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ORIGINAL SCIENTIFIC PAPER

Judicial Impact on Bankruptcy Efficiency: An Empirical Analysis of Case Duration in Serbian Bankruptcy Liquidations

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ABSTRACT

This paper examines how judges shape the efficiency of liquidation proceedings, using case duration as a central indicator of procedural performance. Drawing on a dataset of over 1,300 closed bankruptcy liquidation cases in Serbia from 2010 to 2024, we apply hierarchical and cross-classified random-effects models to quantify the influence of judges, courts, and administrators, while controlling for case-level characteristics such as estate size, case complexity, contested claims, and debtor type. The analysis reveals substantial variation in case duration attributable to both judges and administrators, with administrators emerging as particularly influential in the cross-classified specifications. Moreover, we assess whether specific judge–administrator pairings systematically affect outcomes beyond their individual effects. While interaction effects are modest, they account for additional variation in procedural efficiency. The results highlight the importance of operational capacity and coordination between key institutional actors, offering evidence that agent-level discretion, beyond the legal framework, plays a role in shaping case trajectories. These findings contribute to the literature on judicial behavior, bankruptcy governance, and institutional performance in transitional legal systems.

Keywords: *bankruptcy proceedings, judges, administrators, hierarchical modeling, cross-classified models*

JEL Classification: G33, C21

INTRODUCTION

Bankruptcy laws and procedures play a critical role in enabling efficient resource reallocation and resolving financial distress (Blazy & Stef, 2020; Claessens & Klapper, 2005). The effectiveness of a bankruptcy framework is commonly assessed through three core metrics: recovery rates, costs, and the duration of proceedings (Djankov et al., 2008). Among these, the timely resolution of cases is often viewed as a key policy objective (Garrido et al., 2019), as delays typically reflect deeper systemic inefficiencies such as inflexible procedures, excessive caseloads, or limited institutional capacity (Stripp, 1992). Beyond being a procedural indicator, case duration also serves as a proxy for indirect costs that reduce the overall value recovered in bankruptcy (Bris et al., 2006; Franks & Torous, 1989; Thorburn, 2000).

The duration of bankruptcy proceedings is closely linked to the role of judges. A judge's ability to manage case complexity, schedule hearings efficiently, and make timely decisions can significantly affect both the cost and fairness of outcomes. Understanding the extent to which

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judicial performance shapes bankruptcy efficiency is therefore critical for identifying institutional bottlenecks and informing reforms. This issue is particularly salient in Serbia, where, despite the adoption of a modern bankruptcy (Radović & Radulović, 2018), resolution times remain lengthy compared to peer countries such as Romania, Poland, and Hungary (Blazy & Stef, 2020). Understanding the factors driving these delays is essential to enhance the overall effectiveness of the insolvency framework and reduce the economic costs of prolonged proceedings.

Building on prior research by Radulović & Radović (2020), which highlighted unpredictability in judicial decision-making, largely due to inconsistently exercised discretionary powers, this study examines how judicial behavior influences the duration of bankruptcy cases in Serbia. Drawing on a unique dataset of bankruptcy liquidation cases concluded between 2010 and 2024, the study investigates the time from case initiation to final closure, employing multilevel modeling techniques to empirically assess the judicial and institutional determinants of procedural length. The analytical strategy combines two-level, three-level, and crossed random-effects models, enabling the decomposition of variation in case duration across judges, courts, and their interactions with bankruptcy administrators. This multilevel framework allows us to identify whether inefficiencies stem primarily from individual judges, broader court-level dynamics, or coordination with administrators.

This study makes several distinct contributions to the literature on judicial behaviour and bankruptcy efficiency. First, it introduces a hierarchical modeling framework to analyse judicial decision-making in bankruptcy. Second, by combining multilevel and crossed random-effects models, the study quantifies judicial heterogeneity and isolates systemic inefficiencies, enabling a more precise identification of whether delays stem from individual judges, court-level characteristics, or interactions with bankruptcy administrators. Third, by focusing on Serbia —an emerging economy where empirical research on insolvency systems is limited— the study provides much-needed evidence on the institutional determinants of procedural duration. These findings offer actionable insights for performance-based reform, contributing to more effective resource allocation and capacity-building within the commercial court system.

The remainder of the article is organized as follows. Section 2 reviews the literature on the role of judges in bankruptcy and the determinants of procedural duration. Section 3 outlines the institutional and legal framework governing Serbian bankruptcy proceedings. Section 4 presents the dataset and descriptive statistics. Section 5 details the empirical strategy and findings, comparing three model specifications: a two-level random-intercept model (cases nested within judges), a three-level model (judges nested within courts), and a crossed random-effects model (cases jointly influenced by judges and administrators). Section 6 concludes with a discussion of policy implications and directions for future research.

LITERATURE REVIEW

This article connects two overlapping lines of inquiry in the empirical bankruptcy literature. The first concerns the role and characteristics of bankruptcy judges, particularly how their decisions and discretionary powers shape procedural and substantive outcomes. While scholarly interest in the judicial role has grown, the empirical literature remains relatively limited and predominantly U.S.-focused. Much of the foundational research in this area examines judicial discretion in confirming reorganization plans, ruling on contested claims, and approving debtor applications.

More recent studies have examined judge-level heterogeneity in decision-making and its consequences for case outcomes. For instance, Chang & Schoar (2011) exploit the random assignment of bankruptcy cases in the U.S. to document significant variation in judicial behavior, linking this variation to differences in the efficiency of Chapter 11 proceedings. Similarly, Iverson et al. (2023), using a rotation-based methodology, show that judges with less bankruptcy experience are associated with significantly longer case durations, higher professional fees, and

lower creditor recoveries. These effects are most pronounced early in a judge's tenure and in more complex cases, underscoring the importance of specialization and learning-by-doing in judicial performance. These findings suggest that not only do judges matter, but the extent of their prior experience and exposure to bankruptcy law has measurable economic implications.

Beyond individual characteristics, scholars have also examined institutional factors. For example, Iverson (2017) links higher court congestion to longer case durations, a greater likelihood of liquidation, and lower post-bankruptcy survival rates. Leveraging quasi-random assignment of cases across courts, the study demonstrates that institutional constraints, independent of firm characteristics, significantly affect outcomes. Notably, the impact of congestion is greater for cases with more complex restructuring needs.

Other studies have explored the institutional and ideological dimensions of judicial behavior. (Nash & Pardo, 2012), emphasize that judges' normative commitments and interpretive philosophies can significantly influence how they approach reorganization, discharge, and fairness in bankruptcy. Their work highlights that judicial discretion is not only shaped by experience or capacity but also by underlying legal values, particularly in areas of statutory ambiguity. These insights are complemented by research on cognitive and behavioral biases. For example, Rachlinski et al. (2006, 2007) and Teichman & Zamir (2014) provide evidence that bankruptcy judges, like other decision-makers, are susceptible to subconscious heuristics and psychological framing effects, which can affect rulings in subtle but meaningful ways. Together, this body of work emphasizes that judges influence outcomes not only through formal rulings, but also through behavioral tendencies, interpretive discretion, and the institutional environments in which they operate.

In the U.S. context, scholars have shown that debtors exploit differences in judicial decision-making through forum shopping, strategically selecting jurisdictions perceived as more favorable to reorganization (Eisenberg & LoPucki, 1999; LoPucki & Doherty, 2004). More recently, He et al. (2020) demonstrated that judicial bias may vary systematically by court location.

Outside the U.S., however, empirical evidence remains sparse. Blazy et al. (2011) find that French judges tend to prioritize employee interests in insolvency cases, while Blazy & Esquerré (2021) show that the likelihood of reorganization varies systematically with the composition of the judicial chamber. Individual judge characteristics, such as managerial experience, academic background, and gender, significantly influence outcomes, indicating that procedural discretion persists even in systems designed to constrain it. They also identify a modest appointment bias, suggesting that case allocation is not fully random. In Russia, Lambert-Mogiliansky et al. (2007) document regional favoritism in court rulings.

In the Serbian context, Radulović & Radović (2020) identify significant unpredictability in judicial decision-making, which they attribute to inconsistently exercised discretionary powers. This unpredictability undermines legal certainty and contributes to procedural inefficiency. Together, these studies highlight the pivotal role that judges play in shaping both the pace and outcomes of bankruptcy proceedings, particularly in jurisdictions where judicial discretion is a defining feature of the legal framework.

The second strand of literature explores the determinants of bankruptcy efficiency, focusing on procedural duration, costs, and recovery rates. While many studies investigate the impact of case-related variables, such as creditor structure, presence of litigation, or asset complexity, on recovery outcomes, fewer treat duration itself as the dependent variable. Most commonly, time in bankruptcy appears as an independent variable used to explain variation in recoveries or costs (Bris et al., 2006; Ferris & Lawless, 1997, 2000). However, a more limited set of studies explicitly models the duration of proceedings as an outcome in its own right. Bris et al. (2006), for example, analyze a sample of 303 bankruptcy cases filed in the District of Arizona and the Southern District of New York, and show that procedural timelines are influenced by both case characteristics (such as proceeding type and creditor structure) and institutional variables, including judge and court

effects. Their findings show that judge fixed effects are highly significant, even after controlling for case-level variables.

While the U.S. literature is relatively well-developed, empirical studies from other jurisdictions remain comparatively scarce, though growing. Notable contributions include Bergström et al. (2004, 2005) on Finland, Thorburn (2000) on the Swedish auction model, Blazy & Nigam (2019) on England, Blazy & Stef (2020) on Central Europe, Cepec et al. (2017) on Slovenia, Couwenberg & de Jong (2008) on the Netherlands, Dewaelheyns & Van Hulle (2009) on Belgium, Aguiar-Díaz & Ruiz-Mallorquí (2015) on Spain, and Melcarne & Ramello (2020) on Italy. These studies collectively demonstrate that variation in institutional design, court efficiency, and legal culture can meaningfully affect case outcomes, particularly duration, costs, and creditor recoveries. Yet, evidence from transition economies—and especially from the Western Balkans—remains very limited. This article contributes to filling that gap by offering a systematic analysis of the determinants of case duration in Serbian bankruptcy liquidations, with a specific focus on judicial and institutional effects.

Overall, this literature suggests that case duration, often treated as a technical or administrative outcome, is, in fact, shaped by a complex interplay of case complexity, court capacity, and judicial behaviour. This study builds on that insight by applying multilevel modeling techniques to evaluate the influence of Serbian bankruptcy judges, courts, and administrators on the length of liquidation proceedings, contributing to the still-limited empirical research on insolvency systems in emerging markets.

Finally, hierarchical modelling as a methodological approach remains underutilized despite the inherently nested structure of court systems. Dalton & Singer (2014) use hierarchical linear modelling to examine how court structure influences the duration of civil cases. Drawing on a dataset of approximately 7,000 cases from seven U.S. district courts, they explore how the number of attorneys involved and the number of authorized judgeships per court affect case resolution times. Their findings reveal a counterintuitive interaction: while larger courts resolve simpler cases (those with three or fewer attorneys) more efficiently, smaller courts outperform larger ones in more complex cases involving multiple attorneys.

THE ROLE OF BANKRUPTCY JUDGES IN THE SERBIAN BANKRUPTCY FRAMEWORK

The Serbian Law on Bankruptcy, adopted in 2010, provides a framework for three primary procedures: bankruptcy liquidation, reorganization, and pre-arranged reorganization. While pre-arranged reorganization plans are predominantly utilized by large debtors (Radović & Radulović, 2018), the vast majority of insolvent small and micro-enterprises undergo liquidation, either through piecemeal asset sales or as a legal entity via going concern sales. The Law on Bankruptcy has undergone several subsequent amendments aimed at improving procedural efficiency, strengthening creditor protections, and streamlining the conduct of proceedings to reduce overall costs and duration.

Bankruptcy proceedings in Serbia commence upon the filing of a petition by either the debtor or a creditor. The bankruptcy judge first conducts a preliminary review to assess whether the statutory conditions for opening proceedings are satisfied. If the criteria are met, the court schedules a first hearing to formally initiate the process. At this initial creditors' hearing, the court examines available evidence and determines whether to officially open bankruptcy proceedings. If the motion is granted, the court appoints a bankruptcy administrator to manage the debtor's estate and oversee the liquidation process. This is followed by the examination hearing, during which creditors submit claims, and the financial position of the debtor is assessed. At this stage, the court verifies and confirms the list of creditors and their claims.

Following the examination hearing, the court issues a bankruptcy decision, determining whether the case will proceed to liquidation or reorganization. In liquidation proceedings, the process continues with the sale of the debtor's assets, which is conducted by the bankruptcy

administrator under the court's supervision. Assets may be sold through public auctions or direct sales, with the proceeds distributed to creditors in accordance with the statutory priority of claims. As the proceedings near completion, the administrator submits a final report detailing the asset distribution and settlement of claims. The court reviews this report to ensure compliance with all legal requirements before issuing a decision to close the bankruptcy case. After closure, the legality of the process is subject to final verification to confirm that both procedural and substantive obligations have been fully met.

Throughout the proceedings, the bankruptcy judge plays a key role in directing the course of the case. Core responsibilities include initiating preliminary bankruptcy proceedings, determining whether the legal grounds for opening bankruptcy exist, and supervising the appointment or dismissal of bankruptcy administrators. Judges must also approve costs incurred during the proceedings, including obligations charged to the bankruptcy estate, prior to their disbursement. Effective scheduling of hearings is essential, as judges are responsible for maintaining procedural timelines and ensuring that all parties, creditors, administrators, and other stakeholders receive proper notice and the opportunity to participate. Judges also adjudicate complaints regarding the conduct of bankruptcy administrators, thereby safeguarding accountability and compliance with applicable legal standards. In the final stages of the process, the judge oversees the distribution of the bankruptcy estate, ensuring that creditor claims are satisfied in accordance with the statutory order of priority.

Serbian bankruptcy judges share a relatively homogeneous professional background, as all are career judges with formal legal education and judicial experience. This professional uniformity mirrors practices in other jurisdictions, such as France (Blazy & Esquerré, 2021). However, variations in tenure and specialization in bankruptcy law may still significantly influence judicial decision-making and procedural outcomes. Unfortunately, data on these individual characteristics—such as years of service, prior case experience, or formal specialization—is not publicly available, thereby limiting empirical inquiry into their potential effects.

Judicial performance is also shaped by the institutional capacity and resource constraints of the courts in which judges operate. In smaller jurisdictions, the absence of specialized bankruptcy judges reflects a resource allocation strategy that emphasizes efficiency through an economy-of-scope approach. In Serbia, these judicial functions are carried out across 16 commercial courts, which differ markedly in terms of size, staffing, and caseload, typically in line with the economic significance of the regions they serve. Larger courts, such as those in Belgrade and Novi Sad, handle a disproportionately high volume of cases, often resulting in delays due to excessive caseloads and limited judicial resources. Conversely, smaller courts frequently struggle with insufficient specialization and staffing, impairing their capacity to effectively manage complex or contested bankruptcy proceedings.

In Serbia, bankruptcy cases are assigned to judges in accordance with the internal organizational rules of commercial courts, which include the use of an automated case assignment system. This system is intended to ensure an even distribution of workload among bankruptcy judges and to minimize the risk of subjective influence in the assignment process. The algorithm considers various factors, including the number of cases already assigned to each judge, the type of case, and, in some instances, case complexity and urgency. In smaller courts, particularly those lacking specialized bankruptcy judges, cases may also be assigned to generalist judges based on availability, which may result in variations in the experience and efficiency with which bankruptcy cases are handled across different courts.

While the automated system enhances transparency and reduces the likelihood of manipulation, potential concerns about endogeneity cannot be fully excluded. In practice, certain high-stakes or procedurally complex cases may be reassigned, typically by the President of the Commercial Court, to more experienced judges through internal administrative decisions. Such discretionary reallocation, though infrequent, may correlate with unobserved case characteristics that also affect duration, thereby introducing omitted variable bias and potentially distorting

estimates of judge-specific effects in empirical models. Recognizing these limitations is essential when interpreting the causal influence of judges on procedural outcomes.

DESCRIPTIVE STATISTICS AND VARIABLE CONSTRUCTION

Given that judges in Serbia primarily influence the pace rather than the outcome of proceedings, procedural duration offers a suitable metric for evaluating their impact. The duration of bankruptcy proceedings is typically measured from the commencement of the case to either the liquidation of the debtor's assets or the formal closure of the case. In Serbia, information on case duration can be drawn from both judicial statistics and reports submitted by insolvency administrators. This study relies on a uniquely detailed micro-level dataset compiled by the Bankruptcy Supervision Agency (BSA), the regulatory authority overseeing bankruptcy administrators. As part of its supervisory mandate, the BSA requires standardized reporting on all individual cases, resulting in a comprehensive and structured dataset that far exceeds the scope of typical judicial statistics in both depth and specificity. Comparable data is rarely available in other jurisdictions.

The dataset includes information on key procedural milestones, such as the timing of the first hearing, the examination hearing, the issuance of the bankruptcy decision, and the date of case closure and finality. While it does not contain precise dates related to individual asset liquidations, it offers a detailed breakdown of expenditures associated with estate administration. These include court and regulatory fees, administrator remuneration, expert consultation costs, storage and preservation expenses, auctioneer fees, and applicable government levies. The initial dataset comprises 5,774 closed bankruptcy liquidation cases. To ensure analytical robustness, several filters were applied. First, cases involving no assets or lacking essential data were excluded. Second, extremely short cases, defined as those lasting fewer than 30 days, were removed to avoid distortions caused by procedural anomalies or reporting errors. Third, to focus the analysis on economically meaningful proceedings, only cases with a minimum net inflow of approximately €8,000 were retained. This threshold ensures that the analysis concentrates on cases with substantive financial stakes, where judicial influence on procedural efficiency is more relevant. After applying these filters, the sample was reduced to 1,791 cases.

Finally, cases involving multiple presiding judges were excluded to enable proper attribution of case outcomes to individual judges. The presence of more than one judge over the course of a single proceeding makes it difficult to isolate the effect of any individual judge on case duration or procedural efficiency. Changes in judicial assignment can influence both the timeline and consistency of decision-making, thus complicating empirical attribution. Identification of cases with multiple presiding judges was conducted manually, as this information is not explicitly recorded in the database. In our dataset of 1,791 bankruptcy cases, we identified 443 cases (approximately 24.7%) involving a change in the presiding judge during the proceedings. In practice, changes in the presiding judge may occur for various reasons. These include retirement, reassignments to other departments, promotions (e.g., to the appellate commercial court), long-term illness, or temporary absences. Case reassignment may also be initiated administratively by the court president to balance caseloads or improve procedural efficiency. In exceptional circumstances, judges may be replaced due to substantiated complaints from parties or creditors regarding judicial conduct, or due to conflicts of interest, bias, or relationships that compromise impartiality. In rare cases, procedural errors identified on appeal may also lead to reassignment or recusal.

The dependent variable, *ln (duration in months)*, represents the natural logarithm of the time (in months) from the formal commencement of the bankruptcy procedure to the final closure of the case. This log transformation helps stabilize variance and mitigate the influence of extreme values. The transformed variable has a mean of 3.737 and a standard deviation of 0.771, with values ranging from 0.49 to 5.14, indicating substantial variability in procedural timelines (Table

1). In real terms, this corresponds to an average case duration of 55.2 months, with a standard deviation of 39.5 months. The shortest observed case lasted 1.6 months, while the longest extended to 170.5 months. This wide dispersion reflects underlying heterogeneity in case complexity, procedural efficiency, and the respective roles of judges and administrators.

Serbian bankruptcy judges face several structural and institutional constraints that can affect the duration of proceedings. A key limitation is the reliance on bankruptcy administrators, creditors, and external stakeholders, whose actions—or inactions—can delay the process. Even when judges adhere to prescribed timelines, the process may be prolonged due to late submissions, unverified claims, or protracted asset sales. Case complexity, particularly when involving valuation disputes, contested claims, or reorganization efforts, often extends deliberation periods beyond the judge's direct control. The reliance on external expert reports, especially for asset valuation, frequently creates procedural bottlenecks, as judges cannot move forward with critical rulings until those reports are submitted and reviewed. To account for variation in case size and complexity, several control variables are introduced.

Two continuous variables, *ln(net receipts)* and *ln(total claims)*, are used as proxies for the financial magnitude of bankruptcy cases. The mean of ln(net receipts) is 16.16 (SD = 1.55), corresponding to approximately 10.3 million RSD, or roughly €100,000.[1] In contrast, ln(total claims) has a higher mean of 18.23 (SD = 1.79), equivalent to about 91.2 million RSD, or approximately €887,000. The wide range in logged values—from 13.71 to 21.91 for net receipts and from 10.59 to 24.85 for total claims—translates into variation from about €8,700 to over €29 million in receipts, and from €390 to over €61 million in claims. These figures reflect substantial heterogeneity in case size and financial stakes.

The share of secured claims is included as an additional control variable, reflecting the capital structure of the bankrupt estate. On average, secured creditors account for approximately 19% of total claims, suggesting that in most proceedings, unsecured claims dominate the creditor structure. The standard deviation of 0.256 indicates considerable variation across cases in the distribution between secured and unsecured debt. This variation is relevant for understanding differences in procedural dynamics, as the presence of secured creditors is expected to influence both the complexity and the duration of the proceedings. A higher share of secured claims may be associated with shorter durations, since secured creditors typically have well-defined legal rights and collateral, which can expedite asset realization and reduce disputes. On the other hand, in some cases, the enforcement of security interests—especially when involving large or illiquid assets—may introduce delays. Thus, the net effect of secured claims on duration is theoretically ambiguous and must be determined empirically. Including this variable allows us to account for the degree to which differences in capital structure contribute to variation in procedural efficiency across cases.

In bankruptcies involving state-owned enterprises, the Bankruptcy Supervision Agency (BSA) itself serves as the administrator. These cases typically arise from the legacy of the transition period, where many insolvent enterprises with significant public ownership or unresolved legal obligations continue to appear in bankruptcy courts. In such proceedings, the BSA appoints a trustee from its pool of certified professionals, who operate under the agency's direct supervision. These BSA-appointed trustees are subject to additional reporting and compliance obligations, reflecting the agency's regulatory function as well as its administrative role. In the dataset, these cases are consistently categorized as involving a bankruptcy administrator, allowing for a uniform comparison with proceedings managed by private-sector administrators. Notably, approximately 9% of the cases in our sample involve the BSA. These proceedings often involve larger and more complex estates, substantial employee-related claims, or unresolved obligations toward public creditors such as tax authorities or state-owned utility providers. As such, they may exhibit

[1] All euro values are approximate, as the exchange rate between the dinar and the euro fluctuated during the observation period.

distinct patterns in terms of procedural duration, administrative costs, and judicial involvement. Additional proxies for case complexity include a binary variable indicating the presence of contested creditor claims. Approximately 56.8% of cases involve at least one disputed claim. This high percentage suggests that legal contestation is common and adds a considerable procedural burden, often extending the timeline of the case.

In the Serbian legal framework, the formal closure of bankruptcy proceedings does not necessarily mark the end of all case-related activities. A proceeding may be officially closed by the court while the bankruptcy estate remains active, meaning that certain post-closure tasks, such as asset liquidation, resolution of outstanding claims, or continuation of related litigation, still require administrative follow-up. To capture this distinction, a binary variable is included indicating whether the bankruptcy estate remained active after the formal closure of the case. In 33.8% of cases, the estate continued to exist beyond the official termination of proceedings, implying an extended administrative role for the bankruptcy trustee under ongoing court oversight. This institutional feature reflects a procedural separation between the legal closure of the case and the practical completion of estate-related obligations. A separate binary variable captures whether the bankruptcy procedure involved a going-concern sale, that is, the sale of the legal entity as an operational whole, rather than liquidation of individual assets. Going concern sales are likely to follow a different procedural trajectory, potentially influencing the duration of the case. In the dataset, 260 out of 1,337 cases, or approximately 19.4%, involved a going-concern sale. While still a minority of cases, this share suggests that the practice is not uncommon in Serbian bankruptcy proceedings and may reflect efforts to prioritize economic efficiency and value maximization where feasible.

Table 1. Descriptive Statistics

Variable	Obs.	Mean	Std. dev.	Min	Max
ln (duration in months)	1,337	3.723	0.770	1.110	5.14
ln (net receipts)	1,337	16.156	1.551	13.71	21.91
ln (total claims)	1,337	18.235	1.786	10.59	24.85
Secured creditors share	1,337	0.192	0.256	0	1
BSA as administrator	1,337	0.091	0.287	0	1
Bankruptcy estate	1,337	0.333	0.471	0	1
Contested creditors dummy	1,337	0.568	0.496	0	1
Going Concern Sale	1,337	0.194	0.396	0	1
Law					
2010	1,337	0.710	0.454	0	1
2014	1,337	0.162	0.368	0	1
2017	1,337	0.075	0.262	0	1
2018	1,337	0.054	0.225	0	1

Source: Author's calculation

To account for procedural variation introduced by changes in legislation, we include dummy variables for the applicable version of the Bankruptcy Law. Most cases (71.10%) fall under the 2010 version of the law, with smaller shares under the 2014 (16.2%), 2017 (7.5%), and 2018 (5.4%) amendments. This distribution reflects the legal evolution of the bankruptcy framework in Serbia and enables us to assess whether legislative reforms had any measurable effect on the duration of proceedings. However, it is important to note that a significant number of cases initiated under the 2017 and 2018 amendments were still ongoing at the time of data collection. As a result, these cohorts may be underrepresented in the sample of completed (closed) cases, potentially biasing observed duration estimates downward for more recent reforms. This should be kept in mind when interpreting the estimated effects of the 2017 and 2018 legal changes.

The dataset also reveals the geographic distribution of bankruptcy cases across Serbia's commercial courts, illustrating substantial regional variation. The Belgrade Commercial Court accounts for the largest share, handling approximately 20.5% of all cases in the data, followed by Novi Sad with 11.8%. Other mid-sized courts, such as Kragujevac, Niš, and Valjevo, manage moderate caseloads ranging from 6.7% to 8.6%. In contrast, smaller courts handle significantly fewer proceedings, with each contributing between 2.4% and 2.8% of the total. This distribution reflects the concentration of bankruptcy activity in economically significant regions, where business density and enterprise size are generally higher. Conversely, lower caseloads in smaller courts may be associated with lower levels of commercial activity.

The distribution of bankruptcy judges across courts also varies according to jurisdiction size. The data include a total of 141 judges who presided over at least one closed bankruptcy case. The Belgrade Commercial Court again stands out, with 41 judges represented in the data. In contrast, smaller courts typically have only two to six judges responsible for all commercial matters, including bankruptcy. During the period of elevated bankruptcy activity between 2010 and 2012—likely a residual effect of post-crisis financial distress, a broader group of judges was assigned to handle insolvency proceedings. However, as the number of new filings declined in subsequent years, the number of judges actively presiding over bankruptcy cases was reduced, reflecting changes in workload distribution and specialization at the court level.

A notable limitation of our data set is the lack of publicly available data on individual judges. Information such as years of judicial experience, number of previously handled bankruptcy cases, or formal specialization in bankruptcy law is not accessible. This absence of judge-specific variables limits the ability to control for unobserved heterogeneity in judicial behaviour and prevents the use of judge fixed effects in the estimation strategy. Consequently, differences in case duration that may be driven by variation in experience, decision-making style, or informal practices cannot be fully accounted for, which may lead to biased estimates or obscure important sources of procedural variation.

METHODOLOGY AND RESULTS

Hierarchical, or multilevel, models are designed to analyse data with a nested or clustered structure, allowing researchers to estimate the effect of variables at multiple levels of aggregation (Heck et al., 2020; Hox et al., 2017; Rabe-Hesketh & Skrondal, 2022; Snijders & Bosker, 2012). In this context, bankruptcy cases are nested within judges and courts, as cases handled by the same judge or within the same court may share common features due to similar decision-making styles, experience levels, or resource availability. Hierarchical modelling corrects for the non-independence of observations within these groups, thereby producing more accurate estimates of standard errors and variance components.

Random-effects models are particularly well-suited for this analysis, as they account for unobserved heterogeneity among judges, administrators, and courts by modelling their effects as drawn from underlying distributions. While the dataset includes nearly the full population of relevant agents, treating these institutional units as random effects enables estimation of group-level variance components and improves inference on case-level predictors through partial pooling. This approach is especially appropriate in settings with many groups, such as over 140 judges and 16 commercial courts, where fixed-effects models would require a prohibitive number of parameters and absorb much of the between-group variation. While fixed effects are useful for controlling for unobserved heterogeneity, their use here would limit our ability to assess and quantify how case outcomes vary across institutional actors.

Bankruptcy case duration is shaped by a combination of factors at multiple levels: case-level characteristics (e.g., debtor type, complexity, or contested claims), judge-level factors (e.g., experience, workload management), and court-level features (e.g., staffing, administrative support, or procedural infrastructure). Hierarchical models allow us to decompose the total

variance in case duration into components attributable to each of these levels. For example, some judges may consistently allow longer timelines, while well-resourced courts may resolve cases more efficiently. Random intercepts are used to model systematic differences between groups, such as consistently longer or shorter durations among certain judges, while random slopes would allow the effect of specific predictors to vary across groups. However, due to the lack of detailed judge-level covariates, we focus on random-intercept models, which still yield important insights into multilevel influences on procedural efficiency.

We begin by estimating a two-level random-intercept model to examine the extent to which variation in case duration can be attributed to individual judges. This baseline specification captures between-judge differences, such as variation in decision-making style or caseload management, while controlling for case-level characteristics. In the second stage, we extend the model to a three-level hierarchical structure by introducing court-level random effects, thereby accounting for the institutional environment in which judges operate. Finally, we estimate a crossed random-effects model to capture the independent and non-nested influence of both judges and bankruptcy administrators, acknowledging that these agents jointly affect case outcomes but are not hierarchically organized.

Two-Level Random-Intercept Model

We employ a two-level random-intercepts model to account for unobserved heterogeneity in case duration across judges, while accommodating limitations in the available data. Specifically, the dataset lacks judge-level (Level 2) covariates such as experience, specialization, workload, or appointment history, which precludes the inclusion of such variables in the model. In the absence of judge-level predictors, a random-intercept specification provides a practical and theoretically sound approach to modeling between-judge variation. This model allows each judge to have a unique baseline case duration, capturing systematic but unobserved differences in judicial behavior. It assumes that case-level predictor effects are constant across judges.

The dataset used for the two-level model treats bankruptcy cases as nested within judges and includes 1,337 cases presided over by a single judge. These cases are distributed across 141 unique judges, averaging approximately 9.5 cases per judge. This structure meets the general rule-of-thumb (minimum ~42 clusters) for relying on the asymptotic properties of standard errors in mixed-effects models (Rabe-Hesketh & Skrondal, 2022; Snijders & Bosker, 2012).

Let y_{ij} denote the outcome variable defined as the natural logarithm of case duration in months, for case i presided over by judge j. The baseline model is specified as:[2]

$$y_{ij} = \beta_0 + \beta_1 x_{1ij} + \cdots + \beta_p x_{pij} + \xi_{ij} \qquad (1)$$

Here x_{1ij} through x_{pij} represent case-specific covariates, and ξ_{ij} is a residual term. Assuming independent residuals across cases is likely unrealistic (Grotti & Cutuli, 2018), as multiple cases are handled by the same judge. To model this, we decompose the residual into

$$\xi_{ij} \equiv \zeta_j + \varepsilon_{ij} \qquad (2)$$

where ζ_j is a judge-specific component which remains constant across the cases, and ε_{ij} is a case-specific error term (varies between cases and across judges).

Substituting this decomposition into the model yields the two-level linear mixed model (Rabe-Hesketh & Skrondal, 2022):

[2] Note that different notations and formulations of multilevel models exist; this paper follows the notation and modelling framework of Rabe-Hesketh & Skrondal (2022).

$$y_{ij} = \beta_0 + \beta_1 x_{1ij} + \cdots + \beta_p x_{pij} + \zeta_j + \varepsilon_{ij} = (\beta_0 + \zeta_j) + \beta_1 x_{1ij} + \cdots + \beta_p x_{pij} + \varepsilon_{ij} \quad (3)$$

The random intercept ζ_j captures judge-specific deviations from the mean due to unobserved characteristics. A positive ζ_j implies that judge j tends to preside over longer cases, even after adjusting for case-level characteristics.

To assess the contribution of judge-level heterogeneity, we compute the intraclass correlation coefficient (ICC):

$$\rho(judge) = Corr(y_{ij}, y_{i'j'} | X_j) = \frac{\psi}{\psi + \theta} \quad (4)$$

where $\psi = Var(\zeta_j | X_j)$ is the between-judge variance, and $\theta = Var(\varepsilon_{ij} | X_j, \zeta_j)$ is within-judge (case-level) variance. A higher ICC indicates that a greater portion of case duration variability is explained by judges rather than individual case characteristics. An ICC$= 1$ all variation in case duration is due to differences between cases, not judges, while if $\rho = 0$ judges do not systematically differ in how long their cases take.

Following Rabe-Hesketh and Skrondal (2022), we adopt a modeling approach to investigate variation in case duration across judges. We begin with a between-effects model, which aggregates case-level data to the judge level and captures how variation in average predictor values explains variation in average case duration across judges. This isolates between-judge heterogeneity but omits variation within judges' caseloads. Next, we estimate a within-effects model (also known as a fixed-effects specification in the sense of group-mean centring). This model captures how the same judge handles different types of cases but discards between-judge differences. It estimates only within-judge variation by subtracting each judge's average from the case-level variables.

To leverage both levels of information, we estimate a random-intercepts linear mixed model using restricted maximum likelihood (REML). This model assumes that judges differ by a random intercept that captures unobserved heterogeneity, while allowing us to estimate both within- and between-cluster effects. A likelihood-ratio test confirms that judge-level random intercepts significantly improve model fit, rejecting the null hypothesis that between-judge variance equals zero. This provides strong evidence for the presence of meaningful judge-level heterogeneity in case duration. However, a significant Hausman test suggests that some case-level covariates are correlated with judge-specific effects, violating the random-effects assumption that these covariates are exogenous relative to the judge intercept. Specifically, predictors like claim value and legal regime may not be randomly distributed across judges — for example, some judges may systematically handle more complex cases or interpret reforms differently. This endogeneity introduces bias in standard random effects models and undermines the consistency of estimated coefficients.

To address this, we implement the Mundlak correction (Mundlak, 1978), which augments the random-effects model by including the judge-specific mean of each case-level predictor as an additional covariate. This adjustment controls for unobserved judge-level characteristics that correlate with those predictors. Intuitively, the Mundlak approach separates within-judge effects (how variation in case features affects duration for the same judge) from between-judge effects (how judges with systematically different case profiles differ in outcomes). The result is a model that retains the efficiency of random-effects estimation while relaxing its strict exogeneity assumptions, thereby producing consistent and interpretable estimates.

For each model, the table is divided into a fixed part and a random part, reflecting the structure of multilevel (mixed effects) estimation. The fixed part includes the estimated coefficients for the predictor variables — these represent the average effect of each covariate across all units (cases,

judges, courts). The random part reports the estimated variance components (and standard deviations) at each level of the data hierarchy: case-level residual variance, judge-level intercept variance. These variance components allow us to assess how much of the total variation in case duration is attributable to systematic differences across judges and courts, rather than variation across individual cases. In particular, the random intercepts capture unobserved heterogeneity at each level, and the intraclass correlation coefficients derived from them quantify the proportion of total variance due to clustering at higher levels.

The dataset used for the two-level model includes 1,348 bankruptcy cases, each presided over by a single judge. These cases span 142 judges, with an average of 9.5 cases per judge. As emphasized in the multilevel modeling literature models (Rabe-Hesketh & Skrondal, 2022; Snijders & Bosker, 2012), reliable estimation of between-group variance typically requires at least 42 groups, with stronger precision from 100 or more. With 142 judges, our data supports robust inference.

We now examine the main empirical results, with emphasis on the Mundlak-adjusted random-intercepts model (Model 4), which provides consistent estimates while accounting for judge-level heterogeneity. As the dependent variable is the natural log of case duration (in months), the model coefficients are interpreted as semi-elasticities when the independent variables are in levels (e.g., binary or non-transformed variables) — that is, as the approximate percentage change in duration for a one-unit change in the covariate. For predictors that are also log-transformed (e.g., ln(net receipts), ln(total claims)), the coefficients are interpreted as elasticities — the percentage change in duration resulting from a 1% increase in the predictor.

As expected, both measures of case size and complexity—the log of net receipts and the log of total claims—are positively and significantly associated with case duration. A 1% increase in net receipts is associated with an approximate 0.084% increase in case duration, holding other variables constant. Similarly, a 1% increase in total claims is associated with an additional 0.051% increase in case duration. Cases involving socially- or state-owned companies, captured by the BSA variable, are associated with a 0.226 unit increase in the log of duration, equivalent to an approximate 25.4% increase in case length. This robust and significant effect suggests that these cases are systematically more complex and time-consuming, likely due to bureaucratic constraints, unclear asset ownership, and unresolved liabilities.

