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Cryptocurrency Crises: The Role of Sentiment, Financial Stress, and Economic Policy Uncertainty

Sirine Ben Yaala*, Jamel Eddine Henchiri**

Abstract: This paper investigates the economic and behavioral determinants of crises in three major cryptocurrencies: Bitcoin, Ethereum, and Ripple. It focuses on the impact of key factors such as returns, volatility, investor sentiment, the Financial Stress Index (FSI), and Economic Policy Uncertainty (EPU). Crises are identified using the CMAX method, while their determinants are analyzed using both probit and logit models. The analysis identifies three major crises for Bitcoin – linked to the European sovereign debt crisis, the collapse of Mt. Gox, and the COVID-19 pandemic – along with a prolonged crisis in Ethereum from January 2018 to January 2021, and a persistent crisis in Ripple with no observed recovery. Results show that higher returns significantly reduce the likelihood of crises across all three cryptocurrencies, while increased volatility consistently raises crisis probability, reflecting heightened market uncertainty and risk aversion. Investor sentiment, measured through Google Trends, shows asset-specific effects: both optimistic and pessimistic sentiment increase crisis risk for Bitcoin and Ripple, while only pessimistic sentiment significantly affects Ethereum. Additionally, both FSI and EPU are positively and significantly associated with crisis occurrence, underscoring the influence of macro-financial stress and policy uncertainty on cryptocurrency stability.

Keywords: cryptocurrency crises; Bitcoin; Ethereum; Ripple; Google Trends; Financial Stress Index; Economic Policy Uncertainty.

JEL classification: G01; G11; G41; E44; C25.

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1. INTRODUCTION

Cryptocurrencies have revolutionized the financial landscape by providing a decentralized and secure digital medium for exchange. Since Bitcoin's emergence in 2009, many other cryptocurrencies such as Ethereum, Ripple, and Litecoin have gained popularity, driven by interest in blockchain technology, which ensures transaction security and transparency.

Cryptocurrencies differ from traditional government-issued currencies by relying on cryptography to secure transactions, control new unit creation, and verify asset transfers. Operating on decentralized peer-to-peer networks, they reduce vulnerabilities to manipulation and censorship. Bitcoin's value has soared dramatically, from mere cents to thousands of dollars, attracting investors and media attention and establishing cryptocurrencies as notable investment assets.

The rise of cryptocurrencies carries significant implications beyond finance. Their advantages include faster, cheaper transactions, increased financial access for the unbanked, and enhanced privacy and security. However, criticisms focus on extreme volatility, potential misuse for illicit activities, and high energy consumption. Regulators worldwide remain concerned with protecting investors and preventing abuses, fueling ongoing debates on balancing innovation and regulation.

Financial literature has increasingly examined cryptocurrencies, focusing on price and volatility dynamics and their determinants (Sovbetov, 2018; Katsiampa, 2019; Poyser, 2019). Studies highlight cryptocurrencies' hedge and safe-haven roles during market downturns (Bouri *et al.*, 2019; Paule-Vianez *et al.*, 2020), and analyze their speculative nature and bubble formation (Baur *et al.*, 2018; Corbet *et al.*, 2018). Research also explores interactions between cryptocurrencies and macroeconomic variables (Demir *et al.*, 2018; Kurka, 2019; Tiwari *et al.*, 2019).

Another literature strand focuses on how investor sentiment, the Financial Stress Index (FSI), and Economic Policy Uncertainty (EPU) shape cryptocurrency markets. Investor sentiment notably influences returns and volatility—positive sentiment drives prices up, while negative sentiment raises instability (Nasir *et al.*, 2019; Anamika and Subramaniam, 2022; Güler, 2023). FSI correlates with cryptocurrency returns, emphasizing Bitcoin's perceived safe-haven role during turmoil (Bouri *et al.*, 2018; Nur and Korkmaz, 2022; Yin *et al.*, 2024). EPU also predicts cryptocurrency volatility and returns, with Bitcoin and Ethereum acting as potential hedges during uncertain economic periods (Demir *et al.*, 2018; Paule-Vianez *et al.*, 2020; Mokni, 2021; Al-Shboul *et al.*, 2023). Despite this growing literature, critical gaps remain. Few studies specifically focus on explaining crises in cryptocurrency markets, which behave uniquely compared to traditional financial markets. While many analyze factors affecting returns and volatility, they often neglect the complex dynamics behind market disruptions. Furthermore, innovative measures of investor sentiment, such as direct indicators from Google Trends, are underutilized in forecasting models.

This study addresses these gaps by proposing a comprehensive framework combining a direct Google Trends–based investor sentiment measure with the Financial Stress Index and Economic Policy Uncertainty to explain crises in Bitcoin, Ethereum, and Ripple markets. Employing probit and logit models, the framework captures the interplay of behavioral and fundamental factors driving crises in major cryptocurrencies.

