial ties development, an increase in capital flows between countries, but also the emergence of financial-banking crises, pandemic crises and armed conflicts, which required special attention from the monetary authorities.

The particularities of emerging economies and not only, such as inconsistencies in the mix of economic policies, the expansion of the phenomenon of monetary substitution, uncertainties at the legislative and prudential level, the deterioration of investor dynamics, the structure and cost of financing the twin deficits, the risk of default on non-governmental loans, contribute to increasing the complexity of channels interaction between the banking sector, public administration and the real economy.

The motivation for researching this topic stems from a growing concern highlighted in the specialized literature, particularly among monetary authorities such as the International Monetary Fund, the European Banking Authority, the Bank for International Settlements, and the European Central Bank. This concern relates to the connection between sovereign risk and the probability of banking instability, as reflected in the potentially severe implications of shock propagation in both directions—between public finances and the financial sector—on the dynamics of the real economy.

The justification for this research lies in the vulnerability of the banking sector to sovereign risk, which has become a central topic on the agenda of monetary authorities, particularly after recent crisis episodes, given its systemic importance for the overall economy. Furthermore, banking crises—often occurring alongside other types of crises, such as financial, pandemic, or geopolitical shocks—have underscored the need to develop models based on the key determinants of the interaction between sovereign risk and the probability of banking stress episodes.

The purpose of research is to identify solutions/remedies to compress the interaction channels between sovereign risk and the probability of banking instability.

Regarding the main objectives of the paper, we capture several stages. The first objective refers to analytical framework and preventive/corrective measures and the second one is the construction of macro and micro prudential assessment tools. As a substage of this objective, we analysed the development of analytical framework for sovereign risk propagation at the credit institutions level - Model for quantifying the impact of sovereign risk on the credit institutions solvency. The third objective aims to develop a diagnosis and the substage - Quantification of the impact of extreme but plausible scenarios.

The second substage is the selection of systemic vulnerabilities for hierarchisation of systemic vulnerabilities. The fourth objective consists of proposals for preventive measures and the main substage refers to configuring the set of options at the level of the economic policy mix to mitigate the systemic risk associated with the interaction between sovereign risk and the probability of banking instability.

The research question investigates whether a dependent relationship exists between sovereign risk and the probability of banking instability, and whether increases in government bond yields negatively affect banking profitability, particularly capital adequacy.

As methodology, we use the multivariate regressions and autoregressive vector models, complemented with unifactorial and multifactorial scenarios of resilience to extreme but plausible events. We start from a model for quantifying the sovereign risk impact on the credit institutions solvency through market (interest) risk; respectively, of credit risk. The results refer to the reaction of bank profitability, which is expected to be negative, and of capital adequacy, which is reflected in the increase in government bond yields. The first part of the research aims to assess the sensitivity of banking performance to the dynamics of government bond yields.

Moreover, the results indicate that banking instability can affect the state's solvency and ability to pay its debts on time. This, in turn, has a major impact on the liquidity and solvency of credit institutions, through the lens of performance and risk indicators.

The originality of this research lies in its assessment of the potential severity of existing banking vulnerabilities through the quantification of the effects of financial and fiscal-budgetary shocks on macro-financial dynamics. Thus, capturing some scenarios on a medium time horizon, helps to identify systemic vulnerabilities to formulate proposals and preventive measures to mitigate the severity developed by the connection between sovereign risk and banking instability.

In conclusion, scenario analysis was conducted based on the forecasted results, following the European framework for stress-testing resilience to extreme but plausible events.

The paper continues with the description of the specialised literature review, the methodology and the data used, followed by the estimated results and the conclusions drawn.

## 2. LITERATURE REVIEW

Banking instability increases sovereign risk through the state's inability to honor its obligations arising from commercial relations. This implies an adequate degree of liquidity and solvency of the state and, implicitly, the balance of the state budget, external debt and current account deficit (Fouejieu, 2017). Absorption of sovereign debt issuance by the financial sector is fundamental to financial stability. Sovereign bonds are used on the financial markets, being considered high-quality liquid assets, but also of the last rank in case of low solvency. The ability of investors to absorb additional issues is an important barometer for the discipline of sovereign bond markets (Longaric et al., 2023).

In this context, financial stability can be disturbed due to absorption limits from different sectors of activity (Ortmans and Tripier, 2020). Despite the absence of net purchases of sovereign debt since June 2022 (PSPP), by the Eurosystem, it aims to reinvest maturing bonds under the pandemic emergency purchase program (PEPP) until at least 2024, according to the last Financial Stability Review (European Central Bank, 2023). However, the newly issued government debt was absorbed in 2023, according to models and empirical evidence from the literature. Thus, investors are tempted to purchase bonds, as yields are higher (Kojen, R. et al., 2021).

On the other hand, in situations of uncertainty and high volatility on the financial markets, the absorption capacity of different activity sectors, including non-bank investors or risk-averse sectors, such as insurers, tends to register a downward trend (Fache & Giuzio, 2019), with the exception of credit institutions.

Therefore, the government has strengthened its position regarding the market share of the credit institutions which are the majority of shareholders. The share of these banks' assets increased, from 5% in 2008 to 12.6% in September 2023, according to the Financial Stability Report (National Bank of Romania, 2023).

Consequently, both nationally and internationally, the importance of the interactions between fiscal policy and financial stability is emphasised, as well as the reduction of the less favorable impact of sovereign risk on the solvency of credit institutions, as a result of the strong connection (Holopainen and Sarlin, 2017).

More than that, the interaction between the banking crisis likelihood and the sovereign risk premium are captured using macro and micro prudential assessment tools (Balima, Combes, & Minea, 2017). The crises identification, based on quantitative approaches, can also be substantiated by using a financial stress index, recommended by national and European authorities (European

[Banking Authority, 2023](#)). This approach ensures a more precise definition of the crisis period and allows the adjustment and separation of the crisis period and the post-crisis period, facilitating the model estimation and calibration.

External and internal imbalances can affect the accuracy of the data set, and this information is fundamental in selecting the relevant set of events for calibrating or estimating models designed to study specific aspects of banking crises ([Wijayanti and Rachmanira, 2020](#)). Thus, based on the CDS quotes, together with other specific determining factors, the dynamics of economic growth and the probability of a banking crisis are forecasted.

The macroeconomic context, following the pandemic crisis ([Ortmans and Tripier, 2020](#)), armed conflicts, combined with the high level of uncertainty in the market, led to the development of adverse scenarios that surprised the ability of the banking sector to cope with losses.

Systemic risk can be influenced by the bonds demand and supply on the financial markets. The Eurosystem has stopped net purchases of sovereign debt since June 2022 (PSPP), but government debt continues to be absorbed until 2023. Thus, in the first half of the year, banks, investment funds, pension funds and households register an upward trend in the sovereign bonds purchase from the euro area, opposite the effect observed in the insurance companies.

The European Banking Authority, in cooperation with the Systemic Risk Board (SRB), develops and coordinates EU-wide stress tests to assess the resilience of the banking sector to shocks, capturing EU-wide systemic risk. The methodology used assumes the existence of two macro-financial scenarios - basic, which contains the narrative part and adverse, which captures the severity of the phenomenon - which the banks use in order to carry out the testing exercise. The central (basic) macro-financial scenario for EU countries is based on historical data and projections from December 2020, carried out by central banks (ECB, 2021). The adverse scenario involves the development of hypothetical situations of the triggering and materialisation of the European banking sector risks in order to identify and prioritise systemic vulnerabilities. At the same time, it reflects the concerns of the monetary authorities regarding the developments of the Covid-19 pandemic, with a negative impact on the population confidence and refers to a low interest rates environment, when negative shocks accentuate and prolong the economic contraction.

The stress test involves making a diagnosis, based on scenarios that capture the potential trends in economy and not necessarily the potential negative shocks assessment on the financial system ([Longaric et al., 2023](#)).

The methodology proposed by the EBA contains scenarios with information on the dynamics of real GDP, interest rates, the unemployment rate, the inflation rate, the shares price and extends over a 3 years' time horizon, respectively 2021-2023.

The exercise tests the adverse scenarios impact on the EU banks' solvency, in the sense that they are able to build up enough buffers to cover losses for the economy recovery in times of stress. Its results help to develop strategies that allow exit from the flexibility measures granted to banks during the pandemic or additional measures if the macroeconomic context deteriorates more (Garcia et al., 2021). The baseline scenario contains the EU national central banks projections, and the adverse scenario captures the manifestation of the main financial stability risks.

In order to test the banking sector resilience in the European Union, on a common macroeconomic basis, the monetary authorities (EBA, ECB, ESRB) propose a series of scenarios, covering the period 2021-2023. Despite the low level of interest rates, the severity of the contraction both globally and at the EU level of economic activity, in the adverse scenario, leads to a significant equity revaluation. In 2021, stock prices dropped sharply by 50% in advanced economies and by 65% in emerging economies. According to the EBA (2021), the recovery appeared, to some extent, between 2022 and 2023, so in 2023 share prices were still 35% below their starting point. The increase in the asset revaluation margin is limited to a proportion of the spreads increase in sovereign bonds (Ardakani, Kishor & Song, 2018).

In the following, a model will be developed to quantify the impact of sovereign risk on the solvency of credit institutions through the lens of market (interest) risk and credit risk, respectively. The reaction of bank profitability, which is expected to be negative, and of capital adequacy, respectively, to the upward change in government bond yields is captured.

The hypotheses aim to assess the sensitivity of banking performance to the evolution of government bond yields through the lens of: (i) market (interest) risk and (ii) credit risk and capture the negative reaction of banking profitability and, implicitly, capital adequacy to the increase in government bond yields.

In other words, we evaluate the consequences of changing the sovereign risk premium on the value of government securities portfolios, as well as on the quality of the loan portfolio (non-performing loan rate), due to the increase in the cost of financing and the impact on repayment capacity, along with the negative effect on economic development.

Some of the systemic vulnerabilities caught by the European Banking Authority are also identified in the current research. The research aims to make a diagnosis, by running scenarios similar in profile to those applied in the European exercise to test resilience to extreme but plausible events.

### 3. MATERIALS AND METHODS

#### A. Methodology and estimates in order to capture sovereign risk impact quantification on credit institutions solvency

The methodological framework involves the use of multivariate regression on *annual panel data* to study the multidimensional impact of the variation in government bond yields on bank profitability, as a result of the effects on the government bond and bank portfolios.

The main mechanism through which sovereign risk affects bank solvency is considered, namely the channel represented by the quality of bank assets, expressed by the rate of non-performing loans under the impact of economic growth, which in turn is influenced by the dynamics of the sovereign risk premium (Beutel, List & von Schweinitz, 2018).