Table 2. Two-level models

	(1) Within effects FE		**(2) Between effects BE**		**(3) Random effects REML 2L**		**(4) Random effects plus clustered mean REML MUNDLAK**	
	Est	**(robust se)**	**Est**	**(se)**	**Est**	**(se)**	**Est**	**(se)**
FIXED PART								
ln(net receipts)	0.085***	0.015	0.126*	0.071	0.095***	0.016	0.085***	0.016
ln(total claims)	0.051***	0.012	0.031	0.051	0.051***	0.012	0.051***	0.013
Secured creditors share	-0.071	0.071	0.028	0.373	-0.061	0.075	-0.071	0.077
BSA	0.227***	0.061	0.473	0.295	0.237***	0.060	0.227***	0.061
Bankruptcy estate	0.701***	0.049	0.758***	0.192	0.717***	0.045	0.701***	0.046
Contested creditors	-0.073	0.044	0.168	0.160	-0.058	0.041	-0.073*	0.042
Going Concern Sale	-0.459***	0.056	-0.174	0.234	-0.447***	0.059	-0.460***	0.057
Law (vs. 2010)								
2014	-0.352***	0.067	-0.151	0.180	-0.301***	0.472	-0.352***	0.049
2017	-0.688***	0.096	-0.089**	0.197	-0.574***	0.069	-0.688***	0.074
2018	-1.050***	0.077	-0.379	0.178	-0.898***	0.078	-1.050***	0.086

	(1) Within effects FE		(2) Between effects BE		(3) Random effects REML 2L		(4) Random effects plus clustered mean REML MUNDLAK	
	Est	(robust se)	Est	(se)	Est	(se)	Est	(se)
mean ln(net receipts)							0.068	0.067
mean ln(total claims)							0.016	0.049
mean Secured creditors							0.270	0.306
mean BSA							0.154	0.244
mean Bankruptcy estate							0.041	0.180
mean Contested creditors							0.254	0.156
mean Going Concern Sale							0.304	0.207
mean 2014							0.209	0.166
mean 2017							0.548***	0.189
mean 2018							0.652***	0.201
Constant	1.473***	0.185	0.765	0.921	1.262***	0.208	-0.328	0.843
RANDOM PART								
$\sqrt{\psi}$			0.274	0.036	0.277	0.034	0.218	0.032
$\sqrt{\theta}$	0.577		0.581	0.014	0.583	0.012	0.582	0.012
ρ				0.182		0.184		0.123
Number of observations		1337		1337		1337		1337
Number of judges		141		141		141		141

*Note: Dependent log months duration. For FE robust standard errors. Robust standard errors are not available with the REML option. The Kenward–Roger degrees of freedom correction were applied. * p < 0.10, ** p < 0.05, *** p < 0.01.*

The effect remains consistent across all model specifications. The presence of a bankruptcy estate continuation is associated with a 0.70 unit increase in logged case duration, equivalent to a 99.4% longer duration. This substantial increase underlines the substantial time burden imposed by post-primary estate management, often involving prolonged asset realization and creditor disputes. Conversely, cases resolved via a going-concern sale are associated with a 0.46 unit decrease in log-duration, equivalent to a 35.5% shorter duration. This aligns with theoretical expectations, as going concern sales often reflect more viable businesses and incentivize quicker resolution through structured negotiations. Regarding temporal effects, legal changes introduced in 2014, 2017, and 2018 are associated with successively shorter durations. Compared to the pre-reform period (2010 baseline), durations decreased by 29.7% in 2014, 49,8% in 2017, and 65.1% in 2018, all statistically significant.

Turning to the random part, the estimated standard deviation of judge-level random intercepts $\sqrt{\psi}$ in the model (4) is 0.218, with a residual error standard deviation $\sqrt{\theta}$ of 0.582. These translate into a between-judge variance of ψ = 0.044 and a within-judge (residual) variance of θ=0.339. The intra-class correlation coefficient is calculated as:

$$\rho(judge) = \frac{\psi}{\psi + \theta} = \frac{0.044}{0.044 + 0.339} = 0.123$$

The intraclass correlation coefficient suggests that 12.3% of the total variance in case duration is attributable to differences across judges. This implies that judge-level unobserved characteristics contribute non-trivial variation to case duration and provide empirical justification for the two-level modelling approach.

As stated, the likelihood-ratio test confirms the relevance of including random intercepts, while the Hausman test rejects the assumption of strict exogeneity of case-level predictors, supporting the use of the Mundlak correction. Notably, judge-level averages of certain predictors (e.g., contested creditors, BSA, going-concern sale) are statistically significant, indicating systematic differences in the types of cases handled by different judges. For example, the positive coefficient on mean contested creditors suggests that judges who typically handle more contentious cases preside over longer cases on average.

While not shown, an auxiliary model including sector dummies finds that only agriculture (Sector A) and construction (Sector F) are associated with significantly longer durations—approximately 27% and 33%, respectively—relative to the omitted category. Sectoral controls do not materially alter the core findings and offer limited additional explanatory power. As a robustness check, we estimated the model excluding 27 judges who presided over only one case (singleton clusters), which represent approximately 19% of all judges in the sample. The results remained almost identical in terms of fixed-effect coefficients, standard errors, and the intraclass correlation coefficient (ICC), indicating that the inclusion of singleton judges does not materially affect the findings. This confirms the stability and robustness of the main model specification.

Figure 1 presents a caterpillar plot of judge-specific random intercepts estimated from the mixed-effects model (Model 4). Each point represents an individual judge, ranked by their predicted deviation from the average (BLUP — Best Linear Unbiased Prediction), with 95% confidence intervals indicated by vertical lines. These Empirical Bayes estimates "shrink" individual judge effects toward the grand mean, with the degree of shrinkage depending on the amount of information (i.e., number of cases) available per judge and the variability in the data. The plot reveals substantial heterogeneity in judicial tendencies, with random intercepts ranging from approximately 0.6 to +0.5 in ln(months). This corresponds to case durations that are roughly 45% shorter to 65% longer compared to the average case duration, after controlling for case-level predictors. Judges with only a few cases show greater shrinkage toward zero and wider confidence intervals, reflecting the increased uncertainty in their individual estimates. While some confidence intervals do not overlap with zero, indicating potential between-judge differences, these should not be interpreted as formal significance tests due to the nature of BLUP estimation.

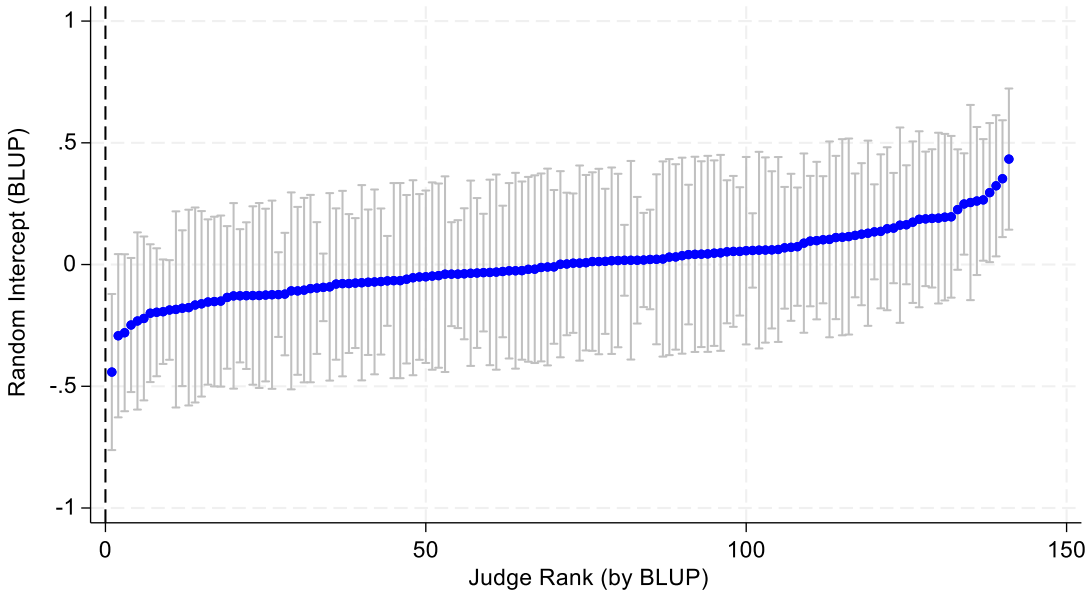


Figure 1. Caterpillar Plot of Judge Random Effects

In sum, the two-level random-intercept model reveals significant and robust differences in case duration attributable to individual judges, even after accounting for case-specific factors and legal context. The estimated intraclass correlation coefficient of 0.125 underscores the importance of unobserved judicial characteristics in shaping procedural efficiency. These findings validate the use of two-level modeling to account for hierarchical data structure and reinforce the relevance of judge-level variation in the design and evaluation of bankruptcy policy. In the next section, we extend the model to introduce court-level variation.

Three-Level Random-Intercept Model

Building on the two-level model presented earlier, we now extend the analysis to a three-level random-intercepts model, in which bankruptcy cases are nested within judges, and judges are further nested within courts. This expanded structure captures multiple layers of dependency in the data (see Figure 2) and allows us to disentangle not only case- and judge-level influences, but also broader court-level institutional variation.

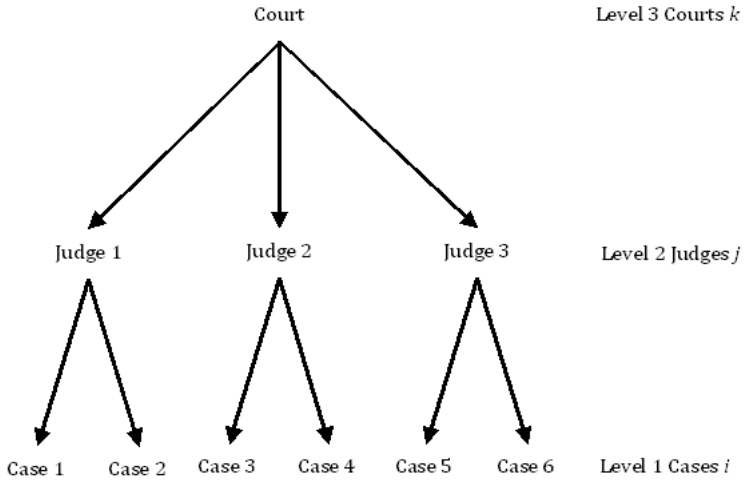


Figure 2. Three-level Model

Cases handled by the same judge are likely to exhibit correlated outcomes due to shared, unobserved characteristics such as the judge's decision-making approach, experience, or administrative efficiency. Likewise, judges operating within the same court are subject to common institutional factors, including resource constraints, administrative practices, and overall caseload management. By adopting a multilevel model, we are able to disentangle the variance in case outcomes attributable to case-specific attributes, judge-level heterogeneity, and broader court-level influences, thereby improving both the precision of estimation and the interpretability of results.

Formally, we specify the following three-level linear random-intercepts model (Rabe-Hesketh & Skrondal, 2022):

$$y_{ijk} = (\beta_1 + \zeta_{jk}^{(2)} + \zeta_k^{(3)}) + \beta_2 x_{1ij} + \cdots + \beta_p x_{pij} + \varepsilon_{ijk} \quad (5)$$

where:

- y_{ijk} is the outcome variable (case duration) for case i handled by judge j in court k,
- $x_{2ijk}, \ldots x_{pij}$ are case-level covariates,
- $\zeta_{jk}^{(2)} \sim N(0, \psi^{(2)})$ represents the judge-level random intercept (nested within court),

- $\zeta_k^{(3)} \sim N(0, \psi^{(3)})$ captures the court-level random intercept,
- $\varepsilon_{ijk} \sim N(0, \theta)$ is the case-specific residual.

This model allows us to decompose variation into three components: (1) within-judge, within-court (case-level) variation θ; (2) between-judge, within-court variation $\psi^{(2)}$; and (3) between-court variation $\psi^{(3)}$. A large $\psi^{(2)}$indicates significant differences between judges in the same court, while a large $\psi^{(3)}$ reflects substantial institutional variation across courts.

This model enables estimation of intra-class correlation coefficients at both the judge and court levels, offering insights into the hierarchical structure of variation and the institutional context shaping bankruptcy case outcomes. In the three-level model, for cases i and i'; within the same court but different judges j and j', the interclass correlation is:

$$\rho(court) = \frac{\psi^{(3)}}{\psi^{(2)}+\psi^{(3)}+\theta} \quad (5)$$

$$\rho(judge) = \frac{\psi^{(2)}+\psi^{(3)}}{\psi^{(2)}+\psi^{(3)}+\theta} \quad (6)$$

As in the two-level model, we assess the potential endogeneity of case-level predictors by applying the Mundlak correction, which augments the model with cluster-level means of level-1 covariates. In the three-level setting, we initially applied the correction at both the judge (Level 2) and court (Level 3) levels by including group means at each level. However, a likelihood ratio test comparing the full model (with both judge and court-level Mundlak terms) to a reduced model (judge-level only) found no significant improvement in model fit (LR $\chi^2(9) = 11.83$, $p = 0.223$). Thus, we retain only the judge-level Mundlak terms in the final model to maintain parsimony and theoretical coherence.

Since the fixed effects in the three-level model closely mirror those from the two-level specification, our discussion focuses primarily on the random part of the model, which provides new insights into the distribution of variance across judges and courts.

The estimated standard deviations of the random effects are as follows: 0.170 for judges within courts $\sqrt{\psi^{(2)}}$, 0.157 for courts $\sqrt{\psi^{(3)}}$, and 0.581 for the case-level residual variance $\sqrt{\theta}$. These values correspond to variance components of approximately 0.029 for judges, 0.025 for courts, and 0.338 for the residual. From these, we calculate the intra-class correlation coefficients (ICCs):

$$\rho(court) = \frac{\psi^{(3)}}{\psi^{(2)}+\psi^{(3)}+\theta} \approx 0.063, \qquad \rho(judge) = \frac{\psi^{(2)}+\psi^{(3)}}{\psi^{(2)}+\psi^{(3)}+\theta} \approx 0.136.$$

The decline in judge-level ICC from 19.6% (unadjusted) to 13.6% (Mundlak-adjusted) suggests that a substantial share of the between-judge variation in case duration arises from systematic differences in case composition, not merely unobserved judicial behavior.

In sum, the three-level model refines our understanding of hierarchical variance by quantifying how much of the observed case duration heterogeneity is driven by judges and courts. While court-level effects appear modest, judge-level variation remains significant even after accounting for case composition. This highlights the need for future research into the determinants of judicial behavior and potential institutional strategies to reduce disparities in bankruptcy case processing.

To account for procedural variation introduced by changes in legislation, we include dummy variables for the applicable version of the Bankruptcy Law. Most cases (71.10%) fall under the 2010 version of the law, with smaller shares under the 2014 (16.2%), 2017 (7.5%), and 2018 (5.4%) amendments. This distribution reflects the legal evolution of the bankruptcy framework in Serbia and enables us to assess whether legislative reforms had any measurable effect on the

duration of proceedings. However, it is important to note that a significant number of cases initiated under the 2017 and 2018 amendments were still ongoing at the time of data collection. As a result, these cohorts may be underrepresented in the sample of completed (closed) cases, potentially biasing observed duration estimates downward for more recent reforms. This should be kept in mind when interpreting the estimated effects of the 2017 and 2018 legal changes.

Table 3. Three-Level Model

	Random effects REML 3L		**Random effects plus clustered mean REML MUNDLAK**	
	Est	**(se)**	**Est**	**(se)**
FIXED PART				
ln(net receipts)	0.094***	0.016	0.085***	0.016
ln(total claims)	0.052***	0.012	0.051***	0.013
Secured creditors share	-0.087	0.076	-0.071***	0.077
BSA	0.231***	0.060	0.227***	0.061
Bankruptcy estate	0.704***	0.045	0.701*	0.047
Contested creditors dummy	-0.053	0.041	-0.073	0.042
Going Concern Sale	-0.443***	0.055	-0.461***	0.057
Law (vs. 2010)				
2014	-0.294***	0.047	-0.352***	0.049
2017	-0.556***	0.068	-0.689***	0.074
2018	-0.882***	0.077	-1.050***	0.086
mean ln(net receipts)			0.054	0.064
mean ln(total claims)			0.031	0.047
mean Secured creditors			0.049	0.317
mean BSA			-0.034	0.229
mean Bankruptcy estate			0.047	0.171
mean Contested creditors			0.169	0.151
mean Going Concern Sale			0.362	0.206
mean 2014			0.243	0.152
mean 2017			0.549***	0.174
mean 2018			0.681***	0.191
Constant	4.379***	0.229	-0.227	0.786
RANDOM PART				
$\sqrt{\psi^{(2)}}$	0.250	0.034	0.170	0.033
$\sqrt{\psi^{(3)}}$	0.139	0.044	0.157	0.040
$\sqrt{\theta}$	0.581	0.012	0.581	0.012
Number of observations	1377		1377	

Cross-Classified Random-Effect Model: Accounting for Bankruptcy Judge and Bankruptcy Administrator Interaction

Previous models assumed a hierarchical structure in which bankruptcy cases are nested within judges, and judges within courts. This structure presumes a strictly nested data-generating process—each judge is uniquely associated with a single court. However, one agent omitted from earlier models is the bankruptcy administrator. Administrators play a central role in the execution of insolvency proceedings. Their responsibilities include identifying and liquidating debtor assets, verifying creditor claims, and ensuring legal compliance. The competence and initiative of administrators can substantially influence case resolution times: while capable administrators may expedite proceedings, procedural errors or disorganization can lead to prolonged proceedings and increased costs.

Moreover, the interaction between judges and administrators is a potentially important but underexplored factor in procedural efficiency. Judges oversee legality and procedure, while

administrators carry out day-to-day operations. The degree of coordination and mutual responsiveness between these agents may affect overall case handling efficiency. Therefore, any comprehensive model of bankruptcy performance should capture not only the independent contributions of judges and administrators but also the possible effects of their collaboration.

To capture this more complex institutional structure, we specify a cross-classified random-effects model, in which both judges and administrators are treated as crossed (rather than nested) random effects. This specification reflects the reality that a single administrator may work with multiple judges, and vice versa. Cases are thus jointly classified by two distinct dimensions: the presiding judge and the appointed administrator. We limit our analysis to cases involving exactly one judge and one administrator, allowing us to avoid the additional complexity of a multiple membership model, which would require estimating membership weights (e.g., based on time contributions). While more flexible, such models can introduce measurement error and complicate estimation. The one-to-one assignment assumption keeps the model tractable while remaining theoretically sound.

In contrast to the earlier two-level hierarchical model, where cases were nested within judges and judges nested within courts, we do not include courts as an additional level in the crossed model. This choice is both theoretically and empirically justified. Empirically, the variance component associated with courts in the hierarchical model was negligible, suggesting that most of the explainable variation occurs at the judge level rather than being attributable to broader court-level institutional factors. Theoretically, once judges are modeled as individual random effects—capturing their procedural styles, workload management, and interpretive tendencies—little residual heterogeneity remains at the court level. Moreover, administrators are not nested within courts and may work across jurisdictions, making it difficult to incorporate courts into a crossed or hierarchical structure without misrepresenting the institutional realities of administrator assignment. Therefore, we omit courts from the crossed model to maintain parsimony and focus on the two key actors—judges and administrators—who directly shape procedural efficiency.

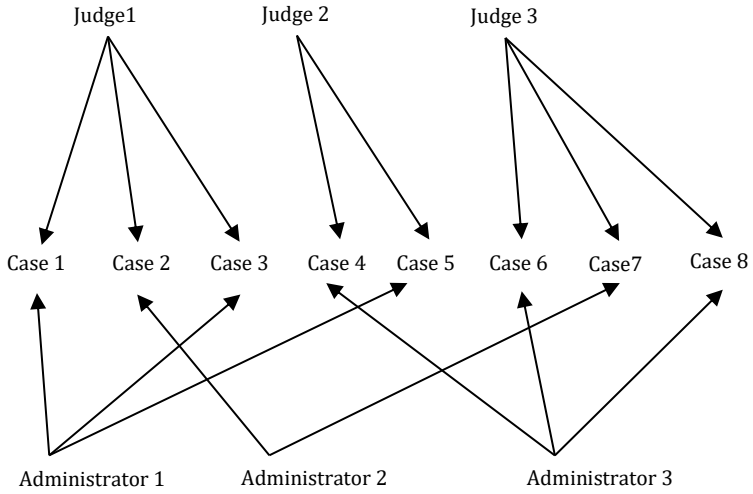


Figure 3. Cross-classified Data Structure

To estimate these effects, we begin with a model that includes only additive random effects for judges and administrators. In this framework, each actor contributes independently to the outcome of interest—in this case, the log of total case duration. The additive model captures systematic differences in case handling that can be attributed to individual judges and administrators, respectively.

The number of observations in the cross-classified estimate is reduced, as, similar to the case where judges may be substituted in individual instances, administrators can also be replaced. Accordingly, we identified an additional 114 cases where more than one administrator was involved. Approximately 39% of judge–administrator pairs appear in only one case, while the remaining 61% involve repeated combinations. This structure provides sufficient information to estimate a random interaction term, allowing us to assess whether certain judge–administrator pairs systematically deviate from their expected performance based on individual tendencies. Singleton pairs (pairs that occur only once) do not provide sufficient within-pair variation to estimate the interaction variance and are thus more heavily influenced by the overall mean due to empirical Bayes shrinkage.

It is also possible that certain specific pairings of judges and administrators perform differently than would be expected based solely on their individual effects. To account for this possibility, we extend the model by introducing a random interaction term between judges and administrators. This interaction term allows the model to capture unique dynamics within specific judge–administrator pairs, for example, more effective communication, mutual trust, or complementary work styles that result in higher efficiency.

The key distinction between the additive and interaction models lies in how they conceptualize influence. The additive model assumes that each actor has an independent and consistent effect on case duration, reflecting individual-level variation. In contrast, the interaction model allows for the possibility that certain pairings have idiosyncratic effects—positive or negative—that arise only in combination. While the additive model captures general tendencies, the interaction model tests whether some pairs perform differently together than would be expected based on their separate contributions.

We first specify the following additive crossed random-effects model (Rabe-Hesketh & Skrondal, 2022):

$$y_{ijk} = \beta_0 + \beta_1 x_{1ij} + \cdots + \beta_p x_{pij} + \zeta_{1j} + \zeta_{2k} + \varepsilon_{ijk} \quad (7)$$

- y_{ijk} is the log duration of case *i*, handled by administrator *j* and presided over by judge *k*,
- ζ_{1j} and ζ_{2k} additive (and uncorrelated) random effects for administrators and judges with zero means and variances $\psi_1$and ψ_2, respectively;
- ε_{ijk} residual represents the deviation of an individual case's efficiency from the mean for administrator *j* and judge *k*. For a given random set of effects, the residual has a mean of 0 and variance θ .

The implied intraclass correlations for two cases i and i' handled by the same administrator but different judges k and k' are:

$$\rho(administrator) = \frac{\psi_1}{\psi_1+\psi_2+\theta} \quad (8)$$

Similarly, the correlation between cases presided over by the same judge, but different administrators, is given by:

$$\rho(judge) = \frac{\psi_2}{\psi_1+\psi_2+\theta} \quad (9)$$

Finally, we can also examine the correlation between different cases presided over by the same judge and handled by the same administrator:

$$\rho(administrator, judge) = \frac{\psi_1+\psi_2}{\psi_1+\psi_2+\theta} \quad (10)$$

In many instances, the same judge–administrator combination appears in multiple cases. This structure raises the possibility that the pairing itself, not just the individual characteristics, affects efficiency. For instance, an administrator may be particularly effective when working with one judge, but less so with another, perhaps due to institutional familiarity or coordination practices. To capture such joint effects, we estimate an extended model with a random interaction term between administrators and judges:

$$y_{ijk} = \beta_0 + \beta_1 x + \cdots + \zeta_{1j} + \zeta_{2k} + \zeta_{3jk} + \varepsilon_{ijk} \quad (11)$$

In this specification, the term ζ_{3jk} represents a random interaction term between administrators and judges in the model. The random interaction term ζ_{3jk} has a mean of 0 and variance ψ_3 and it is uncorrelated with the other random terms (ζ_{1j}, ζ_{2k} and ε_{ijk}), and also uncorrelated across combinations of judges and administrators.

The corresponding intraclass correlations in this specification become:

$$\rho(administrator) = \frac{\psi_1}{\psi_1+\psi_2+\psi_3+\theta} \quad (12)$$

For cases handled by the same administrator j but presided over by different bankruptcy judges k and k', the interaction term $\psi_3 = 0$ if there is no interaction:

$$\rho(judge) = \frac{\psi_2}{\psi_1+\psi_2+\psi_3+\theta} \quad (13)$$

For cases i and i' presided over by the same judge k, but handled by different administrators j and j', the correlation is given by:

$$\rho(administrator, judge) = \frac{\psi_1+\psi_2+\psi_3}{\psi_1+\psi_2+\psi_3+\theta} \quad (14)$$

The results presented in Table 4 summarize the restricted maximum likelihood estimates from two specifications of the crossed random-effects model: an additive model with random effects for judges and administrators, and an interaction model that additionally includes a random effect for judge–administrator pairings.

Table 4. Restricted Maximum Likelihood (REML) Estimates for Crossed Random-Effects Models

	Additive		**Interaction**	
	Est	**(se)**	**Est**	**(se)**
ln(net receipts)	0.078***	0.016	0.077***	0.016
ln(total claims)	0.054***	0.013	0.055***	0.013
Secured creditors share	-0.133*	0.078	-0.130*	0.078
BSA	0.240***	0.061	0.239***	0. 062
Bankruptcy estate	0.686***	0.048	0.682***	0.045
Contested creditors dummy	-0.053	0.042	-0.050	0.042
Going Concern Sale	-0.410***	0.057	-0.410***	0.057
Law (vs. 2010)				
2014	-0.360***	0.051	-0.361***	0.051
2017	-0.659***	0.075	-0.660***	0.075

	Additive		Interaction	
	Est	**(se)**	**Est**	**(se)**
2018	-1.037***	0.086	-1.039***	0.086
Control variables (means)	included		included	
Constant			-0.531	0.776
$\sqrt{\psi_1}$ (Administrator)	0.241	0.026	0.103	0.071
$\sqrt{\psi_2}$ (Judge)	0.161	0.034	0.159	0.034
$\sqrt{\psi_3}$ (Administrator, Judge)			0.235	0.026
$\sqrt{\theta}$	0.530	0.773	0.531	0.776
Restricted log likelihood	-1202.95		-1142.563	
LR test vs. linear model	78.32		78.88	
Number of judges	141		141	
Number of administrators	310		310	
Number of observations	1263		1263	

*Note: Estimates marked with ***, **, * are statistically significant at the 1%, 5% and 10% level, respectively.*

The results of both models confirm findings from the previous section. Size indicators (net receipts and total claims), socially owned companies, as well as the establishment of the bankruptcy estate through going-concern sales, have the expected prolonged effect on the duration of bankruptcy cases. Hence, we will focus on the other part of the results.

The intraclass correlation coefficients (ICCs) derived from both additive and interaction cross-classified models consistently underscore the dominant role of administrators compared to judges in explaining outcome variation. In the additive model, administrators account for approximately 15.6% of the total variance, while judges explain only 7.0%, underscoring the stronger influence of administrators on case-level outcomes. When the model allows for interaction effects between administrators and judges, the administrator-specific variance remains relatively stable at 14.9%, and the judge-related variance slightly decreases to 6.8%. Notably, the combined variance attributed to administrator and judge effects, including their interactions, increases to 24.5% in the interaction model, compared to 22.6% in the additive specification. This suggests that outcomes are not only shaped by individual roles but also by the specific administrator–judge pairings involved in a case. Taken together, these results point to the administrator as the more dominant actor in the decision-making process, and they indicate that the relational context between administrators and judges may further influence outcomes in meaningful ways.

Table 5. Estimated interclass correlations for Crossed Random-Effects Models

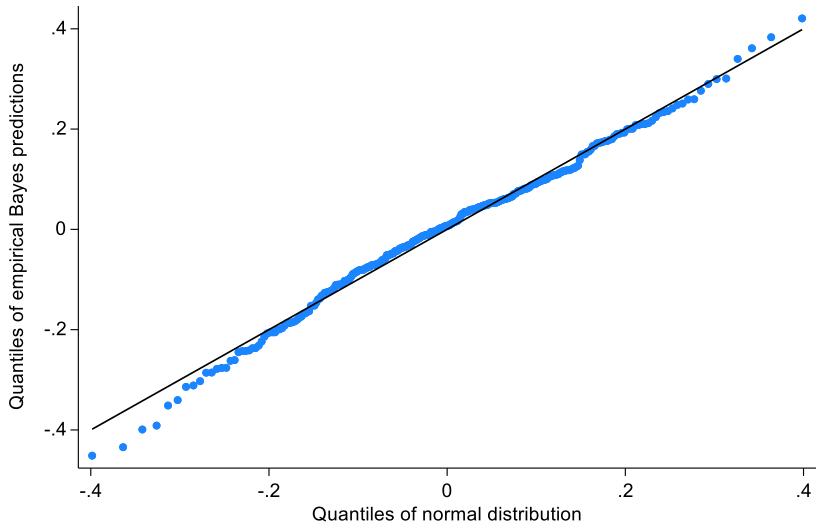
Component	Additive Model ICC	Interaction Model ICC
$\rho(administrator)$	0.156	0.149
$\rho(judge)$	0.070	0.068
$\rho(administrator, judge)$	0.226	0.245

To evaluate the necessity of random effects, we performed a likelihood-ratio test comparing the crossed random-effects model to a standard linear regression. The resulting test statistic (LR = 123.29) strongly rejects the null hypothesis that all variance components are zero, confirming that unobserved heterogeneity at the judge and administrator levels is meaningful. We then tested whether the random interaction term was required. The LR statistic (χ^2 = 0.57, p = 0.4518) was not significant; after adjusting the p-value for boundary conditions, the result (p ≈ 0.226) still fell short of conventional significance levels. We thus retain the additive specification as the more

parsimonious model, while acknowledging that the interaction model captures modestly greater variance (24.5% vs. 22.6%).

As the hypothesis tests conducted above suggested that a random interaction was not required, we use the crossed random-effects model without an interaction. Finally, we obtain empirical Bayes predictions of both the administrator and judge random effects. If the random effects and the level-1 residual are assumed to have normal distributions, these predictions should have normal distributions. Both in the case of administrators and the case of judges, predictions have distributions that are very close to normal (Figure 4), with several outlying judges and administrators.

(a) Administrator predictions



(b) Judge predictions

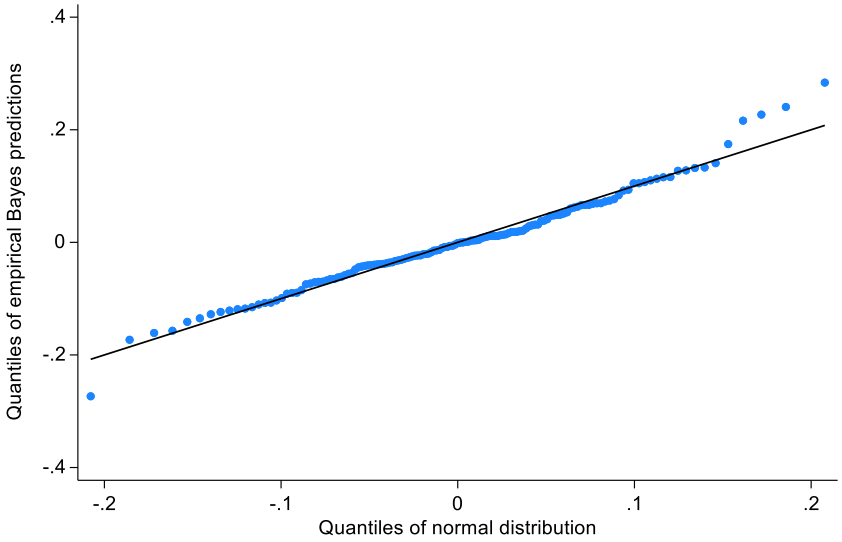


Figure 4. Normal Q–Q plots

This analysis underscores the importance of both judges and administrators in enhancing procedural efficiency. While judges provide legal oversight, administrators exert a stronger operational influence. The ICCs suggest that both roles contribute meaningfully to case variation,

with administrators exerting greater systematic influence. Although the interaction model captures additional variation by modeling specific judge–administrator pairings, the additive specification suffices in explaining most of the observed differences. These findings support a modeling approach that accounts for the independent, and occasionally synergistic, effects of key institutional actors.

CONCLUSION

This study provides empirical evidence on the critical roles that both bankruptcy judges and administrators play in determining the efficiency of bankruptcy proceedings, with case duration serving as a key performance metric. Using hierarchical and cross-classified random-effects models applied to over 1,300 Serbian bankruptcy liquidation cases, the analysis demonstrates the utility of multilevel modeling in isolating actor-specific effects while controlling for a range of case-level characteristics. The estimated effects of covariates align with expectations: larger bankruptcy estates, involvement of socially owned companies, and BSA oversight are associated with longer case durations, reflecting procedural complexity and heightened scrutiny, while going-concern sales significantly reduce duration, likely due to greater incentives for expedited resolution.

The analysis shows that judges, courts, and administrators all influence procedural efficiency in bankruptcy cases. Administrators have the largest impact on case duration by managing insolvency operations like asset liquidation, claim verification, and legal compliance. Judges consistently affect outcomes, albeit to a smaller extent, while courts contribute to institutional procedural variation due to different practices and resource constraints. These findings highlight the importance of considering individual roles, institutional context, and interactions in bankruptcy cases.

Future research should explore other aspects of bankruptcy efficiency, like recovery rates or costs. This study effectively uses hierarchical and cross-classified models on a detailed dataset, but it has limitations. Specifically, it lacks data on judges' and administrators' backgrounds, such as their experience, caseload, tenure, or affiliations. This omission prevents us from distinguishing personal, procedural, and contextual influences on performance. While case-level factors are controlled, without agent-level data, linking variance to specific traits is challenging. Future studies should include agent-level data to provide clearer insights and policy recommendations.

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ORIGINAL SCIENTIFIC PAPER

The Relationship between Green Economic Growth and Trade Openness: Empirical Evidence from Indonesia

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ABSTRACT

This study explores the relationship between green economic growth, regional trade openness, renewable energy consumption, and CO2 emissions in the agglomeration area of Sumatra Island, Indonesia. Using panel data from 2010 to 2023, this research examines the region's efforts to reduce the environmental impact of fossil-based energy consumption by transitioning to renewable energy, supporting ecological resilience. This transition, however, requires significant time and financial investments. The Sumatra Island agglomeration, with its shared environmental characteristics, plays a crucial role in trade openness and presents opportunities for alternative financing mechanisms to ensure economic sustainability. Employing ARDL and VEC model analysis, this study highlights both short- and long-term relationships between regional trade openness and green economic growth, providing insights into the future economic prospects of the Sumatra Island agglomeration. The findings indicate that regional trade openness significantly influences green economic growth in a positive direction in both the short and long terms. The study recommends fiscal policies, including tax incentives for trade that supports the green economy and the implementation of carbon taxes to regulate CO2 emissions, to promote sustainable development in the region.

Keywords: *trade openness; renewable energy consumption; CO2 emission, green economic growth; autoregressive distributed lag; vector error correction model*

JEL Classification: C10, C32, Q51, Q56

INTRODUCTION

The Sumatra Island agglomeration area is located along the strategic trade route of the Malacca Strait, between Malaysia, Singapore, and Thailand, with maritime trade routes to India and passing through ALKI 1, which is a maritime trade route passing through the Karimata Strait, South China Sea, Indian Ocean, Sunda Strait, and Java Sea. Due to this strategic position, maritime trade has developed as a gateway for investment flows into the Sumatra Island agglomeration area. This trade openness can create opportunities for investments in green economic growth in the region, provided there is the appropriate transfer of technology aligned with the capacity and support of ecosystem services to mitigate further environmental degradation. International trade offers benefits for economic growth while also protecting the environment, generating additional revenue that can be used to prevent ecological pollution. (Appiah et al., 2022).

The growth of trade in the Sumatra Island trade agglomeration area has been increasing in line with the rise in Gross Regional Domestic Product (GRDP). This has a positive effect on the domestic economy, which requires strategies and policies to maintain regional economic

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conditions that are both growing and stable within the framework of economic development system stability (Nguyen et al., 2022). Through trade openness and regional cooperation as an alternative form of financing for regional development, it is important to also consider ecological principles, ensuring the preservation of the capacity and support of natural resource ecosystems. The dependence on spatial areas, which can lead to changes in renewable energy consumption patterns, can influence GDP and, in turn, increase the national economy (Chica-Olmo et al., 2020).

The economic activities in the agglomeration area of Sumatra Island have been rapidly growing, driven by the development of various industrial zones to support economic growth. The economic growth in this region is predominantly dominated by the mining and excavation sector, particularly in the provinces of Riau, North Sumatra, Lampung, Jambi, West Sumatra, and South Sumatra. Continuous large-scale exploration and exploitation of coal for industrial fuel accelerate environmental degradation and contribute to global warming. Socio-technical adaptation to rapidly changing environmental conditions is driven by global climate change and the challenges of rapid decarbonization (Swilling et al., 2022). Meanwhile, the global effort to reduce CO2 emissions continues, involving both developed and developing countries, including those in the agglomeration area of Sumatra Island. CO2 emissions from fossil fuel-based energy are regarded as one of the most dangerous and complex issues, sparking debates among scientists about climate change (Lin & Raza, 2019); (Karedla et al., 2021).

Regional and international trade play an important role in green economic growth by enabling technology transfer, improving renewable energy literacy, and supporting the shift to sustainable energy sources. Developed countries have targeted the energy transition by expanding investment in the use of production and implementing energy resources that are adaptive to the environment (Zhang et al., 2023). This challenge opens opportunities for open trade, including importing raw materials and spare part components for renewable energy supply products and exporting energy from renewable sources, as well as renewable natural resources for manufacturing and transportation.

The management of natural resources for renewable energy, a driving factor for environmentally based economic growth, has become an important issue in the trade agglomeration areas of Sumatra Island amid increasingly limited ecological conditions. With trade openness, there is a significant impact on carbon dioxide emissions, with the use of green energy to increase spending on research and development focused on renewable energy (Jóźwik et al., 2022). The transition from fossil-based energy to adaptive, environmentally friendly energy can reduce the negative impacts of global warming due to climate change. This ongoing climate change phenomenon has implications that can pose threats to both the world and specific regions, leading to various climate disasters (Zamora-Pereira et al., 2023). The continuous increase in the consumption of material goods drives environmental crises and the loss of biodiversity and natural resources, thus triggering climate change (Sartzetakis et al., 2023).

Several studies have explored the relationship between trade openness and a country's green economic growth. For instance, Sebri and Ben-Salha (2014) conducted an investigation comparing the impact of trade openness on green economic growth in BRICS countries, finding that it offers greater benefits than in other nations due to the transfer of environmentally friendly technologies through investments in the renewable energy sector. Similarly, Khan et al. (2021) found that trade openness contributes to a reduction in carbon emissions in developed countries while negatively affecting environmental quality in developing nations.

Given the growing need for economic growth and the urgency of preserving environmental resilience in Sumatra Island's trade agglomeration area, the author is motivated to examine the relationship between trade openness and green economic growth despite numerous previous studies on this topic.

DATA AND METHODOLOGY

This approach to variable non-stationarity can result in spurious regressions. Variables that are stationary at both the first level and first difference can be utilized in Autoregressive Distributed Lag (ARDL) model simulations.