This research makes a significant contribution to financial forecasting and cryptocurrency market analysis. Theoretically, this study enriches academic literature by

developing a comprehensive framework to explain crises in Bitcoin, Ethereum, and Ripple. By integrating behavioral finance, sentiment analysis, and macroeconomic indicators, it offers a novel approach to understanding and anticipating cryptocurrency market disruptions. Practically, it equips investors, portfolio managers, and policymakers with tools to assess and manage cryptocurrency crisis risks. Using indicators like the Financial Stress Index (FSI), Economic Policy Uncertainty (EPU) and Google Trends–based investor sentiment, the study provides early warning signals to improve forecasting and guide informed decisions.

Methodologically, the research employs robust probit and logit models to estimate crisis probabilities, demonstrating the value of combining behavioral and macro-financial variables. The inclusion of direct sentiment measures and dual-model estimation enhances empirical rigor and applicability.

At the societal level, these findings promote financial stability by enabling stakeholders to anticipate and mitigate crises, reducing sudden market crashes, minimizing losses, and reinforcing investor confidence for a more resilient financial ecosystem.

From a policy perspective, understanding the drivers of cryptocurrency crises allows regulators to implement timely interventions that protect the real economy from shocks and foster a more stable economic environment.

To our knowledge, this study is among the first to detect and predict cryptocurrency crises using an integrated framework that combines CMAX-based crisis detection, probit and logit models, Google Trends sentiment data, the Financial Stress Index (FSI), and Economic Policy Uncertainty (EPU). This novel methodology advances understanding of cryptocurrency vulnerabilities and offers valuable insights for investment and regulatory strategies in the evolving digital financial landscape.

The remainder of this paper is structured as follows: Section 2 reviews the relevant literature. Section 3 outlines the research methodology, and Section 4 describes the data. Section 5 presents the results and analysis. Finally, Section 6 provides the discussion and conclusions.

2. LITERATURE REVIEW

Previous studies have extensively examined the factors influencing cryptocurrency prices and volatility, highlighting the critical roles of investor sentiment, financial stress, and economic policy uncertainty.

2.1. Investor sentiment and the cryptocurrency market

Traditional financial theory was grounded in the concept of homo oeconomicus, assuming investors were fully rational, possessed perfect information, and always made utility-maximizing decisions based on objective risk-return assessments. However, behavioral finance challenged this framework by incorporating psychological and emotional biases that often drove market behavior, especially under uncertainty. This perspective was particularly relevant to the cryptocurrency market, which lacked intrinsic valuation anchors and was highly sensitive to investor moods and perceptions.

Empirical research increasingly emphasized the crucial role investor sentiment played in shaping cryptocurrency dynamics. Sentiment – whether constructed from fundamentals (rational) or driven by emotions and noise (irrational) – affected not only asset returns but also volatility and cross-asset spillovers.

Güler (2023) investigated the effect of investor sentiment on Bitcoin returns and volatility using several sentiment proxies within an EGARCH model framework. The study found that both rational and irrational components of sentiment significantly impacted Bitcoin price movements and volatility.

Anamika and Subramaniam (2022) analyzed survey-based Sentix data to study Bitcoin price responses. They reported that increased investor optimism boosted Bitcoin prices and caused sentiment spillovers to other cryptocurrencies, reinforcing Bitcoin's role as a benchmark asset.

Indirect investor sentiment, often constructed through internet search activity, was also widely studied. Nasir *et al.* (2019) applied VAR, copula models, and non-parametric methods on weekly data (2013–2017) and found a strong positive link between Google search volume for Bitcoin and its returns and trading volume, indicating that increased retail investor attention predicted market movements.

Akyildirim *et al.* (2021) analyzed sentiment transmission among the 13 largest cryptocurrencies using MarketPsych data. Their dynamic connectedness analysis showed that while altcoins dominated return spillovers, Bitcoin and Ethereum remained central in sentiment flow, reflecting their psychological influence.

Similarly, Bouri *et al.* (2021) applied Twitter-based sentiment data within a DCC-GARCH model to study volatility spillovers among 15 major cryptocurrencies. They found that extreme negative sentiment increased market volatility and interconnectedness, suggesting panic-driven contagion. Conversely, extreme positive sentiment reduced connectedness, allowing greater diversification. These findings demonstrated the asymmetric and nonlinear effects of sentiment on crypto market volatility.

Sun *et al.* (2023) used textual analytics on millions of posts from Chain Node, a major Chinese crypto investor forum, to construct a sentiment proxy. Their study suggested that cryptocurrency prices were more sensitive to sentiment-driven fluctuations than traditional stocks due to the absence of fundamental valuation anchors.

Building on behavioral indicators, Gurdgiev and O'Loughlin (2020) analyzed multiple sentiment measures – including the VIX, CBOE put-call ratio, and U.S. Equity Market Uncertainty Index – and found that investor sentiment significantly influenced crypto prices. They also provided tentative evidence that cryptocurrencies might serve as safe havens during economic uncertainty, though this effect was inconsistent during severe equity market crashes.

Bouteska *et al.* (2022) constructed a composite sentiment index using principal component analysis (PCA) on social media and financial data. Using vector autoregressive (VAR) models, they showed this index reliably predicted short-term Bitcoin returns, particularly during crises such as the COVID-19 pandemic, when emotions heavily influenced markets.