The aim of the paper is to identify, based on annual panel data for 28 countries in the European Union, starting with the year 2005, with a number of 349 observations, respectively 400 observations recorded, the main vulnerabilities to macroeconomic stability by running unifactorial (first model) and multifactorial models (second model) of resilience to extreme but plausible events. The results obtained in this way will facilitate the configuration of the set of options at the level of the economic policy mix to mitigate the systemic risk associated with the interaction between sovereign risk and the probability of banking instability.

The scope of the analysis is to capture systemic vulnerabilities, the consequences of the change in the sovereign risk premium on the value of government securities portfolios, as well as on the quality of the credit portfolio (non-performing loans rate), due to the increase in the cost of financing, and the impairment of repayment capacity, along with the negative effect, is evaluated on economic development.

As exogenous variables for the explanatory model of the non-performing loans rate (BANK\_NONPERFORMING\_LOANS), we consider, in the first instance, factors such as: economic growth (GDP\_GROWTH), the unemployment rate among young people (YOUTH\_UNEMPLOYMENT\_RATE), the ratio of loans to deposits (LOANS\_TO\_DEPOSITS\_RATIO) (*first regression model on panel data, with 349 observations*) (Table 1).

**Table 1:** Description of indicators - first part

Variables	Specification	Data source
The dependent variable		
BANK_NONPERFORMING_LOANS	Bank nonperforming loans to total gross loans (%) (quality of the credit portfolio)	World Bank
The independent variable		
GDP_GROWTH	GDP growth (%) (real GDP variation)	Eurostat
YOUTH_UNEMPLOYMENT_RATE	Youth unemployment rate-% of active population aged 15-24 (3 year change in p.p)	World Bank
LOANS_TO_DEPOSITS_RATIO	Loans to deposits ratio (%)	European Central Bank

Source: European Central Bank, Eurostat, World Bank

These variables are complemented with the interbank interest rate (INTERBANK\_RATES), modeled in turn, through a link function, based on the dynamics of government bond yields (GOVERNMENT\_BOND\_YIELD), the monetary policy interest rate (CENTRAL\_BANK\_POLICY\_RATE) and other exogenous factors (*the second panel data regression model, with 400 observations*).<sup>1</sup>(Table 2)

**Table 2:** Description of indicators - second part

Variables	Specification	Data source
The dependent variable		
INTERBANK_RATES	Interbank Rates for the Euro Area (%)	European Central Bank, Federal Reserve
The independent variable		
GOVERNMENT_BOND_YIELD	Long-term government bond yield (%)	Eurostat
CENTRAL_BANK_POLICY_RATE	Central bank policy rates (euro area) (%)	Bank for International Settlements, International Monetary Fund

Source: Bank for International Settlements, European Central Bank, Eurostat, Federal Reserve, International Monetary Fund

<sup>1</sup> Starting with 2005, but some data are missing due to their distortion, during the pandemic crisis.

The data were taken at the European level from official websites, such as: Bank for International Settlements (BIS), European Central Bank (ECB), Eurostat (EU), Federal Reserve (FD), International Monetary Fund (IMF), World Bank (WB).

The description of the regression equation, by using EViews 8 on panel data, can be summarized as follows (for both estimates):

$$y_{it} = \alpha + X'_{it}\beta + \mu_i + \vartheta_{it}, \quad i=1, \dots, N; \quad t=1, \dots, T^2,$$

The econometric application can estimate two types of models: the fixed effect model or the random effect model. In order to select the best model, we applied the Hausman test, whose hypotheses (Baltagi, 2008) are: a) null hypothesis ( $H_0$ ): the random effect model is appropriate; b) alternative hypothesis ( $H_1$ ): the fixed effect model is appropriate. Therefore, if the test probability (p-value) registers a statistically significant value, we will use the fixed effect model, otherwise the random effect model is appropriate.

In order to obtain a valid model, on which decisions can be based, we analysed only the statistically significant coefficients, taking into account a significance threshold of 1%, 5%, and, respectively, 10% and the stationary ones, being expressed in percentages<sup>3</sup>(Baltagi, 2008).

#### 4. ESTIMATION RESULTS AND DISCUSSIONS

Results are based on descriptive characteristics (natural logs) of the exogenous variables for the explanatory model of the non-performing loan rate respectively: economic growth, youth unemployment rate and loan-to-deposit ratio (Table 3). We add to these the interbank interest rate, modeled in turn, through a link function, based on the dynamics of government bond yields, the monetary policy interest rate and other exogenous factors.

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2 Where:  $i$  = cross-sectional size of the sample,  $t$  = time (time series size),  $\alpha, \beta$  = coefficients of the equation,  $X_{it}$  = observation of exogenous variables,  $u_{it}$  = individual specific unobservable effect and  $\vartheta_{it}$  = residue (remainder disturbance).

3 Probabilities for Fisher tests are computed using an asymptotic Chi.

**Table 3:** Descriptive statistics - first part

	GDP_GROWTH	YOUTH_ UNEMPLOYMENT_ RATE	LOANS_TO_ DEPOSITS_RATIO
Mean	0.020732	-0.001120	1.261367
Median	0.022734	-0.009000	1.149715
Maximum	0.251625	0.296000	3.257310
Minimum	-0.148142	-0.196000	0.592471
Std. Dev.	0.036441	0.082173	0.509747
Skewness	-0.103144	0.760608	1.681422
Kurtosis	9.644254	4.253177	6.024941
Jarque-Bera	642.5769	56.48784	297.5077
Probability	0.000000	0.000000	0.000000
Sum	7.235416	-0.391000	440.2171
Sum Sq. Dev.	0.462137	2.349863	90.42513
Observations	349	349	349

Source: Author’s calculations, using EViews

In order to capture the statistical significance of the regression equation, we eliminated the indicators with strong correlations. Therefore, we identified the linear correlation coefficient for the financial indicators used, highlighting the presence or absence of linear dependence between the variables of the regression model, the direction of the dependence and the intensity (Table 4).

**Table 4:** Correlations matrix - first part

	GDP_GROWTH	YOUTH_ UNEMPLOYMENT_ RATE	LOANS_TO_ DEPOSITS_RATIO
GDP_GROWTH	1		
YOUTH_ UNEMPLOYMENT_ RATE	-0.4730	1	
LOANS_TO_ DEPOSITS_RATIO	-0.1814	0.2007	1

Source: Author’s calculations, using EViews

The *F-statistic test*, as well as the probability associated with it, is another important element that helps explain the model. Thus, the probability does not exceed the 5% significance level and thus we say, with a 95% probability, that

the model is valid. In other words, there is at least one independent variable that can explain the variation of the dependent variable. With the help of this test, it is verified that the regression model is correctly specified.

The results of the estimates are captured in Table 5.

**Table 5:** The regression equation - first part

Dependent Variable: BANK\_NONPERFORMING\_LOANS

Method: Panel Least Squares

Cross-sections

Total panel (unbalanced) observations: 349

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP_GROWTH	-0.274249	0.128761	-2.129908	0.0339
YOUTH_UNEMPLOYMENT_RATE	0.195736	0.057321	3.414740	0.0007
LOANS_TO_DEPOSITS_RATIO	-0.028092	0.008278	-3.393377	0.0008
C	0.104516	0.011775	8.876243	0.0000
R-squared	0.089155	Mean dependent var	0.063177	
Adjusted R-squared	0.081234	S.D. dependent var	0.080052	
S.E. of regression	0.076732	Akaike info criterion	-2.285602	
Sum squared resid	2.031288	Schwarz criterion	-2.241418	
Log likelihood	402.8376	Hannan-Quinn criter.	-2.268013	
F-statistic	11.25633	Durbin-Watson stat	0.129727	
Prob(F-statistic)	0.000000			

Source: Author's calculations, using EViews

Economic growth and the loan-to-deposit ratio have an opposite effect on the non-performing loans dynamics, a fact that is also reflected in the economic reality, in that the well-being of the economy, expressed through economic growth, can also be reflected by a reduction in the non-performing loans rate. On the other hand, a high rate of unemployment among young people can determine the reduction of the ability to repay bank loans and, at the same time, the banking crises appearance, through an increase in the non-performing loans volume. Therefore, there is a direct relationship between debtors, who become insolvent, as a result of the increase in the unemployment rate, and the banks bankruptcy, which fail to adequately manage bank assets and liabilities.

We add to these results the interbank interest rate, which is modeled through a link function, based on exogenous factors, as the government bond yields and the monetary policy interest rate, whose characteristics are found in Table 6.

**Table 6:** Descriptive statistics - second part

	GOVERNMENT_ BOND_YIELD	CENTRAL_BANK_ POLICY_RATE
Mean	0.035130	0.052010
Median	0.034733	0.010000
Maximum	0.224983	5.770000
Minimum	-0.002525	-0.007292
Std. Dev.	0.025068	0.401893
Skewness	1.922291	12.09623
Kurtosis	12.59526	153.6466
Jarque-Bera	1780.831	387994.5
Probability	0.000000	0.000000
Sum	14.05185	20.80403
Sum Sq. Dev.	0.250729	64.44554
Observations	400	400

Source: Author's calculations, using EViews

In order to obtain valid results, we applied the correlation matrix (Table 7), taking into account the confidence interval (-0.5; 0.5):

**Table 7:** Correlations matrix - second part

	GOVERNMENT_ BOND_YIELD	CENTRAL_BANK_ POLICY_RATE
GOVERNMENT_ BOND_YIELD	1	0.0759
CENTRAL_BANK_ POLICY_RATE	0.0759	1

Source: Author's calculations, using EViews

The Table 7 shows that the values are found in the range, and that these are not strongly correlated in such a way that the steps can be continued.

**Table 8:** Hausman test

Correlated Random Effects - Hausman Test

Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	0.128453	2	0.9378

Source: Author’s calculations, using EViews

Next, we used the Hausman test to select the appropriate model (Table 8). According to the Hausman test, the random-effects model is suitable for estimating the equation. Due to the probability value, which is statistically significant ( $p\text{-value} > 0.05$ ), we accept the null hypothesis and reject the alternative hypothesis; thus, we can state that the appropriate model for estimation is the random-effects model.