Table 1. Variables and Data Sources

Variable	Symbol	Definition	Source
Renewable Energy	lnRENEW	Renewable energy consumption (% of total final energy consumption) which is proxied by GRDP share	World Bank, 2017
Economic Growth	lnGRDP	Total Gross Regional Domestic Product	Indonesian Central Statistics Agency
Energy Use	lnEU	Primary energy consumption is proxied by the GRDP share	World Bank, 2017
CO_2 Emission	lnCO_2	CO2 (% of total final gas consumption) is proxied by GRDP share	World Bank, 2017
Trade Openness	lnTRD	Regional trade openness	Indonesian Central Statistics Agency

Source: Authors' Compilation (2025)

The unit root test is used to identify stochastic trends in the data. To study the relationship between variables, the following general equation is proposed:

$$lnGRDP_{it} = \omega_0 + \omega_1 lnRENEW_{it} + \omega_2 lnEU_{it} + \omega_3 lnCO2_{it} + \omega_4 lnTRD_{it} + e_{it} \quad (1)$$

Where: ω_0 is a constant and ω_{1-4} is the coefficient of the exogenous variable, and ε is the error factor. From equation (1) above, this model was first introduced by Pesaran et al. (2001). If the series is stationary at the first level and level of difference or both, the model can be used. If there is a long-term relationship between the variables under consideration, the long-term and short-term ARDL models are as follows:

$$\Delta lnGRDP_{it} = \alpha_0 + \alpha_1 lnGRDP_{it-1} + \alpha_2 lnRENEW_{it} + \alpha_3 lnEU_{it} + \alpha_4 lnCO2_{it} + \alpha_5 lnTRD_{it} + \sum_{i=1}^{n} \beta_1 \Delta lnGRDP_{it-1} + \sum_{i=1}^{n} \beta_2 \Delta lnRENEW_{it-1} + \sum_{i=1}^{n} \beta_3 \Delta lnEU_{it-1} + \sum_{i=1}^{n} \beta_4 \Delta lnCO2_{it-1} + \sum_{i=1}^{n} \beta_5 \Delta lnTRD_{it-1} + ECM_{it-1} + e_{it} \quad (2)$$

where β is volatility in the short term and the error correction term shows how quickly things return to a point of stability after the previous period experienced a shock. The error correction term usually lies between -1 and 0.

The first distinction between renewable energy, green economic growth, export-import trade openness, energy consumption and CO2 emissions is represented in equation (2), where t-i is the Akaike information criterion (AIC) that provides lag selection. For long term impacts α and β are used. The analysis technique used is the long-term and short-term ARDL models in order to evaluate long-term relationships

In the ARDL model equation shown in equation (2) is the period that describes the long-term and short-term responses; e is the error; α_1 to α_5 are variable coefficients in the long term; β_1 to β_5 are variable coefficients in the short term, ε_t is the residual obtained from cointegration estimates whose different equations are shown in equation (3):

$$\Delta lnGRDP_{it} = \varphi_0 + \sum_{i=1}^{n} \gamma_1 \Delta lnGRDP_{it-1} + \sum_{i=1}^{n} \gamma_2 \Delta lnRENEW_{it-1} + \sum_{i=1}^{n} \gamma_3 \Delta lnEU_{it-1} + \sum_{i=1}^{n} \gamma_4 \Delta lnCO2_{it-1} + \sum_{i=1}^{n} \gamma \Delta lnTRD_{it-1} + ECM_{it-1} + \delta e_{it-1} \quad (3)$$

Where: φ_0 represents the parameter coefficient, with γ_1 to γ_5 representing the short-term effect. The coefficient of the error correction term is described with the notation δ which will indicate a measure of how quickly the shock is corrected in the following period until it reaches a point of stability. The value of this influence coefficient is theoretically significant and negative e_{it-1} is the measure of instability in equation 3.

The ARDL model overcomes the shortcomings of the conventional ARDL model for evaluating variable interdependence. The ARDL model is used to estimate, analyze, and provide visualization of changes in the regression variables and their implications for the regression itself for short-term to long-term adjustments in order to keep all other variables in the equation constant. For the ARDL model to be applicable, variables must be stationary at the first difference level and integrated with the variable under evaluation.

RESULTS AND DISCUSSION

Analysis of Economic Growth Variable Movement

The economic structure of the trade agglomeration area of Sumatra Island, based on GDP consumption by the mining and quarrying sector, is influenced by the significant potential of natural mineral resources such as natural gas, coal, and petroleum, which are fossil fuel-based energy sources. These fossil fuels support industrial activities and transportation, including diesel trains and land transport. If these natural resources are explored extensively, it could lead to environmental disruption, ecosystem damage, and potential environmental degradation. At higher income levels, GDP is expected to reduce deforestation, meaning that an increase in GDP per capita will lead to a decrease in deforestation, particularly with strict environmental policies focusing on green economics to control natural resource exploitation (Sotamenou & Nehgwelah, 2024). The condition of economic growth, as reflected in GDP, is shown in Figure 1, with GDP values continually rising along with increased consumption of goods and services to meet the needs of the population. The highest GDP consumption is observed in the regions of Riau, North Sumatra, and South Sumatra.

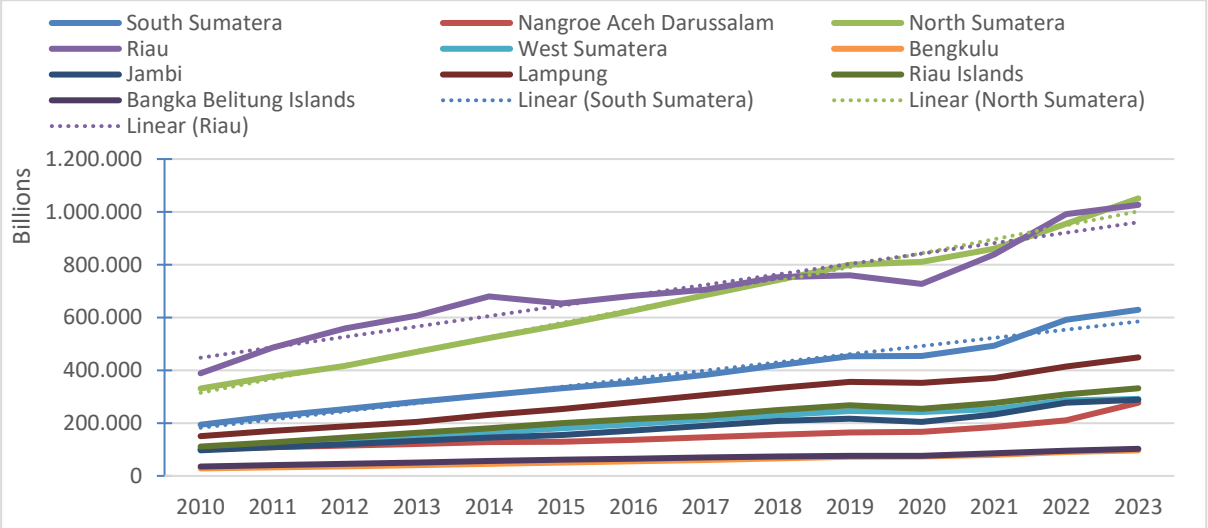

Figure 1. GRDP Growth Trend

Source: Indonesian Central Statistics Agency, (2025)

Analysis of Trade Openness Variable Movement

As shown in Figure 2, the trade value in the agglomeration area of Sumatra Island experiences fluctuations, in line with the need for regional development financing. This trade openness creates alternative opportunities for green economic growth. The influx of global trade flows into the region will stimulate the role and transfer of technology, such as operational equipment for industry and large production machinery. In Pakistan, various efforts have been made to mitigate the negative impact of foreign direct investment inflows on ecological pollution in relation to economic growth (Bakhsh et al., 2017). Meanwhile, the influence of globalization, trade, investment, and technological innovation has a negative impact on CO2 emissions in Pakistan (M. K. Khan et al., 2019).

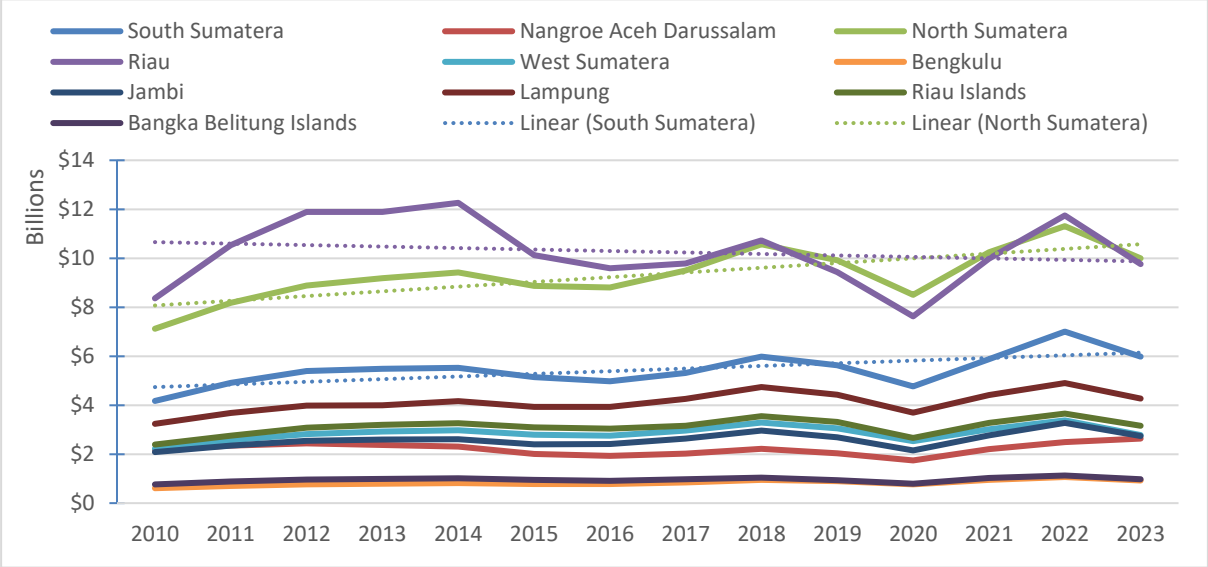

Figure 2. Regional Trade Value Trend

Source: Indonesian Central Statistics Agency, (2025)

Analysis of Renewable Energy Variable Movement

Renewable energy consumption in the trade agglomeration area of Sumatra Island remains highly fluctuating, although the trend in Figure 3 shows very slow progress. Only in the Riau region does the trend in renewable energy consumption show a decline, which is due to the continued dominance of fossil fuel energy use in the area. In China, over the long term, there has been a heavy reliance on carbon energy consumption, driven by abundant mineral and coal resources and high economic growth. This dependence on carbon consumption has led to a significant increase in CO2 emissions (Wang et al., 2016). Green economic growth, combined with the flow of global trade, can economically increase renewable energy consumption, but CO2 emissions remain quite high, even though the gradual adoption of renewable energy in developed countries, particularly in environmentally friendly industrial zones, continues to progress (Ashfaq et al., 2024).

Energy consumption highlights the relationship between total energy use, renewable energy consumption, and carbon emissions. Numerous studies have examined the determinants of carbon emissions in developing countries, with findings indicating that economic growth and energy consumption have a positive effect on carbon emissions in Southeast Asia. Carbon emissions are notably higher in Indonesia and Vietnam compared to other countries in the region. Research by Wang et al. (2016) explored the impact of energy consumption and economic growth on carbon emissions using OLS, fixed effects, Granger causality, and panel cointegration tests

across seventy countries from 1995 to 2013. The study concluded that increased trade openness has fostered greater use of renewable energy. The analysis revealed a negative correlation between renewable energy consumption and economic growth. Furthermore, Ashfaq et al. (2024) examined the long-term relationship between economic growth, carbon emissions, and renewable energy consumption in a global panel.

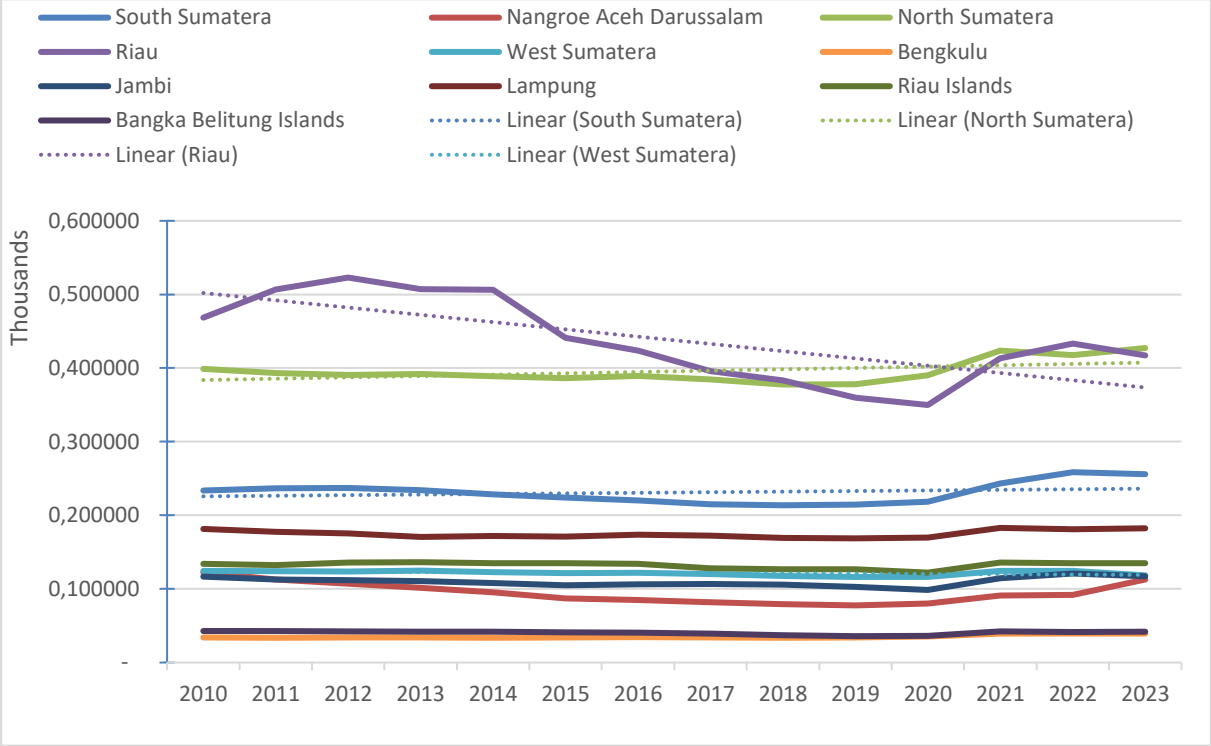

Figure 3. Renewable Energy Consumption Trend

Source: Indonesian Central Statistics Agency, (2025)

Analysis of CO2 Emissions Variable Movement

As shown in Figure 4, efforts to reduce CO2 emissions in the trade agglomeration area of Sumatra Island indicate a downward trend, although the downward movement remains very slow. Local governments have started to consider the environmental degradation impacts, such as increased air temperatures due to rapid growth. Green economic growth has become part of the policy adopted by local governments to reduce carbon consumption and mitigate the impacts of CO2 emissions. An empirical study in China, which divides the region into western and central parts with urbanization development, shows that the impact of urbanization linked to industrial development leads to relatively low energy efficiency, high CO2 emissions, and high energy consumption (Wang et al., 2016). The incomplete combustion of fossil fuel-based emissions is the most harmful to health, and there are complex issues that trigger climate change (Lin & Raza, 2019).

The BRICST countries have entered an economic expansion phase, where there is a positive shock in growth that is unbalanced, with shocks negatively responding to CO2 emission reductions. This predicts an increased demand for energy by exploring alternatives to energy resource potential, aiming to shift the energy base from fossil fuels to a more environmentally friendly direction with a renewable ecological system. This shift makes energy efficiency in these countries more productive, helping to maintain environmental quality (A. Khan & Sun, 2024).

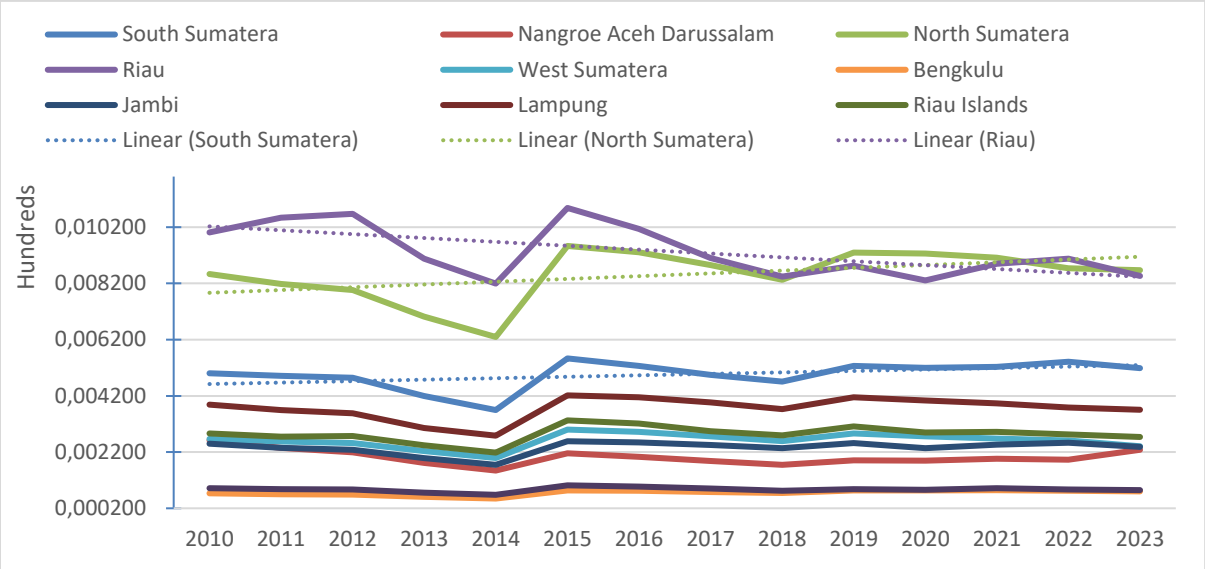

Figure 4. CO2 Emissions Trend

Source: Indonesian Central Statistics Agency, (2025)

Analysis of Primary Energy Variable Movement

Fossil-based primary energy consumption in the trade agglomeration area of Sumatra Island is still in use, but its consumption trend continues to fluctuate, as shown in Figure 5. This is due to the abundant mineral and coal resources in the region. A significant amount of time and investment is required to shift this energy conversion to renewable energy. Nevertheless, efforts have been made to reduce dependence on this primary energy consumption. An empirical study in China mediates the effects of development supported by innovation and appropriate technology transitions, which have contributed to reducing the negative impacts of environmental changes. As a result, development in China has become more environmentally friendly with high-quality standards (Chang & Lai, 2023).

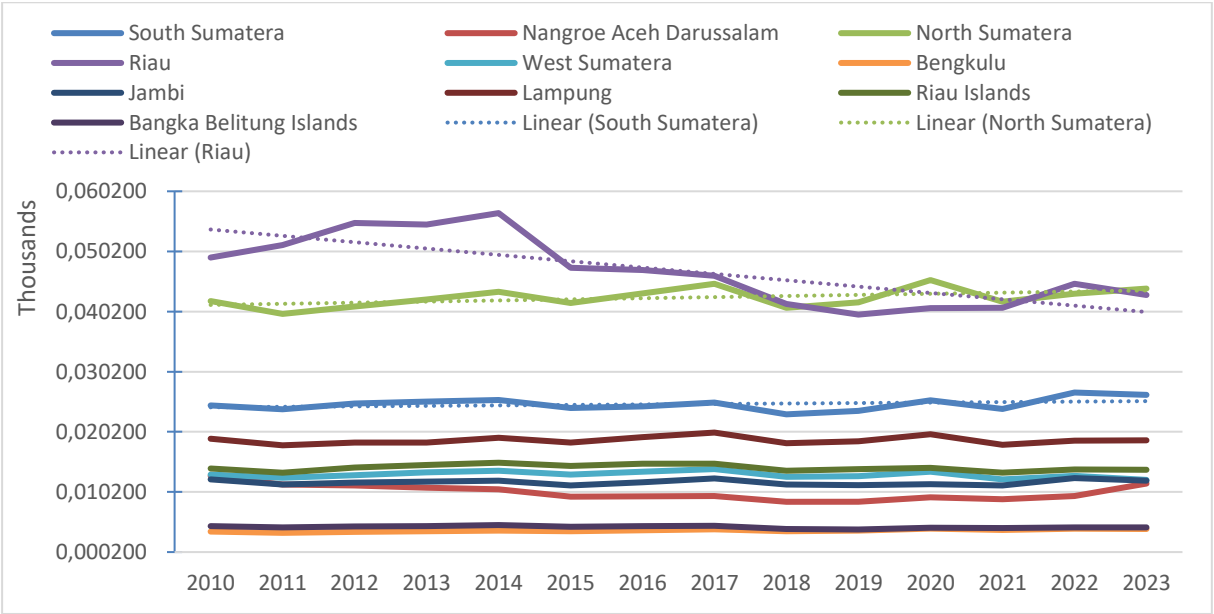

Figure 5. Primary Energy Consumption Trend

Source: Indonesian Central Statistics Agency, (2025)

The use of fossil-based primary energy continues to play a supporting role in regional development and economic growth, contributing to the degradation of environmental ecosystem services. This study focuses on investigating the impact of economic growth on the degradation of environmental ecosystem services in Jordan (Jreisat, 2021). Empirical evidence from other studies shows that international trade cooperation is essential to reduce the negative effects of carbon emissions in order to maintain the resilience of cross-border growth against environmental ecosystem damage and other related negative spillover impacts. Therefore, governments must effectively achieve the goal of reducing carbon dioxide emissions by implementing fiscal spending functions focused on renewable energy (Udeagha & Ngepah, 2022).

Descriptive Statistical Analysis

The results of running data explain descriptive statistics based on Table 2 below, where the data is in natural logarithm form. This illustrates the means for export-import trade, green economic growth, use of renewable energy with a transition to CO2 emissions and energy consumption. The highest average values are the use of renewable energy (177.3338) and economic growth (19.04454); this shows that lnRENEW and lnGRDP have a relatively stable trend level. The standard deviation of all variables is positive, with the highest values for lnRENEW (133.7157) and lnEU (14.33357).

The relationship between the panel data variables is presented in Table 2. To assess the strength and direction of these relationships, the Pearson correlation test was employed. A value of 1 indicates a perfect relationship between the variables. Positive and negative signs represent the direction of the relationship: a positive sign indicates that an increase in one variable leads to an increase in another, while a negative sign indicates the opposite. The results shown in Table 2 reveal that the variables lnGRDP, lnRENEW, lnEU, lnCO2, and lnTRD exhibit positive correlations. Correlation analysis not only aids in understanding linear relationships between variables but also helps to identify the strength and direction of these relationships.

Table 2. Statistical Test Results Description

Description	lnGRDP	lnRENEW	lnEU	$lnCO_2$	lnTRD
Mean	32.96864	177.3338	19.04454	0.380193	21.85357
Median	33.00500	124.7985	13.62768	0.276365	21.84000
Maximum	34.59000	522.9640	56.57213	1.088361	23.23000
Minimum	30.98000	33.58876	3.399634	0.054741	20.23000
Std. Dev	0.859250	133.7157	14.33357	0.286951	0.805895
Skewness	-0.168188	1.021280	1.012083	0.998598	-0.159858
Kurtosis	2.372050	2.875933	2.842959	2.777458	2.204672
Jarque-Bera	2.960243	24.42678	24.04447	23.55686	4.286133
Probability	0.227610	0.000005	0.000006	0.000008	0.117295
Sum	4615.610	24826.73	2666.235	53.22702	3059.500
Sum Sq. Dev	102.6252	2485304.	28557.72	11.44538	90.27581
Observations	140	140	140	140	140
Multicolinearity					
lnGRDP	1.000000	-			
lnRENEW	0.848273	1.000000	-		
lnEU	0.850768	0.996971	1.000000	-	
$lnCO_2$	0.858242	0.983044	0.982979	1.000000	-
lnTRD	0.950352	0.917157	0.916928	0.908464	1.000000

Source: Authors' calculation based on output E-Views 13 (2025)

Panel Unit Root Test

Before estimating with the ARDL model, several econometric requirements must be met, such as testing data stationarity with the unit root test using the Augmented Dickey-Fuller test criteria (ADF-Test), specifically the ADF-Fisher Chi-square and ADF-Choi Z-stat methods. This test was developed by (Levin et al., 2002). The test results indicate that the data is not stationary, with homogeneity (null hypothesis) and heterogeneity (alternative hypothesis).

From the data results, lnRENEW is stationary at the level, while lnGRDP, lnEU, lnCO2 and lnTRD are stationary at the first difference level. No variables are stationary at the second difference level. This is very relevant and has met the criteria for estimating the ARDL model. The complete results of the unit root testing can be seen in Table 3 below.

Table 3. Panel Unit Root Test

Variable	ADF-Fisher Chi-square		ADF-Choi Z-stat		Information
	t-Statistic	Prob	t-Statistic	Prob	
$\Delta\,(lnGRDP)$	35.2897	0.0186	-1.88638	0.0296	stationary
$\Delta\,(lnRENEW)$	31.9372	0.0440	-1.89680	0.0289	stationary
$\Delta\,(lnEU)$	82.1643	0.0000	-6.01017	0.0000	stationary
$(lnCO2)$	38.0914	0.0086	-3.17800	0.0007	stationary
$(lnTRD)$	64.3103	0.0000	-5.31077	0.0000	stationary

Source: Authors' calculation based on output E-Views 13 (2025)

Lag Order Selection Criteria

The criteria and determination of the optimum lag in this research model were carried out to see the optimum lag length for each dynamic variable in the model equation. The optimum lag length was determined following the approach by Papers (1994), using one of the information criteria methods such as the Akaike information equation criterion (AIC) and the Schwarz information criterion (SC). The test results are seen in Table 4 below.

Table 4. Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-291.6898	NA	0.013572	9.889659	10.06419	9.957927
1	73.46518	657.2789	1.62e-07	-1.448839	-0.401667	-1.039233
2	320.5354	403.5481	1.01e-10	-8.851181	-6.931365	-8.100235
3	570.2260	366.2128	5.88e-14	-16.34087	-13.54841	-15.24858
4	667.9838	127.0852	5.68e-15	-18.76613	-15.10102	-17.33250
5	760.0093	104.2955	7.09e-16	-21.00031	-16.46256	-19.22535
6	825.5669	63.37238*	2.34e-16	-22.35223	-16.94184*	-20.23593
7	863.6254	30.44678	2.22e-16*	-22.78751	-16.50448	-20.32987
8	901.7834	24.16673	2.58e-16	-23.22611*	-16.07043	-20.42713*

Source: Authors' calculation based on output E-Views 13 (2025)

Table 4 shows that the lag order selection criteria, based on the Akaike Information Criterion (AIC), has the smallest value (-23.22611) at the optimum lag of 8.

Cointegration Test

According to Hatemi-J (2020), hidden cointegration in cross-sectional data is examined within the Pedroni cointegration framework. To ensure the robustness of the findings, multiple variables are tested for cointegration following Kouton (2019), based on the stationarity properties of the

residuals. The test results presented in Table 5 indicate that the null hypothesis is rejected, leading to the conclusion that hidden cointegration exists.

Table 5. Hatemi J's Hidden Cointegration in Pedroni's Framework

Pedroni-cointegration	Statistic	P-Value	Weighted Statistic	P-Value
Alternative hypothesis: common AR coefs (within-dimension)				
Panel v-Statistic	-1.954840	0.9747	-1.916088	0.9723
Panel rho-Statistic	2.869215	0.9979	2.880170	0.9980
Panel PP-Statistic	3.523847	0.9998	3.490641	0.9998
Panel ADF-Statistic	4.347007	1.0000	4.225725	1.0000
Alternative hypothesis: common AR coefs (between-dimension)				
Group rho-Statistic	4.039067	1.0000		
Group PP-Statistic	3.036694	0.9988		
Group ADF-Statistic	4.846516	1.0000		

Source: Authors' calculation based on output E-Views 13 (2025)

ARDL Model Test Results

To determine the optimal lag length for this research variable, the Akaike Information Criterion (AIC) is used, which is shown in Figure 6. The chosen maximum lag length is 1 (ARDL(1, 1, 1, 1, 1)) for various model variations. Table 6 also shows the results of the ARDL bound test, where the estimated F-statistic value exceeds the critical limit value for I(0) and I(1), surpassing 5,840 at the 1 percent significance level in the cross-section data. This means that the null hypothesis is rejected, indicating the presence of cointegration in the model.

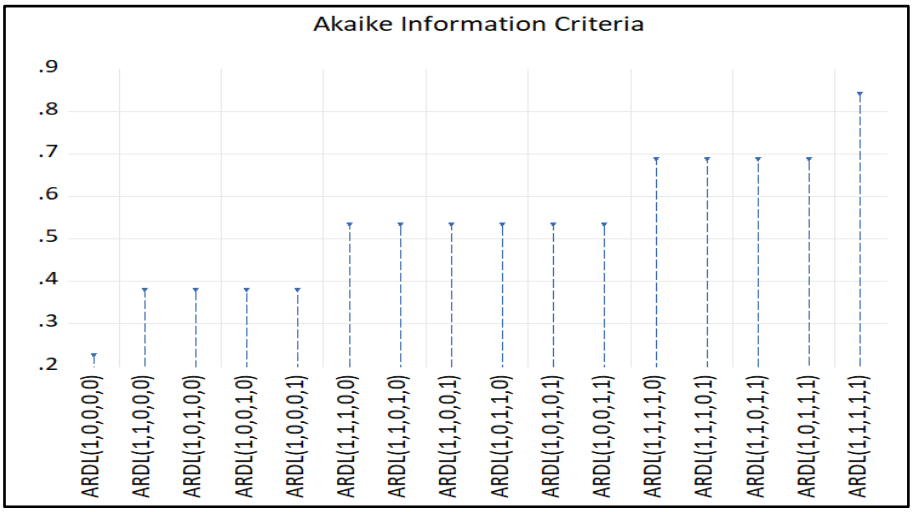

Figure 6. Akaike Information Criteria

Source: Authors' calculation based on output E-Views 13 (2025)

Table 6. ARDL Bound Test Model Results

ARDL Bound Test Model Results					Lag Max	
$lnGRDP_{it} = f(lnRENEW_{it}, lnEU_{it}, lnCO2_{it}, lnTRD_{it})$					1,1,1,1,1	
Criteria	10%		5%		1%	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
Critical Bound Value	2.525	3.560	3.058	4.223	4.280	5.840

Source: Authors' calculation based on output E-Views 13 (2025)

Table 6 presents the results of the ARDL Bound test model. Statistically, the cross-section shows the F-statistic value above the critical bound values at the 10 percent, 5 percent and 1 percent levels, both at level and at the first difference. This indicates that the studied variables influence the performance of the dependent variable in regional economic growth in Sumatra.

ARDL Model Short-Run and Long-Run Estimation

The testing of the ARDL model estimates for both short-run and long-run periods, along with detailed analysis, is presented in Table 7. The dependent variable is economic growth (lnGRDP), and the results show that the Error Correction Term (ECT) coefficient is negative (-0.020305) with a significant confidence level of 1 percent. This indicates a model imbalance in the long term, which has been corrected through adjustments from the short run to the long run, achieving a stability rate of 2.03 percent in the current conditions. The results of testing the ARDL and VEC models in the short term show that the dependent variable, lnGRDP, has a significant influence at lag 1. The lnRENEW variable shows a positive and insignificant coefficient, while lnEU has a positive and significant relationship influence at lag 1. The lnCO2 variable shows a negative and significant influence at lag 0, while lnTRD has a positive and significant relationship influence at lag 1.

Table 7. Long-Run and Short-Run Estimation Results of the ARDL Model

Dependent variable: lnGRDP	**Coefficient**	**Std-Error**	**t-Statistic**	**Prob**
Long-Run Estimation				
$lnRENEW$	0.069259	0.031342	2.209743	0.0291
$lnEU$	-0.645877	0.272261	-2.372273	0.0193
$lnCO2$	-3.032861	1.589536	-1.908017	0.0589
$lnTRD$	3.628636	0.972459	3.731404	0.0003
Short-Run Estimation				
$\Delta lnRENEW$	0.002177	0.001501	1.450214	0.1497
$\Delta lnEU$	0.451643	0.133673	3.378724	0.0010
$\Delta lnCO2$	0.011085	0.004105	2.700331	0.0080
$\Delta lnTRD$	0.170402	0.025278	6.741248	0.0000
ECT_{it-1}	-0.020305	0.004770	-4.256604	0.0000

Source: Authors' calculation based on output E-Views 13 (2025)

Table 7 presents the results showing that the relationship between the elasticity of economic growth in the short-run and long-run periods and exogenous factors is a key characteristic shown in open export-import trade. In the short run, cointegration is negative and significant. This research indicates that, in the long run, the relationship between export-import trade and the use of new renewable energy is significant and profitable, while in the short run, export-import trade has a positive impact. The use of new renewable energy in short-run periods can cause losses and is very rare when associated with other variables. The increase in export-import trade of 3.628636 percent, in the long run, was influenced by short-run gains of 0.170402 percent in regional economic growth in Sumatra.

Diagnostic Test

The results of the diagnostic statistical tests of the data used include autocorrelation tests using the Lagrange multiplier test. The results show that the null hypothesis is rejected, indicating no autocorrelation from the remaining lag one that is determined. The next test is the heteroscedasticity test with cross-product. The heteroscedasticity test of the null hypothesis shows that the null hypothesis is rejected, which means that there is no heteroscedasticity and no specification error. Then, the normality test using the Jarque-Bera test shows that the null

hypothesis is accepted, which means that the observed sample size is normally distributed in Figure 7.

Heteroskedastisitas Test

Table 8 shows the results of the heteroscedasticity test which aims to test whether the ARDL model has a constant residual variance. Based on the p-value, it can be seen that most of the variables are not significant at the 5 percent confidence level, indicating that there is no serious heteroscedasticity problem. This indicates that the ARDL model meets the homoscedasticity assumption, where the variance of the error is constant and there is no indication that the error depends on the independent variable.

Tabel 8. Heteroskedasticity Test Results of the ARDL Model

Dependent Variable: ABS(RESID)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	0.070724	0.058000	1.219389	0.2252
$lnRENEW$	-4.06E-05	8.53E-05	-0.476459	0.6347
$lnEU$	0.000925	0.000782	1.182439	0.2395
$lnCO2$	-0.016841	0.015381	-1.094922	0.2758
$lnTRD$	-0.002887	0.002776	-1.040279	0.3004
Test statistics				
Serial Correlation (LM test)	Breusch-Godfrey		1.232294	0.1616
Ramsey Reset Test			0.260679	0.8009

Source: Authors' calculation based on output E-Views 13 (2025)

Normality Test

The results of the normality test using the Jarque-Bera Test showed a test statistic of 0.385 with a probability (p-value) of 0.824. In normality testing, the null hypothesis (H0) tested is that the data follows a normal distribution. If the p-value is greater than the commonly used significance level (alpha 0.05), then the null hypothesis cannot be rejected, meaning the data does not have enough evidence to state that the distribution is not normal.

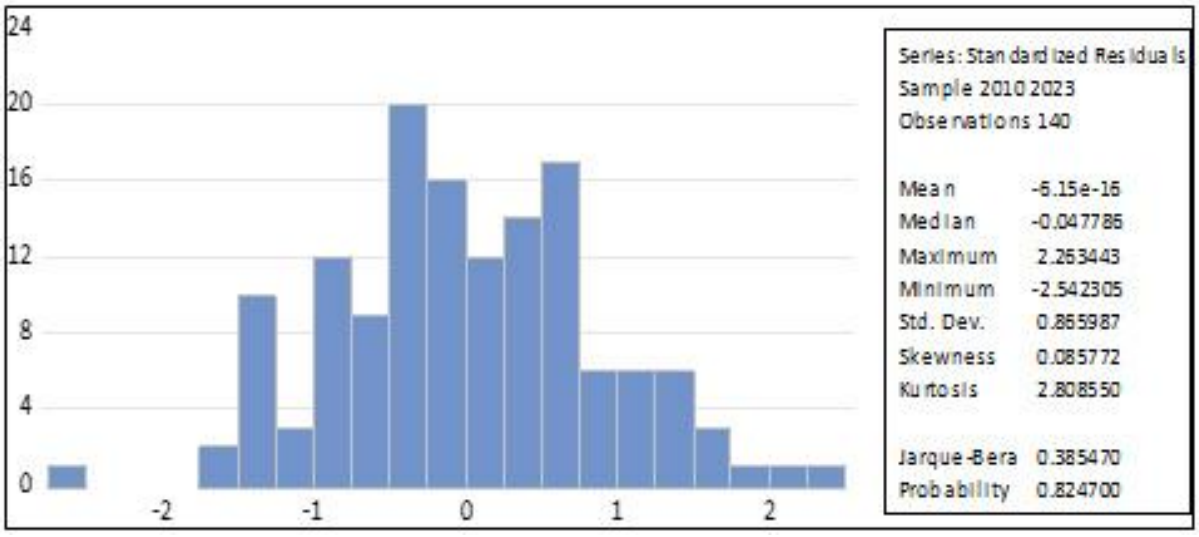

Figure 7. Histogram Normality Test

Source: Authors' calculation based on output E-Views 13 (2025)

CUSUM and cusum of Squares Test

Then, the CUSUM test is conducted to assess the stability of the long-run relationship in the ARDL model estimation. It continuously calculates the regression coefficient and residual within a specified boundary level. Normally, boundary-level identification involves constructing graphs representing various recursive statistics as a function of sequential transition variables. This is a common method applied in practice to determine the level of a significant boundary. Figure 8 shows the Cumulative SUM of Recursive Residue (CUSUM) from the ARDL stability test results. All desired lines are in critical threshold, and none cross it along the curve. Figure 8 provides evidence of the stability of the ARDL model estimation results.