Overall, these studies highlighted investor sentiment's importance in the cryptocurrency market, revealing that both rational and irrational emotions significantly impacted asset returns and volatility.

2.2. Financial stress index and the cryptocurrency market

While investor sentiment significantly shaped cryptocurrency behavior, systemic financial stress was another vital factor that could amplify or mitigate market reactions. The Financial Stress Index (FSI) served as a comprehensive measure of global financial instability, capturing movements in interest rates, credit spreads, and market volatility. It functioned as a key

barometer for investors and policymakers seeking to assess systemic risk and market vulnerability.

Recent empirical studies highlighted the FSI's significant role in cryptocurrency markets, particularly during times of heightened uncertainty.

For instance, Sun *et al.* (2023) employed a Vector Error Correction Model (VECM) to analyze Bitcoin price dynamics before and during the COVID-19 pandemic. Their results revealed that financial stress, alongside blockchain fundamentals (hashrate, transaction volume) and social media sentiment, significantly impacted Bitcoin in both the short and long term. This underscored the importance of combining macro-financial indicators and behavioral signals to understand price fluctuations.

Similarly, Bouri *et al.* (2018) investigated the dependence structure between the global FSI and Bitcoin returns from 2010 to 2017. They found right-tail dependence and significant Granger causality at distribution tails, suggesting that Bitcoin might have acted as a safe-haven asset during periods of extreme financial stress, even though its medium-term predictability remained limited.

Nur and Korkmaz (2022) applied GARCH and IGARCH models over a decade of data (2011–2021) and identified a positive volatility spillover from the FSI to Bitcoin. Their impulse-response analysis also confirmed a bidirectional relationship, indicating that cryptocurrency markets not only reacted to but also contributed to systemic stress, especially during periods of financial turbulence.

Yin *et al.* (2024) took a machine learning approach, employing a Graph Neural Network (GNN) to forecast the prices of Bitcoin, Ethereum, Litecoin, and Dash Coin, integrating Tether (USDT) and FSI data. Their findings emphasized that financial stress and its sub-components significantly enhanced predictive model performance, reinforcing the FSI's value in data-driven risk management strategies.

Zhang and Wang (2021) extended the analysis to cross-market comparisons, examining the effects of financial stress on Bitcoin and gold in both the U.S. and China. Their study, set against the backdrop of immigration crises and the China-U.S. trade conflict, found that both assets exhibited sensitivity to financial stress, particularly over short-term horizons – further confirming the responsive nature of cryptocurrencies to geopolitical and systemic shocks.

2.3. Economic policy uncertainty and the cryptocurrency market

Economic policy uncertainty (EPU) is a crucial macroeconomic risk factor that influences investment decisions, capital flows, and financial stability. As uncertainty surrounding government policies increases, investors often adjust their portfolios, which can lead to changes in asset prices, including those of cryptocurrencies. Due to the global nature of digital assets, EPU can generate spillover effects across different markets (Kang and Yoon, 2019).

The EPU index, originally developed by Baker *et al.* (2016), captures fluctuations in policy-related economic uncertainty and has become a widely used tool in analyzing financial market behavior. Demir *et al.* (2018), using vector autoregression (VAR) models, demonstrated a negative and significant relationship between EPU and Bitcoin returns, suggesting that high policy uncertainty prompts investors to reduce exposure to cryptocurrencies.

Mokni (2021) employed quantile regression and causality-in-quantiles approaches to show that EPU significantly predicted Bitcoin's returns and volatility across different market

states, especially during periods of heightened turbulence. This reinforced the idea that cryptocurrency markets were sensitive to macro-level policy risks.

Yen and Cheng (2021), applying the heterogeneous autoregressive realized volatility (HAR-RV) model, found that China's EPU had a significant effect on the volatility of Bitcoin and Litecoin. Their findings emphasized the importance of region-specific uncertainty in shaping global cryptocurrency dynamics.

Huynh *et al.* (2021) used a nonlinear ARDL (NARDL) framework to explore asymmetries in the relationship between global EPU and Bitcoin's trading activity. They observed that higher EPU levels tended to suppress trading volumes and increase volatility, signaling heightened investor caution.

Paule-Vianez *et al.* (2020), utilizing GARCH and copula-based models, revealed that Bitcoin acted as a safe haven during periods of extreme EPU, with both returns and volatility responding positively to uncertainty shocks. Similarly, Al-Shboul *et al.* (2023), using the Diebold-Yilmaz volatility spillover framework, found that EPU contributed to cross-market volatility transmission between fiat currencies and cryptocurrencies, highlighting the growing integration of crypto markets into the global financial system.

Salisu *et al.* (2023) adopted a predictive regression framework to show that EPU served as a leading indicator for financial market volatility, while He *et al.* (2024), using a regime-switching model, demonstrated that although EPU had a limited influence on crypto markets in the short run, Bitcoin and Ethereum could still serve as short-term hedging instruments during periods of heightened uncertainty.