**Table 9:** Multivariate regression - second part

Dependent Variable: INTERBANK\_RATES

Cross-sections

Total panel (unbalanced) observations: 400

Swamy and Arora estimator of component variances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GOVERNMENT_ BOND_YIELD	0.380177	0.039841	9.542346	0.0000
CENTRAL_BANK_ POLICY_RATE	0.008227	0.002452	3.355202	0.0009
C	0.003283	0.00234	1.402787	0.1615
Effects Specification				
Cross-section random			0.008626	0.1996
Idiosyncratic random			0.017274	0.8004
Weighted Statistics				
R-squared	0.21151	Mean dependent var		0.007899
Adjusted R-squared	0.207538	S.D. dependent var		0.019375
S.E. of regression	0.017233	Sum squared resid		0.117899
F-statistic	53.24694	Durbin-Watson stat		0.561109
Prob(F-statistic)	0			
Unweighted Statistics				
R-squared	0.235617	Mean dependent var		0.017057
Sum squared resid	0.144817	Durbin-Watson stat		0.473531

Source: Author’s calculations, using EViews

The estimation results (Table 9) of the interbank interest rate dynamics, based on exogenous variables as government bond yields and the monetary policy interest rate capture the reaction of bank profitability and, implicitly, capital adequacy to the increase in government bond yields.

Both the increase in the monetary policy rate and the yield of government securities show a change, in the same sense, on the interbank interest rate. This fact can have repercussions in both directions. On the one hand, a debt-financed economy can lead to the triggering of banking crises. On the other hand, adequate management in ensuring the balance between bank liabilities and assets offsets its burden.

In conclusion, the existence of a consistent amount of sovereign bonds in the bank balance sheet can mean the development of an ample channel for propagating fiscal-budgetary vulnerabilities at the banking stability level and, subsequently, through financial intermediation, at the real economy level.

## **B. Methodology and estimates for quantifying impact scenarios and finding solutions to compress the interaction between sovereign risk and banking instability**

Starting from a quantifying model for the banking crises likelihood and an explanatory model for the sovereign risk premium trend based on the estimates, made available by the European Banking Authority, regarding the residential real estate prices indicator, respectively the GDP deviation, we quantified the impact of some extreme but plausible scenarios, taking into account the interaction model of economic growth, sovereign risk and the banking crisis likelihood. In this sense, the dependent variable reactions to an unexpected shock are reproduced at the explanatory variables level, starting from the two scenarios: basic and adverse.

The methodology used assumes the existence of two macro-financial scenarios: basic, which contains the narrative part, and adverse, which captures the severity of the phenomenon. The research relevance lies in the potential solutions analysis, starting from the vulnerabilities diagnoses presented by the macro and microprudential indicators, at the European Union level. One scenario captures the negative reaction of bank profitability and, implicitly, capital adequacy to the increase in government bond yields, similar to the stress test exercise coordinated by the European Banking Authority.

Therefore, the methodological framework assumes, based on the macroprudential and microprudential assessment tools, built on econometric bases, using multivariate regressions and autoregressive vectors, the creation of two scenarios (basic and adverse) on annual panel data for 28 countries in the European Union, starting with the year 2005, with a number of 448 observations recorded, with the help of ANOVA, respectively EViews 8. The data source refers to official websites, such as: World Bank, International Monetary Fund, European Central Bank, Federal Reserve and Bank for International Settlements.

In order to obtain the data robustness, significant indicators were selected, whose standard error is relatively small and insignificant, or whose t-statistic value falls within the confidence interval, all indicators being *stationary* in level (expressed in percentages). The optimal number of lags is checked, as being equal with 2, according to the table below (Table 10):

**Table 10:** Lag Order Selection Criteria

VAR Lag Order Selection Criteria

Endogenous variables: PD CDS GDP

Exogenous variables: C

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-281.036	NA	0.000662	1.19343	1.219682	1.203753
1	-73.1074	412.3632	0.000287	0.357594	0.462605*	0.398886
2	-55.9086	33.89175*	0.000277*	0.323145*	0.506914	0.395406*

\* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Source: Author's calculations, using EViews

After estimating the indicators, by using autoregressive vector model - VAR, in the *baseline scenario*, the first results can be seen in Table 11.

**Table 11:** Estimation results with VAR model equation - baseline scenario

Vector Autoregression Estimates			
Standard errors in ( ) & t-statistics in [ ]			
	PD	CDS	GDP
PD(-1)	0.675343 -0.04447 [ 15.1851]	0.404726 -0.20619 [ 1.96289]	0.016179 -0.00584 [ 2.77093]
PD(-2)	0.001291 -0.04407 [ 0.02930]	-0.21805 -0.20431 [-1.06727]	<b>-0.02458</b> <b>-0.00579</b> <b>[-4.24901]</b>
CDS(-1)	-0.00638 -0.00984 [-0.64837]	0.179546 -0.04561 [ 3.93626]	<b>-0.00806</b> <b>-0.00129</b> <b>[-6.23866]</b>
CDS(-2)	-0.01078 -0.01018 [-1.05898]	-0.01211 -0.0472 [-0.25652]	-0.00144 -0.00134 [-1.07562]
GDP(-1)	0.5842 -0.34186 [ 1.70888]	2.830979 -1.58493 [ 1.78619]	<b>0.333263</b> <b>-0.04488</b> <b>[ 7.42529]</b>
GDP(-2)	-0.88585 -0.35839 [-2.47173]	2.097438 -1.66157 [ 1.26232]	-0.08443 -0.04705 [-1.79442]
C	0.127869 -0.02244 [ 5.69938]	0.095457 -0.10402 [ 0.91772]	<b>0.021048</b> <b>-0.00295</b> <b>[ 7.14571]</b>
R-squared	0.460791	0.066239	0.236963
Adj. R-squared	0.453893	0.054293	0.227201
Sum sq. resids	42.09772	904.8473	0.725611
S.E. equation	0.299601	1.388997	0.039334
F-statistic	66.7989	5.544936	24.27487
Log likelihood	-98.1638	-828.294	868.2911
Akaike AIC	0.441865	3.509637	-3.61887
Schwarz SC	0.503121	3.570893	-3.55761
Mean dependent	0.412446	0.328471	0.018692
S.D. dependent	0.405419	1.428311	0.044744
Determinant resid covariance (dof adj.)		0.000265	
Determinant resid covariance		0.000254	
Log likelihood		-55.9086	
Akaike information criterion		0.323145	
Schwarz criterion		0.506914	

Source: Author's calculations, using EViews

In the *adverse scenario*, the estimations are shown in Table 12.

**Table 12:** Estimation results with VAR model equation - adverse scenario

Vector Autoregression Estimates			
Standard errors in ( ) & t-statistics in [ ]			
	PD	CDS	GDP
PD(-1)	0.647419	0.476935	<b>0.361668</b>
	-0.04453	-0.20898	<b>-0.0866</b>
	[ 14.5393]	[ 2.28222]	[ <b>4.17649</b> ]
PD(-2)	-0.03082	-0.25813	0.101014
	-0.04417	-0.2073	-0.0859
	[-0.69775]	[-1.24525]	[ 1.17596]
CDS(-1)	-0.01027	0.191933	-0.00065
	-0.00971	-0.04556	-0.01888
	[-1.05826]	[ 4.21258]	[-0.03457]
CDS(-2)	-0.01622	-0.03931	0.016628
	-0.00968	-0.04543	-0.01882
	[-1.67591]	[-0.86543]	[ 0.88337]
GDP(-1)	0.069488	0.111894	<b>0.363255</b>
	-0.02698	-0.12661	<b>-0.05247</b>
	[ 2.57566]	[ 0.88374]	[ <b>6.92361</b> ]
GDP(-2)	0.014746	0.020487	-0.47578
	-0.04049	-0.19002	-0.07874
	[ 0.36420]	[ 0.10782]	[-6.04247]
C	0.167141	0.187615	<b>-0.37075</b>
	-0.02421	-0.11364	<b>-0.04709</b>
	[ 6.90261]	[ 1.65097]	[ <b>-7.87335</b> ]
R-squared	0.462444	0.058513	0.201699
Adj. R-squared	0.455567	0.046468	0.191486
Sum sq. resids	41.7659	919.8959	157.9551
S.E. equation	0.298418	1.400499	0.580337
F-statistic	67.24443	4.857991	19.74964
Log likelihood	-96.2804	-832.219	-412.875
Akaike AIC	0.433951	3.526132	1.764182
Schwarz SC	0.495207	3.587388	1.825438
Mean dependent	0.413487	0.308193	-0.19556
S.D. dependent	0.404438	1.434218	0.645412
Determinant resid covariance (dof adj.)		0.0572	
Determinant resid covariance		0.054714	
Log likelihood		-1334.7	
Akaike information criterion		5.696224	
Schwarz criterion		5.879993	

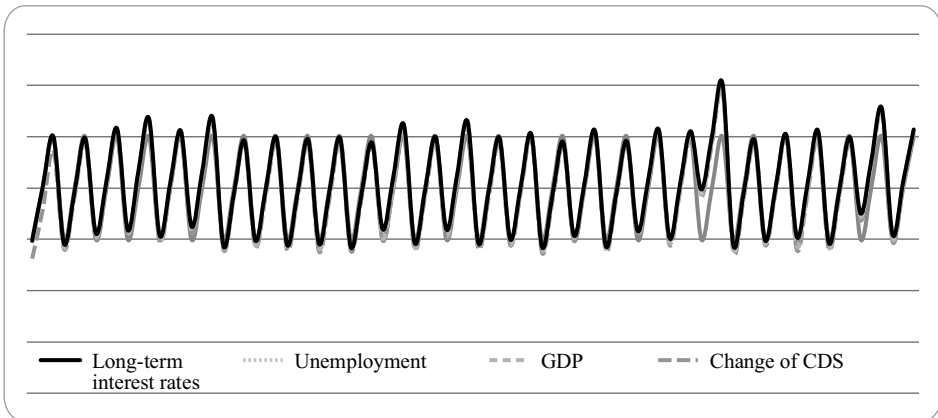
Source: Author's calculations, using EViews

After refining the model, the main conclusions are drawn regarding the GDP index dynamics in relation to the chosen variables.

## 5. ESTIMATED RESULTS AND DISCUSSIONS

Within the model for quantifying the banking stability dependence on sovereign risk, the residential real estate prices impact on the banking crisis likelihood shows a positive effect, which, quantified on the two scenarios, results in similar values.

In the base scenario (Figure 1), residential real estate prices remain at a high level, registering positive values, which is why the probability of a banking crisis maintains a positive trend.



**Figure 1:** Macroeconomic indicators dynamics - Baseline scenario

Source: Author's calculations, using Anova and EViews

On the other hand, the adverse scenario (Figure 2) assumes negative values for residential real estate prices, which generates relatively lower values in the event of a banking crisis. Paradoxically, negative values suggest an unfavorable framework, but, in correlation with positive coefficients, determine a decrease in the banking crises likelihood, in the short term. It is important to mention that the attempt to identify an adequate mechanism for determining the probability of default, especially with the help of empirical evaluations, faces various difficulties, such as: unpredictable developments, data from extreme phenomena (for example: the pandemic crisis), continuous attempts at macroeconomic stabilisation, difficult for emerging countries, due to the lack of interconnection etc.