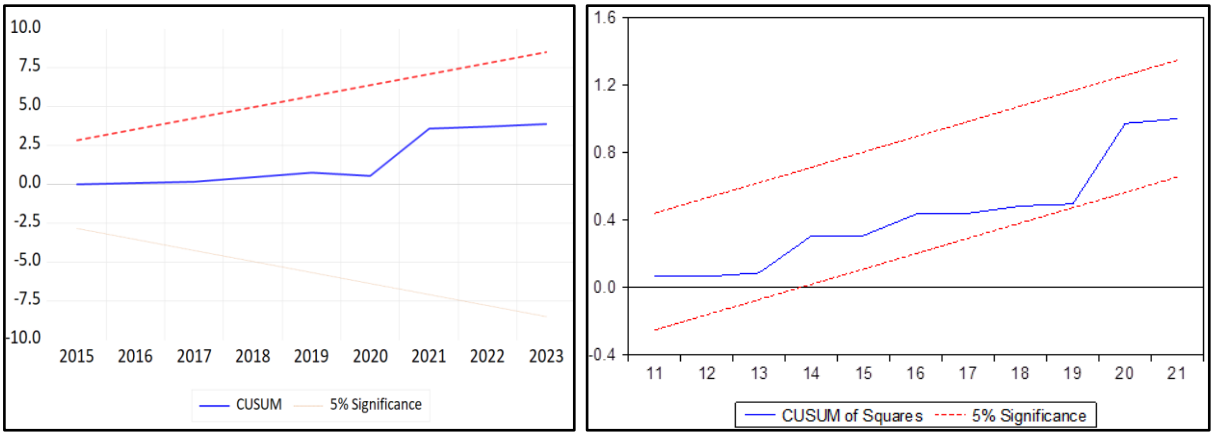

Figure 7. CUSUM and CUSUM of Squares Test

Source: Authors' calculation based on output E-Views 13 (2025)

Discussion

Empirical Results of Renewable Energy

The results of the ARDL model testing estimates for the short and long-term periods in Table 7 show the presence of an error correction term (ECT) indicating the adjustment of the short-run model to the long-run relationship, with a negative value of -0.020305. This means that a 2.03 percent adjustment is expected due to shocks from other variables in the previous period, which will gradually be corrected as time progresses, reflecting the influence of other variables in the study.

In the short-term period, the energy transition towards renewable energy usage value (lnRENEW) in the Sumatra Island trade agglomeration area shows a positive but insignificant impact. The coefficient of 0.002177 indicates that a 1 percent increase in economic growth can raise the performance of renewable energy usage value by 0.002177 percent. This is evident in the development of the Sei Mangkei Special Economic Zone in North Sumatra, which includes various requirements for achieving green economic sovereignty. The concept of developing this special economic zone will help avoid pollutant production, which could have negative environmental impacts. This is also supported by the findings of studies by (Ali et al., 2022); (Taher, 2020); (Degbedji et al., 2024).

Local governments, which have policy authority over the trade agglomeration areas, can implement policies that promote green economic sovereignty, such as providing regional fiscal incentives through tax relief to stimulate growth, while still considering environmental conditions. In trade agglomeration areas, special economic zones, and industrial zones, the imposition of carbon taxes on investors can be applied. This is supported by the views in the studies by (Appiah et al., 2022);(Karedla et al., 2021);(Sun et al., 2023). Supervision, monitoring,

and evaluation of companies investing in the trade agglomeration areas of Sumatra Island can be carried out as a commitment from all parties to the environment by granting green and blue PROPER awards. This is also supported by research by Khan et al. (2021).

In the long term, the results of the study indicate a positive and significant impact of the transition to renewable energy usage on economic development (lnGRDP), with a coefficient of 0.069259. This means that a 1 percent increase in economic growth will lead to a 0.069259 percent increase in the consumption of renewable energy. The utilization of primary energy tends to have a negative and significant relationship with a coefficient of -0.645877, meaning that a 1 percent increase in economic growth in the long term will reduce the consumption of fossil-based primary energy by 0.645877 percent. This suggests that the trade agglomeration area in Sumatra Island is beginning to consider reducing the consumption of fossil-based primary energy and transitioning to environmentally adaptive renewable energy. However, this transition requires a long time, significant investment, as well as technology and knowledge transfer. This is supported by the research of Jóźwik et al. (2022) and Ozkan et al. (2023).

Empirical Results of Primary Energy

The utilization of primary energy, in this case, fossil-based energy, has a positive and significant effect, with a coefficient of 0.451643. This means that a 1 percent increase in economic growth will result in a 0.451643 percent increase in primary energy consumption. This illustrates that the use of primary energy still dominates in the trade agglomeration areas of Sumatra Island compared to the transition period to renewable energy, as the energy transition requires time, significant investment, and technology shifts. This is also supported by the research of Nguyen et al. (2022). The presence of significant natural resources in the trade agglomeration areas of Sumatra Island, such as minerals and coal scattered across regions like Riau, North Sumatra, Lampung, Jambi, and South Sumatra, supports regional economic activities. However, this can be mitigated by developing an environmentally adaptive industrial downstream. This aligns with the research by Taghizadeh-Hesary et al., (2021) and Jacques et al., (2023).

Empirical Results of CO2 Emissions

The use of fossil-based energy in transportation activities supports the trade agglomeration areas of Sumatra Island by utilizing carbon dioxide release technology from petroleum refining processes. This can reduce CO2 emissions compared to the release of CO2 from incomplete combustion processes in transportation. The shift from fossil-based energy to electric energy has also been introduced in public transportation in South Sumatra with the operation of the Light Rail Transit (LRT), a transportation technology powered primarily by electricity. This transition is being implemented gradually, considering that the shift from fossil-based energy to renewable energy requires time and the transfer of environmentally friendly technology, which requires significant investment. This aligns with the findings of Afshan et al. (2024), Chen et al. (2020) and Gao & Chen (2023). Efforts to reduce the use of fossil-based energy in industrial activities include utilizing hydropower plants that use river flows in the trade agglomeration areas of Sumatra Island to drive turbines and generate electricity. This ensures that economic growth activities in the trade agglomeration areas of Sumatra Island continue to grow, in line with Ashfaq et al. (2024).

CO2 consumption in the short term has a positive and significant relationship with economic development in the trade agglomeration areas of Sumatra Island, with a coefficient of 0.011085. This means that a 1 percent increase in economic growth will result in a 0.011085 percent increase in CO2 emissions. This indicates that in this area, with rapid economic growth, there is still a dependence on energy consumption that generates high CO2 emissions, as the region is rich in mineral and coal resources. This needs to be a concern for the government to ensure that the use of CO2-emitting energy is also efficient in supporting economic growth, as supported by the research of Zhang et al. (2023). Long-term CO2 consumption, on the other hand, shows a negative

relationship and does not significantly impact economic development, with a coefficient of -3.032861, indicating that a 1 percent increase in economic growth will reduce CO2 consumption by 3.032 percent.

Empirical Results of Trade Openness

Trade openness in the region has a positive and significant impact on economic development in the trade agglomeration areas of Sumatra Island, with a coefficient of 0.170402. This indicates that a 1 percent increase in economic growth will result in a 0.170402 percent increase in regional trade value. This is supported by adequate regulations issued by the Ministry of Home Affairs, Regulation No. 22 of 2020, on Procedures for Regional Cooperation with Other Regions and Regional Cooperation with Third Parties. This system of trade openness provides opportunities for the region to engage in environmentally friendly technology transfer. China has evaluated trade openness and recommended that the government expand trade to reduce negative impacts and provide financial opportunities to promote renewable resources (Gao & Chen, 2023). This research is supported by Sun et al. (2019) and Taher (2020), who argue that renewable energy has a significant impact on green economic growth, as green economic growth is directly dependent on environmental regulatory policies, which in turn affect renewable energy consumption (Ashraf, 2023).

Trade openness in the Sumatra Island agglomeration areas provides opportunities for investors to invest; however, this must remain within the framework of regulations and policies set by the authorities, particularly in reducing environmental damage. Trade in this area is facilitated through several ports, including Belawan Port in North Sumatra, Dumai Port in Riau, Meulaboh Port in Nangroe Aceh Darussalam, Panjang Port in Lampung, Boom Baru Port in South Sumatra, and the Batam Authority area in the Riau Islands, which has direct trade authority with Singapore. Direct trade has a positive impact on economic growth in this area, but these results are not in line with the results of the study (Sheikh et al., 2020).

Meanwhile, the impact of trade openness in the long term has a positive and significant effect on economic development in the trade agglomeration areas of Sumatra Island, with a coefficient of 3.628636. This means that a 1 percent increase in economic growth will result in a 3.628636 percent increase in regional trade performance. International trade and the influx of economic globalization are closely linked, and due to this interconnection, they can help mitigate the negative effects of carbon emissions (Ali et al., 2022). During this transition period, the development of energy infrastructure connectivity networks and renewable energy technology continues to progress in line with the modernization of the 4.0 industrialization era. Meanwhile, the use of fossil energy is still dominant, as fossil energy reserves in the trade agglomeration areas of Sumatra Island are relatively large.

In the era of trade openness, export and import activities, along with investments that bring in goods and services, also influence the consumption of renewable energy (Sotamenou & Nehgwelah, 2024; Sun et al., 2023). Previous studies have emphasized that the negative impact of trade openness on export-import activities and investments, which leads to an increase in value-added production, has not been accompanied by internal controls and environmental risk management. This is due to the pollution generated and the failure to consider environmental degradation, which can hinder the utilization of renewable energy and lead to continuous environmental damage. Overall, this study aligns with existing literature. For example, research by Khan & Sun (2024) and Khan et al. (2021) found that international trade openness can result in a decrease in demand for primary fossil energy consumption. This is because trade openness encourages the transfer of innovation, technology literacy, and knowledge about the importance of sustainable green economies, which can reduce the demand for primary energy and promote the adoption of renewable energy.

The transition to renewable energy has not yet reached an optimal point, with various challenges that continue to be managed to replace environmentally harmful fossil energy sources (Taghizadeh-Hesary et al., 2021; Dzwigol et al., 2023). The establishment of regulatory policy controls in the environmental sector serves as a regulatory tool when granting investment permits, controlling impacts by monitoring environmental quality standards, and conducting evaluations in case of violations in the implementation of environmentally friendly investment policy principles, which are based on strategic environmental assessments that consider ecological values as well as the capacity and environmental support capacity. The adoption of renewable energy is faced with both technical challenges and opportunities, such as the significant utilization of natural gas in Nangroe Aceh Darussalam, which could lead to fluctuations during the energy transition. The transition to energy through the current electricity system also presents the opportunity for two-phase fluctuations, preventing the occurrence of a dual burden.

This situation can result in a return to the use of fossil-based energy, which is easier to manage but can lead to increased CO2 emissions and have negative long-term impacts, as supported by research from Zamora-Pereira et al. (2023), Jacques et al. (2023), and Sartzetakis et al. (2023). The long-term consequences of CO2 emission reductions indicate that investing in and transitioning to renewable energy sources can be an effective solution to address climate change and reduce the global carbon impact. These findings highlight the importance of promoting sustainable policies and practices that support the use of renewable energy as a strategic step in mitigating climate change. This conclusion is supported by research from Ozkan et al. (2023), where the development of electricity infrastructure and the transfer of technology for new renewable energy sources play a crucial role and represent a sensible course of action (Jreisat, 2021); (Ashraf, 2023).

For local governments with authority in the Sumatra Island trade agglomeration area, a special regulatory policy is needed for investment or strong cooperation between the government and business entities in the field of trade openness. This policy should consider green economic development as a criterion and requirement in the audited aspects and environmental sustainability performance assessments. Multilateral cooperation with developed countries that have implemented environmentally friendly economic development will have the potential to utilize environmentally friendly energy and play an important role in reducing CO2 emissions, as these countries have advanced economies. Local governments in this area are conducting regulatory studies to increase renewable energy consumption by providing subsidies for blue and green certification, as well as reducing carbon taxes to encourage renewable energy (Sun et al., 2023). The implications of regional policies in the Sumatra Island trade agglomeration area that can be applied from this research are that regional governments must adopt more intensive planning, regulation, monitoring, and internal control policies in implementing trade openness or cooperation in this area.

CONCLUSION

Sustainable regional development, guided by green economy principles, fosters innovation and renewable energy technology literacy. It serves as a driving factor to stimulate the region's macroeconomic growth during environmentally friendly phases of study and implementation, amid global challenges of climate change in several areas. Negative impacts and environmental degradation have become strategic issues in the trade agglomeration areas of Sumatra Island, particularly in regions with growth based on mining, excavation, and wetland agriculture sectors. This study highlights the importance of renewable energy for economic sovereignty and environmental ecosystem services, as it can be used as a policy tool in the non-biological natural resources sector, which significantly relates to energy transition policies in the region.

Using the ARDL and VEC model analysis approaches, this study shows that the relationship between green economic growth variables and new renewable energy, primary energy

consumption, CO2 reduction, and trade openness significantly impacts environmentally friendly economic growth. The time series from 2010 to 2023, with panel data from 10 provincial regions in the Sumatra Island trade agglomeration areas, reveals how renewable energy utilization in this region, in the long term, is influenced by renewable energy usage implications through trade openness mechanisms or regional, bilateral, and multilateral cooperation with developed countries. This study contributes significantly to climate change risk mitigation efforts by controlling environmental performance against the impact of rising global temperatures, reducing the harmful CO2 emissions that threaten environmental health.

Government cooperation with business entities in the field of green economic development through trade openness, both internationally and regionally with developed countries, can encourage the utilization of renewable and environmentally friendly energy sources, reduce the consumption of fossil-based primary energy, reduce CO2 emissions, and pave the way for the divestment of pollutant sources for the environmental ecosystem. The future and energy transition in regional development in the Sumatra Island trade agglomeration areas, through the sustainability of environmental ecosystem services within the regional trade cooperation scheme, can promote inclusive and environmentally friendly economic development. The regulatory policy framework in the areas of trade, regional cooperation, and investment is directed at utilizing environmental ecosystem services efficiently, considering the limited non-biological resources and enhancing the added value of renewable energy utilization in the Sumatra Island trade agglomeration areas.

Trade openness or regional cooperation that considers renewable energy utilization, reduction in fossil fuel primary energy consumption, and CO2 emission reductions can provide insights for potential investors looking to invest in the Sumatra Island trade agglomeration areas, serving as an alternative financing option for green economic development to mitigate ecological pressure. The findings indicate that trade openness in the Sumatra Island trade agglomeration areas contributes positively and significantly, both in the short and long term. This suggests that trade openness in this area could become an alternative driver for sustainable, environmentally friendly green economic development, enhancing the efficient and productive use of resources according to the environmental carrying capacity and support capacity of the region.

This study demonstrates that the Sumatra Island trade agglomeration areas, with abundant mineral and coal resources, are gradually shifting towards renewable energy utilization. The research also explains that investment or cooperation between the government and business entities in the renewable energy service sector is still in its early stages, and the transition from conventional energy use—specifically fossil-based fuels—to renewable energy will take time, significant investment, technological shifts, and knowledge literacy. These factors positively influence the sustainable use of environmental ecosystem services. Wise economic development in utilizing environmentally friendly energy will increase productivity, create ecosystem stability, improve public health, and enhance community welfare.

Environmental ecosystem degradation, currently occurring due to massive natural resource exploration without control, and the extraction of resources without considering ecological carrying and support capacity, can lead to flooding, landslides, and increased global temperatures. These empirical issues highlight the importance of considering renewable energy utilization in this region and how the transition to renewable energy consumption plays a role in green economic development.

A limitation of this study is that the technology transfer variable was not included in the control variables. Therefore, we recommend that future research consider the use of technology transfer in subsequent studies. The gap and inequality between energy needs, renewable energy availability, and the use of technology transfer present new challenges for future research.

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ORIGINAL SCIENTIFIC PAPER

The Effects of Patriotism, Consumer Xenocentrism, Cultural Sensitivity, Cultural Heritage, and Country of Origin Image on the Purchase of Luxury Foreign Brands

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ABSTRACT

The process of globalization has led to an increase in the number of multinational companies. However, current global crises such as the COVID-19 pandemic, the war in Ukraine, population migrations, and economic instability have led certain countries to implement protectionist measures in the form of sanctions against other countries, as well as the closure of national economies and a shift towards deglobalization policies. In times of crisis, conservative views, respect for one's own culture, and concern for the national economy come to the fore. On the other hand, consumers who have preferences for foreign cultures often travel abroad, visit cultural landmarks of other countries and prefer luxury brands that originate from countries known for their production. The research was conducted with the aim of analyzing the impact of patriotism, consumer xenocentrism, cultural sensitivity, cultural heritage of other countries, and country of origin image on consumers' decision to purchase foreign luxury brands. Empirical research was conducted through a survey method in early 2024 in the territory of the Republic of Serbia (Belgrade, Novi Sad, Kragujevac). The total number of respondents in the sample was 488. Their responses were analyzed using appropriate statistical methods with the SmartPLS 4 software. The research results showed that patriotism has a negative impact on consumers' purchase of luxury brands, while consumer xenocentrism, cultural sensitivity, cultural heritage of other countries, and country of origin image have a positive impact on consumers' purchase of luxury brands. The research provides useful information for marketers of multinational companies, and based on the results, it can be concluded that during crises, instead of a global or local marketing strategy, it is optimal to apply a glocal marketing strategy that considers the needs of consumers with pronounced nationalist sentiments, as well as consumers with cosmopolitan views.

Keywords: *patriotism, consumer xenocentrism, cultural sensitivity, cultural heritage of other countries, country of origin image, luxury foreign brands, global crises, marketing strategy*

JEL Classification: A14, F60, M31, Z10

INTRODUCTION

The geopolitical situation is highly unstable and unpredictable due to numerous crises, such as the recent COVID-19 pandemic (Vukmirović & Nedeljković, 2023), the Russia-Ukraine conflict, population migration, inflation, and others (Rahbari et al., 2023). The process of globalization, along with the development of communication and transportation channels and information

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systems, has significantly facilitated the operations of multinational companies in markets around the world (Rodrigo et al., 2023). However, these crises pose a substantial threat, potentially shifting the trend from globalization towards deglobalization (Pavlović et al., 2020). Due to geopolitical tensions, there are disruptions in the supply of goods and services, the closure of national borders, bans on exports and imports, and the imposition of sanctions on countries with a war or political animosity (He & Harris, 2020). Consequently, there is a turn towards domestic resources, products, and services that are generally available on the market. By purchasing these, the domestic industry is strengthened, and employment rates and the gross domestic product (GDP) increase, ultimately reinforcing the national economy (Jin et al., 2024).

Based on Social Identity Theory (Tajfel & Turner, 1979) and Social Conflict Theory (Sherif, 1966), which are grounded in the principle that unity and cohesion are necessary during times of crisis, *patriotism* has been chosen as the first research variable in this study. Patriotism represents the sense of love and pride that an individual feels towards their own country, which can significantly influence the purchase of domestic products (Marinković, 2017). Certain individuals perceive the cultural values of other countries as more advanced, and dominant compared to the values promoted by their own domestic culture (Zhang & Zhang, 2023). As a result, they tend to choose foreign luxury brands during the purchasing process, which is why *consumer xenocentrism* was selected as the second research variable. On the other hand, a certain group of people possesses cosmopolitan views and thinking, exhibits a high degree of cultural openness, and embraces values and ideas from other cultures. Such individuals often travel abroad to step out of their comfort zones, meet people of different nationalities, learn foreign languages, and visit cultural landmarks, museums, and architectural structures that symbolize other cultures, thereby enhancing their cultural knowledge and experiencing unforgettable and authentic moments while traveling (Zdravković & Peković, 2021). This is why *cultural sensitivity* and *cultural heritage of other countries* have been chosen as the third and fourth research variables. Additionally, a large number of consumers pay attention to the country of origin of a product during the purchasing process, which has been chosen as the fifth research variable in this study. It is crucial that the product comes from a highly economically developed country that uses innovative production technologies, as this assures consumers that the product will be of high quality, reliable, and possess exceptional characteristics (Oduro et al., 2024). Certain countries are synonymous with certain products, such as Switzerland being recognized for watchmaking, Italy for quality footwear, and France for exceptional wines. *The primary objective of this study* is to examine the effects of patriotism, consumer xenocentrism, cultural sensitivity, the cultural heritage of other countries, and country-of-origin image on *consumers' decisions to purchase luxury foreign brands*. Additionally, *the secondary objective of this study* is to, based on the obtained results, provide a recommendation to marketers of multinational companies on whether it is optimal to apply a *global, local, or glocal marketing strategy* in the Serbian market, which reflects the *originality and contribution of this research*. In the *domestic literature*, there are few studies (Marinković, 2017; Zdravković & Peković, 2021) examining the impact of the aforementioned variables on consumers' decision to purchase foreign brands, while in the *international literature*, studies (Moscatelli et al., 2023; Mueller et al., 2020; Rambocas & Mahabir, 2021; Rodrigo et al., 2023) have mostly investigated the partial influence of *patriotism, consumer ethnocentrism, cultural sensitivity, cultural heritage of other countries and country-of-origin image* on the purchase of foreign luxury brands. This study, however, adopts a holistic approach, and a conceptual model has been developed to examine the comprehensive impact of these variables on consumers' decisions to buy foreign luxury brands. In this way, certain limitations of previous studies are addressed, and a *research gap in the academic literature is filled*.

The primary reason why *patriotism* was chosen as a research variable lies in the geopolitical tensions (pandemics, wars, migration crises) that disrupt economic markets. In this context, it is crucial to analyze how patriotic sentiments and emotional attachment to one's home country influence the purchase of foreign luxury brands. On the other hand, a certain group of individuals holds exclusively globalist views, which is why the research model includes the variables of

consumer xenocentrism, cultural sensitivity, and the *cultural heritage of other countries*. These variables can be significant factors in shaping cosmopolitan attitudes, which, in turn, may influence consumers' purchasing intentions regarding foreign luxury brands. Additionally, the final research variable, the *country-of-origin image*, attracts significant attention from both consumers and marketers. The country of origin of a product can serve as an indicator of its quality and technical reliability. A model developed through a holistic approach can yield comprehensive results and assist marketers in determining the optimal marketing strategy (global, local or glocal) for implementation in the Serbian market.

Following the introduction, the literature review will define the research variables of *patriotism, consumer xenocentrism, cultural sensitivity, cultural heritage,* and *country-of-origin image*. A holistic approach will be applied to analyze their interrelationships and, ultimately, their comprehensive impact on consumer decisions regarding the purchase of luxury foreign brands. In this section of the study, hypotheses will be formulated, and a research model will be developed. The third part of the study pertains to the sample structure of the respondents, as well as the statistical analyses applied using the SmartPLS4 statistical software. The fourth part will focus on the results of an empirical study conducted in the Republic of Serbia at the beginning of 2024. The conclusion will summarize the main contributions of the research based on the obtained results, as well as the implications that marketers can use to develop appropriate strategies for entering the Serbian market. In other words, recommendations will be provided on whether it is optimal to apply a global, local, or glocal marketing strategy. Additionally, certain research limitations will be discussed, along with recommendations for expanding this topic in future studies by analyzing other variables that are significant determinants of consumer purchases of foreign luxury brands.

THEORETICAL BACKGROUND

Based on Social Identity Theory (Tajfel & Turner, 1979) and Social Conflict Theory (Sherif, 1966), *patriotism* was chosen as the first research variable in this study. During times of crisis, research on consumers' patriotic sentiments and their implications for the purchase of foreign products gains significance. Conversely, it is also necessary to analyze variables related to consumers' cosmopolitan attitudes, such as *consumer xenocentrism, cultural sensitivity,* and *cultural heritage of other countrie*s, in the context of their influence on purchasing foreign luxury brands. Additionally, in the absence of other information during the purchasing process, a large number of consumers pay attention to the *country-of-origin image* of a product to minimize the risk of a poor purchasing decision and reduce cognitive dissonance. Within the literature review, the selected research variables will be defined, and previous studies examining their partial influence on luxury brand purchases will be analyzed. Subsequently, a holistic approach will be applied, and a research model will be designed to investigate the comprehensive impact of these variables as determinants of *foreign luxury brand purchases*.

Patriotism can be described as a feeling of love, care, and concern that an individual shows toward their country, essentially an emotional and sentimental component that reflects the degree of connection between an individual and their nation (Marinković 2017; Nugraha et al., 2023). People who possess patriotic feelings fully embrace the values of their culture, their attitudes and thoughts are compatible with the values, customs, and norms of behavior promoted by their culture. During certain crises such as COVID-19, economic downturns, and inflation, they are willing to make sacrifices and prioritize their nation's interests over their own to ensure the overall welfare and well-being of society (Mishra et al., 2023). Patriotism, to some extent, serves as a cohesive factor during societal crises and can act as a catalyst for the emergence of ethnocentric tendencies among consumers, which imply the purchase of domestically produced goods to support the national economy (Maro et al., 2023). Previous research (Güngördü Belbağ, A. 2023; Li et al., 2022; Miguel et al., 2023; Nugraha et al., 2023) has established that individuals with strong patriotic sentiments tend to avoid purchasing foreign products, as they believe that

imports have negative economic implications for the domestic economy. Based on the above, the first research hypothesis can be formulated:

H1*: Patriotism has a negative relationship with the purchase of foreign luxury brands.*

The concept of xenocentrism has sociological origins and is characterized by an individual valuing the cultures of other nations more highly than their own. Individuals with a pronounced degree of xenocentrism believe that other societies are more advanced, dominant, and superior compared to their home country, leading them to exclusively adopt values, ideas, attitudes, and perspectives from other diverse cultural environments (Zhang & Zhang, 2023). Consumer xenocentrism is a subvariant of the basic concept and refers to an economic category, fundamentally involving the purchase of foreign products and brands that possess global recognition (Zdravković, 2022). Certain groups of people who exhibit a high level of innovativeness purchase foreign luxury brands because these brands confer a certain prestige and respect within society. Previous research (Areiza-Padilla & Cervera-Taulet, 2023; Mahmoud et al., 2023; Mueller et al., 2020) has found that individuals with pronounced consumer xenocentrism do not wish to purchase domestically produced goods, believing that they lack adequate quality. Instead, they prefer foreign luxury brands believing these purchases minimize the risk of a poor decision and prevent cognitive dissonance, as globally recognized brands inspire confidence in their choices. Cleveland & Balakrishnan (2019) found that the concepts of cosmopolitanism and xenocentrism are interrelated and based on preferences for foreign cultures over domestic ones. Cosmopolitan individuals exhibit a strong cultural openness, a global mindset, and a desire to experience foreign cultures, whereas individuals with a high degree of xenocentrism express a clear preference for foreign cultures over their own. Diamantopoulos et al. (2019) concluded in their study that consumer xenocentrism is positively related to the purchase of foreign brands and negatively related to the purchase of domestic brands. Balabanis & Diamantopoulos (2016) emphasize that consumer xenocentrism is a significant determinant in the purchase of foreign products. Based on the above, the second research hypothesis can be formulated:

H2: *Consumer xenocentrism has a positive relationship with the purchase of foreign luxury brands.*

Cultural sensitivity implies that an individual possesses certain cognitive abilities that allow them to adapt to an intercultural environment. Such individuals employ a holistic approach to their thinking, are open-minded, and demonstrate a strong desire, interest, and enthusiasm to communicate with people from different cultural backgrounds (Rambocas & Mahabir, 2021). These individuals believe that learning foreign languages and understanding the values of other cultures is a true wealth, as it enhances their level of cultural knowledge, broadens their horizons, and expands their perceptions (Katitas, 2024). Given that employees in multinational companies come from various countries around the world, and that consumers have access to brands originating from different countries during the purchasing process, cultural sensitivity is highly important in international marketing (Saragih, 2024). Previous research (Cui et al., 2019; Frias-Jamilena et al., 2018; Pratono & Arli, 2020, Zdravković & Peković, 2021) has found that individuals who possess cultural sensitivity are often employed abroad and prefer to purchase innovative products and luxury brands. Based on the above, the third research hypothesis in the study can be formulated:

H3: *Cultural sensitivity has a positive relationship with the purchase of foreign luxury brands.*

The cultural heritage of a country refers to its history, traditions, the spirit of past times, cultural monuments, libraries, monasteries, opera, ballet, theater performances, and more (Vareiro et al., 2020). Understanding and visiting the cultural heritage of one's own country should be a priority for every individual, but it is also very important to travel abroad and become acquainted with the cultural heritage of other countries. Certain groups of people possess a high level of cultural

intelligence, global awareness, and a cosmopolitan outlook on the world, and when given the opportunity, they travel to foreign tourist destinations to learn about the cultural heritage of other nations (Šagovnović & Kovačić, 2023). Such behavior by certain groups of people has implications in the field of marketing, as previous research (Moscatelli et al., 2023; Rahman et al., 2020; Saničanin et al., 2019; Zdravković & Peković, 2021) has established that individuals who frequently travel abroad, become familiar with the cultural heritage of other countries and develop their cultural intelligence tend to modify their purchasing patterns and choose to buy globally recognized and luxury products. Based on the above, the fourth research hypothesis can be formulated:

H4: *Visiting the cultural heritage of other countries has a positive relationship with the purchase of foreign luxury brands.*

Country of origin image is defined as the place of production of a particular product and has always captured the attention of consumers and marketers (Oduro et al., 2024). Some consumers believe that the country of origin of a product holds immense value and prefer to buy products from countries known for their production, such as Italian footwear or German cars (Rodrigo et al., 2023). Every product must have a label indicating its country of origin; however, some manufacturers use marketing tricks to obscure the country of origin (e.g., "Made in PRC" indicates China; "Made in EU" but without specifying the exact European Union country of origin), and many companies have their subsidiaries in low-cost labor markets where product components are manufactured and then assembled into the final product in a technically advanced and sophisticated country, which is then listed as the place of production (Zdravković, 2022). However, previous research (Bernard et al., 2020; Esmaeilpour & Abdolvand, 2016; Lee, 2020; Zolfagharian et al., 2020) shows that consumers pay significant attention to the country of origin image of products and are willing to spend considerable sums of money on luxury products that originate from countries synonymous with their production and quality. Based on the above, the fifth research hypothesis can be formulated:

H5: *Country of origin image has a positive relationship with the purchase of foreign luxury brands.*

Based on the research hypotheses and research objectives, a research model has been designed (Figure 1) to examine the influence of patriotism, consumer xenocentrism, cultural sensitivity, cultural heritage of other countries, and country of origin image on consumers' decisions to purchase luxury foreign brands.

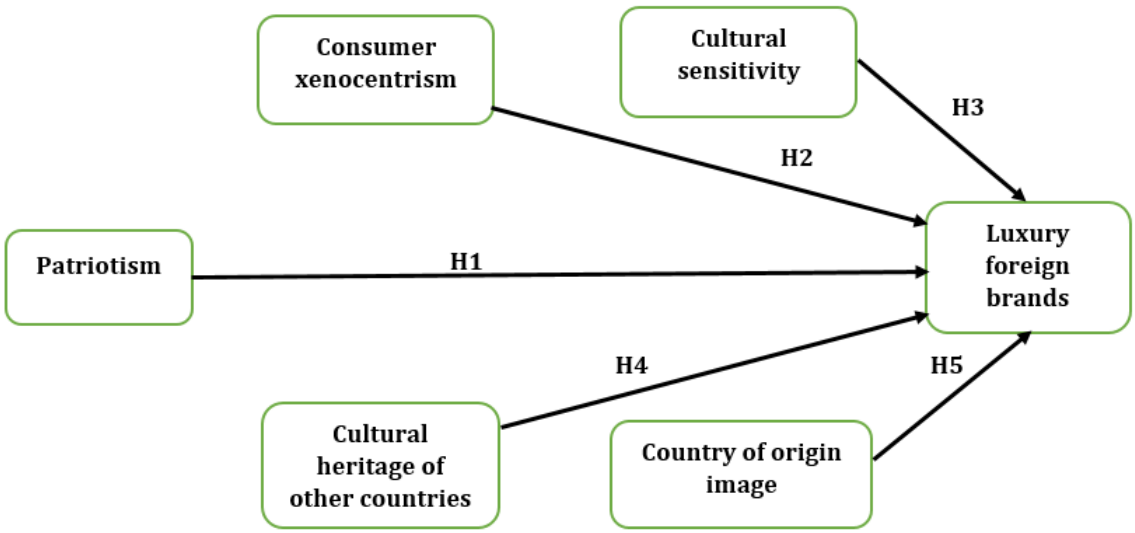

Figure 1. Research model within the statistical software SmartPLS 4
Source: Authors

Marketers of companies conduct market research before deciding to internationalize their business in order to gather information about the characteristics of local consumers and to identify their desires, needs, and purchasing patterns. One of the objectives of this research is to provide practical contributions to marketers regarding which marketing strategy is optimally applied for successful and profitable operations in the territory of the Republic of Serbia.

After conducting market research and examining the impact of the mentioned variables on consumers' decision to purchase foreign luxury brands, it is necessary to formulate and implement an appropriate marketing strategy based on the obtained information. This will enable the company to achieve profitability while simultaneously satisfying consumer needs in the target market. According to the author (Hollensen, 2017), there are 3 marketing strategies (Table 1):

1. Global marketing strategy 2. Local marketing strategy 3. Glocal marketing strategy.

Table 1. Three marketing strategies

Marketing strategy	Characteristics of local consumers
Global marketing strategy	-Global consumer culture -Cultural intelligence -Cultural openness
Local marketing strategy	-Ethnocentrism and patriotism -Conservatism, respect for tradition -Pronounced national identity
Glocal marketing strategy	-Respect for one's own culture as well as the cultures of other countries -Cosmopolitanism and ethnocentrism -Cultural sensitivity as well as respect for one's own history

Source: Authors

METHODOLOGY

Field research was conducted in early 2024 in the territory of the Republic of Serbia (Belgrade, Novi Sad, Kragujevac) using a survey method personally. This study employs a simple random sampling method. At the beginning of the questionnaire, there was an eliminatory question: "*Do you purchase foreign luxury brands*?" No classification of foreign luxury brands was made based on product categories (such as clothing, furniture, accessories); instead, luxury brands are observed in general, regardless of the product category they belong to. A total of 535 respondents were surveyed, but 47 of them answered that they do not purchase foreign luxury brands, so they are ultimately excluded from the sample. The total number of respondents in the sample was 488, and they rated statements related to research variables - patriotism, consumer xenocentrism, cultural sensitivity, cultural heritage of other countries, country of origin image, and luxury foreign brands - on a *Likert scale from 1 to 7*. From the statistical analyses, *Confirmatory factor analysis (CFA)* and *Structural Equation Modeling (SEM model)* were applied using the *statistical package SmartPLS 4*.

The overview of the demographic structure of the respondents is provided in Table 2.

Table 2. Demographic characteristics of respondents

		Number of respondents	Percentage of respondents
Gender	Female	214	43.9%
	Male	274	56.1%
	Total	**488**	**100%**
Age	Up to 20 years	24	4.9%

		Number of respondents	Percentage of respondents
	21-35 years	208	42.6%
	36-55 years	167	34.3%
	56 years and older	89	18.2%
	Total	**488**	**100%**
Status	Unemployed	37	7.6%
	Employed	167	34.2%
	Student	224	45.9%
	Retired	60	12.3%
	Total	**488**	**100%**

Source: Authors

In the total sample, there are 214 women and 274 men. The largest number of respondents belong to the age group of 21-35 years, totaling 208 (42.6%). Regarding the status, the largest number of respondents in the sample are students, 224 (45.9%).

Table 3 presents the statements used in the survey questionnaire, which were adapted from previous studies in the literature that dealt with a similar thematic area.

Table 3. Statements from the questionnaire

Research variables	Statements	Source
Patriotism	1. I feel love for my country. 2. Symbols that are characteristic of my country are important to me. 3. Respecting traditional values is important for a society.	Adapted to: Nugraha et al. (2023)
Consumer xenocentrism	1. I pay more attention to foreign cultures than my own. 2. I buy exclusively foreign brands. 3. I believe that only foreign brands are of good quality.	Adapted to: Zdravković (2022)
Cultural sensitivity	1. I am open to accepting ideas that come from other cultures. 2. I value the opinions of people from other cultures. 3. I believe it is very important to know the values that are characteristic of various cultural areas.	Adapted to: Rambocas & Mahabir (2021)
Cultural heritage of other countries	1. I travel abroad to visit museums in other countries. 2. I enjoy visiting cultural monuments in other countries. 3. I like to get to know the cultural heritage of other countries.	Adapted to: Zdravković & Peković (2021)
Country of origin image	1. I always pay attention to the country of origin of the products I want to buy. 2. The country of origin image reflects the quality of the product. 3. I buy products that come from countries with a high level of technical and economic development.	Adapted to: Rodrigo et al. (2023)
Luxury foreign brands	1. Luxury brands provide status in society. 2. I buy luxury brands because they have a high level of reliability and quality. 3. Buying luxury brands gives me a sense of satisfaction.	Adapted to: Saruchera & Mthombeni (2023)

Source: Authors

RESEARCH RESULTS

Table 4 presents the coefficient values used to analyze the relevance of the model.

Table 4. Model validity analysis

Indicators of model validity	Research model – Luxury foreign brands	Recommended value
χ2/df	1.588	<3
GFI	0.928	>0.9
IFI	0.944	>0.9
TLI	0.919	>0.9
CFI	0.931	>0.9
RMSEA	0.038	<0.08

Source: Authors' calculation using SmartPLS 4 software

Respectively, the χ^2/df ratio should be less than 3, according to the authors Bagozzi & Yi (1998). Additionally, the Goodness of Fit Index (GFI), Incremental Fit Index (IFI), Tucker-Lewis Index (TLI), and Comparative Fit Index (CFI) should each exceed 0.9, according to the author Byrne (1998). The Root Mean Square Error of Approximation (RMSEA) value is required to be less than 0.08 (Hair et al., 2006). The values of all parameters fall within the statistical margins, indicating that the conceived research model is relevant.

Confirmatory factor analysis (CFA) was conducted to examine the degree of correlation and internal consistency between statements used to measure the research variables (Table 5).

Table 5. Confirmatory factor analysis (CFA)

Research variables	Cronbach's alpha	Composite reliability (rho_a)	Average Variance Extracted (AVE)
Patriotism	0.816	0.830	0.611
Consumer xenocentrism	0.838	0.851	0.687
Cultural sensitivity	0.737	0.744	0.639
Cultural heritage of other countries	0.865	0.869	0.655
Country of origin image	0.724	0.804	0.678
Luxury foreign brands	0.862	0.885	0.711

Source: Authors' calculation using SmartPLS 4 software

The values of *Cronbach's alpha* and *Composite reliability (rho_a)* indicators show that all research variables are measured through statements that exhibit an appropriate degree of correlation values greater than the statistical threshold of 0.70 according to the author Nunnally (1978), indicating the relevance of the research model. Also, the Average Variance Extracted (AVE) should surpass the threshold of 0.50 (Fornell & Larcker, 1981) and all the values are within the required statistical range.