Despite extensive research on factors influencing cryptocurrency returns and volatility, limited attention has been given to the dynamics of cryptocurrency crises. In particular, there is a lack of empirical studies that integrate behavioral and macroeconomic factors – such as investor sentiment, financial stress, and economic policy uncertainty – in explaining crisis episodes in major cryptocurrencies like Bitcoin, Ethereum, and Ripple.

This study addresses this gap by systematically analyzing the drivers of cryptocurrency crises. By integrating both behavioral and macro-financial indicators, it aims to offer practical insights for investors and policymakers seeking to better anticipate and manage extreme market events.

3. METHODOLOGY

In this study, we first identify crisis periods in Bitcoin, Ethereum, and Ripple using the CMAX approach (current index level relative to historical maximum), as proposed by Patel and Sarkar (1998). We then examine the determinants of these cryptocurrency crises using both the probit and the logit models.

The following sections detail the implementation of the CMAX methodology and the specification of the econometric models employed in the analysis.

3.1. Cryptocurrency crisis detection: CMAX approach description and sensitivity analysis of threshold choice

This section describes the methodology used to detect cryptocurrency crises using the CMAX approach and presents a sensitivity analysis to validate the robustness of the chosen threshold level.

3.1.1. CMAX methodology for crisis detection

To detect **cryptocurrency crises**, we used the CMAX methodology suggested by Patel and Sarkar (1998). This method involves calculating the ratio of the current cryptocurrency price at time t to its maximum value over a specified period.

$$CMAX_{it}= P_{it}/ \max [P_{it,lag...,}P_{it}] \quad (1)$$

where: P_{it}: the level of cryptocurrency price i at time t.

A cryptocurrency crisis is identified when the CMAX value for a specific cryptocurrency i at time t falls below the average CMAX for that cryptocurrency minus 1.5 standard deviations (which can be considered a threshold level).

The indicator representing the cryptocurrency crisis of cryptocurrency i at time t, Ci,t, is defined as:

$$C_{it}=1, \text{ if } CMAX_{it}< CMAX\text{-}1.5\ \sigma_i \quad (2)$$
$$C_{it}=0, \text{ otherwise}$$

Following the study by Ben Yaala and Henchiri (2024b, 2025a), we define the beginning date of the crisis, the trough date, the recovery date, and the amplitude as the key dimensions of the crisis.

The beginning of the crisis "the peak" corresponds to the day when the cryptocurrency price reaches its maximum prior to the day when the critical level is exceeded.

The trough date corresponds to the day on which the cryptocurrency price reaches its minimum level during the crisis.

The recovery date is defined as the day on which the cryptocurrency price regains its maximum level reached before the crash.

The duration of crises is the time elapsed between the date of the start of the crisis and the date of recovery of the loss.

The amplitude corresponds to the maximum loss observed during the crisis, i.e. the variation of the cryptocurrency price between the peak and the trough.

3.1.2. Sensitivity analysis of threshold choice

To ensure the robustness of our crisis identification approach using the CMAX method, we conducted a sensitivity analysis by varying the threshold level used to define a crisis. While the baseline threshold was set at 1.5 standard deviations below the average CMAX, we also tested alternative thresholds of 1.3 and 1.7 standard deviations.

3.2. Model selection, specification, and diagnostic checking

In this section, we describe the model selection process, specify the models used to analyze the risk of cryptocurrency crises, and discuss the diagnostic checks performed to ensure robustness.

3.2.1. Model selection

To analyze the risk of crises, we focus on limited dependent variable regression models suitable for binary outcomes. The dependent variable in our study is qualitative, taking the value 1 if a crisis occurs and 0 otherwise, which makes probit and logit models appropriate choices.

We initially consider both the probit and logit models due to their widespread use in binary outcome modeling:

- The probit model assumes that the error terms follow a standard normal distribution. It models the probability of crisis occurrence as:

$$\text{Prob}\,(\text{CRISIS}_i = 1 \mid X_i, \beta) = F\,(X_i' \ , \beta) \tag{3}$$

with:

F: distribution function of the reduced centered normal law

X_i: vector of exogenous variables

β: vector of parameters to be estimated.

- The logit model assumes a logistic distribution of the error terms. The probability function is given by:

$$\text{Prob}\,(\text{CRISIS}_i = 1 \mid X_i, \beta) = \Phi\,(X_i' \ , \beta) = \frac{1}{1+e^{-X_i' \ \beta}} \tag{4}$$

with:

Φ: logistic cumulative distribution function

Variables description

After presenting the general framework of the models, we proceed with a detailed description of all the variables used in the analysis.

- **Dependent variable**

The CRISIS variable is a binary variable and appears as the endogenous variable of the models. It takes the following two values:

$$\text{CRISIS}_t = \begin{cases} 1 & \text{For crisis periods} \\ 0 & \text{For quiet periods} \end{cases}$$

- **Explanatory variables**

The model's explanatory variables include various factors, such as stock market returns and volatility, the financial stress index, economic policy uncertainty, and behavioral variables like investors' optimistic and pessimistic sentiments.