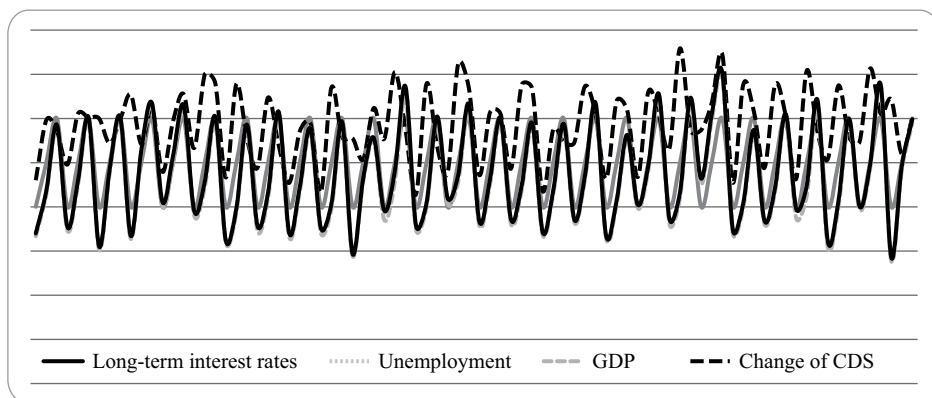


Figure 2: Macroeconomic indicators dynamics - Adverse scenario  
Source: Author's calculations, using Anova and EViews

The dynamics of sovereign risk is highlighted, both through the dependence on banking stability and through the influence of GDP dynamics, but also its deviation. Compared to the base scenario, the adverse scenario registers negative values, quantified on the basis of a direct relationship in the same sense, and develops an apparently favorable framework. However, it is necessary to take into account several vulnerabilities. They refer to the contraction accentuation of the global economy and, implicitly, a decrease in the population confidence, followed by a decrease in GDP and the registration of an unemployment upward rate. Thus, a downward trend could generate reduced corporate earnings, combined with a reevaluation of participants' expectations of the market, causing a revaluation of asset prices and, implicitly, a decrease in the house price index.

The banking crises imposed the need to capture, in the most refined form, the banking system vulnerabilities. Early warning indicators help in capturing signals that predict, in due time, the probability of a banking crisis. In addition to these, the sovereign risk, captured by CDS 5Y, proved to have a major impact on the probability of default, influencing, in a negative sense, economic growth.

In the baseline scenario, the results indicate, in the first phase, a negative impact of the banking crisis likelihood on the economic growth, following the harmful effects, felt with a delay, propagated by the banking instability. An evolution in the opposite direction also appears between the sovereign risk premium and the gross domestic product, a fact that has its explanation in the high costs of public debt. On the other hand, there is an inertia effect in the GDP dynamics, its past evolutions having a positive effect on the present evolutions. This fact also has its counterpart in economic reality, as the effects of changes in the gross domestic product in an economy appear over time.

$$GDP = 0.021048 - 0.02458*PD(-2) - 0.00806*CDS(-1) + 0.333263*GDP(-1)$$

In the adverse scenario, the same inertia appears in the GDP dynamics, the effects remaining with one lag delay. On the other hand, in the opposite scenario compared to the basic scenario, there is a relationship, of the same sign, between the banking crisis likelihood and economic growth. Moreover, an additional argument refers to the rapid recovery of the economy, after the onset of the pandemic crisis, including armed conflicts, which surprised economies much better prepared, in terms of financial health indicators, than in the period before the global financial crisis.

$$GDP = -0.37075 + 0.361668*PD(-1) + 0.363255*GDP(-1)$$

Generally, across all scenarios, the magnitude of the coefficients and their inverse effects may indicate a slowdown in economic growth, while increases in risk premiums challenge debt sustainability in both the public and private sectors in the EU, further highlighting the link between sovereign risk and the probability of banking instability.

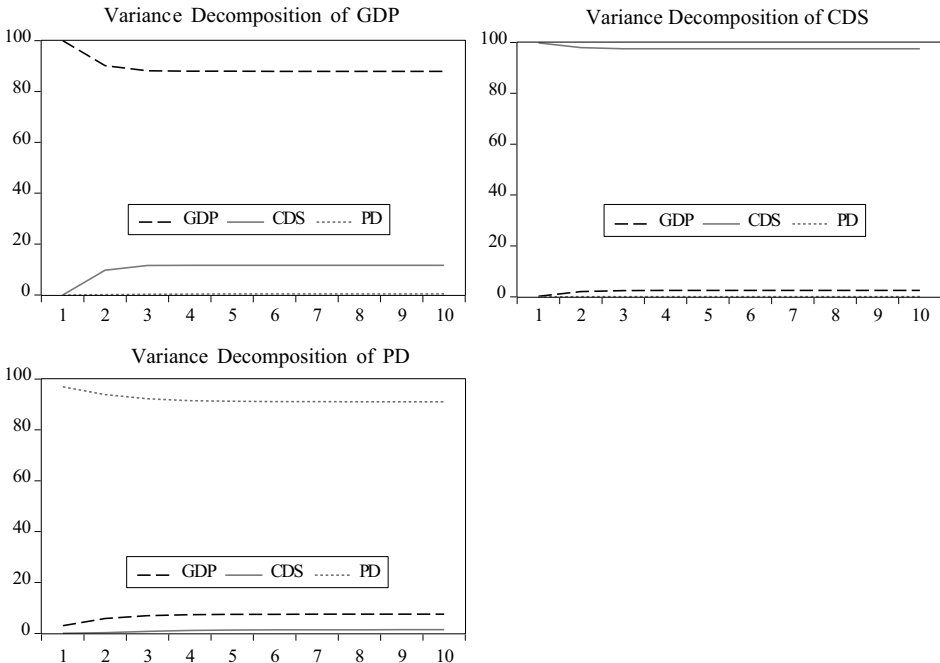
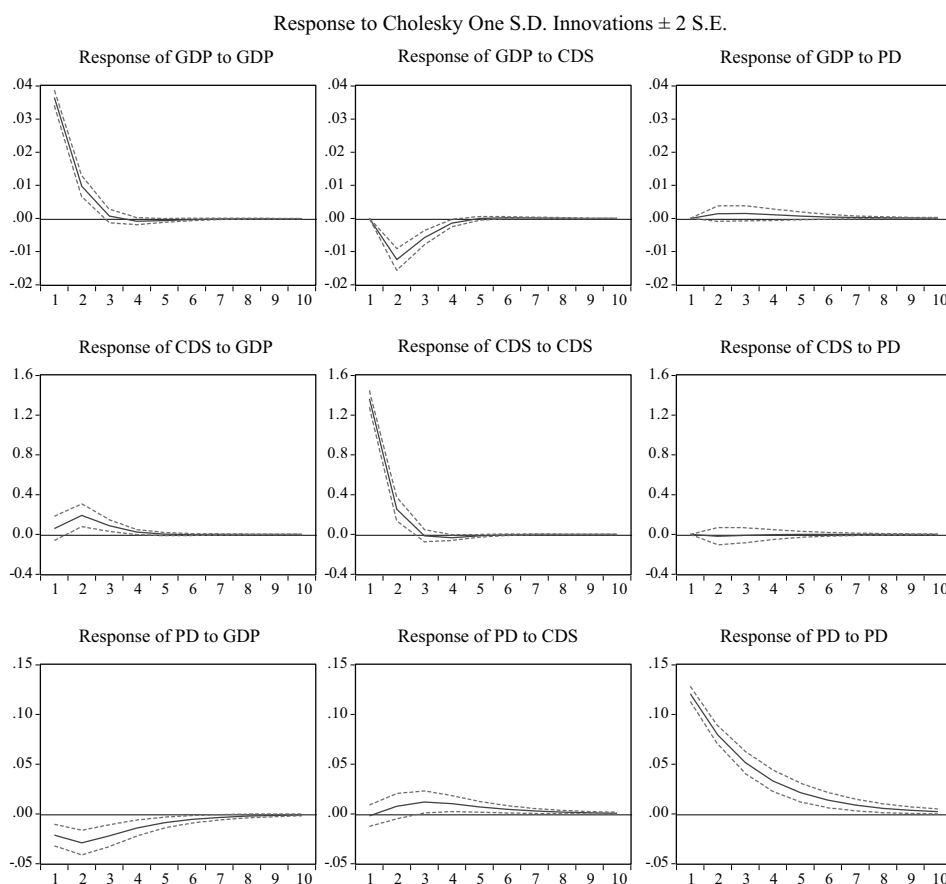


Figure 3: Variance Decomposition - Baseline Scenario  
 Source: Author's calculations, using EViews

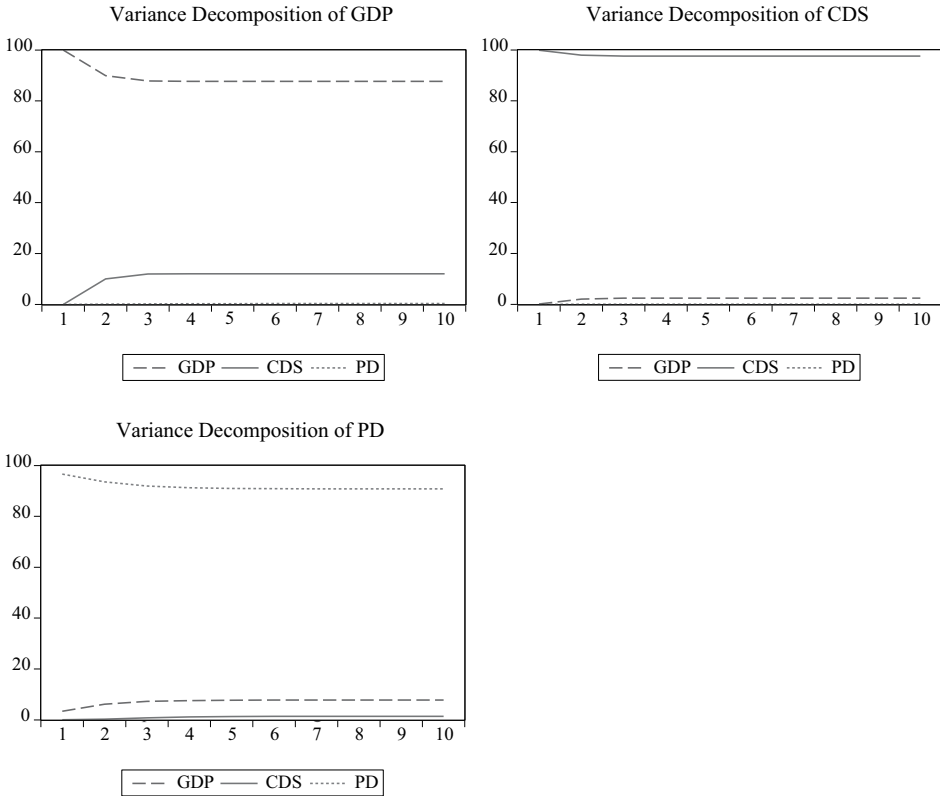
Next, the variance decomposition (Figure 3) captures the relative importance of external shocks in explaining the dependent variable trend. In the base scenario, CDS dynamics explain about 15% of the GDP variation, and in the adverse scenario, the dependent variable can be explained by the PD variation, the effect being visible, starting with the 2nd year, while about 90% of its own changes are found in GDP dynamics.