The *Structural equation model (SEM model)* was implemented to analyze the effects of *patriotism*, *consumer xenocentrism*, *cultural sensitivity*, *cultural heritage of other countries*, and *country of origin image* on consumers' purchasing behavior of luxury brands (Table 6).

Table 6. Structural equation model (SEM model)

Hypothesis	Original sample (O)	Standard deviation (STDEV)	T statistics (IO/STDEVI)	P values
Patriotism → Luxury foreign brands	-0.226	0.054	4.195	0.000**
Consumer xenocentrism → Luxury foreign brands	0.345	0.047	7.333	0.000**
Cultural sensitivity → Luxury foreign brands	0.267	0.046	5.804	0.000**
Cultural heritage of other countries → Luxury foreign brands	0.167	0.047	3.558	0.000**
Country of origin image → Luxury foreign brands	0.279	0.054	5.172	0.000**

Level of statistical significance: **0.01; R square=0.491

Source: Authors' calculation using SmartPLS 4 software

The coefficient of determination *R square* is 0.491, which means that 49.1% of consumers' decision to purchase luxury foreign brands is explained by the given regression model. *Patriotism (coefficient= -0.226, p values=0.000)* has a negative statistically significant impact on consumers' decision to purchase luxury foreign brands, thus confirming research hypothesis H1. On the other hand, *consumer xenocentrism (coefficient= 0.345, p values=0.000), cultural sensitivity (coefficient= 0.267, p values=0.000), cultural heritage of other countries (coefficient= 0.167, p values=0.000), and country of origin image (coefficient= 0.279, p values=0.000)* have a positive statistically significant impact on consumers' decision to purchase luxury foreign brands, confirming research hypotheses H2, H3, H4, and H5.

DISCUSSION OF RESULTS

The research results showed that patriotism has a negative impact on the purchase of foreign luxury brands, confirming research hypothesis H1. These results are similar to previous studies that found patriotism to be one of the key factors in consumer ethnocentrism, negatively influencing the purchase of foreign products, luxury brands, and globally recognized brands (Güngördü Belbağ, A. 2023; Li et al., 2022; Miguel et al., 2023; Nugraha et al., 2023). On the other hand, the research results showed that consumer xenocentrism positively impacts the purchase of foreign luxury brands, confirming research hypothesis H2. Previous studies have established that xenocentrism, as a sociologically derived concept, implies people's preferences for foreign cultures over their own, and that consumer xenocentrism, as an economic extension of this concept, positively impacts the purchase of foreign products and negatively impacts the purchase of domestic products (Areiza-Padilla & Cervera-Taulet, 2023; Balabanis & Diamantopoulos, 2016; Cleveland & Balakrishnan, 2019; Diamantopoulos et al., 2019; Mahmoud et al., 2023; Mueller et al., 2020). Additionally, the results show that cultural sensitivity positively influences the purchase of foreign luxury brands, thus confirming research hypothesis H3. Previous studies have found that a high level of cultural openness, cosmopolitanism, and cultural intelligence positively impacts consumers' intentions to purchase foreign brands (Cui et al., 2019; Frias-Jamilena et al., 2018; Pratono & Arli, 2020; Zdravković & Peković, 2021). According to the research results, the

desire to visit the cultural heritage of other countries has positive effects on the purchase of foreign luxury brands, confirming research hypothesis H4. Prior studies have found that visiting the cultural heritage of other countries increases levels of cosmopolitanism and fosters the development of cultural intelligence, which in turn positively impacts decisions regarding the purchase of foreign brands (Moscatelli et al., 2023; Rahman et al., 2020; Saničanin et al., 2019; Zdravković & Peković, 2021). The results showed that the country-of-origin image has a positive impact on the purchase of foreign luxury brands, confirming research hypothesis H5. Previous studies emphasize that the country-of-origin image is a variable that may have a decisive impact on consumer purchasing decisions (Bernard et al., 2020; Esmaeilpour & Abdolvand, 2016; Lee, 2020; Zolfagharian et al., 2020).

The number of studies in the domestic scientific literature that have focused on this topic is relatively small, so this study fills an existing research gap. On the other hand, the foreign scientific literature includes a significantly larger number of studies on this subject, yet these studies generally analyze the specified variables as partial determinants of foreign brand purchases. This study, however, takes a holistic approach to developing the research model by examining the comprehensive influence of patriotism, consumer xenocentrism, cultural sensitivity, cultural heritage of other countries, and country-of-origin image on consumers' decisions to purchase foreign luxury brands. Additionally, this study was conducted after the COVID-19 pandemic and during the Russia-Ukraine conflict, events that caused significant geopolitical tensions and led certain countries to shift from globalization to deglobalization trends in their economic policies.

In times of crisis, governments prioritize protecting the domestic economy and national interests. According to Social Identity Theory (Tajfel & Turner, 1979) and Social Conflict Theory (Sherif, 1966), crises tend to strengthen national identity, pride, and patriotic sentiments, which, in turn, increase consumer ethnocentrism. From this perspective, the results show that patriotism is a significant determinant (negative) of luxury foreign brand purchases by consumers in the Serbian market. Conversely, consumer xenocentrism, cultural sensitivity, the cultural heritage of other countries, and country-of-origin image are positive significant factors influencing luxury foreign brand purchases. Thus, this study recommends that when multinational companies enter the Serbian market, marketers should develop and implement a "glocal" marketing strategy—one that recognizes the needs of consumers with strong patriotic feelings as well as those with cosmopolitan attitudes and perspectives, instead of adhering solely to a global or local approach.

In line with these findings, this study not only expands scientific knowledge in the field of intercultural marketing but also provides important practical implications for multinational company marketers.

CONCLUSION

The research was conducted with the aim of analyzing the effects of patriotism, consumer xenocentrism, cultural sensitivity, cultural heritage of other countries, and country of origin image on consumers' decisions to purchase luxury foreign brands. The results indicate that patriotism has a negative impact, while consumer xenocentrism, cultural sensitivity, cultural heritage of other countries, and country of origin image have a positive and statistically significant impact on the purchase of luxury foreign brands by consumers. *The originality and relevance of the research* lie in the application of a holistic approach, where the combined effect of all these variables on the purchase of luxury foreign brands was examined. The limitations of previous studies, which were partial in nature, as they analyzed only the individual impact of the mentioned variables on consumers' decisions to purchase luxury foreign brands, are compensated in this way. Additionally, the time period in which this research was conducted represents a significant contribution. During crisis situations, there is an intensification of patriotic feelings and cohesion among people, with a unified intention to strengthen the national economy through the purchase of domestic products. Therefore, it was particularly interesting to analyze consumers' thoughts and their desire to purchase luxury foreign brands under the influence of the analyzed

determinants. *The theoretical implications of the study* are reflected in filling the research gap existing in the literature, and the confirmed research hypotheses become relevant scientific knowledge that can serve as a basis for new studies in the fields of marketing and management. *The practical implications of the study* suggest that for entering the market of the Republic of Serbia, it is optimal to apply a *glocal marketing strategy*, as local consumers exhibit pronounced patriotic feelings and ethnocentric tendencies, but also a high degree of xenocentrism, cultural openness, a desire to explore the cultural heritage of other countries, as well as emphasizing the importance of the country of origin of products. All these variables influence the preference for foreign luxury brands in the purchasing process. Brands need to have global recognition and provide social prestige, but on the other hand, they should also incorporate, for example, certain symbols on the product packaging that reflect the local market they are entering. Additionally, it is possible to a certain extent to customize products according to the characteristics of the local market, as McDonald's, for instance, makes its products with special bread in France and specific spices in India. On the other hand, applying either a *global or local marketing strategy* would only partially satisfy the needs of the local market. The results of the empirical study indicate that patriotic sentiments are strongly expressed in Serbia, meaning that citizens' emotional attachment to their home country implies the presence of ethnocentric tendencies that influence the purchase of domestically produced goods. This suggests the necessity of applying a localized marketing strategy. However, the findings also reveal that Serbian consumers exhibit a high degree of consumer xenocentrism and cultural sensitivity, showing significant interest in learning about the cultural heritage of foreign countries and the country-of-origin image of products. These factors contribute to the formation of cosmopolitan attitudes, indicating that a global marketing strategy should also be considered for the Serbian market.

Nevertheless, the final conclusion of the study, based on a holistic approach and the developed integrative research model, suggests that a glocal marketing strategy should be implemented. This strategy would accommodate the needs of consumers with strong patriotic and ethnocentric tendencies as well as those with pronounced cosmopolitan and globalist orientations.

A limitation of the research is that it was conducted in only one country. Cross-cultural studies provide much more precise and comprehensive results and offer the possibility for comparative analysis and comparison of attitudes among members of different nations regarding the impact of certain determinants on their purchasing decisions. *Future research directions* could focus on conducting studies in additional European countries, as well as expanding the research model by introducing other significant determinants of consumer decisions regarding the purchase of luxury foreign brands, such as cosmopolitanism, personal innovativeness, the impact of influencer marketing, and similar factors.

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ORIGINAL SCIENTIFIC PAPER

Mapping Agility Factor Dependencies in the IT Sector of Humanitarian Organizations Using the ISM Approach

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ABSTRACT

Organizations are gradually relying on Information Technology (IT) to assist them in addressing unexpected challenges they face in their daily operations. The reliance is particularly essential in humanitarian settings where agility and adaptability are crucial. To examine the factors influencing IT agility in the humanitarian context, Interpretive Structural Modeling (ISM), along with MICMAC analysis, were applied. After identifying interconnections among the factors, they were classified according to their driving and dependence power. This study emphasizes the importance of continuous monitoring and flexible strategies to maintain operational efficacy. While the diverse insights gained from the research are valuable, this diversity could also be considered a limitation. The IT experts, who participated in the study, hold diverse positions across different IT sectors within the organization. The consistency of the results may be impacted by differences in how these factors are seen and prioritized in their specific work settings, rather than a unified perspective on IT agility. Future studies can explore the dynamics across different sectors or with a larger sample size to validate the results in a broader context. This study contributes to the understanding of how IT agility can be managed and optimized in humanitarian contexts, providing valuable insights for practitioners and researcher.

Keywords: *IT agility, humanitarian organization, ISM, MICMAC analysis*

JEL Classification: L20, M54

INTRODUCTION

Over the past few years, the variety of studies on the topic of agility has increased remarkably. Under Agile Alliance (n.d.), agile practices are described as a form of action focused on delivering solutions through continuous cooperation, teamwork, and a foundation of trust, and are frequently followed by informal communication. The important elements of the term 'agility' are responsiveness and flexibility, with responsiveness implying the capacity to detect operational risks and respond to them properly, and flexibility referring to the ability to act quickly (L'Hermitte et al., 2015; Lee, 2017; Kirkpatrick et al., 202). Bambauer-Sachse and Helbling (2021) note that the focus is on its ambiguity, intermittent approach, and flexible reactions to change regardless of the project phase. Agile methods are based on the principles introduced in the *Manifesto for Agile Software Development* (Beck et al., 2001). In line with the same document, four main values were defined: prioritizing people and their interactions over procedures and tools; focusing on delivering functional software instead of extensive documentation; valuing

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collaboration with customers rather than adhering strictly to contracts; and being adaptable to change more than sticking rigidly to a predefined plan.

Given the fact that companies and non-profit organizations are faced with a fast-evolving environment, the decision to accept agility and keep up with it has become standard (Rigby, 2016). In agreement with that, Nguyen et al. (2024) assert that volatile and complex circumstances now prevail over structured approaches. To organizational performance, agility is deemed advantageous, but these advantages depend on a variety of factors, such as the form of agility, the outcome desired, and the conditions necessary for agility to achieve these outcomes (Wieland & Wallenburg, 2012).

The purpose of this paper is to identify the relationships between the factors affecting agility in IT and to determine relationships among these factors in the setting of humanitarian activity. The paper starts with an introduction to the concept of agility in different spheres, with a particular emphasis on the IT sector, providing an overview of its significance in IT operations. This is followed by a portrayal of the methodology applied, specifically the Interpretive Structural Modeling (ISM) and MICMAC analysis, explaining how these tools were used to identify and classify the relationships between the factors. The paper concludes with a discussion of the results, offering insights into the effects these factors have. Additionally, the article provides recommendations for future studies and suggests areas that could lead to new and invaluable discoveries.

The study's relevance stems from its increasing significance of agility in the IT management of humanitarian organizations. Although corporate agility in IT has been thoroughly examined in business environments, its role in humanitarian settings is still under research. Therefore, this research contributes to the humanitarian field by examining interactions between IT's agility variables in its settings. In doing so, it provides both academic insights and practical guidance on agility for improving operational efficacy in humanitarian organizations.

THEORETICAL BACKGROUND

Organizational Agility

To better understand the foundation of organizational agility, this section explains its core elements through different studies and industries.

Across numerous studies, organizational agility (OA) has been shown to have a great impact on organizational performance. Vázquez-Bustelo et al. (2007) consider OA a 'holistic concept' that necessitates attention to its specific segments. Organizational agility is described as flexibility, swiftness, velocity (Sing et al., 2013), and the capacity to react to change and increase opportunities (Ravichandran, 2018).

Three components of OA were presented in Wendler's (2014) research: agile values, technology, and people. Leonhardt et al. (2016) conducted a quantitative meta-analysis and outlined the specifics of IT and OA. Puthenpurackal et al. (2021) present existing insights on how project portfolios facilitate IT agility while integrating agile practices. They present different meanings of OA depending on the dimension: customer, partnering, and operational agility — focused on supply chain, customer responsiveness, and internal processes (Chen & Siau, 2012; Zaini & Masrek, 2013; Mao et al., 2014); entrepreneurial and adaptive agility — highlighting the ability to be proactive, perceive and respond to changes (Chakravarty et al., 2013); market capitalizing and operational adjustment — presenting capability to tailor business processes to improve services or products (Cai et al., 2017; Panda & Rath, 2017; Zhou et al., 2018).

Over time, the concept of agility has been examined across diverse areas, with a focus on different elements. Various researchers have identified critical factors that enable organizations to effectively respond to change: agility enablers (Overby et al., 2006; Aravindraj et al., 2013); workforce agility (Sumukadas & Sawhney, 2004; Alavi et al., 2014), supply chain agility (Eckstein

et al., 2015; Chen, 2019), implementation methodologies (Hazen et al., 2017; Nejatian et al., 2018), information systems agility (Rabah et al., 2015), strategic agility (Fourné et al., 2014; Morton et al., 2018).

While the theoretical foundation of organizational agility has been studied across many sectors, there remains a gap in recent literature on how these concepts relate to the nonprofit and humanitarian IT spheres. The need to better understand agility enablers in specific settings is emphasized in recent literature, especially considering emerging technologies and increasingly challenging environments. As a result, this research examines and analyzes agility factors more closely by looking at the interrelationships among them, enhancing the existing knowledge base, and identifying opportunities for future studies.

Agility in IT and the Humanitarian Sector

Nonprofit organizations play an essential role and are vital in providing services to communities. In their research on strategic IT alignment and OA in nonprofits, Azevedo et al. (2024) observe that nonprofits also face pressure for enhanced performance and value creation for stakeholders. Based on previous studies concerning the topic of OA, three practices shape agile organizations — perceiving, comprehending, and responding (Butler & Surace, 2015; Tallon et al., 2019), meaning that organizations must sense the change, grasp the information, and react accordingly. Tallon et al. (2019) illustrate how agility is perceived and draw attention to the critical role that IT plays in decision-making and managing challenges. The fusion of artificial and human intelligence is becoming increasingly relevant in today's world. For instance, Singh (2024) shows that digital platforms can significantly enhance agility by facilitating coordination among supply chain actors. Similarly, Wang et al. (2024), also highlight the importance of understanding the enablers of such integration for achieving faster and sharper response in volatile settings.

Marjerison et al. (2022) affirm that agile organizations are more inclined to nurture a culture of knowledge sharing, which has a positive impact on amplifying their adaptability and collaboration, but policies, activities, and strategies can affect organizational agility by restricting the organization's capacity to serve its stakeholders (Azevedo et al., 2024). Besides these factors, as noticed by the same authors, IT alignment, technologies, leadership, and the entire organizational structure can impact organizational agility. Lee (2017) emphasizes the significance of IT alignment with an organization's strategic roadmap process. In addition to that, Setiawati et al. (2022) emphasize the vital role of top management, while also acknowledging the equally important role in fostering the agility of other employees across HR, operations, IT, and different departments.

It's crucial for both humanitarian organizations and for-profit companies to identify and implement best practices to enhance organizational agility and achieve sustainable performance in rapidly changing environments.

Recent empirically based frameworks developed for evacuation agility underline the complex nature of agility in humanitarian contexts. Achieving operational responsiveness has been found to depend highly on core elements such as stakeholder engagement, staff empowerment, information flow, and inter-organizational collaboration. These elements reflect the interconnected factors examined in this study, reinforcing the relevance of a systems-based approach in managing IT agility in humanitarian settings (Rodríguez-Espíndola et al., 2021). In line with that, Tickle et al. (2024) argue that embracing fourth-party logistics models can enhance adaptability and responsiveness in the humanitarian chain.

Novel studies aim to examine the concept of agility in the humanitarian sector, whereas former studies were focused on understanding agility in corporate settings. Pereira and Shafique (2024), for example, illustrate how emerging technologies like AI and real-time data analytics are transforming the agility of the humanitarian supply chain. Similarly, Abou-AL-Ross and Shatali (2022) discuss the potential of workforce agility when operating in unpredictable circumstances.

In keeping with Kelly et al. (2022), these practices underscore the crucial role of flexibility in responding to evolving humanitarian needs.

Despite these contributions, the structural relationships among agility enablers have not been thoroughly examined, principally in IT departments of humanitarian organizations. This study aims to shed light on that by implementing ISM and MICMAC methodologies to unveil the agility factor dynamics in such a unique operational context. Therefore, it not only deepens our theoretical understanding but also offers practical insights that can help organizations respond more effectively to change.

DATA AND METHODOLOGY

The analysis begins with a determination of factors that affect agility. Interpretive Structural Modeling (ISM) was applied to identify the relationship among the factors influencing agility in IT operations within a humanitarian organization. After various factors were determined, a Structural Self-Interaction Matrix (SSIM) was developed to establish how these factors influence or interact with each other. This matrix is then converted into a Reachability Matrix (RM), where its transitive relationship is tested. MICMAC analysis has been used to classify factors based on their driving and dependence power.

Sl. No	Enablers	Definition	Factors-meanings
1	Flexibility	Ability to change or react with little penalty in time, effort, cost, or performance.	Volume flexibility (F1) – ability to change the level of aggregated output. Delivery flexibility (F2) – ability to change planned or assumed delivery time.
2	Responsiveness	Ability to respond to changes within an appropriate time frame.	Reactivity (F3) – ability to evaluate and take needs into action quickly. Velocity (F4) – ability to cover needs quickly
3	Effectiveness	Doing all the right things at the right place and at the right time.	Reliability (F5) – ability to deliver the correct product at the correct place at the correct time. Completeness (F6) – ability to realize goals.
4	Skills and learning	Requirement for greater skills to overcome linguistic and contextual differences.	Multi-skilled and flexible people (F7) – ability to work at different phases of the event. Informal learning and development (F8) – learning from the previous events/ancestors.
5	Change	Ability to improve oneself by updating towards improvement.	Change of culture (F9) – paradigm shifting and culture changes. Continuous improvement (F10) – use of lessons learned from the previous events practices.

Figure 1. *Enablers affecting agility identified by Suresh et al. (2019)*

Source: Suresh, Ganesh & Raman (2019)

A survey was conducted among 25 IT experts, specifically heads and managers of various IT departments within a humanitarian organization. Twenty-one people responded to the survey, which represents 84% of the total participants. While quantitative studies usually require larger samples to achieve statistical generalization, the nature of ISM, as a qualitative method with quantitative elements, relies on expert knowledge and judgment rather than probability-based sampling. Literature, along with recent studies, suggests that a sample of 10–25 experts is considered justifiable for ISM research (Qazi et al., 2022; Tasnim et al., 2023; Dohale et al., 2024; Niazi et al., 2024), considering that respondents possess relevant expertise in the area of research. This study assures a strong level of representativeness and diversity of insights from IT professionals within a humanitarian organization, as depicted by the 84% response rate.

The survey was presented as a questionnaire containing 90 statements, utilizing a 5-point Likert scale with possible responses (Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree). The statements were designed as pairwise comparisons of factors, with the most frequently chosen response among the experts being identified as the prevailing opinion. They were formulated based on the question model used by Suresh et al. (2019) in their research, where the ISM model has also been used to identify and analyze relationships between the factors. The agility enablers and the corresponding factors, which we have adopted, were originally identified and derived from the literature survey and expert interviews conducted in the same work. Those factors are presented in Figure 1. By analyzing the interaction of each factor with the others, as well as their direct and transitive relationship, we can determine the driving and dependent power of each factor.

The extract of the questionnaire used in this research is presented in Figure 2.

Factor i – factor j	*Pair wise questions*	*V*	*A*	*X*	*O*
F1–F2	Sudden change in volume requirement impacts the flexibility of delivery time.				
F1–F3	Sudden change in volume requirement impacts the decision-making capability.				
F1–F4	Sudden change in volume requirement impacts the ability to quickly cover the needs of the customers.				
F1–F5	Sudden change in volume requirement impacts the capability to produce the right output at the right place and at the right time.				
F1–F6	Sudden change in volume requirement impacts the members' ability to realize goals.				
F1–F7	Sudden change in volume requirement impacts the effectiveness of IT professionals.				
F1–F8	Sudden change in volume requirement impacts the informal learning and development in IT teams.				
F1–F9	Sudden change in volume requirement impacts the ability to implement changes in IT culture.				
F1–F10	Sudden change in volume requirement impacts the continuous improvement of IT processes and solutions.				

Figure 2. A sample of the questionnaire used in the research

Source: Author's questionnaire

A structural self-interaction matrix (SSIM) was created based on the contextual relationships identified between the pairs of factors using the symbols listed below:

- V: Factor i influences or alters factor j,
- A: Factor j influences or alters factor i,
- X: Factors i and j influence or alter each other,
- O: Factors i and j are not related.
- Conversion steps are explained below:

Table 1. SSIM conversion steps

SSIM (i, j) entry	Initial reachability matrix (i, j) entry	Initial reachability matrix (j, i) entry
V	1	0
A	0	1
X	1	1
O	0	0

Source: Suresh, Ganesh & Raman (2019)

Based on that, Table 2 illustrates SSIM for agility in the IT sector of a humanitarian organization.

Table 2. Structural Self-Interaction matrix (SSIM)

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	1	X	V	X	V	X	X	V	X	X
F2		1	X	X	X	X	X	O	X	X
F3			1	V	X	V	X	X	X	X
F4				1	X	X	X	A	X	X
F5					1	A	X	A	X	A
F6						1	X	A	X	X
F7							1	X	X	X
F8								1	X	X
F9									1	X
F10										1

Source: Author's calculation

The initial reachability matrix (IRM) is presented in Table 3.

Table 3. Initial Reachability Matrix (IRM)

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	1	1	1	1	1	1	1	1	1	1
F2	1	1	1	1	1	1	1	0	1	1
F3	0	1	1	1	1	1	1	1	1	1
F4	1	1	0	1	1	1	1	0	1	1
F5	0	1	1	1	1	0	1	0	1	0
F6	1	1	0	1	1	1	1	0	1	1
F7	1	1	1	1	1	1	1	1	1	1
F8	0	0	1	1	1	1	1	1	1	1
F9	1	1	1	1	1	1	1	1	1	1
F10	1	1	1	1	1	1	1	1	1	1

Source: Author's calculation

The final reachability matrix (FRM) shown in Table 4 was derived from the initial reachability matrix through transitivity analysis, where:

- First-level transitivity (for 1*): if A = B, and B = C, then A = C
- Second-level transitivity (for 1**): if A = B, B = C, and C = D, then A = D

The final reachability matrix table includes both driving power and dependence power. Driving power is determined by summing the entries in the rows, while dependence power is calculated by summing the entries in the columns.

Table 4. Final Reachability Matrix (FRM)

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	1	1	1	1	1	1	1	1	1	1
F2	1	1	1	1	1	1	1	1*	1	1
F3	1*	1	1	1	1	1	1	1	1	1
F4	1	1	1*	1	1	1	1	1*	1	1
F5	1*	1	1	1	1	1*	1	1*	1	1*
F6	1	1	1*	1	1	1	1	1*	1	1
F7	1	1	1	1	1	1	1	1	1	1
F8	1*	1*	1	1	1	1	1	1	1	1
F9	1	1	1	1	1	1	1	1	1	1
F10	1	1	1	1	1	1	1	1	1	1

Source: Author's calculation

Table 5. Level Partitioning - 1st iteration

Factors	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	I
2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	
3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	
4	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	
5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	
6	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	
7	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	
8	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	
9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	
10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	

Source: Author's calculation

The final reachability matrix is composed of three categories: the reachability set, the antecedent set, and the intersection set. The reachability set contains elements from the rows of the matrix, while the antecedent set consists of elements from the columns. The intersection set contains elements that are shared between both rows and columns, thereby placing them at the same level. Therefore, there is no need for further iterations to eliminate elements that are shared among all factors within the reachability set.

RESULTS AND DISCUSSION

The analysis results are presented through a diagram (Figure 1) that displays a linear hierarchy of factors. The diagram illustrates how each factor influences or relates to the next, starting from the initial factor and continuing to the last, without any branching or feedback loops. It shows a direct line from one factor to the next, illustrating a chain of influence where each factor sets off the next one in line. In the context of ISM, this kind of diagram suggests that each factor relies on the one before it, with the final factor at the top, dependent on all the preceding ones. Since the

diagram is linear, all factors are connected in one direction with no possibility of reciprocal interaction. In practical terms, this framework suggests that interventions aimed at improving agility should consider sequencing, ensuring that fundamental elements such as leadership commitment and information flow are addressed promptly, as they build the stage for improvements in responsiveness and adaptability.

These findings align with the earlier work of Suresh et al. (2019), confirming a high level of structural dependence among agility factors in humanitarian settings. However, unlike prior research that emphasizes singular drivers such as leadership or technology (Lee, 2017; Azevedo et al., 2024), this study demonstrates that all ten factors act simultaneously as drivers and dependents. This points to a more intricate system, where no single enabler dominates.

Moreover, while studies like Wang et al. (2024) and Singh (2024) highlight the role of technology and the use of platforms to improve responsiveness, findings in this article suggest that these cannot be effective without synchronous attention to less tangible elements, like the culture of knowledge sharing and leadership alignment. In a humanitarian context, this provides a more holistic framework for IT agility.

In contrast to corporate environments, where certain factors tend to demonstrate independent influence, the humanitarian context appears to require greater mutual coordination, likely as a result of higher environmental volatility and stakeholder diversity (Ravichandran, 2018). The need to develop context-specific agility models for nonprofit sectors is highlighted by this distinction.

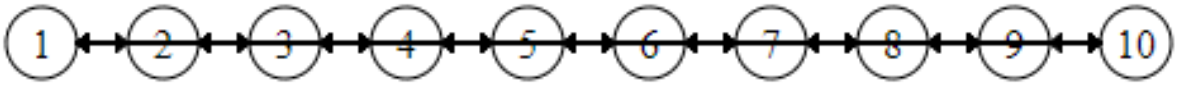

Figure 1. Diagraph

Source: Author's calculation

MICMAC Analysis

The MICMAC analysis categorizes factors into four clusters based on their driving and dependence power: autonomous, dependent, linkage, and independent. Quadrant I, for example, holds the autonomous factors, which have little influence on others and don't depend much on them either. Quadrant II consists of dependent factors — they rely heavily on other factors but don't influence them much in return. Quadrant III contains linkage factors. They both influence a lot of other factors and are heavily influenced in return, indicating that any change to them could have a dynamic and wide-ranging impact across the system. Finally, Quadrant IV includes independent factors, which have a strong influence on other factors but are not easily influenced in return.

This analysis helps identify areas for focus, especially when it comes to strategic planning and decision-making. In our case, as shown in Table 5 and the MICMAC graph, all factors fall within Quadrant III, implying that they should be closely monitored, as they can both trigger changes and be affected by them, impacting overall performance. This underscores their importance in maintaining stability.

Table 6. Classification of factors

Zones	Measures	Contents	Factors falling in the zone
Zone 1	Autonomous factors	Weak driving power and weak dependence power	None
Zone 2	Dependent factors	Weak driving power and strong dependence power	None
Zone 3	Linkage factors	Strong driving power and strong dependence power	F1-F10
Zone 4	Independent factors	Strong driving power and weak dependence power	None

Source: Author's calculation

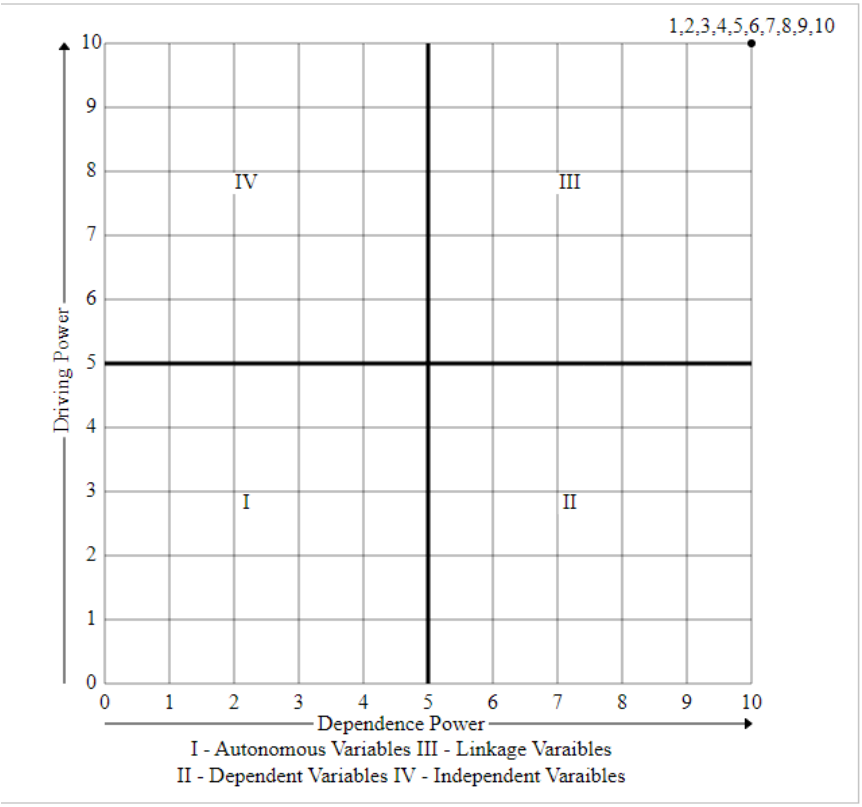

Figure 1. MICMAC graph

Source: Author's calculation

CONCLUSION

In this study, Interpretive Structural Modeling (ISM) was applied to explore the factors that influence agility in IT operations within a humanitarian organization. We categorized them based on their driving and dependence power by examining how they connect and interact with each other. The findings demonstrate that all factors are interlinked, underscoring a significant degree of interdependence within the system. This highlights the need to take a more holistic approach when managing IT agility, considering that any change in a single factor can have a cascading effect on others. The study also emphasizes the importance of continuous monitoring and flexible strategies to maintain efficiency and responsiveness, especially in the humanitarian field characterized by dynamic environments.

While this study provides significant insights into the elements impacting IT agility, it comes with certain limitations. Primarily, the IT experts, who participated in the study, occupy different roles across various sectors within the organization, and their responses may reflect specific demands and practices of their specific work settings rather than a unified perspective on IT agility. This context-specific framework could result in discrepancies in how the determinants are observed and prioritized, potentially affecting the consistency of the results. While this diversity can provide a broad range of insights, it may also limit the focus to certain areas.

Another possible limitation is that the use of the ISM framework is derived from subjective perceptions, which might influence the correctness of detected relationships. Also, the research is centered exclusively on the IT sector within a humanitarian organization, plausibly reducing the application of the findings to other sectors or industries. Although significant progress has been made in research on agility and its impact on organizational performance, there are still gaps that are inevitable given the daily changes in the time we live in. Future research could extend the sample size, include a greater range of organizations, and implement other methods to verify the findings. Moreover, incorporating external factors and conducting longitudinal studies, especially considering the potential offered by new technologies, could provide a more holistic understanding of IT agility across different scenarios.

This paper fills a research gap and offers practical guidance for applying agility in nonprofits by framing agility factors through ISM and MICMAC within a humanitarian IT context. Strong connections between factors reduce simple, step-by-step models and show the need for more flexible strategies. As such, the study contributes to the broader knowledge supporting tailored ways to manage organizational agility in highly uncertain and changing environments. From a practical perspective, this research demonstrates that initiatives to increase agility should be carried out in a specific order that prepares the ground for better responsiveness and flexibility, starting with essentials like leadership support and communication systems, as they enable further progress.

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ORIGINAL SCIENTIFIC PAPER

Economic Determinants of Export Diversification in Algeria: An Empirical Analysis through Quantile Rregression

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ABSTRACT

This study aims to identify the key economic determinants of export diversification in Algeria, a rentier state, over the period 1995–2022. Using annual data from various official sources, a quantile regression model is employed to assess the heterogeneous effects of selected variables across different levels of export diversification. The results show that foreign direct investment does not support export diversification, while oil rents and trade openness are factors that hinder the process. Conversely, domestic investment and manufacturing exports contribute positively to a more diversified export structure. The study contributes to the literature by offering new insights into how structural economic factors shape diversification patterns in resource-rich countries, emphasizing the role of targeted investment and industrial development policies in reducing dependence on natural resources.

Keywords: *export diversification, Algeria, Herfindahl-Hirschman Index, quantile regression*

JEL Classification: F43, C54, O1

INTRODUCTION

Export diversification has guided the policies of many countries. Resource-rich nations, including Algeria, seek to reduce their dependence on these resources by diversifying their exports and sources of revenue. The need for export diversification is frequently highlighted by periodic fluctuations or cycles of rising and falling international commodity prices, as evidenced in 2014, as well as during recent global disruptions caused by imbalances between oil supply and demand, particularly during the COVID-19 pandemic in 2020 and the Russia-Ukraine conflict in 2022. The studies by Singer (1950) and Michaely (1958) emphasized the importance of shielding economies from excessive price variations. More recently, research has demonstrated that diversifying trade partners is an effective strategy to reduce vulnerability to external shocks (Jansen et al., 2011). Furthermore, diversification is now recognized as a key element of economic development, particularly in countries highly dependent on natural resources (Agosin, Alvarez, & Bravo-Ortega, 2011).

This study aims to identify the economic determinants of export diversification. By relying on a literature review that highlights the crucial role of local and foreign investments, hydrocarbon and manufacturing exports, as well as trade openness, and by examining their influence on export

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diversification, the study seeks to answer the following question: what is the impact of economic factors at different levels of export diversification during the period 1995–2022 in Algeria?

To address our research question, we have drawn upon relevant literature on the subject, as well as data covering the period from 1995 to 2022, to test the assumed effects of the various studied variables on export diversification. We have adopted a recent econometric approach, which we deem most appropriate for our study. Following the introduction, a relevant literature review is presented. Subsequently, an empirical analysis is conducted, applying the quantile regression model.

LITERATURE REVIEW

In their study on the determinants of export diversification in a large sample of 79 countries between 1962 and 2000, Agosin et al. (2011) highlighted the key factors influencing export diversification. Their findings showed that trade openness promotes specialization, which negatively impacts export diversification. The study underscores the importance of understanding the complex relationships between economic policies and export diversification. Arawomo et al. (2014), in their article examining the impact of foreign direct investment (FDI) on export diversification in Nigeria, found that FDI hinders export diversification in the country. In contrast, domestic investment fosters diversification. Other discouraging factors include exchange rate fluctuations and democratic accountability.

Conversely, another study analysed the determinants of export diversification in Pakistan from 1980 to 2015. The findings indicated that foreign direct investment and global income positively influence export diversification, whereas trade openness encourages export concentration and limits diversification in Pakistan. The study suggests exploring new export markets as a strategy for diversification (Mubeen & Ahmad, 2016).

Regarding the analysis of factors influencing export diversification, Osakwe and Kilolo (2018) demonstrated that the share of manufacturing value-added in GDP is a key determinant of diversification, while dependence on natural resources tends to increase export concentration. Their study also highlights the importance of adequate infrastructure in supporting diversification processes, which is particularly relevant for least developed countries (LDCs) facing specific economic diversification challenges.

A study on the determinants of export diversification in the West African Economic and Monetary Union (WAEMU) countries over the period 1995–2015, using the fully modified ordinary least squares (FMOLS) method, found that trade openness, human and physical capital accumulation, and a competitive real exchange rate significantly favor export diversification. However, abundant natural resource endowment and small economic size are major obstacles to this process. These findings highlight the need to adopt strategies aimed at diversifying exports to strengthen the economic resilience of these countries (Diop, 2019).

In Brazil, an analysis of export diversification over a ten-year period, where the authors employed a dynamic panel methodology, examined the determinants of diversification. The findings by Oliveira et al. (2020) identified education, patents per capita, credit access, and public investment as significant positive determinants of export diversification.

Handoyo et al. (2021) conducted a study on the determinants of export diversification in 62 developing countries between 2010 and 2018, using the Poisson pseudo-maximum likelihood (PPML) estimation method. The study emphasized the importance of developing human capital, improving global competitiveness, and optimizing R&D resources to stimulate export diversification in developing economies.

Touati and Keddari (2022) highlighted in their study the importance of a diversification strategy for ensuring sustainable economic growth in Algeria, emphasizing the central role of private sector credit and advocating for structural reforms. Their study found that while trade openness is linked to diversification, its impact is complex and can sometimes reduce export

diversification. However, the study demonstrated the positive impact of private sector credit, underlining the importance of financial access for exporting firms.

The study by Abiola (2024) examined the role of Nigeria's manufacturing sector in export diversification efforts between 1985 and 2022. The findings revealed a weak and negative association between the manufacturing sector and export diversification, indicating that this sector has not significantly contributed to Nigeria's export growth. The study calls for targeted interventions to unlock the sector's potential and enhance Nigeria's export portfolio.