Cryptocurrency market performance: indicator of price acceleration

To capture price acceleration, we incorporated year-on-year cryptocurrency price changes into our models. This measure is computed as the logarithmic ratio of the closing price at time *t* to the closing price at time *t – n*.

$$R_t = ln\left(\frac{P_t}{P_{t-n}}\right) \tag{5}$$

with:

R_t: The return of the cryptocurrency price on day (t).

P_t: The price of the cryptocurrency on day (t).

P_{t-n}: The price of the cryptocurrency on the day (t-n).

Returns volatility

In order to calculate the cryptocurrency volatility, we used the GARCH (1,1) modeling developed by Bollerslev (1986). The GARCH (1,1) process is written in the following form:

Mean equation: $R_t = \mu + \varepsilon_t$ (6)

Conditional variance equation: $\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2$ (7)

with:

σ_t^2 : is the conditional variance of the GARCH model.

εt: Are residues

ω, α and β: are coefficients and must satisfy the following conditions: $\omega > 0$, $\alpha \geq 0$, $\beta \geq 0$

Optimistic and pessimistic investor sentiment

To measure the optimistic and pessimistic sentiments of investors, we employed a direct measure obtained from the search volume of terms on Google Trends. Google Trends provides the search volume of words on a specific topic as a proportion of all searches within a given location and time frame, normalized to a scale of 0 to 100, where 100 signifies a high search activity.

To calculate the sentiment index, we curated two sets of twenty words each: one set comprising positive words and the other negative words, all relevant to the cryptocurrency domain. These sets were selected based on keywords such as "Cryptocurrency," "Bitcoin," "Digital Currency," "Ripple," "Blockchain," and "Ethereum."

Following a methodology similar to Da *et al.* (2011), we mitigated the effects of seasonality present in the time series of word search volume by regressing each term on daily binary variables and retained the residuals. Subsequently, we standardized each residual series by its standard deviation to ensure comparability across all series.

The subsequent step in constructing the sentiment indices involved identifying the most significant search terms for the crisis variable by examining the historical relationship between each term and the crisis variable. We selected the top 20 search terms (10 positive words and 10 negative words) with the highest correlation with the crisis variable.

Finally, we applied principal component analysis to the two groups of positive and negative words obtained from Google Trends to derive the optimistic and pessimistic sentiment of investors, as described in Da *et al.* (2015) and García Petit *et al.* (2019).

The financial stress index

To assess the influence of financial uncertainty on cryptocurrency crises, we employ the Financial Stress Index (FSI). The FSI, as conceptualized by Borio and Lowe (2002), is a composite measure that captures various dimensions of financial stress, including stock market volatility, credit spreads, interest rate spreads, banking sector health, liquidity measures, and exchange rate volatility. This index provides a comprehensive measure of the overall level of financial instability in the financial system.

The economic policy uncertainty

As a measure of Economic Policy Uncertainty (EPU), we utilized the daily US EPU index as developed by Baker *et al.* (2016) (available at policyuncertainty.com). This index is constructed based on the frequency of newspaper articles in the US that contain at least one of the following combinations of terms: "economy" or "economic"; "uncertain" or "uncertainty"; and "legislation", "deficit", "regulation", "Congress", "Federal Reserve", or "White House".

3.2.2. Model specification

To analyze the explanatory factors behind cryptocurrency crises, we estimate a binary response model where the dependent variable indicates the presence (1) or absence (0) of a crisis. The probability that a crisis occurs at time t is modeled as a function of key economic and behavioral variables:

$$\Pr(CRISIS_t=1)=f(\alpha_1+\beta_1(RETURN)_t+\beta_2(VOLATILITY)_t+\beta_3(OPTIMISM)_t+\beta_4(PESSIMISM)_t+\beta_5(FSI)_t+\beta_6(EPU)_t+\epsilon_{1,t}) \quad (8)$$

with:

CRISIS : Cryptocurrency crises
RETURN : Cryptocurrency return
VOLATILITY: Cryptocurrency volatility
OPTIMISM: Optimistic investor sentiment derived from Google Trends
PESSIMISM: Pessimistic investor sentiment derived from Google Trends
FSI: Financial stress index
EPU: Economic policy uncertainty

We apply both the probit and logit models to each of the three cryptocurrencies – Bitcoin, Ethereum, and Ripple – independently. This separate estimation strategy allows us to capture the distinct dynamics and sensitivities of each cryptocurrency to the selected explanatory variables.

3.2.3. Robustness checks

To evaluate the performance of the estimated probit/logit models, we compared the predicted probabilities with the actual occurrence of cryptocurrency crises. As illustrated in Table no. 1, four scenarios can arise: correct crisis prediction (Type C), correct calm prediction (Type D), missed crisis (Type A error), and false alarm (Type B error). The goal is to minimize Type A and Type B errors while maximizing correct predictions.

In line with the methodologies proposed by Boucher (2004) and Coudert and Gex (2008), we present our evaluation results using two probability thresholds: 50% and 25%. These thresholds represent the minimum probability level at which a crisis signal is issued. A threshold of 50% reflects a stricter criterion – only higher predicted probabilities trigger crisis warnings, favoring specificity (reducing false positives). Conversely, a 25% threshold is more lenient, favoring sensitivity (reducing missed crises) by issuing warnings at lower predicted probabilities. Presenting results at both levels allows us to assess the trade-off between

detecting true crises and avoiding false alarms, thus offering a more comprehensive evaluation of model performance.