The similarity of results across the two scenarios can be explained by the relatively short forecast period compared with the historical data period, as well as by data limitations or distortions caused by the pandemic.



**Figure 4:** Impulse-response functions - Baseline scenario  
Source: Author's calculations, using EViews

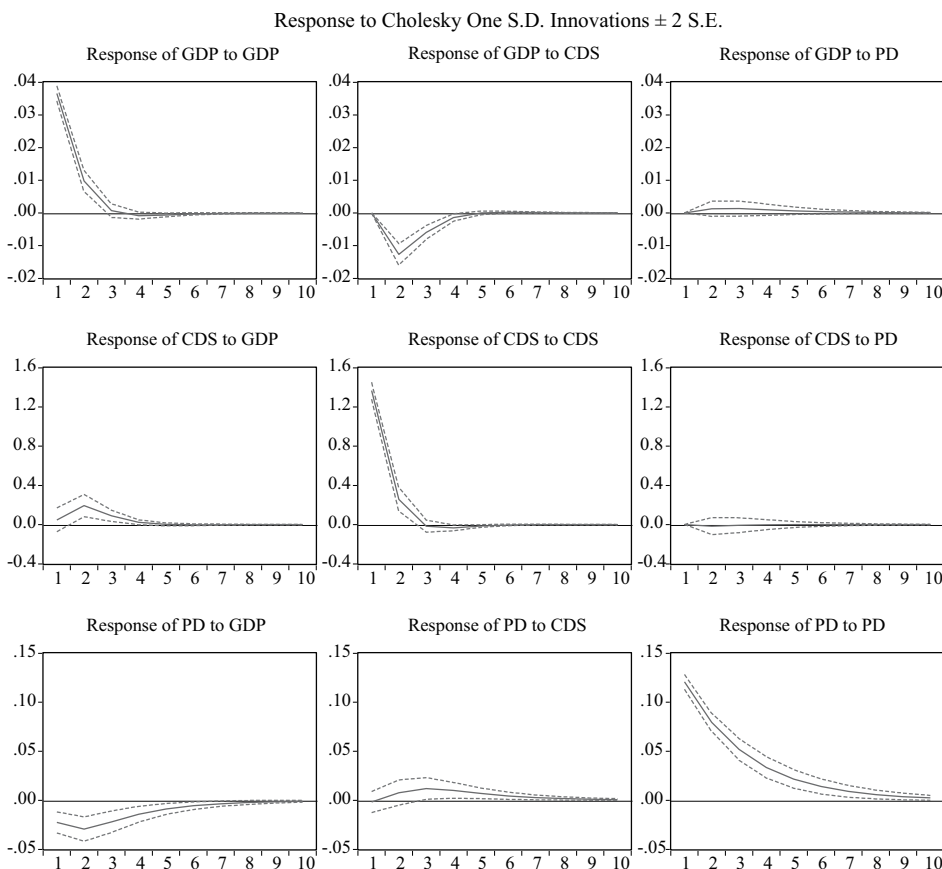
Moreover, we followed the dependent variable reaction to an unexpected shock at the explanatory variables level, using the impulse-response function (Figure 4). In baseline scenario, it is observed that in the case of applying a negative shock to the CDS, GDP will register the most significant reaction in the first 1-2 years, while the influence of PD is the least in the 3–5-year interval.



**Figure 5:** Variance Decomposition - Adverse Scenario

Source: Author’s calculations, using EViews

In the adverse scenario, the relationship between the probability of banking crisis and the economic growth is accentuated, therefore, the increase in the banking crisis likelihood shows an effect of diminishing the economic growth, significant from a statistical point of view, after approximately 1 year, reaching a peak after 2 years, after which the shock effect starts to dilute. After 4-6 periods it becomes asymptotically towards 0 (Figure 5).



**Figure 6:** Impulse-response functions - Adverse scenario  
Source: Author's calculations, using EViews

However, the most pronounced influence on the GDP variable is presented by the CDS dynamics (Figure 6). The increase of the risk premium causes a change, in the opposite direction, of the economic growth indicator, reaching a maximum after 2 years, at which time the shock effect on GDP begins to dilute, and after 5-6 periods it becomes asymptotically towards 0. The strong influence between these CDS and GDP variables reinforces the idea mentioned above, further emphasising the connection between sovereign risk and banking instability, a visible effect also in adjacent macroeconomic indicators case, such as: long-term rates, unemployment etc., for the next period, respectively until 2025.

The adverse scenario is severe, starting from the declining macroeconomic dynamics, following the severe recession induced by the pandemic crisis and armed conflicts.

## 6. CONCLUSIONS

The banking sector is closely interconnected with the sovereign, with effects propagating in both directions and significant consequences for the real economy. To mitigate the interaction between sovereign risk and the probability of banking instability, measures are being considered to reduce the state's reliance on bank financing and the banks' reliance on the stability and yields of sovereign bonds.

The attractiveness of government securities investments leads credit institutions to invest in these financial instruments, especially from the perspective of the trinomial profitability - liquidity – the cost of capital.

However, heightened sovereign risk can lead to a decline in the value of banks' asset portfolios and, through the bank solvency channel, may result in a reduction in credit availability for firms, households, and other economic agents.

This part of the research results underlines the idea according to which a significant tendency towards the growth of the portfolio of government bonds can lead to an effect of credit eviction for the private sector, having negative consequences on the potential growth in the economy.

Moreover, the governmental burden reduction by the credit institutions appears as a necessity, considering the insolvency and liquidity unfavorable level, described in the bank balance sheet.

It is also observed that vulnerable credit institutions tend to increase their share of government bonds in total banking assets, as yields increase.

In this sense, the monetary authorities are trying to maintain balance on the market by restoring the risk weights for the public administration exposures, or even by changing the requirements to limit large exposures, with an emphasis on dosage and cadence, in order to avoid procyclicality and, implicitly, macroeconomic instability.

To reduce the unfavorable impact on the credit solvency of institutions, decreasing their sovereign exposures can be a plausible solution, by revising the liquidity requirements.

However, this solution would not be possible without the additional capital necessary to accommodate the losses from the periods of public debt crises, provided in advance by the vulnerable banks. On the contrary, the buffers lack can damage private sector lending and, implicitly, amplify the imbalance of public finances, affecting the real economy.

On the other hand, the dynamics of investors' behavior should not be influenced in any way, regardless of the fact that the risk level depends on a bond price.

Consequently, facilitating the request for additional capital for systemic risk, as a fundamental element in the macroprudential policy scope, may constitute another element that could contribute to mitigating the unfavorable impact of sovereign risk on the credit institutions liquidity and solvency.

Regarding the main vulnerabilities that threaten the financial sector stability, it is, by far, the pandemic crisis and armed conflicts, which affect the proper development of the economy branches. The longer the duration of the crisis, the more attention is needed on the non-performing loans dynamics and, implicitly, the provisions establishment. The losses recognition, at an early stage, is beneficial for maintaining the balance sheets transparency and, also, the adequate support of the non-financial sectors lending.

However, regarding the banking sector, the pandemic and armed conflicts have shown that the economy was much better prepared than prior to the global financial crisis, as evidenced by prudential indicators remaining within moderate-to-low risk ranges, in line with European Banking Authority standards (NPL rate, provision coverage, capital adequacy ratio).

Moreover, maintaining balance and financial stability, at the European Union member states level, represents one of the main objectives of international financial institutions in the sense of reducing the tensions caused by the close connection between the sovereign and the banking sector stability.

Although the eurozone states are trying to adjust the dependence between banks and sovereign risk, the political decision-makers are trying different methods, also related to the prudential field, which will affect the economies of all the countries belonging to the European Union.

In this sense, reforms were also taken into account, regarding different categories of risk exposures, placed in a credit institution, as well as the revision of liquidity requirements in order to reduce sovereign exposures from the banks (ECB, 2023).

Moreover, the fundamental causes of systemic risk, due to the association of sovereign risk and banking instability, are taken into account, such as: public finances situation. As a result, the restructuring of an adequate fiscal-budgetary policy can represent one of the potential solutions. In other words, as government liabilities are reduced, the risk of investing in government bonds can be reduced, as well as the financial resource cost in the economy.

Another preventive measure to mitigate sovereign risk is the implementation of macroprudential policies, which may require capital buffers to address systemic risk.

Consequently, recent experience such as the collapse of Silicon Valley Bank, one of the most important American financial institutions, has proven, once again, that government bonds are quite risky and that regulations on capital requirements for bank exposures to sovereign risk need to be revised in order to reduce the connection between sovereign risk and banking instability.

As future research directions, the paper aims to analyse a wider range of indicators to reduce possible limitations of research on econometric model statistics. Moreover, the database can also be extended to countries outside the European Union, in particular, those of the United States, in order to make comparisons and derive some solutions for ensuring and maintaining the well-being of economies.

The potential severity assessment of vulnerabilities associated with the substantial connection between sovereign risk and banking instability was made possible by re-running quantitative analysis mechanisms developed based on scenarios similar in profile to those applied in the European stress test exercise. The results contribute to improving policy recommendations by formulating measures to mitigate their severity.

The main results, concerning both the assessment of banking soundness and the use of the analytical framework to formulate proposals aimed at mitigating the interaction between sovereign risk and the probability of banking stress, based on multifactorial forecast scenarios under adverse but plausible conditions, underscore the scientific contribution. These findings complement those provided by the European Banking Authority and offer valuable insights for both monetary policy decision-makers and academic researchers.

### **Conflict of interests**

The author declares there is no conflict of interest.