Based on the literature review presented above, we formulate two main hypotheses. First, we posit that foreign direct investment (FDI) has a negative effect on export diversification, a hypothesis supported by the work of Arawomo et al. (2014). Second, we assume that trade openness positively contributes to export diversification, a proposition backed by the research of Diop (2019).

DATA AND METHODOLOGY

In this section, we describe the empirical methodology and the data used to address the research question.

Measurement of Variables and Data Sources

To empirically examine the impact of Foreign Direct Investment (FDI), Oil Exports (HYDRO), Gross Fixed Capital Formation (GFCF), Manufactured Exports (MANU), and Trade Openness (OUV) on export diversification (measured inversely using the Herfindahl-Hirschman Index (HHI) as an indicator of export concentration) in Algeria, the model is specified as follows:

$$HHI_t = f(FDI_t, HYDRO_t, GFCF_t, MANU_t, OUV_t) \quad for\ t = 1995, 1996 \ldots\ldots\ldots\ldots, 2022$$

We utilize data covering the period 1995–2022, sourced from various national and international institutions.

Variables	Description	Source
HHI	Herfindahl-Hirschman Index (measure of export concentration)	UNCTAD (United Nations Conference on Trade and Development)
FDI	Foreign Direct Investment (FDI) as a percentage of GDP	WDI (World Development Indicators) - World Bank
HYDRO	Oil Exports (in millions of dollars)	ONS (National Office of Statistics)
GFCF	Gross Fixed Capital Formation (in millions of dollars)	WDI (World Development Indicators) - World Bank
MANU	Manufactured Exports (in millions of dollars)	WTO (World Trade Organization)
OUV	Trade Openness (as a percentage of GDP)	World Bank, Sherbrooke University - World Perspective

Methodology

The model adopted in this study is inspired by the empirical literature on the subject. Specifically, it is based on the works of Agosin et al. (2011), Arawomo et al. (2014), Osakwe and Kilolo (2018), and Abiola (2024). Unlike previous studies in the literature that have relied on traditional empirical methods, we adopt a new empirical approach that is rarely used in this context, namely, quantile regression, as proposed by Bulut and Yaşar (2023).

Regression analysis is an essential tool for studying the relationship between quantitative variables. Traditional regression methods focus on the mean of the dependent variable, but in

some cases, this method may not capture the full complexity of the relationship between the variables, especially in economics (Cristina & Dominico, 2014). This is because traditional regression is subject to requirements such as homogeneity of variance, normal distribution of the random error, and the absence of outliers, which are rarely met in practice. These constraints can lead to misleading regression results (Koenker & Bassett, 1978). Therefore, new tools have been developed to address these limitations (McMillen, 2013).

Quantile regression (QR), proposed by Koenker and Bassett (1978), is an extension of linear regression used to model conditional quantiles. It allows modelling of the conditional quantiles of the dependent variable, such as the 25th, 50th, or 90th percentiles. Median regression is a particular case of quantile regression when the quantile is equal to 0.50 (Koenker & Bassett, 1978). The fundamental superiority of QR over multivariate regression lies in its ability to analyze data whose conditional distributions are heterogeneous. This type of data has been observed in various fields, such as econometrics, survival analysis, and ecology. QR can illustrate the effect of a variable when a group of percentiles is studied, and it does not assume any distributional hypothesis on the error term in the model (Koenker & Machado, 1999).

Let y be a random variable with a distribution function

$$F(y) = prob(Y \leq y) \quad (1)$$

The τ -th quantile of Y is defined as the inverse function:

$$Q(\tau) = inf\{y: F(y) \geq \tau\} \quad (2)$$

Where $0 < \tau < 1$, we consider the Median as a special case, Q(0.5)Q(0.5)Q(0.5). The equation (2) can also be extended as follows:

$$Qy(\tau)\ (x_1,x_2,...,x_k) = \beta_0(\tau) + \beta_1(\tau)x_1 + ... + \beta_k(\tau)x_k \quad (3)$$

Where: $0 < \tau < 1$, $\beta\ \tau = (\beta_0(\tau), \beta_1(\tau),...,\beta_k(\tau))$ this vector represents the set of parameters that need to be estimated in the model

Let $y_1,y_2,...,y_n$ be a random sample of the variable Y, the sample median is known as the value that minimizes the sum of absolute deviations, defined as:

$$min\xi \in R \sum_{i=1}^{n} |y_i - \xi| \quad (4)$$

The τ-th sample quantile, $\xi(\tau)$, which is the sample analogue of the theoretical quantile function $Q(\tau)$, can be formulated as the solution to the following optimization problem:

$$min\xi \in R \sum_{i=1}^{n} \rho\tau|y_i - \xi| \quad (5)$$

here: $Q\tau(z) = z(\tau - I(z < 0))$, $0 < \tau < 1$, and I (0) is the indicator function (Pauline & Xavier, 2013). This contrasts with the sample mean, which minimizes the sum of squared deviations:

$$\hat{\mu} = argmin\mu \in R \sum_{i=1}^{n} (y_i - \mu)^2 \quad (6)$$

This concept can be extended to the conditional mean, given by the expectation function $E(Y|X = x) = x\beta$, with the estimator defined as:

$$\dot{\beta} = argmin\beta \in R^p \sum_{i=1}^{n} (y_i - x\beta)^2 \quad (7)$$

Similarly, the linear conditional quantile function, defined as Q (Y|X = x) = ẋβ(τ) can be estimated by solving:

$$\dot{\beta}\ (\tau) = argmin\beta \in R^p \sum_{i=1}^{n}\ \rho\tau\ (y_i - x_i\beta) \qquad (8)$$

for any quantile 0 < τ < 1. The estimated parameter vector$\hat{\beta}(\tau)$ is referred to as the τ-th quantile regression, which, for τ = 0.5, corresponds to median regression, minimizing the sum of absolute residuals. The estimated conditional quantile model is expressed as:

$$\hat{Q}\tau(y_i/x_i) = \dot{x_i}\hat{\beta}\tau \qquad (9)$$

The interpretation of the estimated parameters in quantile regression (QR) is similar to that of Ordinary Least Squares (OLS) in terms of rate of change (Koenker & Bassett, 1978). To assess the goodness-of-fit of a simple linear regression model, we typically use the coefficient of determination R^2, or the$\overline{R^2}$ in the multivariate case.

In quantile regression, however, we rely on the pseudo-coefficient of determination or pseudo-R^2, which measures the proportion of the variation in the dependent variable explained by the model at quantile τ (Koenker & Machado, 1999), where:

$$Pseudo\ R^2 = 1 - \frac{ln\ L(\widehat{B})}{ln\ L\ (0)} \qquad (10)$$

where ln $L(\widehat{B})$ is the log-likelihood of the estimated model, and ln L (0)is the loglikelihood of the null model, that is, a model without explanatory variables.

The regression model used in our study is given by the following equation:

$$Q\tau(HHI/X) = \beta_0\ (\tau) + \beta_1\ (\tau)FDI + \beta_2\ (\tau)HYDRO + \beta_3\ (\tau)GFCF + \beta_4\ (\tau)MANU + \beta_5\ (\tau)OUV + \varepsilon\tau$$

Where:
$Q\tau(IHH)$: This is the τ-th quantile of the dependent variable HHI

$\beta 0(\tau)$: This is the intercept of the regression. It depends on the selected quantile τ.

$\beta 1(\tau), \beta 2(\tau), ..., \beta 5(\tau)$: These are the regression coefficients associated with each explanatory variable. They indicate the effect of a one-unit increase in the explanatory variable on the τ-th quantile of HHI. These coefficients may vary depending on the chosen quantile, allowing for the analysis of heterogeneous effects.

$\varepsilon\tau$: This is the error term of the regression. It captures the portion of the variability in HHI that is not explained by the explanatory variables.

RESULTS AND DISCUSSION

An Overview of Export Diversification in Algeria

Oil plays a crucial role in the Algerian economy, supporting numerous development projects since independence. However, this abundance of natural resources can hinder economic growth—a phenomenon known as the 'natural resource curse' (Mansour, 2015). The 2020 health crisis, marked by a decline in oil prices (Chellai, 2024), illustrated this impact, leading to a drop in hydrocarbon revenues.

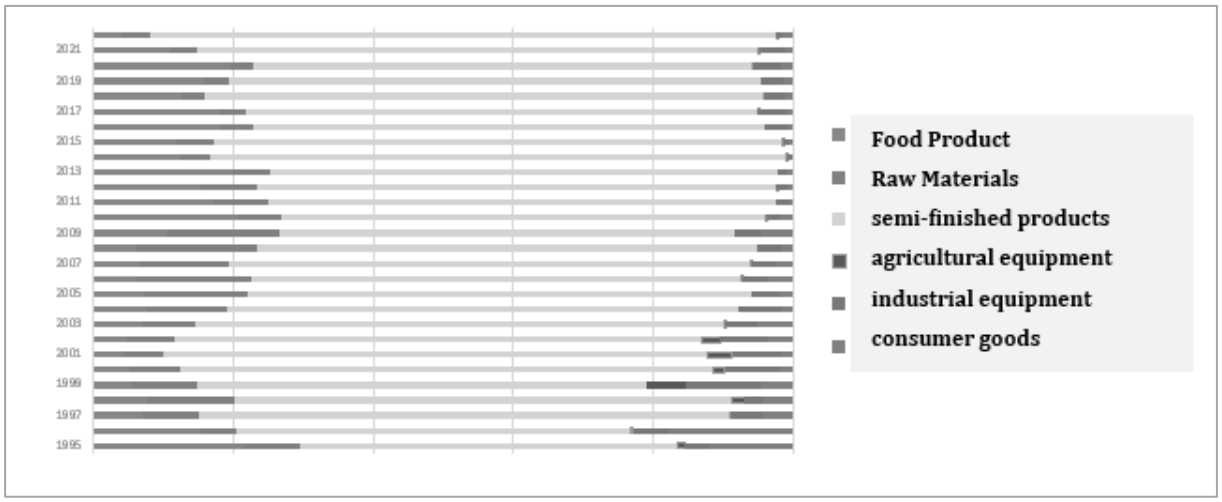


Figure 1. Evolution of the Structure of Algerian Non-Hydrocarbon Exports
Source: (UNCTAD, 2024)

In 2022, non-hydrocarbon exports accounted for only 10.40% of Algeria's total exports, which remain dominated—over 90%—by hydrocarbons. The main non-hydrocarbon export products include semi-finished goods (such as fertilizers, solvents, and ammonia) and dates. Algeria continues to rely on imports for essential goods such as wheat and barley.

Measurement Of Export Diversification

In 2022, Algerian exports reached approximately 63 billion USD (National Institute of Statistics, 2025). The analysis of exports is not limited to their value but also includes indicators such as the concentration index and the diversification index, which are essential for assessing export specialization and diversification (Canada Statistics, 2018).

Export Concentration Index

The Herfindahl-Hirschman Index (HHI) measures export concentration, which is the inverse of diversification (Cadot et al., 2011; Christophe & Nicole, 2012). Ranging between 0 and 1 (UNCTAD, 2019), it indicates a diversified export basket when HHI < 0.15, moderate concentration when 0.15 ≤ HHI ≤ 0.25, and high concentration when HHI > 0.25 (Djaha, 2021). In Algeria, the HHI is closely tied to hydrocarbon exports (see Figure 2), decreasing when these exports fall and increasing when they rise. The index reached its lowest level in 2020 (0.44), due to the drop in oil exports linked to the COVID-19 pandemic, and its highest level in 2006 (0.6), driven by a sharp rise in exports. The average value of 0.52 over the period 1995–2022 reflects.

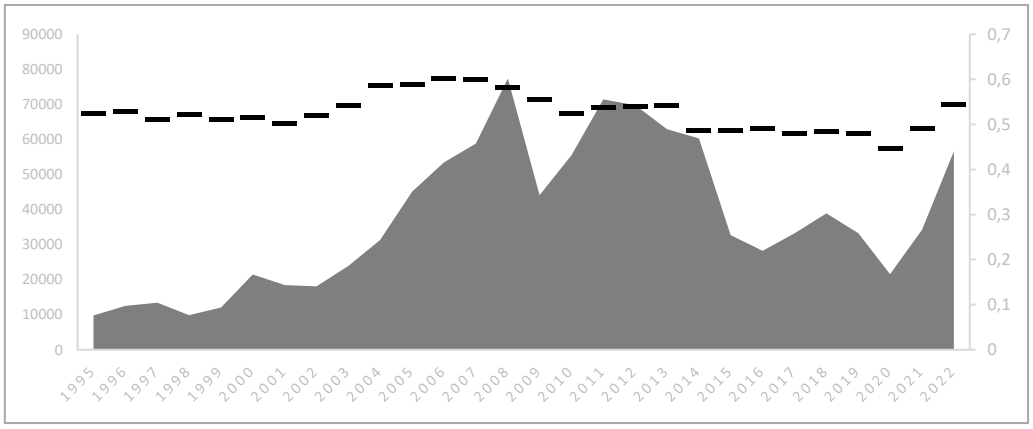


Figure 2. Evolution of the Herfindahl-Hirschman Index in Algeria

Source: (UNCTAD, 2024)

Export Diversification by Product

With 63.1 billion USD in exports in 2022, Algeria, the 55th largest exporter in the world, recorded a growth of 60.77% between 2021 and 2022, driven by the economic recovery. Its main exports include nitrogen fertilizers (2.3 billion USD), chemical products (1.6 billion USD), ferrous materials (1.61 billion USD), and cement (0.8 billion USD). However, these low-complexity products reflect a limited use of modern technologies. Since 2006, six new products have generated 18 USD per capita in 2022.

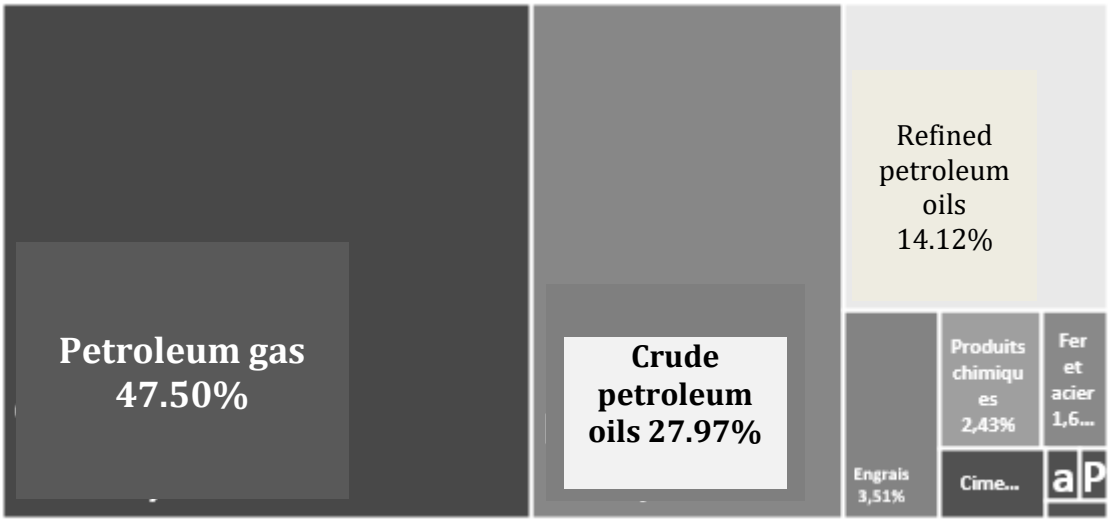


Figure 3. Algeria's Export Basket in 2022

Source: (UNCTAD, 2024)

Geographical Diversification

Algeria's foreign trade, focused on raw materials, is dominated by exports to Europe, mainly Italy, France, and Spain, due to geographical proximity and economic agreements. In 2023, 53% of Algerian exports were directed to the European Union and the OECD. Trade with Africa remains limited due to the low energy and industrial demand from these countries.

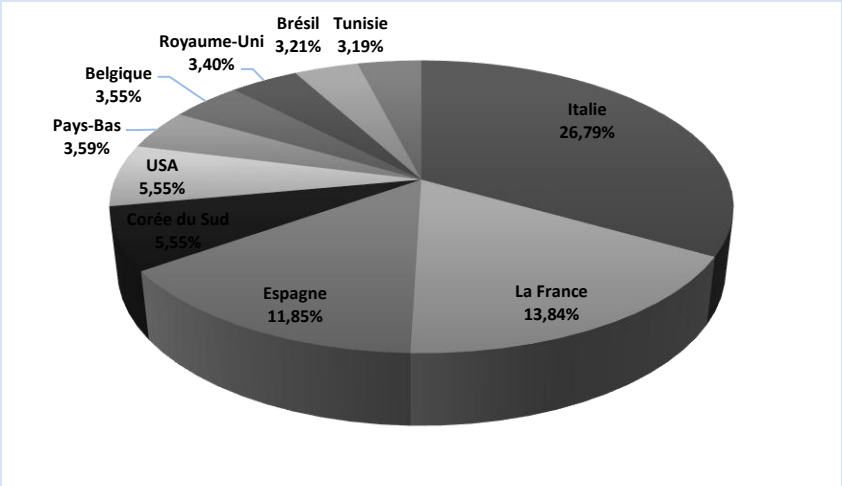


Figure 4. Main Clients of Algeria in 2023

Source: (TRADE MAP, 2024)

Empirical Results

Preliminary Analysis

In econometric traditions, we must carry out a set of preliminary tests (pre-tests) before conducting any study (Campêlo, 2023). These tests provide an in-depth analysis of the data, in other words, a visualization of the data.

Analysis of Outliers

Statisticians have developed a graphical technique called the 'box plot,' also known as the 'box-and-whisker plot' in English, which provides a clear indication of extreme values (Tukey, 1977). According to the graph below, it appears that none of the study variables exhibit extreme values, except for the variable MANU.

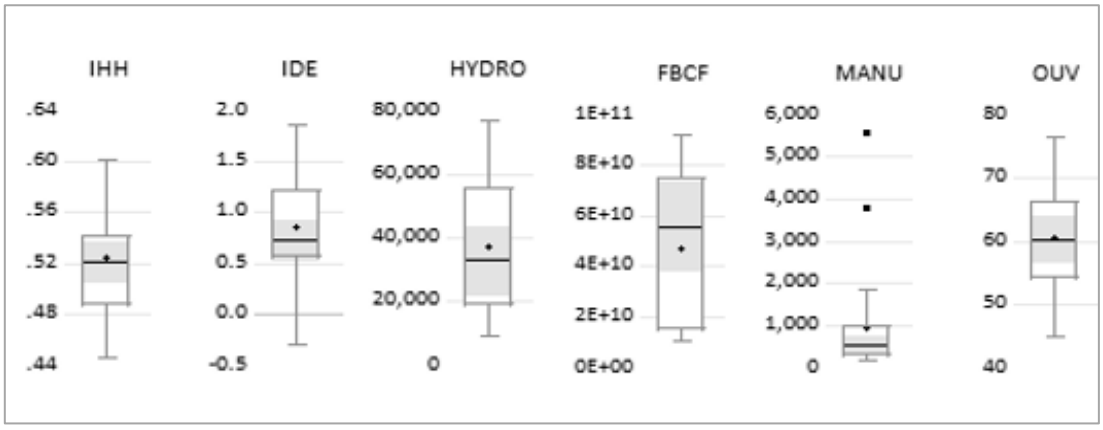


Figure 5. Box-and-Whisker Plots of the Study Variables

Source: prepared based on the output of Eviews 13

Linearity Test

The BDS test is one of the most popular linearity tests used in the context of time series (Brock, Dechert, & Scheinkman, 1996). The test yields the following results:

BDS Test for RESID
Date: 07/31/24 Time: 18:19
Sample: 1995 2022
Included observations: 28

Dimension	BDS Statistic	Std. Error	z-Statistic	Prob.
2	-0.021704	0.010555	-2.056254	0.0398
3	-0.038720	0.017272	-2.241748	0.0250
4	-0.053814	0.021183	-2.540468	0.0111

Figure 6. Results of the BDS Test

Source: prepared based on the output of Eviews 13

The results show that the residuals of the model exhibit some form of non-linear structure in the three dimensions (p-value < 0.05) at the 5% significance level. Therefore, we reject the null hypothesis of no non-linear dependence between the residuals. Given that the data contain outliers and exhibit a non-linear relationship, our choice to opt for quantile regression is therefore relevant (Rousseeuw & Leroy, 1987), and we will proceed to estimate the model parameters.

Estimation of the Model Parameters

Using EViews 13 and SPSS V26, we will estimate the impact of the explanatory variables on the three quartiles (levels) Q1 (25%), Q2 (50%), and Q3 (75%) of the conditional distribution of export diversification.

Table 1. Regression Coefficients

EXOGENOUS VARIABLES	**OLS**	**Q_1 25%**	**Q_2 50%**	**Q_3 75%**
		Low Diversification	**moderate Diversification**	**High Diversification**
C	0.407**	0.441**	0.430**	0.409**
FDI	-0.020*	-0.003**	-0.007*	−0.016*
HYDRO	-1.16**	-1.15**	−1.36**	−1.60**
GFCF	1.11***	1.19**	1.19*	1.23*
MANU	2.69**	1.07**	3.93**	4.47***
OUV	−0.002*	−0.005**	−0.002*	−0.001**
N	28	28	28	28

A statistically significant coefficient at the 5% or 1% level under a two-tailed test is indicated with (*) or (**), respectively.

Source: prepared based on the output of Eviews 13

The table above represents the coefficients and their statistical significance for the model estimated for the three quartiles (Q1, Q2, Q3). The constant is significant and almost the same across all levels of diversification. Secondly, it can be noted that the relationship between export diversification and the variable (FDI) is inverse; it is statistically significant for all quartiles of the variable of interest, and as we move towards higher quantiles (high diversification), its coefficient increases. For Algeria, the value is (-0.016). We can conclude that the lower the diversification, the greater the negative impact on FDI. It can be said that foreign investments have been focused on the hydrocarbons sector in Algeria, contributing to the country's continued reliance on this sector, which hinders the export diversification process.

Regarding petroleum exports, which measure dependence on natural resources, a negative impact is observed, meaning that as oil exports increase, the level of export diversification decreases, and the country becomes more concentrated on a specific activity. It is noted that the country becomes less diversified (Q1) when the impact of this variable is stronger (-1.15). This

result is typical of rentier economies, where dependence on natural resources, especially petroleum products, limits and hinders export diversification.

On the other hand, local investments, represented by gross fixed capital formation (GFCF) in our study, have a positive and significant impact on export diversification, meaning that the more we invest locally, the more we increase export diversification (Q3), as seen in Algeria. The impact of GFCF is larger (1.23), indicating that local investments promote export diversification.

Manufactured product exports have a positive impact on diversification, and the more diversified the country is, the larger this impact (4.47). This highlights the role of the industrial sector in combating dependence on natural resources, creating a more robust and dynamic manufacturing ecosystem, and subsequently diversifying exports and building a more diversified export structure.

Trade openness is significantly negative, and the less diversified the export basket, the greater the effect (-0.005). In other words, it has a negative impact on diversification in countries like Algeria, where the degree of concentration is high. This is due to the fact that trade liberalization can lead to greater specialization in the hydrocarbons sector rather than in the production of other new products.

Model Validation

Goodness of Fit

We observe that the pseudo R^2 determination coefficient exceeds 0.6 for all three levels of export diversification (Table 2), reflecting the good explanatory power of the model, from high export diversification (Q3) to low diversification, which is typically the case for economies characterized by monopolistic exports. In other words, 60% of the changes in export diversification are explained by the estimated model, with this percentage decreasing as diversification decreases. In other words, the greater the diversification of the export basket, the greater the impact of the explanatory variables included in the model. It can also be said that the explanatory power of the model in the case of measuring the average effect through Ordinary Least Squares (OLS) is good (R^2 = 0.82), but it does not provide a clearer picture of the effect at different levels of the response variable distribution.

Table 2. Model Quality

	OLS	**Quantile Regression**		
		$\boldsymbol{Q_{75\%}}$	$Q_{50\%}$	$Q_{25\%}$
R^2	0.820			
Pseudo R^2		0.655	0.640	0.605

Source: prepared based on the output of Eviews 13

Model Specification Issue

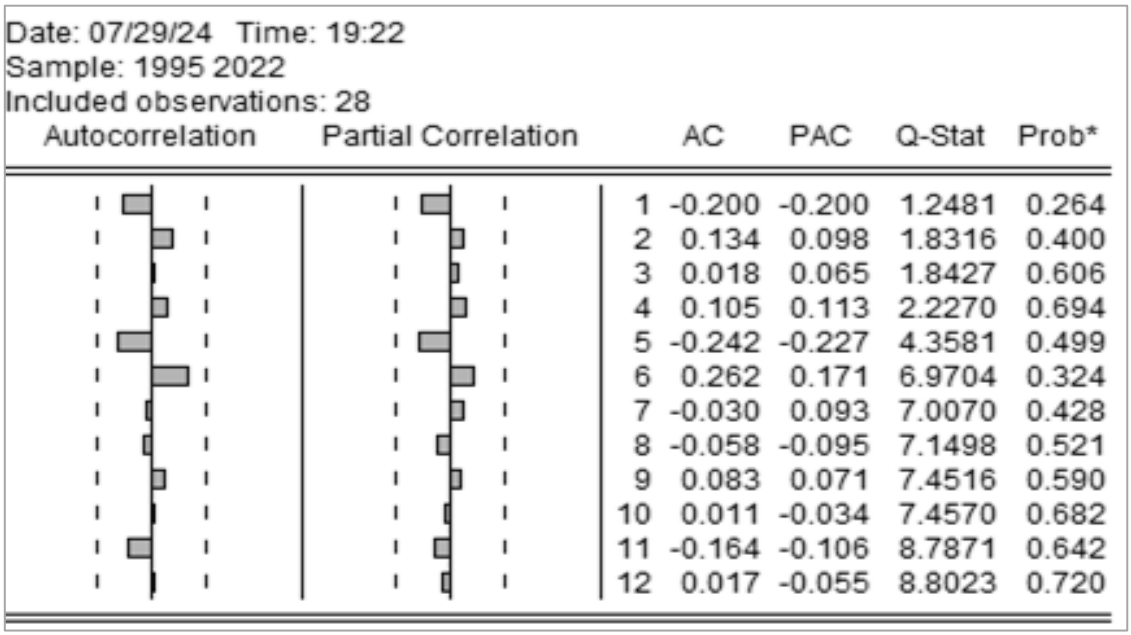
In order to ensure that the specified model is correct, we need to conduct a series of tests on the model parameters and residuals (White, 1982).

Table 3. Diagnostic Tests

Tests	**Statistic Test**	**p-value**	**H_0**
Quasi LR Test (Likelihood Ratio)	31.31	0.008	The parameters are equal to zero across the entire distribution of the variable of interest
Ramsey RESET Test	2.24	0.324	The model is correctly specified

Source: prepared based on the output of Eviews 13

The first test (Table 4) is the test of equality of parameters (Quasi LR). The p-value of the test is below the 5% significance threshold, so we reject H_0. The effect of the explanatory variables on the dependent variable changes significantly depending on the quantiles of the conditional distribution of the variable of interest. The second test concerns specification errors, particularly the functional form (Eboulet & Matei, 2013). The results of this test show that H_0 is accepted (p-value = 0.324 > 0.05), indicating that the model appears to be correctly specified (Ramsey, 1969).



	AC	PAC	Q-Stat	Prob*
1	-0.200	-0.200	1.2481	0.264
2	0.134	0.098	1.8316	0.400
3	0.018	0.065	1.8427	0.606
4	0.105	0.113	2.2270	0.694
5	-0.242	-0.227	4.3581	0.499
6	0.262	0.171	6.9704	0.324
7	-0.030	0.093	7.0070	0.428
8	-0.058	-0.095	7.1498	0.521
9	0.083	0.071	7.4516	0.590
10	0.011	-0.034	7.4570	0.682
11	-0.164	-0.106	8.7871	0.642
12	0.017	-0.055	8.8023	0.720

Figure 7. Heteroscedasticity Test

Source: prepared based on the output of Eviews 13

The heteroscedasticity test shows that the p-values for the different lags are all greater than 0.05. This means that at the 5% significance level, we accept the null hypothesis, confirming that the errors of the model are homoscedastic. Finally, the model is accepted both statistically and empirically.

DISCUSSIONS

The results of our quantile regression (QR) highlight the effects of Foreign Direct Investments (FDI), Oil Exports (HYDRO), Gross Fixed Capital Formation (GFCF), Manufactured Exports (MANU), and Trade Openness (OPEN) on export diversification in Algeria between 1995 and 2022. We observe a growing negative impact of FDI on the HHI across the distribution quantiles. It can be said that foreign investments have been concentrated in the hydrocarbons sector in Algeria, contributing to the country's continued focus on this sector, which hinders the export diversification process. These results align with those found by Arawomo et al. (2014). Oil exports, for their part, also have a negative impact, meaning that as oil exports decrease, the level of export diversification increases. This is reflected in the natural resource curse phenomenon, which paralyzes specialization in the production of other products, and these results are similar to those of Osakwe and Kilolo (2018). Gross Fixed Capital Formation has a positive impact, indicating that local investments promote export diversification (Arawomo et al., 2014). The manufacturing sector positively influences the creation of a more diversified export structure (Abiola, 2024). Trade openness has a significantly negative effect, as shown by Agosin et al. (2011). This is because trade liberalization can lead to greater specialization in the hydrocarbons sector rather than in the production of other new products. However, our results regarding trade openness

contradict those of Arawomo et al. (2014), who assert that openness guarantees diversification. This difference could be explained by the more sensitive methodology we employed. These conclusions highlight the complexity of export diversification, with links that depend on geographical and temporal realities. Our analysis suggests that national specifics must be considered to optimize their impact on the diversification of the export basket.

CONCLUSION

This study provides innovative perspectives on Algeria's foreign trade by utilizing quantile regression (QR) to assess the impacts of Foreign Direct Investments (FDI), Oil Exports (HYDRO), Gross Fixed Capital Formation (GFCF), Manufactured Exports (MANU), and Trade Openness (OPEN) on export diversification in Algeria from 1995 to 2022. The QR analysis deepens our understanding of the relationships between these variables. Our results highlight the growing sensitivity of local investments and manufactured exports across the distribution quantiles, reinforcing the importance of industrial orientation as a lever for export development. Additionally, we have confirmed that trade openness, foreign investments, and oil resources negatively impact export diversification, contrary to some findings in the existing literature. These findings contribute to advancing the academic discourse on the interrelationships of foreign trade and provide policymakers with insights to design more targeted interventions that capitalize on Algeria's comparative advantages. Our methodology and the Algerian case study offer new perspectives for research on export diversification. Future studies could involve comparing QR estimates across different countries or exploring sectoral heterogeneities.

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ORIGINAL SCIENTIFIC PAPER

Assessing Economic Takeoff and Growth in the Arab World: An Econometric Study (1990–2023)

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ABSTRACT
Economic takeoff is a critical phase in the development of emerging economies, signifying a transition towards sustained economic growth. This study assesses the relationship between economic takeoff and economic growth in 11 Arab countries from 1990 to 2023 using econometric methods. Employing panel unit root tests, the Pedroni cointegration test, and the Fully Modified Ordinary Least Squares (FMOLS) estimation technique, the study examines the long-term equilibrium relationships between investment, capital accumulation, foreign trade, and economic growth. The findings reveal that economic takeoff is characterized by overcoming structural constraints through investment and capital formation. The study confirms that investment, capital accumulation, and trade balance positively and significantly influence economic growth, highlighting the need for policies that enhance infrastructure, financial systems, regional trade integration, and human capital development to sustain long-term economic expansion in Arab economies.

Keywords: *Economic Takeoff, Economic Growth, Arab Countries, Panel Cointegration, FMOLS Estimation*

JEL Classification: O40, O47, O53, C33, C22

INTRODUCTION

The concept of economic takeoff has been extensively studied in economic literature as a crucial phase in the transition from stagnation to sustained growth. Arab economies, despite their resource wealth, have faced structural challenges that impede their ability to achieve long-term economic resilience. Economic takeoff is not solely a matter of increased output but rather an economic transformation driven by investment, capital accumulation, technological advancements, and trade expansion.

Historically, economic takeoff has been associated with key policy reforms, industrialization, and financial system improvements that create a conducive environment for sustained growth. The Arab world presents a unique case where the interplay of natural resources, governance structures, and regional economic policies plays a significant role in determining the trajectory of economic development. While some countries have leveraged oil revenues to invest in

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infrastructure and human capital, others have struggled with political instability, economic mismanagement, and insufficient diversification strategies.

A deeper understanding of the mechanisms underlying economic takeoff is essential for policymakers seeking to formulate effective development strategies. This study investigates whether Arab economies exhibit a long-run equilibrium relationship between economic takeoff and growth determinants such as investment, capital accumulation, and trade openness. By identifying these relationships, the research aims to provide empirical evidence that can inform policy measures designed to sustain economic momentum and prevent growth stagnation.

To achieve these objectives, this study employs robust econometric techniques, including panel cointegration analysis and the Fully Modified Ordinary Least Squares (FMOLS) estimation method. These techniques allow for a comprehensive examination of economic dynamics, ensuring that the findings are not only statistically significant but also relevant for long-term policymaking. Through this approach, the study contributes to the broader discourse on economic takeoff, offering insights into how Arab countries can enhance their economic structures to achieve sustainable growth.

The primary objectives of this study are as follows:

- To analyze the determinants of economic takeoff and its long-run relationship with economic growth in Arab countries.
- To assess the role of investment, capital accumulation, and foreign trade in driving economic expansion.
- To determine whether economic growth in the Arab world is constrained by structural factors or facilitated by policy-driven interventions.
- To employ advanced econometric techniques to ensure the robustness and reliability of findings, particularly in assessing stationarity, cointegration, and long-run equilibrium relationships.
- To provide policy recommendations that support sustainable economic takeoff and growth in Arab economies.

LITERATURE REVIEW OF THE IMPACT OF ECONOMIC TAKEOFF ON ECONOMIC GROWTH

The concept of economic take-off refers to the critical phase in a country's development when it transitions from stagnation to sustained economic growth. Rooted in classical development theory, this notion was first formalized by Rostow (1960), who described take-off as the stage where investment rates, industrialization, and institutional modernization converge to launch self-sustaining growth. While economic growth denotes a continuous increase in a nation's output over time, often measured by GDP per capita, economic take-off is characterized by its catalytic nature: it marks a structural transformation rather than mere quantitative expansion (Lucas, 1988; Romer, 1990). Economic growth can persist without a genuine take-off, particularly in economies driven by extractive institutions or transient commodity booms (Acemoglu & Robinson, 2006). In contrast, take-off implies a durable shift underpinned by technological innovation, human capital accumulation, and institutional reform (Barro, 1991; Levine & Renelt, 1992). This distinction is crucial in the development literature, as it underlines the role of initial conditions and policy choices in enabling countries to escape the "poverty trap" and converge toward higher-income trajectories (Hausmann, Rodrik, & Velasco, 2005; Sachs, 2005).

Against this theoretical backdrop, the empirical literature has devoted considerable attention to understanding how various structural and policy-related factors facilitate or hinder a country's economic take-off and subsequent growth. Key areas of focus include total factor productivity (TFP), foreign direct investment (FDI), institutional quality, infrastructure development, and financial sector deepening. These elements are frequently cited as catalysts that enable economies to transition from low-growth equilibria to high-growth paths. Accordingly, this literature review

draws upon influential contributions from both theoretical and empirical studies, aiming to elucidate the pathways through which these factors affect economic performance and to uncover areas where further research is needed to close persistent knowledge gaps.

To begin with, Koopman and Wacker (2023) underscore the dominant role of TFP in growth accelerations, attributing 90% of growth to productivity-enhancing reforms, while capital accumulation contributes only 9%. Their findings challenge traditional neoclassical convergence models, advocating for technological adoption and structural changes over investment-driven strategies. However, they overlook sectoral heterogeneities, especially in capital-scarce economies, necessitating further exploration of how micro-level constraints influence macroeconomic productivity.

Building on the discussion of growth determinants, debt sustainability emerges as another critical factor. Agyeman et al. (2022) demonstrate that external debt and capital flight jointly suppress growth in Sub-Saharan Africa, with their interaction exacerbating negative effects. Their dynamic GMM approach effectively isolates these impacts but does not account for institutional mechanisms such as governance reforms that could mitigate fiscal leakages. This suggests that economic takeoff strategies must integrate debt sustainability with anti-corruption measures to enhance long-term growth.

Closely related to these financial constraints is the interplay between FDI, urbanization, and energy usage. Voumik et al. (2023) identify a cointegration relationship among these variables in Australia, finding that urbanization reduces long-run energy demand. However, this finding is less applicable to developing economies, where rapid urbanization often overburdens infrastructure. Similarly, Hossain et al. (2024) highlight the negative impact of geopolitical risk (GPR) on FDI in Southeast Asia, although GDP growth somewhat counterbalances this effect. These findings emphasize the need for economic launch strategies to focus on macroeconomic stability and geopolitical risk management.

A broader perspective on FDI is provided by Banday et al. (2021), who confirm bidirectional causality between FDI and growth in BRICS nations, but their ARDL model overlooks sectoral differences. Emako et al. (2022) further illustrate that manufacturing FDI has positive growth effects in developing economies, while service FDI often crowds out domestic firms. Additionally, Saidi and Ochi (2023) identify a governance threshold for FDI to positively impact growth, yet their PTR model does not consider sectoral dynamics. These insights underscore the need for sector-specific FDI incentives and governance frameworks tailored to the institutional contexts of developing economies.

Trade policies also play a significant role in economic takeoff. Naito (2022) shows that larger economies set lower tariffs due to welfare costs, yet this endogenous growth model does not apply to developing economies where protective tariffs may still be necessary for fostering infant industries. This is echoed by Sekine (2022), who highlights a 20 trillion-yen gap between Gross Domestic Income (GDI) and GDP in Japan, advocating for independent GDI estimation. However, this focus on advanced economies marginalizes developing contexts where measurement inaccuracies can distort policy targeting.

In addition to trade and investment, infrastructure development remains a cornerstone of economic takeoff. Palei (2015) links infrastructure development to competitiveness but notes that institutional weaknesses, such as corruption, limit returns. Meka'aa et al. (2024) find that energy infrastructure investment in Cameroon positively influences growth, while telecom investment can crowd out private capital. Similarly, Traoré (2022) underscores the significance of transport infrastructure in Mali's growth trajectory, while Ismail and Mahyideen (2015) demonstrate that ports and ICT infrastructure enhance Asian trade. Furthermore, Agu et al. (2022) emphasize the predictive accuracy of Principal Component Regression (PCR) for GDP forecasting in Nigeria, advocating for machine learning as a key tool in economic takeoff diagnostics. These findings call for a more strategic approach to infrastructure investment, ensuring alignment with governance reforms and technological advancements to maximize economic impact.