Table no. 1 – Performance evaluation of probit/logit models

		Model prediction	
		Transmitted signal	**No signal transmitted**
Effective crises	CRISIS=0	Correct crisis announcement (C)	type A error; signal missing
	CRISIS=1	type (B) error; false alarm	correct non-crisis announcement (D)

Source(s): authors' own creation

4. DATA

Our sample comprises both fundamental data (returns, volatility, Financial Stress Index, and Economic Policy Uncertainty) and behavioral data (optimistic and pessimistic sentiment of investors obtained via Google Trends). All data were collected at daily frequencies. For returns and volatility, we considered the prices of three cryptocurrencies, Bitcoin, Ethereum and Ripple, obtained from the website investing.com. The direct measure of optimistic and pessimistic sentiment was derived from relevant positive and negative keywords extracted from Google Trends. The Financial Stress Index and Economic Policy Uncertainty were gathered from the website policyuncertainty.com.

Price data span from July 18, 2010, to December 31, 2023, for Bitcoin; from March 10, 2016, to December 31, 2023, for Ethereum; and from January 22, 2016, to December 31, 2023, for Ripple, to examine the factors determining crises in each cryptocurrency.

5. RESULTS

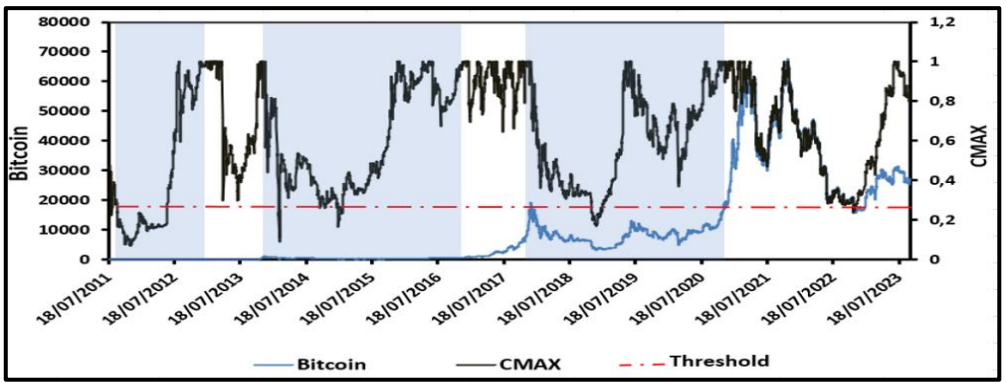
5.1. Cryptocurrency crises detection and analysis results

This section presents the results of crisis detection for Bitcoin, Ethereum, and Ripple using the CMAX method and evaluates the robustness of these results with respect to the choice of threshold.

5.1.1. Cryptocurrency crises detection results

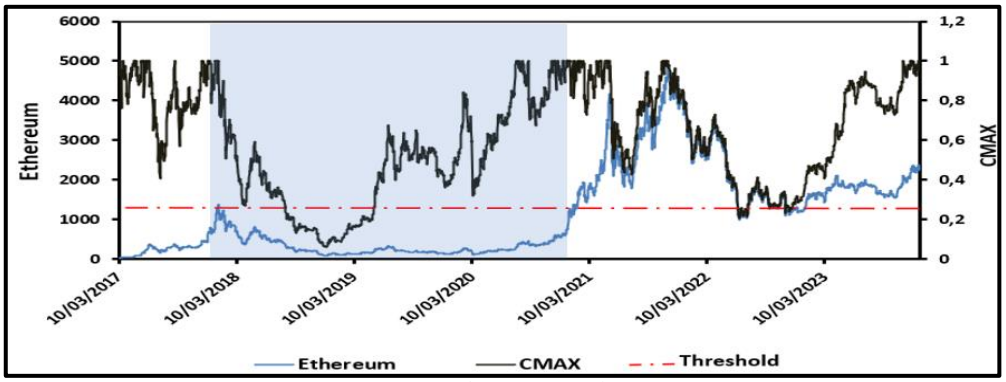
Using the CMAX method, we define the CMAX indicator as equals to 1 when cryptocurrency prices exhibit an upward trend over the analyzed period, indicating a bullish scenario. As prices decline, the CMAX value approaches 0. A crash is identified only when the price reaches its lowest point after exceeding a specified threshold.

Figures no. 1 to no. 3 illustrate the price trends of the cryptocurrencies and their alignment with the CMAX indicator.