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## **БАНКАРСКА НЕСТАБИЛНОСТ И ПОСЉЕДИЦЕ У КОНТЕКСТУ СУВЕРЕНОГ РИЗИКА – ЕВРОПСКЕ ЕКОНОМИЈЕ**

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### **САЖЕТАК**

Банкарска нестабилност, као посљедица појаве сувереног ризика, током времена је изазвала потребу за детаљном дијагнозом од стране доносилаца одлука у монетарним властима, представљајући тему трајне релевантности и сложености у оквиру економских политика. Главни проблем односи се на постојање веома блиске, зависне везе између вјероватноће банкарске нестабилности и сувереног ризика. Ригорозност овог питања захтијева дубинску анализу, због чега овај рад има за циљ да обухвати аспекте микро и макропруденцијалног карактера, засноване на панел скупу података за земље Европске уније, почев од 2005. године. У том контексту, истраживање идентификује, на основу постављених циљева, главне рањивости макроекономске стабилности кроз микроанализу ликвидности и солвентности кредитних институција, али и алате макропруденцијалне процјене, користећи као методе вишеструке регресије и моделе ауторегресивних вектора, уз допуну једнофакторским и вишефакторским сценаријима отпорности на екстремне, али могуће догађаје. Још један циљ је да се изврши дијагноза уз примјену аналитичког оквира који омогућава процјену осјетљивости банкарских перформанси на динамику приноса државних обвезница, кроз призму тржишног и кредитног ризика. Значај истраживања и добијени резултати односе се на уочавање негативне реакције профитабилности банака и, конкретно, адекватности капитала на повећање приноса државних обвезница. С друге стране, оригиналност истраживања огледа се у процјенама које доприносе формирању скупа опција на нивоу мјешавине економских политика, као и у приједлозима превентивних мјера за ублажавање системских ризика изазваних интеракцијом између сувереног ризика и вјероватноће банкарске нестабилности.

**Кључне ријечи:** *банкарска нестабилност, спровођење стрес теста, финансијски шокови, ненаплативи кредити (или проблематични кредити), сценарији, суверени ризик.*

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**СТРУЧНИ ЧЛАНЦИ**  
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# DIGITAL MARKETING IN THE SERVICE SECTOR: OPPORTUNITIES, CHALLENGES AND TRANSFORMATION STRATEGIES<sup>1</sup>

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## ABSTRACT

This research investigates how service companies can optimize digital marketing strategies to harness emerging opportunities and overcome persistent challenges in a rapidly evolving digital economy. Despite the sector's growth and the availability of established frameworks—such as Rogers' diffusion of innovation, the AIDA model, and the 7Ps marketing mix—a gap remains in understanding how these models can be practically integrated to address barriers like resistance to change, digital skills shortages, and technology integration. The study adopts a qualitative, three-stage methodology: (1) analysis of trends including artificial intelligence, immersive technologies, hyper-personalization, and ethical practices; (2) benchmarking best practices through industry reports and agency case studies, focusing on personalized customer experiences and omnichannel engagement; and (3) in-depth examination of documented digital transformation cases from leading firms such as Nike, IKEA, Lego, and Starbucks. The findings demonstrate that digital marketing enhances visibility, targeting, engagement, and operational efficiency while also presenting challenges related to change management, skills gaps, integration complexity, and data security. The study contributes an integrated framework linking opportunities, challenges, and success strategies and recommends further research on small and medium-sized enterprises and the ethical dimensions of digital marketing. This work offers practical advice for service companies navigating digital transformation.

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## 1. INTRODUCTION

Digital marketing has become a critical driver for service companies seeking to remain competitive in an increasingly digitalised economy. The sector has witnessed spectacular growth, with the digital marketing market expanding from € 14 billion in 2017 to over € 26 billion in 2024 (Chamouleau, 2024). This evolution is underpinned by a convergence of theoretical frameworks, including Everett Rogers' diffusion of innovation theory, which provides a framework for understanding how digital marketing innovations are disseminated within organisations and markets. This process unfolds across five adopter categories: innovators (e.g., companies pioneering AI-driven personalisation), early adopters (those embracing trends like influencer marketing), the early majority (adopting established tools such as marketing automation), the late majority (implementing basic digital presence due to competitive pressure), and laggards (resisting digital transformation). Key factors driving adoption include relative advantage, demonstrated through ROI improvements such as the 82% boost from AI in marketing, compatibility, ensuring alignment with existing organisational processes, and testability, facilitated by pilot programs that enable risk-free experimentation. This framework enables companies to assess their position on the adoption curve and develop strategies to accelerate integration (Rogers, 1983). The AIDA model, which stands for attention, interest, desire, and action, is a fundamental approach to analysing and enhancing the digital customer journey. In the first stage, brands employ strategies such as search-optimised content, targeted ads, and viral campaigns to capture people's attention in a crowded digital space. Once you have someone's attention, it is important to keep it. You can achieve this by providing potential customers with personalised information and engaging experiences that keep them interested and engaged. To keep people interested in the buying process and encourage them to choose a brand's products or services, marketers use tactics such as social proof, personalised offers, and AI-powered recommendations. Clear calls to action and real-time retargeting make the conversion path as smooth as possible, making the last step—taking action—easy. AI enhances each part of the AIDA model, making it work more effectively. During the interest phase, AI can use real-time data to come up with several different headlines and then test them to see which ones work best to get people to read them.

At this point, AI analyses behavioural data to determine what content will keep users engaged and automatically provides them with the information they need. AI tools utilise sentiment analysis and predictive modelling to identify emotional triggers as customers express their wants. This lets marketers automate and personalise their (King, 2022; Simon, 2025; Zhao, 2025). The marketing mix

theory, extended to the 7Ps for services, complements this framework by analysing the digital impact on each component: product, price, distribution, promotion, process, people, and physical evidence. This holistic approach is essential for a successful digital transformation, offering a comprehensive view of the necessary changes. Together, they provide a robust foundation for analysing how digital marketing practices are adopted and optimised in the service industry.

The main objectives of this research are to:

Analyse the opportunities offered by digital marketing in terms of visibility, targeting, and customer engagement.

Identify significant challenges related to its adoption, particularly regarding skills, technological integration, and evolving consumer expectations.

Propose strategic recommendations for a successful transition to digital marketing in the service sector.

The central research question guiding this study is: “How can service companies optimise their digital marketing strategy to maximise opportunities and overcome challenges in a constantly evolving digital economic environment?” By integrating these theoretical foundations and addressing these objectives, this study aims to provide a comprehensive understanding of the digital marketing challenges faced by service companies while proposing practical solutions for a successful digital transformation.

The 7Ps framework is applied in the service sector through specific examples: Product encompasses digital service bundles like Starbucks’ app, which integrates ordering, payment, and loyalty programs; Price leverages dynamic models using real-time demand analytics; place employs omnichannel optimization, exemplified by IKEA’s AR app bridging online and offline experiences; promotion utilizes AI-driven personalization across channels; people focuses on upskilling for digital competencies; Process includes automated customer journeys like Nike’s app-to-store integration, and physical evidence relies on digital trust signals such as SSL certificates and user reviews. Complementing this, the RACE model (Reach, Act, Convert, Engage) serves as a customer-centered planning framework for digital marketing strategies, emphasizing practical, omnichannel engagement across the customer journey, from initial awareness to long-term loyalty.<sup>2</sup> This approach aligns with the 7Ps by prioritizing seamless integration of touchpoints and data-driven optimization.

## 2. METHODS

This research adopts a three-part qualitative approach to examine digital marketing opportunities and challenges in the service sector: First, it investigates emerging trends, including artificial intelligence, immersive technologies (AR/VR), hyper-personalization, ethical and transparent practices, social commerce expansion, phygital experiences (digital-physical fusion), and micro-influencer impact. Second, it evaluates best practices through industry benchmarks, analyst reports, and case studies from leading agencies, with a focus on personalized customer experiences, omnichannel engagement, and data-driven campaign optimization. Third, it analyzes documented case studies of companies such as Nike, IKEA, Lego, and Starbucks—selected for their measurable performance outcomes and industry relevance—to identify concrete, innovative strategies and critical success factors in digital marketing implementation.

This study bases its analysis on both qualitative evaluations and the application of sector-specific frameworks like the 7Ps marketing mix. Additionally, the research incorporates performance metrics and visual representations—including comparative tables—to substantiate and illustrate the findings.

## 3. RESULTS

### 3.1 Opportunities for Service Digitalisation

Digital marketing enables service companies to significantly expand their visibility and audience reach by leveraging a range of online platforms, including social media, blogs, and websites, which surpass the limitations of traditional marketing channels (Cumberland College, 2024). Through the integration of artificial intelligence and data analytics, these companies can achieve highly accurate targeting and deliver personalised experiences at every stage of the customer journey (Brevo, 2024). Engagement is further enhanced by leveraging interactive technologies and real-time communication tools, such as AI-powered chatbots, which foster stronger relationships and immediate support (Sauvage, 2018; Brevo, 2024). Additionally, digital marketing offers a cost-effective approach, making impactful campaigns accessible even to small and medium-sized enterprises (Sauvage, 2018; Rothe, 2022). The ability to monitor and adjust strategies in real time ensures that marketing efforts remain relevant and optimised in a dynamic environment (Cumberland College, 2024). Ultimately, digital marketing fosters innovation and differentiation, allowing brands to explore new forms of customer engagement, such as NFTs and decentralised communities (Brevo, 2024). These multifaceted advantages are best interpreted

through established frameworks like Rogers' diffusion of innovation, the AIDA model, and the 7Ps, as well as models that emphasise interactivity and customer retention, providing a comprehensive understanding of how digital marketing can be adapted and optimised in the service industry (Stone, 2023, Molony, 2021; Vynogradova et al., 2020; Sharipova, 2025).

### **3.2 Challenges of Service Digitalisation**

The digitalization of services presents numerous interconnected challenges for companies seeking digital transformation. Resistance to change constitutes a significant obstacle, manifesting as a reluctance to adopt new working methods and a fear of skill obsolescence (Cathy, 2020; YeePLY, n.d.). Companies must implement an effective change management strategy to overcome this resistance, including transparent communication, adequate training, and continuous employee support (Octalysisgroup, 2024).

This approach is closely linked to the lack of digital skills, which manifests in key areas such as data analysis, cloud technologies, and cybersecurity. Companies must invest in the continuous training of their employees and attract new talent to bridge this skills gap, which is essential to meet the challenge of the complexity of integrating new technologies. This integration requires a gradual and planned approach to ensure a smooth transition while minimizing disruptions (Octalysisgroup, 2024; Cathy, 2020).

Security and data protection represents another crucial challenge, requiring companies to adopt a proactive approach to cybersecurity and regulatory compliance. This concern is directly linked to the rapid evolution of customer expectations, which demand seamless and personalized digital experiences. To address this, companies must invest in advanced personalization technologies and rethink their processes to offer an optimal customer experience across all channels (Cathy, 2020).

Finally, budget constraints constitute a cross-cutting challenge that impacts all aspects of digital transformation. Companies must develop a clear and targeted investment strategy, prioritizing the most impactful initiatives to optimize the allocation of limited resources. This strategic approach is essential to overcome all digitalization challenges and maximize digital transformation's benefits.