Turning to financial development, Qayyum et al. (2025) reveal that financial innovation dampens long-term growth in India and China due to globalization pressures. Jie and Lan (2024) show that financial development mediates the energy-growth link in China, suggesting that economic policies should align financial sector growth with broader sustainability objectives. Ullah et al. (2024) further demonstrate that regulatory quality stabilizes financial development-growth links in developed nations but stifles growth in developing ones, indicating a need for calibrated regulatory frameworks.

Beyond financial factors, demographic and social dimensions also influence economic takeoff. Temsumrit (2023) finds that an aging population increases social spending while reducing education budgets, hindering long-term growth. Similarly, Alfalih (2024) confirms that oil price thresholds affect employment levels in Saudi Arabia, advocating for economic diversification. Khana et al. (2023) highlight that natural disasters disproportionately impact low-income countries, with FDI and infrastructure investment serving as mitigating factors. Moreover, Vishandass (2022) links inclusive growth to equity, skills, and institutions, emphasizing the importance of social policies in economic takeoff. These insights suggest that economic takeoff strategies must account for demographic transitions, fiscal sustainability, and disaster resilience.

Equally important, education and human capital remain vital drivers of sustained economic growth. Hanushek (2013) argues that cognitive skills drive economic growth more than schooling duration, calling for a shift toward education quality improvements. Grant (2017) finds that secondary education yields significant growth returns in low-income countries, reinforcing the need for targeted educational investments. Similarly, Maccelli and van Leeuwen (2025) examine Italy's skill shifts from deskilling (industrialization) to polarization (ICT), urging education-technology alignment in economic takeoff strategies. Additionally, Pakrashi and Frijters (2017) define takeoffs as sustained growth exceeding the U.S., emphasizing policy-driven structural change as a core economic launch pillar.

Entrepreneurship and innovation also play a fundamental role in economic takeoff. Acs (2006) distinguishes between opportunity entrepreneurship, which fosters innovation and growth, and necessity entrepreneurship, which often fails to drive economic takeoff. Gibson et al. (2013) advocate for community economies to support equitable growth, while Doran et al. (2018) highlight how entrepreneurial attitudes boost growth in developed economies but hinder it in developing ones due to resource constraints. Tellis et al. (2003) further show that cultural traits influence innovation adoption, suggesting that economic takeoff policies must consider cultural dimensions when designing innovation-driven strategies.

Finally, historical perspectives provide additional depth to the understanding of economic takeoff. Rostow (1956) and Smith (1960) debate the investment-sectoral-institutional trinity of economic takeoff, emphasizing the need for stage-specific policies. Ismail and Mahyideen (2015) reinforce this by linking trade infrastructure improvements to growth, while Meka'aa et al. (2024) highlight the importance of channeling investments into high-return sectors. These historical and contemporary insights continue to shape discussions on economic takeoff strategies.

In conclusion, the literature highlights the multifaceted nature of economic takeoff, with TFP, FDI, governance, infrastructure, financial development, education, and entrepreneurship all playing critical roles. While the literature provides valuable insights into the drivers of economic take-off, it often overlooks sectoral heterogeneity, institutional constraints, and the interplay between key growth factors. This paper addresses these gaps by empirically analyzing the combined effects of investment, capital accumulation, and trade balance on economic growth, offering a more integrated perspective tailored to developing economies.

METHODOLOGY

This study examines the economic takeoff process in the Arab world using a general econometric framework. It adopts a panel data approach to assess long-term trends in economic

growth and identify key drivers influencing this transition. By analyzing data over multiple decades, the study seeks to capture both cyclical and structural patterns that shape economic performance in the region.

The research is based on a broad sample of Arab economies, ensuring that findings are representative of diverse economic structures. The study considers various macroeconomic indicators, including investment, capital accumulation, and trade performance, to evaluate their role in supporting economic takeoff. The data is sourced from credible international databases to ensure accuracy and consistency.

To examine the relationship between economic takeoff and growth, the study applies widely used econometric techniques. Specifically, it utilizes panel data methods, cointegration analysis, and regression techniques to explore long-run relationships between economic variables. The methodology incorporates unit root tests to assess stationarity and cointegration tests to determine whether long-term equilibrium relationships exist among the variables. The Fully Modified Ordinary Least Squares (FMOLS) method is employed to obtain reliable coefficient estimates while addressing potential endogeneity concerns. FMOLS is preferred over other panel estimators such as Dynamic Ordinary Least Squares (DOLS) or Generalized Method of Moments (GMM) because it corrects for serial correlation and endogeneity in cointegrated panels without requiring additional instrumental variables or dynamic specifications, making it especially suitable for studies focused on long-run equilibrium relationships in heterogeneous panels.

In conducting the analysis, emphasis is placed on ensuring methodological rigor. The study employs appropriate statistical techniques to validate findings and ensure robustness. Sensitivity tests and model validation techniques are used to confirm the reliability of the results. By adopting a structured and systematic approach, the research aims to contribute to policy discussions on economic development and offer insights into strategies for fostering sustainable growth in Arab economies.

While this section provides an overview of the study's methodological framework, detailed econometric modeling and statistical results are presented in the subsequent econometric study section. This ensures a focused discussion on both the theoretical foundation and empirical validation of the findings, enhancing the clarity and applicability of the research outcomes.

Methodology and Tools

This study examines the effect of key economic takeoff requirements on economic growth in Arab countries using econometric methods, particularly dynamic panel models. The analysis employs both the Pedroni residual cointegration test and the Johansen-Fisher panel cointegration rank test to identify and validate long-run equilibrium relationships among the study variables. While the Pedroni test confirms cointegration across dimensions, the Johansen-Fisher test additionally determines the number of cointegrating vectors, which supports the presence of a single long-run relationship.

Sample, Period, and Data Sources

The study utilizes a sample of 11 Arab countries from North Africa (Algeria, Egypt, Tunisia, Morocco, Mauritania) and Asia (Saudi Arabia, United Arab Emirates, Bahrain, Kuwait, Oman, Jordan, Lebanon). The analysis covers the period from 1990 to 2023, selected based on data availability for all sampled countries. All data were obtained from the World Bank.

Study Model

This study considers economic growth as the dependent variable, while the independent variables include investment, the financial system, and foreign trade:

$LY = F(LX_1, LX_2, LX_3)$

Where:
- (LY): The Logarithm of economic growth, represented by Gross Domestic Product (GDP)
- **(**LX_1**)**: The logarithm of investment, the first independent variable, is a key determinant of economic growth. Empirical evidence suggests that investment has been the primary driver of growth in emerging economies over the past decades (Mankiw & Romer, 1992). This aligns with Young's (1995) study on East Asian economies, which emphasizes capital accumulation as a fundamental mechanism in the catch-up theory of economic development.
- **(**LX_2): The financial system, represented by the logarithm of capital accumulation, serves as a fundamental driver of investment projects designed to enhance productive capacity. The effectiveness of financial policies plays a crucial role in shaping capital accumulation, either facilitating or constraining investment dynamics (Bouharb & Belkharchouche, 2021).
- (LX_3): Foreign trade, measured by the logarithm of the trade balance, plays a pivotal role in economic growth by facilitating access to technological advancements from developed countries. This occurs through the importation of capital goods and exposure to innovative products in global markets, fostering productivity and competitiveness (Berthélemy & Söderling, 1999).

Accordingly, the model can be summarized as follows:

Log(GDP)=f(Log(investment), Log (capital accumulation), Log (trade balance))

Where:
- **Log GDP**: Natural logarithm of real GDP (economic growth proxy);
- **Log investment**: Natural logarithm of gross capital formation;
- **Log capital accumulation**: Natural logarithm of capital stock (proxy for the financial system);
- **Log trade Balance**: Natural logarithm of net exports (foreign trade).

Unit Root Tests

Before estimating the dynamic panel model, it is essential to verify the stationarity properties of the variables involved. This ensures that spurious regression results are avoided and that the underlying time series are suitable for cointegration analysis. To this end, various panel unit root tests are available. In this study, the Levin, Lin & Chu (LLC, 2002) test, the Breitung test (2002), the Im, Pesaran & Shin (IPS, 2003) test, along with the Fisher-type tests based on ADF and PP statistics, are employed. These tests are among the most widely accepted methods for evaluating stationarity in panel datasets and provide robust and consistent results.

Following confirmation of the integration order, the Pedroni residual cointegration test is applied to assess the presence of a long-run equilibrium relationship among the variables. In addition, the Johansen-Fisher panel cointegration rank test is used to determine the number of cointegrating vectors, offering deeper insight into the nature and dimensionality of the long-term associations.

Finally, to capture short-run dynamics and the speed of adjustment toward long-run equilibrium, the study estimates a Vector Error Correction Model (VECM) based on the Fully Modified Ordinary Least Squares (FMOLS) method. This FMOLS-VECM framework integrates both long-run relationships and short-run fluctuations, thereby providing a comprehensive picture of the underlying economic processes.

Pedroni Residual Cointegration Test

Similar to unit root tests, panel cointegration tests offer more reliable results than individual tests. Building on the Engle-Granger (EG) individual cointegration framework, Pedroni developed a comprehensive panel cointegration test based on estimated residuals. Pedroni's methodology derives seven test statistics, categorized into two groups: the first group assumes common autoregressive parameters ("within-dimension"), while the second allows for individual autoregressive parameters ("between-dimension") (Mitić, Munitlak Ivanović, & Zdravković, 2017). This approach enhances the robustness of cointegration analysis in panel data settings.

The following equation serves as the foundation for Pedroni's panel cointegration test:

$$y_{i,t} = \beta_i' x_{i,t} + \alpha_i + \delta_{i,t} + \varepsilon_{i,t} \quad (1)$$

where:
- $y_{i,t}$: Dependent variable for country ***i*** at time ***t.***
- $\boldsymbol{\alpha_i}$: Country-specific fixed effect.
- $\boldsymbol{\delta^*_{i,t}}$: Time trend for country i.
- $\boldsymbol{\beta_i}$: Long-run elasticity coefficient.
- $\boldsymbol{x_{it}}$: Vector of explanatory variables.
- $\boldsymbol{\varepsilon_{it}}$: Cointegration residual.
- $x_{i,t}$The independent variable, or more generally, the array of independent variables, plays a crucial role in determining the model's explanatory power and robustness:
- $x_{i,t} = x_{i,t-1} + \varepsilon_{i,t}$ (Carlsson, Lyhagen, & Österholm, 2007, p. 8).

Consistent with the EG procedure, the cointegration test relies on auxiliary regressions of residuals derived from Equation (1). The test specification depends on parameter assumptions, with two distinct test types: a semi-parametric test represented by Equation (2) and a parametric test represented by Equation (3):

$$\hat{\varepsilon}_{i,t} = \rho_i \hat{\varepsilon}_{i,t-1} + \mu_{i,t} \quad (2)$$

where:
- $\boldsymbol{\hat{\varepsilon}_{i,t}}$**:** Error term from cointegration regression.
- $\boldsymbol{\rho_i}$**:** Autoregressive parameter for country i.
- $\boldsymbol{\hat{\varepsilon}_{i,t-1}}$: Lagged residual term.
- $\mu_{i,t}$**:** White noise error.

$$\hat{\varepsilon}_{i,t} = \rho_i \hat{\varepsilon}_{i,t-1} + \sum \emptyset_{ip}\, \rho_i \Delta\hat{\varepsilon}_{i,t-p} + \mu^*_{i,t} \quad (3)$$

where:
- $\hat{\varepsilon}_{i,t}$: Residual from the cointegration regression for unit **i** at time **t**.
- ρ_i: Autoregressive coefficient indicating persistence of the residual.
- $\hat{\varepsilon}_{i,t-1}$: One-period lag of the residual term.
- $\sum \emptyset_{ip}\, \rho_i \Delta\hat{\varepsilon}_{i,t-p}$**:** Summation over **p** lags of the first-differenced residuals, capturing short-run dynamics.
- $\emptyset_{ip}$: Coefficients associated with each lag **p**.
- $\Delta\hat{\varepsilon}_{i,t-p}$: First difference of the residual lagged by **p** periods: **(**$\hat{\varepsilon}_{i,t}, \rho\hat{\varepsilon}_{i,t-1}$**).**
- $\mu^*_{i,t}$: White noise disturbance term.
- p: Lag order of the augmentation.

The cointegration test statistics are as follows:

Panel v-Statistic $Z_{\hat{V}NT} = \left(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1}$

Panel rho-Statistic $Z_{\hat{\rho}NT-1} = \left(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{\varepsilon}_{i,t-1}^{2}\Delta\hat{\varepsilon}_{i,t-1}^{2} - \hat{\lambda}_i$

Panel PP-Statistic (semi-parametric)

$$Z_{tNT-1} = \left(\tilde{\sigma}_{NT}^{2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\left(\hat{\varepsilon}_{i,t-1}^{2}\Delta\hat{\varepsilon}_{i,t-1}^{2} - \hat{\lambda}_i\right)$$

Panel ADF-Statistic (parametric)

$Z_{tNT}^{*} = \left(\tilde{\sigma}_{NT}^{*2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^{2}\Delta\hat{\varepsilon}_{i,t-1}^{2}$

Group rho-Statistic $\tilde{Z}_{\hat{\rho}NT-1} = \sum_{i=1}^{N}\left[\left(\sum_{t=1}^{T}\hat{\varepsilon}_{i,t-1}^{2}\right)\sum_{t=1}^{T}\left(\hat{\varepsilon}_{i,t-1}^{2}\Delta\hat{\varepsilon}_{i,t-1}^{2} - \hat{\lambda}_i\right)\right]$

Group PP-Statistic (semi-parametric) $\tilde{Z}_{tNT} = \sum_{i=1}^{N}\left[\left(\tilde{\sigma}_i^{2}\sum_{t=1}^{T}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1/2}\sum_{t=1}^{T}\left(\hat{\varepsilon}_{i,t-1}^{2}\Delta\hat{\varepsilon}_{i,t-1}^{2} - \hat{\lambda}_i\right)\right]$

Group ADF-Statistic (parametric) $Z_{tNT}^{*} = \sum_{i=1}^{N}\left[\left(\tilde{\sigma}_i^{*2}\sum_{t=1}^{T}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1/2}\sum_{t=1}^{T}\left(\hat{\varepsilon}_{i,t-1}^{2}\Delta\hat{\varepsilon}_{i,t-1}^{2}\right)\right]$

Ultimately, all Pedroni test statistics converge to a normal distribution, allowing the use of the following hypothesis (Mitic et al, 2017):

Common autoregressive parameter (within-dimension) $\begin{cases} H_0: \rho_i = 1 \\ H_1: \rho_i = \rho < 1 \end{cases}$

Individual autoregressive parameter (between-dimension) $\begin{cases} H_0: \rho_i = 1 \\ H_1: \rho_i = \rho_i < 1 \end{cases}$

Presenting the FMOLS Estimation Method

To estimate this model, the FMOLS (Fully Modified Ordinary Least Squares) method is employed. Originally introduced and developed by Phillips and Hansen (1990), this method is designed to estimate a first-degree cointegration relationship among variable series (I(1)). The FMOLS approach ensures more reliable estimates, particularly in small sample sizes (Bashier & Jaser Siam, 2014).

The method was later reformulated by Pedroni (2000). It relies on the asymptotic properties of adjusted-FM residuals, focusing on data integration through the within-dimension. For data integration based on the between-dimension, the Group-FM estimator is applied.

The FMOLS (Fully Modified Ordinary Least Squares) estimation method provides consistent parameter estimates that asymptotically follow a standard normal distribution, enhancing its robustness. This approach is particularly effective in addressing endogeneity in explanatory variables, serial correlation in errors, and potential heteroskedasticity in long-run parameters.

Additionally, FMOLS delivers unbiased estimators with minimal variance (Laacab, 2015).

The estimator can be expressed as follows:

$$\hat{\beta}_{NT} = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \left(x_{i,t} - \bar{x}_i \right)^2 \right)^{-1} \sum_{i=1}^{N} \left(x_{i,t} - \bar{x}_i \right) \left(y_{i,t} - \bar{y}_i \right)$$

The FMOLS estimator is presented as a modified version of the OLS estimator as follows:

$$\hat{\beta}_{FM} = \left(\sum_{i=1}^{N} \hat{L}_{22i}^{-1} \sum_{t=1}^{T} \left(x_{i,t} - \bar{x}_i \right)^2 \right)^{-1} \sum_{i=1}^{N} \hat{L}_{11i}^{-1} \hat{L}_{22i}^{-1} \sum_{t=1}^{T} \left(x_{i,t} - \bar{x}_i \right) y_{i,t}^{*} - T\hat{\delta}_i$$

Where: $y_{i,t}^{*} = \left(y_{i,t} - \bar{y}_i \right) - \left(\frac{\hat{L}_{21i}}{\hat{L}_{22i}} \right) \Delta x_{i,t} + \left(\frac{\hat{L}_{21i} - \hat{L}_{22i}}{\hat{L}_{22i}} \right) \beta \left(x_{i,t} - \bar{x}_i \right)$

$\hat{\delta}_i \equiv \hat{\Gamma}_{21i} + \hat{\Omega}_{21i}^{0} - \left(\frac{\hat{L}_{21i}}{\hat{L}_{22i}} \right) \left(\hat{\Gamma}_{21i} + \hat{\Omega}_{21i}^{0} \right)$

Where:

- $\boldsymbol{\hat{\beta}_{FM}}$: Fully Modified OLS estimator of the long-run coefficient vector.
- $\boldsymbol{x_{it}^{*}}$**:** Transformed regressor for unit i at time t, corrected for serial correlation and endogeneity.
- $\boldsymbol{x_{it}^{*}}'$: Transpose of the transformed regressor.
- $\boldsymbol{y_{it}^{*}}$**:** Transformed dependent variable (e.g., GDP), also corrected for serial correlation.
- $\sum_{\boldsymbol{i}} \sum_{\boldsymbol{t}}$: Double summation over countries (i = 1 to N) and time (t = 1 to T).
- $[\ ]^{-1}$: Matrix inverse.

The FMOLS estimator for panel data is obtained by estimating the following regression (Mitić, Munitlak Ivanović, & Zdravković, 2017):

$$y_{i,t} = \beta_i' x_{i,t} + \sum_{j=-q}^{q} \varepsilon_{ij} \Delta x_{i,t+j} + \gamma_{li}' D_{li} + \varepsilon_{i,t}$$

Where:

- $\boldsymbol{y_{it}}$**:** Dependent variable for unit i at time t (e.g., log of GDP).
- $\boldsymbol{x_{it}}$: Independent variable(s) (e.g., investment, capital accumulation, trade balance).
- $\boldsymbol{\beta}$: Long-run slope coefficient.
- $\sum_{\boldsymbol{j=-q}}^{\boldsymbol{q}} \boldsymbol{\varepsilon_{ij}} \Delta \boldsymbol{x_{i,t+j}}$**:** This summation includes the leads and lags of the first differences of the independent variables x.
- $\Delta x_{i,t+j}$: denotes the first difference of x at time t+j.
- $\boldsymbol{\varepsilon_{it}}$: Residual term (cointegration error).
- $\boldsymbol{\gamma_{li}'}$**:** Coefficients corresponding to the deterministic terms D_{li}
- D_{li} : Vector of deterministic terms or time dummy variables for unit i.

RESULTS AND DISCUSSION

This section presents the empirical results. It begins with unit root tests to verify stationarity, followed by cointegration analysis using Pedroni and Johansen-Fisher tests. The long-run relationships are estimated using FMOLS, and short-run dynamics are captured through an FMOLS-based VECM model.

Panel Unit Root Tests

This part presents the results of five-panel unit root tests (LLC, Breitung, IPS, Fisher-ADF, and Fisher-PP), as shown in Table 2. The results indicate that all variables become stationary after first differencing, confirming they are integrated of order one, I(1).

Table 1. Results of Breitung, IPS, ADF-Fisher, PP-Fisher, and LLC tests for variables' stationarity

	LLC	Breitung	IPS	ADF-fisher	PP- fisher
LY	LEVEL				
	-5. 3820	1.9597	-2.8778	79.6548	15.6474
	(0.000)***	(0.9685)	(0.0057)***	(0.000)***	(0.8633)
	1st Difference				
	-0.9784	-3.5065	-3.3387	52.2820	95.8912
	(0.1639)	(0.000)***	(0.0004)***	(0.000)***	(0.000)***
LX1	LEVEL				
	2.3141	0.8948	1.0173	17.7080	40.2928
	(0.9897)	(0.8146)	(0.8455)	(0.8169)	(0.0199)**
	1st Difference				
	-0.48072	-2.1042	-3.9766	58.0598	378.171
	(0.3154)	(0.0177)**	(0.0000)***	(0.000)***	(0.000)***
LX2	LEVEL				
	1.2271	1.4412	-0.0789	28.0775	279.696
	(0.8901)	(0.9253)	(0.4686)	(0.2568)	(0.000)***
	1st Difference				
	-3.7666	-2.1800	-5.2082	70.2178	366.538
	(0.00)***	(0.0146)**	(0.000)***	(0.000)***	(0.00)***
LX3	LEVEL				
	1.8994	1.2602	-0.07807	27.0806	27.4451
	(0.9712)	(0.8962)	(0.4689)	(0.3007)	(0.2841)
	1st Difference				
	-3.1305	0.3840	-4.1304	62.0237	207.797
	(0.000)***	(0.6495)	(0.0000)***	(0.000)***	(0.00)***

Values in parentheses (***) (**) are statistically significant at the 1% and 5% levels, respectively.
Source: Computed by the authors using EViews 12 software outputs.

The table above presents the results of various panel unit root tests (Breitung, LLC, IPS, ADF-Fisher, PP-Fisher) applied at the level and first difference. At level, the p-values for most tests across all variables (LY, LX1, LX2, LX3) exceed the 0.05 threshold, indicating failure to reject the null hypothesis of a unit root. Therefore, the variables appear to be non-stationary in level. However, when the tests are applied to the first differences, the p-values are consistently below 0.05 for nearly all test statistics, except for a few cases, such as the Breitung test for LY and LX3. These results provide strong evidence against the null hypothesis, confirming that the series become stationary after first differencing. Hence, the variables are integrated of order one, (1).

Cointegration Rank Determination: Johansen-Fisher Panel Test

Table 2. Generalized Results of Johansen-Fisher Panel Cointegration Rank Test

Hypothesized No. of CE(s)	Fisher Stat (Trace)	Prob.	Fisher Stat (Max-Eigen)	Prob.
None	61.85	0.000	39.21	0.000
At most 1	46.17	0.024	25.80	0.043
At most 2	13.02	0.326	9.83	0.447
At most 3	5.77	0.680	5.77	0.680

Source: Computed by the authors using EViews 12 software outputs.

The Johansen-Fisher panel cointegration test results reveal statistically significant evidence of cointegration. Specifically, the null hypothesis of no cointegrating relationship (rank = 0) is rejected at the 1% significance level, while the null of at most one cointegrating vector (rank ≤ 1) is rejected at the 5% level, but not at the 1% level. Although the hypotheses of at most two cointegrating relationships cannot be rejected, given the theoretical findings from the previous literature, we opt for a single normalized cointegrating vector between growth, investment, capital accumulation, and trade balance.

Panel Cointegration Analysis

The Pedroni and Johansen-Fisher tests confirm the presence of a stable long-run relationship among the variables.

Table 3. Results of Pedroni Residual Cointegration Test

Prob	Statistic	
Cointegrating regression parameter (within-dimension)		
(0.0000)***	Panel v-Statistic	11.0317
(0.7817)	Panel rho-Statistic	0.7778
(0.0070)***	Panel PP-Statistic	-2.4553
(0.0007)***	Panel ADF-Statistic	-3.1876
Individual autoregressive parameter (between-dimension)		
(0.9730)	up rho-Statistic	9262
(0.0387)**	up PP-Statistic	.7662
(0.0008)***	up ADF-Statistic	.1740

Values in parentheses (**) (*) are statistically significant at the 1% and 5% levels, respectively.
Source: Computed by the authors using EViews 12 software outputs.

After confirming that the variables are stationary at first difference and thus integrated of order one, the next step is to investigate the presence of a long-run equilibrium relationship among them using the Pedroni cointegration test. As shown in Table 3, most of the reported p-values are less than 0.05, particularly for the Panel PP-Statistic, Panel ADF-Statistic, Group PP-Statistic, and Group ADF-Statistic, indicating statistical significance at conventional levels. These results lead to the rejection of the null hypothesis of no cointegration for several dimensions of the test. Although the Panel v-Statistic and Group rho-Statistic yield p-values above 0.05, the overall evidence from the majority of tests supports the existence of a long-run cointegrating relationship among the study variables. Accordingly, these findings justify the use of a Vector Error Correction Model (VECM) in the subsequent analysis.

Following the confirmation of cointegration between economic growth and its key determinants, investment (LX1), capital accumulation (LX2), and trade balance (LX3), the final step involves estimating the long-run equation of the model. The results reveal a high coefficient of determination (R^2=0.97R 2 =0.97), indicating that the independent variables jointly explain 97% of the variation in economic growth (LY). This high level of goodness-of-fit reflects the strong explanatory capacity of the model.

Long-Run Estimation Using FMOLS

The normalized long-run coefficients, estimated using the FMOLS method and presented in Table 4, show that investment, capital accumulation, and trade balance have significant and positive impacts on economic growth.

Table 4. Normalized Co-integrating Vector Estimates from FMOLS Regression

Variable	Coefficient	Std. Error	t-Statistic	Significance Level
Log(Investment)	0.02199	0.00421	5.22	*** (1%)
Log(Capital Accumulation)	0.0963	0.01075	8.96	*** (1%)
Log(Trade Balance)	0.6234	0.0921	6.77	*** (1%)
Constant	0.378	0.1103	3.43	** (5%)

Source: Computed by the authors using EViews 12 software outputs.

All coefficients are statistically significant and exhibit the expected positive signs, confirming a stable long-run equilibrium relationship.

The normalized coefficients further validate the theoretical expectations, emphasizing the significant contribution of investment, capital accumulation, and trade balance to economic growth in the long run.

Short-Run Dynamics and Error Correction: FMOLS-VECM Estimation

To complement the long-run results, Table 05 presents the FMOLS-VECM estimates, capturing short-run effects and the adjustment speed toward equilibrium. The error correction term (ECT_{t-1}) reflects how quickly deviations from the long-run path are corrected.

Table 5. FMOLS-VECM Estimates: Short-Run Dynamics and Error Correction Term (1990–2023)

Variable	Coefficient	Std. Error	t-Statistic	Significance
Δ Log (Investment)	0.0087	0.0029	3.00	** (5%)
Δ Log (Capital Accumulation)	0.0154	0.0053	2.91	** (5%)
Δ Log (Trade Balance)	0.1126	0.0398	2.83	** (5%)
Error Correction Term (ECT_{t-1})	-0.3672	0.0881	-4.17	*** (1%)

Source: Computed by the authors using EViews 12 software outputs.

The results presented in Table 5 provide insights into the short-run dynamics of the model and the adjustment process toward the long-run equilibrium. All differenced explanatory variables (investment, capital accumulation, and trade balance) exhibit positive and statistically significant effects on short-run economic growth.

Notably, the coefficient of the error correction term (ECT_{t-1}) is negative (−0.3672) and significant at the 1% level. This confirms the presence of a stable long-run relationship and indicates that approximately 36.7% of any disequilibrium from the previous period is corrected in the current period.

These results reinforce the findings from the Pedroni and Johansen tests and justify the use of a cointegration framework. They also highlight that, in addition to long-run determinants, short-run adjustments play an important role in the dynamic behavior of GDP in Arab economies.

Overall, the results confirm that investment, capital accumulation, and trade balance play a significant and consistent role in explaining economic growth in the Arab region. The long-run estimates align with theoretical expectations, while the short-run dynamics further validate the stability of the model through a significant error correction mechanism. These findings highlight the importance of both sustained capital formation and external trade performance in fostering macroeconomic resilience.

CONCLUSIONS

Economic takeoff remains a crucial focus for researchers and policymakers, particularly in the context of Arab countries striving for sustainable development and long-term economic resilience. This transition is not merely an economic shift but a multidimensional process requiring coordinated efforts across governments, the private sector, and civil society. Sustained economic growth in the Arab world depends on an enabling environment that supports investment, innovation, infrastructure development, and human capital formation.

This study examined the economic takeoff in 11 Arab countries using the Fully Modified Ordinary Least Squares (FMOLS) methodology over the period 1990–2023. Panel unit root tests confirmed that the variables were non-stationary at level but became stationary after first differencing, and the Pedroni cointegration test established the existence of long-run equilibrium relationships. The results revealed statistically significant positive effects of investment, capital accumulation, and trade balance on economic growth, validating their role as key drivers of structural transformation in the region.

By integrating these core variables within a unified empirical framework and applying them to the underexplored context of Arab economies, this study offers a novel contribution to the literature on economic takeoff. Unlike prior research that tends to isolate growth determinants or focus on global samples, this paper provides region-specific insights grounded in long-run dynamics. Future research may enhance this model by incorporating variables related to governance, institutional quality, and environmental sustainability, or by exploring country-level heterogeneities and threshold effects that shape the trajectory of economic development.

Based on these findings, the following policy recommendations are proposed to support economic takeoff and long-term stability in Arab economies:

- Strengthen Infrastructure Development & Investment in Key Sectors: Focus on large-scale projects in renewable energy, transportation, and digital infrastructure to enhance productivity and attract investment.
- Diversify Economic Activity & Encourage Private Sector Growth: Broaden the economic base beyond oil by promoting investment in agriculture, industry, and services to build resilience and generate employment.
- Develop Financial Systems & Improve Financial Literacy: Expand access to finance and implement financial literacy programs to empower households and SMEs, enabling capital formation and innovation.
- Enhance Regional Trade Integration: Promote intra-Arab trade by reducing barriers, harmonizing policies, and investing in trade facilitation.
- Invest in Human Capital & Education: Align educational systems and vocational training with labor market demands to boost productivity and innovation-driven growth.

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ORIGINAL SCIENTIFIC PAPER

Empowering Sustainable Growth Through Emerging Technologies in Serbia and North Macedonia

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ABSTRACT
This study explores the perceived economic, social, and environmental impacts of emerging technologies (including artificial intelligence, IoT, and big data) on sustainable growth in Serbia and North Macedonia. Drawing on survey responses from participants across professional sectors, the analysis employs descriptive statistics, Mann–Whitney U, and Kruskal–Wallis H tests to assess motivational factors, barriers to adoption, and sectoral differences. Findings indicate that innovation an competitiveness are dominant motivators, especially in North Macedonia, while high costs, skill shortages, and limited awareness remain key barriers. Economic benefits such as cost savings and operational efficiency are widely recognized, though environmental outcomes, particularly renewable energy adoption, are less developed. Sectoral comparisons reveal that business organizations lead in benefit realization, whereas government entities lag behind. The study highlights the need for context-specific policies and inclusive digital strategies to ensure that the adoption of emerging technologies supports long-term, sustainable development across varying institutional and sectoral environments.

Keywords: *emerging technologies, digital transformation, dustainable development, Innovation, Serbia, North Macedonia, technology adoption, environmental sustainability*

JEL Classification: O33, O38, O57, Q01

INTRODUCTION

In the era of fast-moving technological advances, enormous opportunities are opened for both economic and sustainable development. The growing uptake of emerging technologies, including 5G, the Internet of Things (IoT), artificial intelligence (AI), and data analytics, is revolutionizing industries, improving resource use, and enabling enhanced sustainability efforts. Businesses are increasingly accepting them as important in making efficient environmental changes: enterprises all over the world apply them to decrease their carbon emissions and put greener business practices into action. As found by a survey conducted by Ernst & Young, 76% of polled enterprises claimed that emerging technologies played a vital role in cutting their organization's carbon emissions, representing a significant move toward the integration of digital tools in corporate sustainability strategies (Baschnonga, 2023). Companies investing in 5G, IoT, and AI are already enjoying several benefits, such as “greater operational efficiency, improvement measurement capabilities, and the adoption of virtualized products and processes” (Baschnonga, 2023). Additionally, these technologies could enable companies to manage energy use and waste more

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efficiently. According to the same survey, the polled enterprises consider reduced energy use to be the highest benefit from the deployment of digital technologies, followed by improved measurement and planning, as well as waste reduction in production. Digital tools are progressively taking center stage in corporate sustainability programs that have accelerated with the push toward virtual services and digital workforce solutions (Baschnonga, 2023). This is a trend that reflects digitalization as evolving from an efficiency tool to a critical part of environmental responsibility.

However, enterprises remain acutely aware of the risks and trade-offs posed by digital transformation. Of the businesses surveyed, 54% believe that emerging technological innovations can aid the growth of their sustainability agenda. Whereas another 41% regard such innovations as being largely positive but recognize them with some potential risks (Baschnonga, 2023). With a sense of caution, these sentiments broadly align with other research indicating that the information and communication technology (ICT) sector alone is responsible for anywhere between 1.8% and 2.8% of total global greenhouse gas emissions, plus a huge consumption of electricity (Baschnonga, 2023). Thus, digitalization does hold effective solutions; however, they should also pick up measures to reduce such impacts on the environment as well. By embedding emerging technologies into sustainability programs, companies can better measure and manage emissions, optimize resources in their processes, and be more circular and efficient in their operations.

This will be very much needed to make Serbia and North Macedonia change paradigms, where balancing economic growth against ecological responsibility remains a big task. Governments, the business community, and higher education institutions need to come together to demonstrate that digital transformation may not be mutually exclusive to long-term sustainability goals, but rather a conduit for technology-driven innovation that 1) generates an inclusive, 2) green, and 3) resilient economic development.

This paper looks at the relationship between the adoption of emerging technologies and sustainable economic growth in Serbia and North Macedonia. By analyzing industry trends and potential impacts, this study provides insights into how these economies can leverage technological advances in achieving sustainable and innovation-led growth.

THEORETICAL FRAMEWORK

For a long time, economic growth theories have recognized the role that technology has in driving productivity and economic growth. Neoclassical growth models, for example, suggest that technological progress enhances productivity and provides for long-term economic growth (Solow, 1956). Similarly, endogenous growth models, such as those by Romer (1990) and Lucas (1988), see human capital investment, innovation in technology, and knowledge accumulation as the basic forces underlying sustained economic growth. In this context, technological improvements, particularly in information and communication technology (ICT), serve as the means to promote efficiency gains and thus economic growth.

Over the past six decades, the world economy has witnessed a shift from the traditional labor-intensive production phase to the capital-intensive and ICT-driven phase. From the rise of modern computing in the 1990s, through the advent of the Internet, to the recent surge in the popularity of artificial intelligence (AI), the way goods are produced and companies operate has continuously evolved (Gonzales, 2023). Zeira (1998) elaborated an economic growth model that specifically addresses technological innovations that require reduced labor input but, at the same time, higher capital investment. This transition goes in line with empirical findings indicating that digitalization and emerging technologies inject economies of scale into their operations that reduce costs and raise efficiency (Nightingale, 2000; Wang et al., 2011; Nchake & Shuaibu, 2022).

Endogenous growth models are at the heart of the technology and economic growth literature. Arrow (1962) assumes that technical change, a product of knowledge and experience, gets

embodied in new physical capital. It enters the production process, resulting in increased productive efficiency. The lines of thought in the technology and growth literature follow suit by assuming that technological change creates an increase in capital productivity. In the Schumpeterian tradition, Zeira (1998) presents a theoretical framework that has intermediate goods in production. The intensity of capital is increased with technology adoption, thus labor is substituted in the production process. Thereafter, technology is adopted when it increases output. Since some technologies require more capital inputs, some countries may not be able to continue on the technological frontier. Thus, the technology disparities between nations translate into differences in total output and productivity.

At the same time, Acemoglu and Restrepo (2018) have constructed a "task-based" framework treating automation and the creation of new tasks as types of technological innovation. There are, in fact, technologies necessary to complement one another if output or productivity is to improve. Acemoglu and Restrepo (2018) first assumed that all tasks could actually be performed by labor, while "lower-indexed" tasks could automatically be automated; however, automation is capital-intensive, raising the share of capital and reducing the share of labor. But more sophisticated tasks are created, where labor has a comparative advantage. In the long run, there is stability and a balanced growth path along which the two innovations coexist and grow, allowing for the same rate of growth.

The above-mentioned theoretical works perform well to illustrate the relationship of modern science with developments in ICT and economic growth. Yet, there are still inadequacies in more recent forms of technological innovation brought by AI and machine learning. This can be due to the unavailability of data, both at the firm level and at the macro level, especially when analyzing long-run growth. However, this study is an attempt to address such literature gaps within the limits of data availability. The number of patents and scientific journals is commonly used as a measure of technological innovation in empirical studies. In the Schumpeterian sense, patent possession signifies monopoly rent accruing from the creation of a new technology. Firms, therefore, pursue rights to exclusivity over these monopoly rents; through invention and the generation of new technologies, they modify outdated infrastructure. This phenomenon is thus termed creative destruction. So, when new technologies are developed, they increase the productivity of firms by enabling them to achieve increasing returns to scale in the process. Consequently, patents may be interpreted, in this context, as a reflection of greater productivity in conjunction with the effort. Patents stand as a sign of higher production and, of course, higher national growth. In standard growth models, technological progress represents the arrival of knowledge, and knowledge is accumulated as a consequence of constant R&D endeavors. Using panel data estimation and data from Latin American economies, Kim and Lee (2015) found a negligible impact of scientific knowledge, with patents being significant and positively related to economic growth.

Numerous studies examining patents and growth generally reach similar conclusions (e.g., Lach 1995; Sinha 2008; Kim et al. 2012). Wong et al. (2005), modeling innovation and entrepreneurship alongside economic growth, showed that patent grants, used as an indicator of innovation, have a significant and positive effect on country growth rates. Yet, recent studies such as Sweet and Eterovic (2019) and Blind et al. (2022) have found no important effect of patents on economic growth. In another recent study, Nguyen and Doytch found a positive and significant effect of total patents on economic growth for high economies, while for lower economies, the effect of this variable related to technology diminishes. Additionally, ICT patents contribute to economic growth only in high-income economies. Also, they established that total patents in the long run are never significant in any area, while ICT patents stay positive and significant.