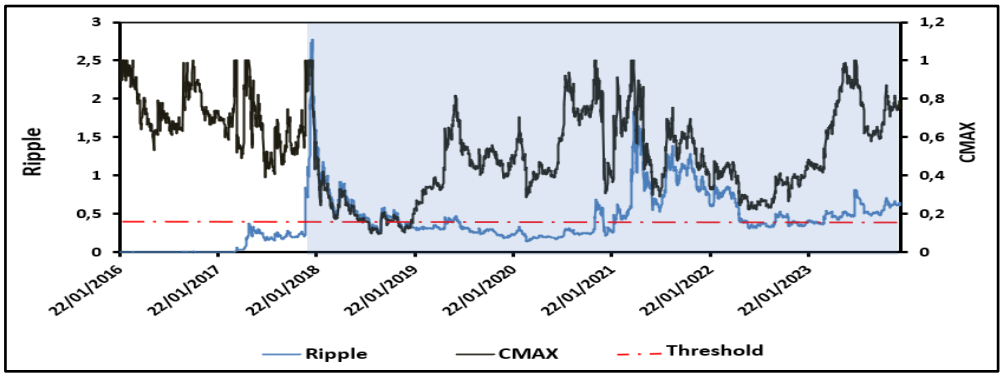
Source: authors' own creation

Figure no. 1 – The relationship between the Bitcoin price and the CMAX indicator from 2011 to 2023



Source: authors' own creation

Figure no. 2 – The relationship between the Ethereum price and the CMAX indicator from 2017 to 2023



Source: authors' own creation

Figure no. 3 -The relationship between the Ripple price and the CMAX indicator from 2017 to 2023

5.1.1.1. Bitcoin crises identified

Three major crises have marked the history of Bitcoin, each characterized by a significant drop in its price followed by a period of recovery. The first crisis, from 25/07/2011 to 12/01/2013, lasted 1 year, 5 months, and 18 days, with a magnitude of 6.05%. This crisis coincides with the European sovereign debt crisis, illustrating Bitcoin's vulnerability to major economic disruptions.

The second crisis, from 04/12/2013 to 02/03/2017, lasted 3 years, 2 months, and 26 days, and was marked by a magnitude of 10.09%, indicating a sharper decline and a slower recovery. This crisis was strongly influenced by the collapse of the Mt. Gox exchange in 2014, highlighting the impact of specific events within the cryptocurrency ecosystem on its volatility.

Finally, the crisis from 16/12/2017 to 30/11/2020 lasted 3 years, with a magnitude of 5%. This crisis occurred during a period of increased cryptocurrency regulation and the COVID-19 pandemic, which heightened uncertainty in financial markets.

Table no. 2 presents the three crises identified in Bitcoin.

Table no. 2 – Crises identified by the CMAX approach in Bitcoin

The beginning of the crisis	The date of trough	The date of recovery	The duration of the crisis		Magnitude (%)
			From the beginning of the crisis to the trough	From the trough to the recovery	
25/07/2011	18/11/2011	12/01/2013	3 months and 23 days	1 year, 1 month, and 25 days	6.05
04/12/2013	21/02/2014	02/03/2017	2 months, and 17 days	3 years, and 9 days	10.09
16/12/2017	15/12/2018	30/11/2020	11 months, and 15 days	2 years, and 15 days	5

Note: The lapse of time between the beginning of the crisis and the date of the through correspond to the duration of the crash.

Source: authors' own creation

5.1.1.2. Ethereum crises identified

Applying the CMAX approach to the price of Ethereum, we identified a single crisis that began on January 13, 2018, and extended until January 24, 2021. This crisis, marked by a prolonged decline in prices of 15.47%, reached its lowest point on December 14, 2018. The crisis period lasted for 3 years and 27 days. This period was characterized by a series of regulatory crackdowns on cryptocurrencies globally and the economic disruptions caused by the COVID-19 pandemic, which contributed to significant market instability.

Table no. 3 presents the three crises identified in Ethereum.

Table no. 3 – Crisis identified by the CMAX approach in Ethereum

The beginning of the crisis	The date of trough	The date of recovery	The duration of the crisis		Magnitude (%)
			From the beginning of the crisis to the trough	From the trough to the recovery	
13/01/2018	14/12/2018	24/01/2021	11 months, and 17 days	2 years, 1 month, and 10 days	15.47

Note: The lapse of time between the beginning of the crisis and the date of the through correspond to the duration of the crash.

Source: authors' own creation

5.1.1.3. Ripple crisis identified

The Ripple crisis, identified by the CMAX approach, began on January 17, 2018, and reached its lowest point on March 12, 2020. Lasting over two years, Ripple's value declined by 19.44%, with no recovery yet observed. This prolonged crisis highlights the significant and ongoing challenges Ripple has faced in recovering its market value.

Table no. 4 summarizes the crisis identified in Ripple.

Table no. 4 – Crisis identified by the CMAX approach in Ripple

The beginning of the crisis	The date of trough	The date of recovery	The duration of the crisis		Magnitude (%)
			From the beginning of the crisis to the trough	From the trough to the recovery	
17/01/2018	12/03/2020	Not yet	02 years, 01 month, and 24 days	-	19.44

Note: The lapse of time between the beginning of the crisis and the date of the through correspond to the duration of the crash.

Source: authors own work

Cryptocurrency crises highlight their sensitivity to global economic events and regulatory shifts, which significantly influence market stability and investor sentiment. External shocks – such as the European sovereign debt crisis or regulatory responses during the COVID-19 pandemic – underscore the strong link between cryptocurrencies and the broader financial environment.