Digitalizing services presents numerous challenges for companies, which must overcome several obstacles to achieve their digital transformation successfully (Cathy, 2020).

### 3.3 Examples of Successes in Digital Transformation

Digital transformation has become imperative for companies seeking to remain competitive in the current economic environment. Several major brands have successfully managed this transition, demonstrating the significant benefits that a well-executed digital strategy can bring. Here are some concrete examples of companies that have brilliantly succeeded in their digital transformation:

**Nike:** A customer and data-centric approach has accelerated its digital transformation by investing heavily in digital technologies to strengthen its e-commerce and supply chain. The company has focused on developing mobile applications like Nike, Nike Training Club, and Nike Run Club, offering an enriched and personalized user experience. Using AI and data analysis, Nike has been able to personalize the customer experience on a large scale ([Consultport, 2025](#)).

Adopting a strong Direct-to-Consumer (DTC) strategy has allowed Nike to control its brand image better and establish a more direct relationship with its consumers. The results of this transformation are impressive: a 33% increase in online sales in 2022, with 26% of total revenue generated through digital platforms. This approach has also significantly improved customer engagement and the personalization of offers ([Team Calibo, 2025](#)).

**Ikea:** Reinventing the furniture shopping experience, it has invested heavily in its digital transformation, particularly improving the customer experience. One of the flagship initiatives was the launch of the IKEA Place app, which uses augmented reality to allow customers to visualize furniture in their own space before purchasing. This innovation has revolutionized how consumers buy furniture online ([Golden Owl Solutions, 2025](#); [AIA Marketing Team, November 29, 2023](#)).

The introduction of the Shop and Go payment service has simplified the in-store shopping process. At the same time, optimizing the supply chain through AI and machine learning has improved operational efficiency. These efforts have borne fruit: 15.4% of IKEA's revenue is now generated through e-commerce, with an impressive 44% increase in online sales over the past year. The omnichannel customer experience has also significantly improved, strengthening IKEA's market position ([Golden Owl Solutions, 2025](#); [AIA Marketing Team, 2023](#)).

**Lego:** Saving the company through digital innovation, managed to avoid bankruptcy thanks to a bold digital transformation, focusing on innovation and customer engagement. Launching the 3D design platform «Digital Designers»

allowed fans to create and share their own Lego designs, stimulating creativity and community engagement (Song, 2024).

The development of mobile applications and video games has extended the Lego universe beyond physical bricks while creating a connected ecosystem around the brand and strengthening customer loyalty. These initiatives led to a 20% increase in revenue in 2009, the loyalty of an intergenerational community, and strengthened Lego's position as a leader in the toy industry (Song, 2024).

**Starbucks:** Starbucks has indeed bet on digital to transform the customer experience and optimize its operations, thus becoming a success story in digital transformation in the coffee industry. The company has developed a digital strategy centred on the human experience, aiming to improve the customer experience while preserving the importance of its physical stores.

The Starbucks mobile app, launched in 2011, is at the heart of this transformation. This app has revolutionized the coffee experience by offering key features such as mobile ordering and payment, drink customization, personalized recommendations based on purchase history, and an integrated loyalty program. This application has helped reduce wait times, improve customer satisfaction, and strengthen brand loyalty (DIGITAL Conseil, n.d.; Fact R, n.d.).

The impact of these digital technologies has been significant. Today, the app has over 31 million active users in the United States and generates about 20% of Starbucks' revenue through mobile orders. This digitalization has not only improved the customer experience but also allowed Starbucks to collect valuable data on consumption habits, thereby facilitating the personalization of offers and strengthening customer loyalty (DIGITAL Conseil, n.d.; TF1, 2014).

Starbucks continues its digital transformation by integrating artificial intelligence through the «Deep Brew» platform. This initiative aims to personalize customer interactions further and optimize in-store operations. The company also uses machine learning to create personalized incentives and influence consumption habits (Christophe, 2020; Sellsy, 2021).

In addition to the mobile app, Starbucks has implemented other digital innovations, such as the «Starbucks Digital Network» in its U.S. stores, which offers access to media content, and the «Mobile Pickup» service, which allows customers to pick up their orders at a dedicated counter without going through the checkout (DIGITAL Conseil, n.d.; Fact R, n.d.).

These initiatives demonstrate how Starbucks has used digital technology to enhance the customer experience, optimize its operations, and maintain its

position as a leader in the coffee industry while preserving the importance of human interaction in its physical stores.

**Amazon**, founded by Jeff Bezos in 1994 as an online bookstore, has transformed into a diversified technology conglomerate. This evolution is based on strategic and technological innovations. In 2015, Amazon launched Amazon Business, a B2B marketplace generating approximately 35 billion dollars in annual sales. It offers business-oriented features like bulk purchase discounts and recurring delivery options. Furthermore, Amazon Web Services (AWS), initially designed to meet Amazon's internal needs, has become a global leader in cloud computing, significantly contributing to the company's revenue. AWS revolutionized the industry with its pay-as-you-go pricing model, making cloud services accessible to startups and large enterprises (Kaziukėnas, 2023, Colvin, 2022).

**Microsoft** began its digital transformation under the leadership of Satya Nadella, focusing on cloud computing and collaborative solutions. The Microsoft 365 suite, including tools like Teams, OneDrive, and SharePoint, has enabled companies to adapt to remote work and improve their productivity. Microsoft has also strengthened its presence in the digital communities space with the strategic acquisitions of LinkedIn (2016) and GitHub (2018). These initiatives have consolidated its position as a cloud leader while expanding its ecosystem to include developers and professionals worldwide. Azure, its cloud platform, is now a central pillar of its digital strategy.

Implementing a digital loyalty program has allowed Starbucks to collect valuable data on customer preferences. At the same time, using AI to personalize offers has increased sales and customer loyalty. The results are compelling: over 20% of transactions are now conducted via the mobile app in the United States, and the loyalty program has 19 million members. This approach has led to a significant improvement in customer engagement and operational efficiency.

These examples demonstrate that digital transformation can significantly benefit growth, customer engagement, and operational efficiency when well executed. Companies that successfully undergo digital transformation focus on improving customer experience, technological innovation, and adapting their business model to the new realities of the digital market. A comparative overview of key digital transformation outcomes for these companies is presented in table 1.

**Table 1:** Digital Transformation Outcomes at Leading Companies

Company	Digital Transformation Focus	Pre-Transformation Metrics	Post-Transformation Metrics	Key Lessons & Insights
Nike	Customer-centric digital shift: suite of mobile apps (Nike, SNKRS, NTC, NRC); AI-driven personalization; DTC model	Digital revenue not dominant (2019); moderate online sales growth; limited app engagement	26% of total revenue from digital (2022); 33% YoY online sales growth; 30% sales surge in China via NTC (pandemic)	DTC boosts brand control and loyalty but needs robust digital infrastructure; AI personalization lifts revenue when tailored to user behavior
IKEA	Augmented reality (AR) for omnichannel shopping; supply chain digitization	Minimal e-commerce revenue (2017); low online sales; manual operations	15.4% of revenue from e-commerce; 44% YoY online sales growth; 24/7 warehouse drones	AR bridges online-offline gap, reducing purchase hesitation; supply chain digitization cuts costs but requires AI investment
Starbucks	Mobile-first experience: app for ordering/payment, loyalty program, AI (Deep Brew) personalization	No mobile transactions or app users (pre-2011); no loyalty program	20% of U.S. transactions via mobile; 31M app users; 19M loyalty members; Rewards members drive 57% of U.S. revenue	Frictionless mobile experience drives repeat business and revenue; loyalty data enables hyper-personalization but demands strong privacy
Amazon	Cloud (AWS) commercialization; Alexa and Prime ecosystem	AWS as internal tool (pre-2006); no Prime (pre-2005); limited B2B	AWS: \$35B annual revenue (2023); 220M+ Prime subscribers; \$35B Amazon Business sales	Internal tech (AWS) can become market leaders; ecosystems (Prime) create sticky customers but require constant innovation
Microsoft	Azure cloud platform; Microsoft 365; developer ecosystem (LinkedIn, GitHub)	Low cloud market share (pre-2014); unmeasured productivity	Azure: 24–25% global cloud share (2025); 22% faster task completion via AI	Cloud enables scalability but hybrid flexibility is key; developer platforms accelerate innovation through open source

Source: Nike and Ikea from (Golden Owl, 2025), Starbucks (Stamp me, 2025), Amazon (Red stag fulfilment, 2025) and Microsoft (2025)

The application of digital marketing frameworks in the service sector is best understood through sector-specific examples and integrated models. The 7Ps framework, for instance, is operationalized as follows: Product encompasses digital service bundles, such as Starbucks’ app that combines ordering, payment, and loyalty programs; price leverages dynamic models using real-time demand

analytics; place is optimized through omnichannel strategies, as seen in IKEA's AR app bridging online and offline experiences; Promotion utilizes AI-driven personalization across channels; people emphasize upskilling for digital competencies; The process includes automated customer journeys, like Nike's app-to-store integration, and physical evidence relies on digital trust signals such as SSL certificates and user reviews. Complementing this, the RACE model (Reach, Act, Convert, Engage) provides a practical, customer-centered planning framework for structuring digital marketing strategies, emphasizing seamless omnichannel engagement throughout the customer journey. When combined, these methods facilitate a comprehensive examination of the implementation of digital marketing, paving the way for the subsequent detailed case studies.

### 3.3.1 Further Practical Examples from the Service Sector

ING Bank stands out as a leader in digital transformation. By adopting agile working methods and launching a highly rated mobile banking app, ING has enabled customers to manage accounts, make payments, and apply for loans or insurance entirely from their smartphones. This shift from traditional branch-based banking to a digital-first approach improved customer convenience and drove financial inclusivity, making banking services more accessible to a broader population. ING's example highlights how banks can leverage technology to enhance operational efficiency, personalize services, and remain competitive in a rapidly evolving market (Santos, 2024).

The **insurance** sector has also embraced digitalization, particularly through integrating artificial intelligence and automation. Many insurers now use AI-powered chatbots to provide 24/7 customer support and streamline claims processing. For instance, insurance companies have outsourced routine tasks such as claims management and policy administration to specialized digital service providers, resulting in faster settlements and improved customer satisfaction. Additionally, bundling insurance products with banking services—such as travel or health insurance offered directly through digital banking apps—demonstrates how cross-sector digital integration can add value and convenience for customers (Santos, 2024).