While growth theories provided the rationale for understanding technological progress, modern literature explores ways in which DT intertwines with sustainability. AI, IoT, and 5G have become increasingly recognized as sustainability enablers that facilitate business in optimizing resource utilization, enhancing operational functionality, and eventually transforming into

virtualized processes that play into sustainability objectives. While these digital tools may have many other contributions, one aspect explored by many scholars is the transparency and accountability provided by digital transformation. Businesses are able to monitor their environmental footprint in real time through AI and IoT, thereby aligning operations with sustainability principles (Kristoffersen et al., 2020). Such integration specifically advocates for sustainable development goals (SDGs) by enhancing the efficient utilization of natural resources, minimizing waste, and fostering responsible consumption and production via digital technologies (Rejeb et al., 2022). Applying strategies of net-zero economy models by Stern and Valero (2021) signifies how digitalization can be engaged to ensure overall environmental and economic sustainability in the long run.

This paper approaches economic growth theoretically from a neoclassical and endogenous perspective, which seeks to explore the role of technological advancement as it propels productivity and economic growth. While traditional models link technology to growth, modern sustainability literature often frames the challenge using the Environmental Kuznets Curve (EKC) hypothesis, which posits that environmental degradation initially rises with economic growth before declining at higher income levels (Mitić, Kresoja, & Minović, 2019). This paper expands these theoretical frameworks since the study shows the importance of artificial intelligence and other digital innovations affecting economic, social, and environmental sustainability. By enhancing efficiencies, optimizing resource use, and boosting long-term resilience, emerging technologies contribute to sustainable economic growth and tackle broader sustainability challenges. Thus, this study aims to answer the following research questions:

1. How do emerging technologies influence sustainable economic growth?
2. What are the economic, social, and environmental impacts of emerging technologies?
3. To what extent do emerging technologies contribute to achieving long-term sustainability goals, including resource efficiency, carbon footprint reduction, and social inclusion?

LITERATURE REVIEW

The effect of emerging technologies on economic, social, and environmental sustainability has attracted increasing academic research. The existing literature investigates various dimensions of technological advancements and their implications for the broader foundational categories of sustainable development, focusing on artificial intelligence (AI), Internet of Things (IoT), blockchains, and big data analytics. In this section, major findings of the previous studies are synthesized under these three categorizations: economic sustainability, social sustainability, and environmental sustainability.

Emerging Technologies and Economic Sustainability

Economic sustainability refers to ways in which economies and businesses can maintain growth with continued long-term productivity and resilience. Traditional economic theory, explained by Solow (1956) and Romer (1990), established the fact that technological development has always been at the heart of economic growth. Recent empirical studies pinpoint that digital technologies have made significant contributions to improving economic efficiency and even encouraging invention.

For example, Brynjolfsson and McAfee (2014) suggest that AI and automation boost productivity by optimizing workflows while lowering operational costs. AI contributes to economic growth through both the supply side (by automating work and enhancing labor productivity) and the demand side (by allowing for enhanced personalization and quality of goods and services) (Rao and Verweij, 2017). Thus, it is estimated that artificial intelligence will contribute about $15.7 trillion to the global economy by 2030. Lu (2021) further proposes a theoretical framing correlating AI to the growth of human capital. This framework is significant in

demonstrating that AI can become a scalable production input due to its ability to learn and accumulate knowledge. Empirical studies investigating the economic effects of AI have been few in number, mainly due to the absence of data (Gonzales, 2023). Still, existing studies have pointed to a positive relationship between AI and growth. He (2019) examined the impact of AI on regional economic growth in China, using ICT investment as a proxy for AI adoption, while Fan and Liu (2021) confirmed the role of AI in advancing sustainable economic growth across Chinese provinces. Yang (2022), in a similar context, looked into productivity and employment at the firm level in Taiwan, demonstrating that both AI and non-AI patents contribute to total factor productivity. Interestingly, Yang discovered that AI technology has a comparatively larger impact on industrial capital than on labor productivity, confirming previous theoretical discussions on the same by Arrow (1962) and Zeira (1998).

However, this optimistic view has often been contrasted with the lack of empirical evidence explaining the contribution of ICT to economic growth, primarily in the case of developing countries. According to Niebel (2014), much of this uncertainty arises from the lack of high-quality micro and macro-level datasets on ICTs in these economies. The World Bank (2012) took an optimistic view: "Information and communication technologies (ICTs) have great promise to reduce poverty, increase productivity, [and] boost economic growth." However, there are compelling reasons for skepticism regarding the application of ICT that are valid a priori. Developing economies maintain limited absorption capacity, such as human capital and complementary factors like research and development (R&D) expenditures, which prevents them from harnessing ICT investments.

Conversely, some scholars suggest that emerging markets could leapfrog traditional development paths by registering digital solutions that circumvent traditional productivity-boosting methods (Steinmueller, 2001). In these contexts, ICT-related spillovers and network effects, which reduce transaction costs and accelerate the diffusion of knowledge, may yield greater results when a critical mass of firms in a specific region or industry adopts similar levels or types of ICT. Empirical studies conducted in developed economies have yielded equivocal results concerning the relationship between ICT and productivity. Stiroh (2002) originally found a negative output elasticity for ICT capital in U.S. manufacturing data from 1984 to 1999; however, later revisions (Stiroh, 2005), citing newer data, found positive ICT capital coefficients. Other studies by O'Mahony and Vecchi (2005) and Dimelis and Papaioannou (2011) confirmed a significant contribution of ICT capital to output growth in the UK and in the US. Dahl et al. (2011) enlarged the scope of the inquiry to eight European economies, using EU KLEMS data, contributing further to the argument that ICT investments would bring positive magazine performance.

Moreover, in a similar vein, Acemoglu and Restrepo (2018) unearth task displacement and task creation, showing that while automation obviates certain jobs, it creates economic opportunities and industries. As such, Saberi et al. (2019) demonstrate that the integration of blockchain technology in supply chains raises their economic effectiveness through improved transparency and decreased transaction costs. In addition, studies conducted by Wang et al. (2011) and Nchake & Shuaibu (2022) further highlight the achievement of economies of scale through the digitalization of firms.

As far as this topic is concerned in terms of Western Balkan countries, Levkov and Kitanovikj (2024) studied the level of digital, computer, and other skills in evaluating data, information, and digital content, comparing it with that of the EU region. In the WB context, Serbia has almost converged with the EU average in areas of computer skills, while North Macedonia was ahead in skills for evaluating data, information, and digital content. The results indicate that currently, the higher the level of digital skills in WB countries, the greater the labor productivity and GDP per capita. We explored the potential relation between the level of digital skills of the countries in WB and their economic performance, measured through labor productivity and GDP per capita for 2023. In this age of AI, a higher level of digital skills of the WB country's population suggests greater labor productivity value. They then investigated the relationship between the level of

digital skills in WB countries and their economic performance, with GDP per capita as the measure for the year 2023. They also found a correlation (R2 = 0.74409) between digital skills and GDP per capita, akin to labor productivity.

Emerging Technologies and Social Sustainability

Social sustainability promotes fair and equal distribution of benefits from technological innovation, workforce flexibility, and digital inclusion. Studies show that integrating emerging technologies within the traditional scope of education, healthcare, and jobs can be transformative. While West (2018) states AI-enabled educational platforms enable personalized learning to greater access by diverse populations, Chui et al. (2016) found automated healthcare to improve service delivery, specifically by enhancing diagnostic accuracy and remotely monitoring patients. These trends witnessed a significant boom during the coverage of COVID-19, as AI-based telemedicine platforms helped to ease pressure on healthcare systems while allowing continuity of care (Topol, 2019). But mixed feelings arise regarding job displacement and digital inequality. Frey and Osborne (2017) elucidate that such increased automation may have disproportionate effects on low-skilled workers. This calls for targeted policies for workforce reskilling and digital literacy programs. Bessen (2019) draws attention to the necessity for governments and organizations to adopt the following substantive strategies to avert technological unemployment and promote inclusive growth.

Emerging Technologies and Environmental Sustainability

The environmental impact of emerging technologies is a critical area of study, with particular reference to energy efficiency, carbon emissions, and resource management. Emerging research shows both positive and negative effects. Kristoffersen et al. (2020) and Rejeb et al. (2022), for instance, point to AI, IoT, and data analytics, enabling companies to optimize energy consumption, reduce waste, and do predictive maintenance with, consequently, significant environmental benefits. The smart cities concept, driven by IoT and big data, attracts much interest as a model for sustainable urban development, as demonstrated in Batty et al. (2012) and Angelidou (2017). On the contrary, Koomey et al. (2011) inform that higher computing power for AI, blockchain, and cloud services means higher electricity consumption. Thus, the sustainability of digital transformation actually depends on transitioning to green computing practices and using energy-efficient technologies. Technology-related policies such as carbon pricing and investment in renewable energy are critical for decent progress in mitigating the environmental footprint of digitization, according to Stern and Valero (2021).

TECHNOLOGICAL LANDSCAPE IN SERBIA AND NORTH MACEDONIA

Over the last few years, advancements in technology have been one of the most important factors influencing global economic development, competitiveness, and innovation. Serbia and North Macedonia, two emerging economies in Southeast Europe, have made important progress in developing national technological ecosystems. This section provides a brief overview of each country's progress in key areas such as human capital, digital connectivity, government policy, infrastructure, and investment in research and innovation, with particular focus on the adoption of digital technologies.

Human Capital and Digital Skills

Serbia and North Macedonia understand the role of human capital in facilitating technological change. Serbia has a fairly well-established ICT workforce of about 80,000 people, while North Macedonia has been steadily increasing its digital talent pool. Having skilled professionals in information and communication technologies (ICT) is the result of investments in education and

the workforce. Universities and vocational training centers in both countries provide specialized programs in software development, data science, and cybersecurity. This is a response to the increasing demand for digital savvy experts. Senior professionals are now helping young people to broaden their experience and assist in start-up & other projects owing to the increase in incubators and hubs. Serbia's 'Digital Serbia Initiative' and North Macedonia's 'Smart Specialization Strategy' are improving digital skills and boosting investigations into new 'emerging' technologies.

Digital Connectivity and Integration of Digital Technology

Both countries have taken significant steps towards strengthening digital connectivity. The Internet penetration in Serbia is greater than 80%, closely followed by North Macedonia at approximately 79%. High-speed broadband penetration has increased, supported by infrastructure investments and regulatory reforms. Both Serbia and North Macedonia widely use 4G networks and are now preparing for 5G deployment. Many businesses and consumers are more frequently using digital tools, e-commerce, and fintech, which is making the digital economy more vibrant. Yet, the rural areas of both countries are struggling with connectivity issues which must be resolved.

The use of digital technology is at the center of economic transformation in both countries. In North Macedonia (NM), the use of big data stands at 13%, which is higher than the Western Balkans (WB) average. On the other hand, 10% use cloud and AI. However, only 26% of SMEs have a basic level of digital intensity, below the WB average of 35%. The level of e-commerce is notably low, with only 9% of SMEs selling online and 1% engaging in cross-border e-commerce. National strategies such as the Economic Reform Program (2021-2023) or the Strategic Plan of the Ministry of Information Society and Administration (2021-2023) incorporate the digital transformation agenda. Though long-term strategic documents like the ICT Strategy (2021-2026) have not yet been adopted and the National Strategy for Artificial Intelligence is being developed (Tintor et al., 2022).

Though Serbia has made some progress in the digital front, it still faces challenges regarding digital adoption. Only 22% of businesses use enterprise resource planning (ERP) systems for the electronic exchange of information, and 16% do so on social media (both below WB averages). Advanced digital technology uptake is low, as just 1% of enterprises use AI and 4% make use of big data. Cloud computing is adopted more readily than before. The percentage of enterprises using cloud solutions is 22%. This is higher than 16% which is the WB average. Almost 50% of Serbian SMEs reach at least a basic level of digital intensity, indicating that they are more digitally intensive than their competitors. E-commerce uptake is also more advanced, as 26% of SMEs sell online, although e-cross-border commerce is still very limited to 3 percent (Tintor et al., 2022).

Serbia has started using various strategic policies to speed up its digital transformation. The goal of the Industrial Policy Strategy (2021-2030) is to utilize the available means and resources for industrial digitalization, financial incentives, and education programs (for digital skills). North Macedonia, on the other hand, developed a National Strategy for SMEs (2018-2023) and, in turn, put forward key digital laws that would facilitate e-governance and online services.

Government Policies and Strategic Initiatives

Both the governments in Serbia and North Macedonia have taken steps to enable digital transformation. While North Macedonia has its own 'National Strategy for Digital Transformation' focusing on e-governance and cybersecurity, Serbia wants its 'Strategy for the Development of Artificial Intelligence 2020-2025' to position itself as a leader in artificial intelligence research and applications. Strategies at the national level pertaining to digitalization, e-governance, and cybersecurity have been devised to enhance the efficiency and security of public administration and the private sector. Reforms to facilitate business registration and tax administration, as well

as e-government services, have improved the ease of doing business. Further, there are tax concessions and grants for foreign direct investment (FDI) in the technology sector. This focus is critical, as a high quality of government, specifically the Rule of Law and political stability, has been proven to significantly and positively influence the attraction of foreign direct investments in Southeastern European countries including Serbia and North Macedonia (Jovanović, Domazet, & Marjanović, 2023). Government officials are also prioritizing the digitization of educational and health facilities for the citizens.

Infrastructure Development

Infrastructure investment has been a priority for enhancing digital and technological capabilities in the two countries. Serbia is strongly investing in its National Broadband Plan, which aims to enable high-speed internet access for all households by 2025. Similarly, North Macedonia has invested in fiber-optic networks to promote digital inclusion as well as in the upgrade of fiber-optic networks, data centers, and cloud computing services. Smart city projects and digital public services have also been developed. However, investment should continue in order to outpace the urban-rural digital divide and scale up cybersecurity measures. Both governments are looking to partner with the private sector to enhance 5G roll-out and build digital infrastructure even further.

Investment in Research, Innovation, and Digitalization

Serbia and North Macedonia have been investing in research and innovations with the help of national governments and international organizations. Serbia invests about 0.9 percent of its GDP in R&D, while North Macedonia invests 0.4 percent. There was an opportunity for innovation and science and technology thanks to innovation funds, research grants and cooperation with the EU's Horizon programs. Tech startups and research facilities in areas like AI, Blockchain and Biotech are emerging, creating a more innovative ecosystem. However, we must boost private participation in research and industry-academy cooperation efforts. The key industries (manufacturing, logistics, agriculture, etc.) are undergoing digitalization, which is improving, but further investment is needed to fully utilize Industry 4.0 technologies. Although these technologies can significantly raise productivity and competitiveness, the rates of adoption of automation, IoT applications, and AI growth vary across sectors. More financial incentives and policy support will be crucial to ensure that the digital transformation of the economy reaches all sectors.

DATA AND METHODOLOGY

The research employed a quantitative survey-based design to investigate the adoption of emerging technologies and their associated economic, social, and environmental impacts across sectors in Serbia and North Macedonia. The study was based on responses from 81 participants, following data cleaning procedures applied to the initial sample. Data were collected through an online structured questionnaire targeting ICT professionals, academics, policymakers, and other relevant stakeholders, over the period from 15 December 2024 to 31 January 2025.

The analysis was conducted using both descriptive and inferential statistical methods. Descriptive statistics included frequencies and percentage distributions to capture the demographic and professional profiles of respondents. Inferential statistics were applied to assess variations in technology-related perceptions and motivations. Specifically, the Mann–Whitney U test was used to compare economic, social, and environmental motivations and barriers across groups, while the Kruskal–Wallis H test was employed to examine differences in perceived benefits of emerging technologies across various sectors. All statistical processing and visualization were conducted using Microsoft Excel and the R programming environment.

The collected data were analyzed using appropriate nonparametric statistical methods based on variable characteristics and distribution patterns. Categorical variables were presented as frequencies and percentages.

For comparing two independent groups, the Mann-Whitney U test was employed as it effectively evaluates distribution differences without requiring normality assumptions. The Kruskal-Wallis H test, extending this rank-based approach to multiple groups, was utilized when comparing three or more independent groups, assessing significant distribution differences without assuming normal distribution or variance homogeneity.

Associations between categorical variables were examined using the Chi-square test of independence, which evaluates significant relationships by comparing observed frequencies against those expected under independence assumptions.

It must be noted that, while the sample of this survey offered insightful findings into sectoral differences, it does not completely reflect the population at large. Most of the respondents came from an academic and urban context, which may limit the generalizability of the findings to other sectors and experiences in rural areas. Therefore, caution should be taken when applying findings to the national level. Future research should strive to have a larger and broader sample to improve external validity and offer more perspectives.

RESULTS AND DISCUSSION

Table 1 presents the demographic and professional profile of the 113 survey respondents. The majority of participants were between 25 and 54 years of age, with the largest group aged 25–34. Most respondents were from North Macedonia (54%) and held postgraduate qualifications, with nearly half holding a PhD. Gender representation was balanced, with a slight majority of female participants. A large proportion of respondents (79%) had personally adopted emerging technologies, while 51% indicated their organization had done so. Most were employed in medium-sized organizations and in urban areas. The academic and research sector accounted for the largest share (49%), followed by the ICT sector (27%). Since the majority of respondents were based in urban areas, and almost half of all respondents were connected to academic or research institutions, responses may have been impacted by this composition, especially in regards to awareness, motivation, and perceptions of sustainability-related outcomes, which may have varied in samples that were more focused on the government or industry.

Table 1. Descriptive statistics

Dimension	Summary
Age	18–24 (6%); 25–34 (33%); 35–44 (22%); 45–54 (25%); 55–64 (11%); 65 and above (3%)
Country	MK (54%); RS (46%)
Education	High School (9%); Bachelor's Degree (20%); Master's Degree (25%); PhD candidate (1%); Doctorate (PhD) (44%); Post-Doctoral (1%)
Gender	Female (52%); Male (44%); Prefer not to say (4%)
Org Tech Adoption	Organization adopted (51%)
Organization Size	Micro (<10) (15%); Small (<50) (17%); Medium (50–250) (48%); Large (>250) (20%)
Personal Tech Adoption	Personally adopted (79%)
Residential Area	Urban (88%); Rural (12%)
Sector	Academic/Research (49%); Business organization (1%); Government (12%); ICT Sector (27%); NGO (11%)
Specific Tech Adoption	Artificial Intelligence (AI) (88%); Internet of Things (IoT) (51%); 5G (37%); Big Data (35%); Blockchain (10%); Smart Farm Implementation (2%)

Dimension	Summary
Tech Adoption Awareness	Yes (59%); No (19%); Not aware (22%)
Work Experience	<1 year (1%); 1–5 years (38%); 6–10 years (22%); 11–15 years (14%); 16–20 years (11%); 21–25 years (6%); >26 years (8%)

Source: Authors` calculation.

Artificial Intelligence (88%) was the most commonly adopted technology, while awareness of emerging technologies was relatively high (59%). Work experience was well distributed, with the largest group having between 1 and 5 years of experience.

Overall, 59.3% of respondents indicated personal awareness of emerging technologies, while 18.5% reported no awareness, and an additional 22.2% expressed varying degrees of unfamiliarity (18.5% unaware of adopted technologies and 3.7% unaware of any emerging technologies). When comparing countries, awareness was higher among respondents from Serbia, where 67.6% stated they were personally aware of emerging technologies, compared to 52.3% in North Macedonia. Conversely, a higher proportion of respondents in North Macedonia (25.0%) reported no awareness, compared to 10.8% in Serbia, see Figure 1. Despite these differences, the Chi-square test indicated that the association between country and awareness was not statistically significant ($\chi^2 = 3.169$, $p = 0.366$). These results suggest that while there are observable differences in awareness levels between the two countries, they are not strong enough to infer a significant association statistically.

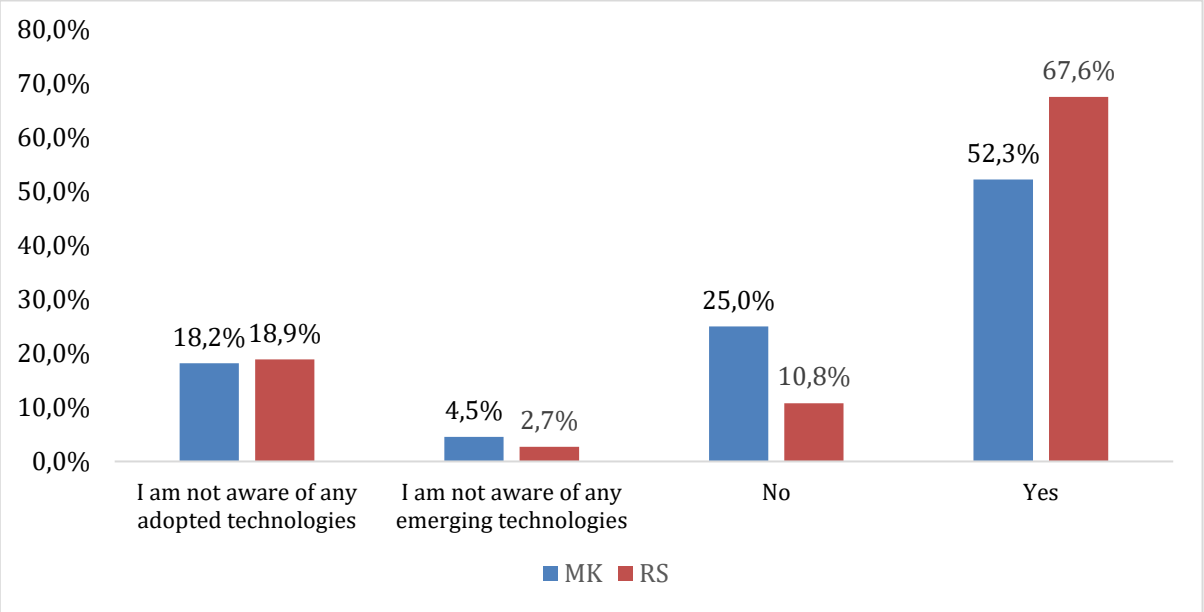

Figure 1. Have you personally, or the organization you work for, adopted any emerging technologies? (e.g., AI, Blockchain, IoT, 5G, Big Data, etc.)

Motivation and Challenge Ratings

The distribution of motivation ratings (Table 2) reveals that the strongest drivers for the adoption of emerging technologies among respondents are related to driving innovation and digital transformation (44% rating "5 – very motivated"), gaining a competitive edge in the market (38%), and complying with sustainability-related regulations (42%). These findings suggest that market and innovation pressures represent more immediate incentives for engagement with new technologies than altruistic or long-term environmental goals. By contrast, motivations such as

promoting social sustainability and advancing environmental sustainability received the lowest proportion of "very motivated" responses (both at 12%). This may reflect either the perceived difficulty in measuring these benefits or a lower prioritization of non-economic outcomes in respondents' operational settings.

Table 2. Distribution of Motivation Ratings

Rating	Enhancing economic sustainability	Promoting social sustainability	Advancing environmental sustainability	Gaining a competitive edge in the market	Driving innovation and digital transformation	Complying with sustainability-related regulations or policies	Complying with sustainability-related regulations or policies
1	6%	10%	16%	10%	4%	8%	16%
2	8%	14%	12%	10%	8%	6%	16%
3	22%	26%	36%	22%	22%	22%	28%
4	36%	38%	24%	20%	22%	22%	26%
5	28%	12%	12%	38%	44%	42%	14%

Source: Authors` calculation.

To test for differences in motivation between Serbia and North Macedonia, Mann–Whitney U tests were conducted across all motivation categories. The analysis revealed two statistically significant differences: gaining a competitive edge in the market ($p = 0.036$) and driving innovation and digital transformation ($p = 0.020$). In both cases, the results indicate higher motivation levels among respondents from North Macedonia compared to their Serbian counterparts. These results suggest a stronger market-driven and innovation-oriented technology adoption context in North Macedonia, potentially reflecting national policy incentives, sectoral dynamics, or institutional support systems. A third variable - supporting research, education, and knowledge - approached significance ($p = 0.051$), suggesting a marginal difference that may become statistically significant with a larger sample size or longitudinal data.

Table 3. Mann–Whitney U Test Results for Motivation Ratings

Motivation Category	Mann-Whitney U	p-Value	Significance
Enhancing economic sustainability	267.5	0.383	Not significant
Promoting social sustainability	308.5	0.968	Not significant
Advancing environmental sustainability	232.5	0.116	Not significant
Gaining a competitive edge in the market	207	0.036	Significant
Driving innovation and digital transformation	197.5	0.020	Significant
Supporting research, education, knowledge	215	0.051	Marginal
Complying with sustainability-related policies	242.5	0.174	Not significant

Source: Authors` calculation.

Conversely, there were no significant cross-country differences for motivations related to enhancing economic, social, or environmental sustainability, nor for complying with sustainability-related regulations. These findings indicate a shared baseline appreciation for sustainability as a value, but one that is not strongly differentiated by national context. The data suggest that competitive positioning and innovation ecosystems are the most differentiating

forces in technology adoption between Serbia and North Macedonia. Meanwhile, motivations linked to sustainability, though present, are more evenly distributed, implying a common normative recognition rather than a context-specific strategic driver.

The distribution of challenge ratings (Table 4) indicates that the most prominent barriers to adopting emerging technologies are related to human capital limitations and financial costs. Specifically, the highest shares of "very significant challenge" responses were recorded for lack of skilled personnel (24%), limited understanding of potential benefits (22%), and high costs (20%). Conversely, the lowest ratings were observed for resistance to organizational change (12%), lack of infrastructure or technological support (16%), and regulatory or compliance issues (14%). These findings suggest that respondents perceive cognitive and capability-related barriers as more pressing than structural or institutional ones—possibly reflecting a degree of organizational readiness or a stable regulatory environment.

Table 4. Distribution of Challenge Ratings

Rating	High costs	Lack of skilled personnel	Resistance to change within the organization	Lack of infrastructure or technological support	Regulatory or compliance issues	Limited understanding of potential benefits
1	10%	6%	16%	8%	16%	18%
2	20%	18%	18%	22%	24%	18%
3	34%	30%	30%	26%	40%	22%
4	16%	22%	24%	28%	6%	20%
5	20%	24%	12%	16%	14%	22%

Source: Authors` calculation.

Mann–Whitney U test results (Table 5) revealed statistically significant differences between Serbia and North Macedonia for two challenges: high costs ($p = 0.017$) and limited understanding of potential benefits ($p = 0.038$). In both cases, further interpretation of the rankings indicates that respondents in North Macedonia experience these barriers more acutely. This likely reflects different levels of institutional support, financial resources, or exposure to innovation ecosystems. In addition, lack of infrastructure or technological support showed a marginally significant difference ($p = 0.063$), suggesting this may also represent a more prominent constraint in North Macedonia.

Table 5. Mann–Whitney U Test Results for Challenge Ratings

Challenge	Mann-Whitney U	p-Value	Significance
High Costs	191.5	0.017	Significant
Lack of Skilled Personnel	264.5	0.356	Not significant
Resistance to Change	269.5	0.412	Not significant
Lack of Infrastructure	218.5	0.063	Marginal
Regulatory/Compliance Issues	283	0.576	Not significant
Limited Understanding of Benefits	206	0.038	Significant

Source: Authors` calculation.

In contrast, there were no statistically significant differences between countries regarding the perceived challenge of a lack of skilled personnel, resistance to change, or regulatory and

compliance issues. This suggests that these are shared barriers across national contexts, possibly rooted in broader regional trends in workforce development, organizational culture, or institutional capacity.

Overall, the findings imply that tailored policy approaches may be warranted. In North Macedonia, targeted interventions such as subsidies, awareness campaigns, and workforce training could help overcome financial and knowledge-related obstacles. In Serbia, the emphasis may need to shift toward upskilling initiatives and long-term investment strategies to sustain digital transformation momentum.

Perceived Economic, Social, and Environmental Benefits of Emerging Technology Adoption

The results in Table 6 indicate that respondents widely recognized and experienced economic benefits from the adoption of emerging technologies, particularly in areas related to operational efficiency, cost reduction, and customer satisfaction.

Table 6. Economic benefits from adopting emerging technologies

Benefit	Do not know	Not at all	Slightly	Moderately	Extensively
Improved operational efficiency or faster processes (e.g., automated tasks, quicker decision-making)	18%	10%	14%	32%	26%
Reduced operational costs (e.g., reduced paper usage, energy costs, or staffing needs)	6%	6%	22%	34%	32%
Increased funding or revenue opportunities (e.g., new grants, funding from donors, or service fees)	12%	10%	20%	32%	26%
Enhanced ability to innovate or stay competitive (e.g., staying ahead of industry trends, developing	16%	10%	24%	28%	22%
Improved customer or stakeholder satisfaction and retention	10%	2%	20%	32%	36%
Better resource allocation or optimization (e.g., better use of time, materials, or funds)	16%	6%	10%	32%	36%
Streamlined reporting or administrative processes (e.g., automated forms, digital records management	12%	8%	18%	36%	26%
Improved financial planning and forecasting through data analysis tools	16%	8%	22%	36%	18%

Source: Authors` calculation.

The most extensively realized benefits include improved customer or stakeholder satisfaction (36%), better resource allocation or optimization (36%), and reduced operational costs (32% moderately, 32% extensively). These findings suggest that tangible, efficiency-driven improvements are the most visible and valued outcomes of technology integration. In contrast, benefits such as enhanced innovation capacity and improved financial planning were less frequently reported as extensively achieved, with only 22% and 18% of respondents respectively selecting the highest rating. This disparity points to potential barriers in leveraging technologies for strategic functions, such as innovation and predictive analytics, which may require more advanced capabilities, longer timeframes, or greater organizational maturity.

The data show that social benefits related to employee well-being are the most widely experienced outcomes of emerging technology adoption (Table 7).

Table 7. Social benefits from adopting emerging technologies

Benefit	Do not know	Not at all	Slightly	Moderately	Extensively
Enhanced support for employees (e.g., flexible work schedules, professional development opportunities)	10%	6%	16%	32%	36%
Improved accessibility or inclusivity (e.g., tools for remote work, features supporting individuals with disabilities)	8%	6%	28%	36%	22%
Strengthened relationships with external communities or stakeholders (e.g., engagement with local communities, collaboration with partner organizations)	12%	8%	20%	36%	24%
Expanded access to education, training, or public services (e.g., online platforms, e-learning tools, digital service delivery)	18%	6%	20%	28%	28%
Increased employee satisfaction or morale (e.g., greater job satisfaction from improved tools or work processes)	8%	4%	16%	36%	36%
Improved internal collaboration (e.g., enhanced teamwork through digital communication tools and virtual platforms)	12%	8%	20%	42%	18%
Greater transparency and accountability (e.g., improved progress tracking, clearer reporting of operations and goals)	8%	14%	22%	28%	28%
Empowerment of underrepresented groups (e.g., increased opportunities for women, minorities, or marginalized communities)	12%	20%	24%	24%	20%

Source: Authors` calculation.

Specifically, enhanced employee support and increased employee satisfaction or morale both received the highest share of "extensively experienced" responses (36%), indicating strong recognition of technology's role in improving job conditions and satisfaction. Other benefits, such as improved accessibility or inclusivity and strengthened relationships with external communities, were also commonly reported, though to a slightly lesser extent. Notably, internal collaboration tools were frequently cited as moderately beneficial (42%), yet fewer respondents rated them as extensively impactful (18%), suggesting only partial realization of their potential. Meanwhile, transparency and accountability and expanded access to education or public services showed moderate uptake, with balanced distributions across response categories. Empowerment of underrepresented groups received the lowest scores, with only 20% indicating extensive benefits, reflecting that diversity-focused outcomes may be underdeveloped or deprioritized. Overall, while social benefits tied to internal human resources are well established, broader inclusion, transparency, and external collaboration remain areas with room for strategic enhancement and future investment.

The findings on environmental benefits from emerging technology adoption (Table 8) suggest that resource efficiency and logistics optimization are the most consistently recognized outcomes.

Table 8. Environmental benefits from adopting emerging technologies

Benefit	Do not know	Not at all	Slightly	Moderately	Extensively
Reduced physical resource use in operations (e.g., less paper, materials, or energy consumption)	8%	11%	25%	38%	18%
Lower energy consumption from efficient processes or remote work	15%	11%	32%	36%	6%
Reduced carbon emissions (e.g., from reduced commuting, automation, or clean energy transitions)	18%	18%	22%	32%	10%
Adopted renewable energy sources (e.g., solar or wind energy for offices or data centers)	14%	40%	14%	24%	8%
Optimized logistics or transportation processes (e.g., fewer physical deliveries, better route optimization)	18%	27%	8%	32%	15%
Improved waste management efficiency (e.g., better recycling practices, digital waste monitoring)	19%	18%	23%	30%	10%
Implemented circular economy practices (e.g., material reuse, extending product lifecycle)	18%	19%	18%	30%	15%

Source: Authors` calculation.

Specifically, reduced physical resource use and lower energy consumption through efficient processes were among the most commonly reported benefits, with 38% and 36% of respondents respectively, rating them as experienced "moderately." However, extensive recognition remains limited, with only 18% or fewer respondents selecting the highest rating for any single environmental benefit. This indicates that while progress is evident, full realization of environmental outcomes remains in development. Notably, renewable energy adoption lags significantly behind other areas, with 40% of respondents reporting they have not experienced it at all, suggesting either limited infrastructure, financial constraints, or low prioritization of clean energy transitions. Similarly, benefits such as carbon emissions reduction, waste management efficiency, and circular economy practices were moderately acknowledged but rarely rated as extensively achieved, pointing to a potential gap between environmental aspirations and practical implementation. These results emphasize the need for stronger incentives and institutional support to translate technological capabilities into a more comprehensive environmental impact.

While these findings align with much of the existing international literature that has emphasized the positive economic and operational efficiency benefits of transformative digital organizational development (Brynjolfsson & McAfee, 2014; Song, 2025), they shed some doubt on the findings of other researchers who have found more neutral or even negative results regarding the aforementioned issues. Such studies, like Koomey et al. (2011) and Stern and Valero (2021), express concern that increasing energy consumption of new technology, ranging from AI to blockchain to cloud computing, may displace sustainability benefits without real commitment to a future green energy transition. Frey and Osborne (2017) and Bessen (2019) also highlight that technology-enabled automation may worsen job polarization and inequality in low digital inclusion and low retraining economies. In this sense, this study highlights a broader challenge in achieving environmental and inclusivity-related benefits within a rapidly growing digital transformation sector, highlighting the need for policy to integrate considerations of a green transition, promote equitable access to emerging opportunities across all sectors, and the responsibility of ensuring that innovation does not lead to permanent job loss in any economy.

Sector-Specific Impact of Technology Adoption

The Kruskal–Wallis H test results (Table 9) indicate statistically significant differences across sectors for both economic (p = 0.016) and social (p = 0.021) benefits derived from emerging technology adoption, with environmental benefits showing a marginally significant variation (p = 0.097). These findings confirm that the perceived impacts of technological adoption are not uniformly distributed but are influenced by the sectoral context.

Table 9. Kruskal-Wallis H Test Results

Dimension	Chi square	p-Value	Significance
Economic	12.120	0.016	Significant
Social	11.559	0.021	Significant
Environmental	7.846	0.097	Marginally

Source: Authors` calculation.

Descriptive statistics further clarify these differences (Table 10). Business organizations reported the highest levels of benefit across all three dimensions—economic (32.00), social (32.00), and environmental (28.00)—highlighting a broad and impactful engagement with emerging technologies in the private sector. In contrast, academia and research institutions showed strong outcomes in the social (23.58) and environmental (15.67) dimensions, while maintaining moderate levels of economic benefit (22.88). This pattern suggests that research-driven environments may prioritize long-term societal and sustainability goals more than immediate financial gains.

Table 10. Descriptive Statistics by Sector

Sector	Economic	Social	Environmental
Business Org.	32.00	32.00	28.00
Academia/Research	22.88	23.58	15.67
ICT Sector	20.25	19.06	13.69
NGO	16.20	16.00	11.20
Government	7.75	9.00	7.00
Overall Mean	20.34	20.38	14.14

Source: Authors` calculation.

The ICT sector demonstrated a relatively balanced focus, with moderate economic (20.25) and social (19.06) benefits, but a lower score on environmental outcomes (13.69), implying potential for further engagement in green digital strategies. NGOs placed emphasis on social sustainability (16.00) but recorded the lowest economic (16.20) and environmental (11.20) benefit levels outside of the government sector, reflecting their mission-driven focus and resource constraints.

Finally, government institutions consistently ranked lowest across all dimensions, particularly in economic (7.75) and environmental (7.00) domains, indicating limited realization of technological benefits. These findings highlight the need for targeted strategies and policy support to foster more equitable and effective adoption of technologies across different sectors.

CONCLUSION

This study highlights how emerging technologies are perceived to contribute to sustainable growth across different sectors and national contexts in Serbia and North Macedonia. The findings reveal that while economic benefits, such as cost reduction and operational efficiency, are broadly recognized, social and especially environmental impacts remain underdeveloped in practice. Innovation and competitive positioning drive adoption more strongly than normative sustainability goals, with significant cross-country differences suggesting that national policy frameworks and institutional support systems matter.

Barriers such as limited skills, high costs, and knowledge gaps remain persistent, particularly in North Macedonia, where financial constraints and lower organizational readiness were more frequently reported. Meanwhile, Serbia shows a stronger need for long-term investment and capacity building. Sectoral analysis confirms unequal realization of benefits: business organizations lead in impact realization, while government sectors lag significantly. This disparity underscores the importance of targeted policy design that reflects sector-specific conditions and national readiness.

To fully leverage the sustainability potential of digital transformation, both countries must reinforce cross-sector collaboration, support innovation ecosystems, and promote inclusive access to digital capabilities. Investments in skills development, renewable energy integration, and smarter regulation are essential to ensure emerging technologies become enablers—not obstacles—of a resilient and sustainable future.

This analysis raises a number of open questions for future study. Why are the environmental benefits from emerging technologies so much more under-realized, particularly in relation to public institutions and less digitally mature sectors, compared to the economic ones? How would we design inclusive and environmentally sound digital approaches to ensure that social and environmental benefits line up with economic ones? Answering these questions would require larger, longitudinal, and cross-institutional studies that would help us identify the mechanisms through which equitable and sustainable technological transformation occurs in different national and institutional contexts.

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