In **tourism**, digital transformation has revolutionized the customer experience. Marriott International's mobile app allows guests to check in and out, request services, chat with staff, and even unlock their rooms using smartphones. This enhances guest convenience, streamlines hotel operations, and reduces wait times. Marriott is also experimenting with Internet of Things (IoT) integrations, enabling guests to personalize room settings such as temperature and lighting

via the app. Similarly, IKEA’s digital transformation included augmented reality (AR) and virtual reality (VR) to let customers visualize furniture in their homes before purchase, as well as the Shop & Go feature for seamless in-store and online shopping. These innovations have led to significant e-commerce revenue growth and improved the customer journey (Santos, 2024).

These cases demonstrate that successful digital transformation in the service sector involves more than adopting new technologies. It requires a strategic focus on customer experience, operational integration, and continuous adaptation to changing consumer expectations. The practical examples from banking, insurance, and tourism show how digital innovation can drive growth, enhance engagement, and optimize service delivery—while also underscoring the need to address challenges such as resistance to change, skills gaps, and technology integration (Verhoef et al., 2021, Tyagi et al., 2025).

### 3.4 Examples of failures in digital transformation

Kodak, once the world leader in photography, tragically illustrates the failure to adapt to technological revolutions. Although the company invented the first digital camera in 1975, thanks to Steven Sasson, it chose to marginalize this innovation, fearing it would cannibalize its lucrative film market. Motivated by a short-term vision and organizational inertia, this strategic decision led to a critical delay in adopting digital technology. While competitors like Canon and Fujifilm invested heavily in this technology, Kodak continued prioritizing its traditional products. Entering the digital market late in the 1990s, the company could not catch up with the rise of digital cameras and smartphones. This lack of foresight and investment led to a drastic decline in its market share, a financial crisis, and its bankruptcy in 2012, marking the end of an era for this photography giant (Vinokurova & Kapoor, 2025; Lucas & Goh, 2009).

Once a giant in video rentals, Blockbuster made a fatal strategic error by rejecting Netflix’s \$50 million buyout offer in 2000, illustrating its inability to anticipate the streaming revolution. Despite the late recognition of the threat posed by Netflix, particularly by its CEO John Antiaco, who attempted to adopt a “hybrid” strategy in 2004, Blockbuster remained trapped in its traditional business model, heavily reliant on revenue generated by late fees - up to 800 million dollars at one point. This rigidity and a restrictive financial structure due to its acquisition by Viacom prevented Blockbuster from investing sufficiently in innovation and adapting to the digital era. The company thus missed the streaming shift, gradually losing its relevance to more agile competitors like Netflix, which led

to its inexorable decline, going from over 9,000 stores to its near disappearance today (Dalton & Logan, 2024, Chabani, 2024).

Nokia, once the undisputed giant of mobile telephony, experienced a spectacular fall in the face of the smartphone revolution, illustrating the devastating consequences of a lack of adaptation in a rapidly changing sector. Nokia resisted technological change through several crucial strategic errors (EDITORIAL TEAM, 2025). First, the company stubbornly insisted on keeping its Symbian operating system, which had become obsolete due to the intuitive interfaces and application ecosystems offered by iOS and Android (Paul, 2024). This adherence to Symbian, coupled with a reluctance to adopt touch screens fully, prevented Nokia from effectively meeting the new expectations of consumers (Vuori & Tushman, 2024, Saatcioglu et al., 2025; Bouwman et al, 2014).

Nokia's organizational structure, marked by heavy bureaucracy and internal rivalries, hindered its ability to innovate and make quick decisions in a constantly evolving market. A conservative corporate culture exacerbated this organizational inertia resulting from years of success, which led to risk aversion and an underestimation of the threat posed by new market players.

The strategic partnership with Microsoft in 2011, aimed at adopting Windows Phone as the primary operating system, was a costly mistake (Paul, 2024). This alliance limited Nokia's flexibility and failed to close the gap with the well-established Android ecosystem. This unfortunate choice accelerated Nokia's decline, with its global market share dropping from 49.4% in 2007 to a mere 3.4% in 2012, marking the end of its reign in the mobile industry (Vuori & Tushman, 2024; Saatcioglu et al., 2025; Bouwman et al, 2014).

#### **4. DISCUSSIONS**

This study on the opportunities and challenges of digital marketing for service companies reveals crucial insights that align with the existing literature while bringing new perspectives.

The results regarding the advantages of digital marketing, particularly in terms of increased visibility, precise targeting, and improved customer engagement, corroborate the findings of several previous studies. For example, (Sauvage, 2024) also emphasizes the importance of personalization and cost optimization enabled by digital marketing. Similarly, (Cumberland College, 2024) highlights the ability to accurately measure and analyze digital campaigns, a crucial point that our study has also identified. However, this research further identifies emerging opportunities, such as using AI for personalized content creation and

campaign optimization. This aspect has been little explored in previous studies. This evolution reflects the rapid pace at which digital marketing is evolving.

The challenges identified in this study, such as resistance to change, lack of digital skills, and the complexity of integrating new technologies, echo the obstacles highlighted by other researchers. (Cathy, 2020) has highlighted these aspects as significant barriers to digital transformation. The study confirms the persistence of these challenges, even several years later, suggesting the need for continuous efforts to overcome them. This research's original contribution is identifying the rapid evolution of customer expectations as a significant challenge. Although mentioned by some authors like (Psico-smart, 2024), this study delves deeper into this aspect by directly linking it to personalization and omnichannel strategies.

The analysis of success cases like Nike, IKEA, and Starbucks reveals strategies that align with the recommendations of existing literature. For example, (Bota, 2020) emphasizes the importance of technological innovation and omnichannel customer experience, which are highlighted in the case studies. However, this research adds an important nuance by showing how these companies have adapted these general principles to their specific contexts.

We can more deeply understand the observed successes and challenges in digital marketing implementation across leading service companies through the lens of established frameworks such as the 7Ps and the RACE model. The sector-specific application of the 7Ps—ranging from digital service bundles and dynamic pricing to omnichannel integration and AI-driven personalization—demonstrates how companies like Starbucks, IKEA, and Nike have operationalized these principles to enhance customer experience and streamline processes. Meanwhile, the RACE model (Reach, Act, Convert, Engage) offers a practical, customer-centered structure for digital marketing strategy, ensuring that engagement is sustained throughout the customer journey and across multiple channels. By aligning these frameworks with data-driven insights and performance metrics, the study illustrates how a holistic, integrated approach enables organizations to address both the technical and human dimensions of digital transformation. This synthesis clarifies the pathways to success and highlights the persistent barriers—such as skills gaps and integration complexity—that require ongoing strategic attention.

The study contributes to the theory by proposing an integrated framework that links the opportunities, challenges, and success strategies of digital marketing in the service sector. By adding a service-specific dimension, this framework enriches existing models, such as that of (Verhoef et al., 2021), on customer

experience in the digital age. On a practical level, The results provide managers with a roadmap to navigate the complexity of digital transformation. In particular, the emphasis on the need for a holistic approach, combining technology, organizational culture, and customer focus, provides a more comprehensive perspective than is often presented in management literature.

Although The study provides valuable insights, it has certain limitations. The focus on large companies limits the generalization of the results to SMEs in the service sector. Future research could explore how small service businesses adapt digital marketing strategies to their limited resources. Moreover, the rapid evolution of the digital field highlights the need for longitudinal studies to capture emerging trends. Future research could examine the long-term impact of digital marketing strategies on the performance of service companies, an aspect that is underexplored in the current literature.

This study contributes to understanding digital marketing dynamics in the service sector while identifying promising avenues for future research, particularly on ethics and social responsibility in digital service marketing. This field is gaining importance but remains under-research.

## **5. CONCLUSIONS**

This in-depth study on the opportunities and challenges of digital marketing for service companies highlights several key points:

Digital marketing offers significant advantages to service companies, including increased visibility, precise targeting, better customer engagement, and cost optimization. These opportunities allow companies to stand out in an increasingly digitized and competitive environment.

However, digital transformation comes with significant challenges, such as resistance to change, a lack of digital skills, the complexity of integrating new technologies, and data security issues. To overcome these obstacles effectively, a strategic and holistic approach is required.

Successes like Nike, IKEA, and Starbucks demonstrate that a well-executed digital strategy can lead to impressive growth, customer engagement, and operational efficiency. Conversely, failures like Kodak, Blockbuster, and Nokia highlight the risks of late or inadequate adaptation to technological changes.

To succeed in their digital transformation, service companies must adopt a customer-centric approach, invest in technological innovation, develop their employees' digital skills, and remain agile in the face of rapid market changes.

This study highlights the crucial importance of service companies fully embracing digital marketing while remaining aware of the challenges to be faced. A balanced approach, combining technological innovation and a focus on customer experience, is the key to success in the current digital era.

### Conflict of interests

The author declares there is no conflict of interest.

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## ДИГИТАЛНИ МАРКЕТИНГ У СЕКТОРУ УСЛУГА: МОГУЋНОСТИ, ИЗАЗОВИ И СТРАТЕГИЈЕ ТРАНСФОРМАЦИЈЕ

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### САЖЕТАК

Ово истраживање испитује како компаније у сектору услуга могу да оптимизују стратегије дигиталног маркетинга како би искористиле нове могућности и превазишле постојеће изазове у брзо развијајућој дигиталној економији. Упркос расту сектора и постојању утврђених оквира, као што су Роџерсова теорија дифузије иновација, AIDA модел и маркетиншки микс 7P, и даље постоји празнина у разумијевању како се ови модели могу практично интегрисати ради рјешавања препрека као што су отпор према променама, недостатак дигиталних вештина и интеграција технологија. Студија примјењује квалитативну, тростепену методологију: (1) анализу трендова, укључујући вјештачку интелигенцију, имерзивне технологије, хиперперсонализацију и етичке праксе; (2) упоредну анализу најбољих пракси кроз извјештаје из индустрије и студије случаја маркетиншких агенција, са фокусом на персонализована искуства корисника и омниканалну комуникацију; и (3) детаљно испитивање документованих случајева дигиталне трансформације водећих компанија као што су Nike, IKEA, Lego и Starbucks. Налази показују да дигитални маркетинг повећава видљивост, прецизно циљање, ангажовање и оперативну ефикасност, али истовремено доноси изазове у вези са управљањем промјенама, недостатком вјештина, сложености интеграције и безбједности података. Студија доприноси развоју интегрисаног оквира који повезује могућности, изазове и стратегије успјеха, и препоручује даља истраживања малих и средњих предузећа, као и етичких димензија дигиталног маркетинга. Овај рад нуди практичне савјете за компаније у сектору услуга које пролазе кроз процес дигиталне трансформације.

**Кључне ријечи:** *дигитални маркетинг, дигитална трансформација, компаније услуга, дигитална стратегија, искуство купаца.*