5.1.2. Robustness of crisis detection to threshold choice

The results of the sensitivity analysis confirm that the crisis periods identified for Bitcoin, Ethereum, and Ripple remained consistent across various threshold values. This stability demonstrates that the CMAX method generates robust and reliable crisis signals. The fact that crisis detection is not dependent on a specific threshold reinforces the methodological soundness and credibility of our identification approach.

5.2. Descriptive statistics analysis

Table no. 5 presents the descriptive statistics for Bitcoin (Panel A), Ethereum (Panel B), and Ripple (Panel C). The variables include the frequency of crisis periods (expressed as a

proportion of total trading days), daily returns and volatility (expressed in decimal form), investor sentiment indices—OPTIMISM and PESSIMISM (in index points)—as well as macroeconomic indicators, namely the Financial Stress Index (FSI) and Economic Policy Uncertainty Index (EPU), both measured in index units. In addition to central tendency and dispersion (mean and standard deviation), distributional characteristics such as skewness, kurtosis, and the Jarque-Bera test for normality are also reported.

Bitcoin experienced crises on 61.64% of trading days. Its average return is 0.0018 (equivalent to 0.18%) with a standard deviation of 0.0541 (5.41%). Returns are highly positively skewed (3.58) and extremely leptokurtic (156.94), suggesting frequent large positive deviations. Volatility averages 0.0424 (4.24%), with strong right skewness (6.42) and high kurtosis (76.03), reflecting substantial tail risk. The average investor sentiment indices are 4.17 (OPTIMISM) and 3.04 (PESSIMISM). FSI and EPU average 100.31 and 176.49, respectively, both showing leptokurtic behavior. All distributions significantly deviate from normality according to the Jarque-Bera test.

Ethereum has a crisis frequency of 44.55%. The average return is 0.00192 (0.192%) with a standard deviation of 0.0523 (5.23%). The return distribution is slightly negatively skewed (–0.60) and leptokurtic (12.91). Volatility averages 0.0497 (4.97%) and shows moderate skewness (1.50) and kurtosis (7.45). Sentiment indices average 4.01 (OPTIMISM) and 3.00 (PESSIMISM), with both distributions displaying leptokurtosis. FSI (100.15) and EPU (213.35) also show leptokurtic characteristics. All variables reject normality.

Table no. 5 – Descriptive statistics

Variables	Mean	Max	Min	Std. Dev	Skewness	Kurtosis	Jarque Bera	Prob
Panel A: Descriptive statistics of Bitcoin								
CRISIS	0.6164	1	0	0.4863	-0.4788	1.2292	768.12	0.000
RETURN	0.0018	1.4741	-0.8488	0.0541	3.5758	156.938	4501250	0.000
VOLATILITY	0.0424	0.5101	0.0132	0.0281	6.4231	76.0323	1042252	0.000
OPTIMISM	4.1719	7.4067	-0.8621	1.2898	1.4194	4.98653	2275.582	0.000
PESSIMISM	3.0439	8.3713	-0.4835	1.0072	2.5034	10.6378	15808.95	0.000
FSI	100.31	103.31	99.0589	0.6340	1.5750	6.85630	4699.424	0.000
EPU	176.49	428.98	90.3272	65.887	1.1927	4.22765	1364.274	0.000
Panel B: Descriptive statistics of Ethereum								
CRISIS	0.4455	1	0	0.4971	0.2192	1.0481	414.739	0.000
RETURN	0.00192	0.2586	-0.5896	0.0523	-0.5959	12.906	10317.03	0.000
VOLATILITY	0.04973	0.1492	0.0172	0.0172	1.4964	7.4518	2981.868	0.000
OPTIMISM	4.01067	7.4067	-0.8621	1.3745	0.9309	3.9356	449.9206	0.000
PESSIMISM	3.00280	8.3712	-0.4835	1.1939	1.8775	7.2969	3374.545	0.000
FSI	100.152	101.91	99.0589	0.4851	0.9400	4.8726	729.6837	0.000
EPU	213.3454	428.98	105.5618	65.943	0.8034	3.4592	289.4178	0.000
Panel B: Descriptive statistics of Ripple								
CRISIS	0.7534	1	0	0.4310	-1.1760	2.383175	714.508	0.000
RETURN	0.00164	1.0279	-0.6533	0.0669	2.05198	37.29171	144125.6	0.000
VOLATILITY	0.00509	0.4052	0.00129	0.0144	17.0815	408.3479	19994.47	0.000
OPTIMISM	4.11563	7.4067	-0.8621	1.3638	1.00222	4.031833	614.1347	0.000
PESSIMISM	3.274388	8.3713	-0.4835	1.1613	1.93509	7.523891	4282.815	0.000
FSI	100.1528	101.91	99.0589	0.4687	0.92883	4.951589	877.2100	0.000
EPU	199.1701	428.98	92.6370	70.383	0.76360	3.261701	290.1041	0.000

Notes: CRISIS variable represents the proportion of trading days classified as crisis periods, ranging from 0 to 1. RETURN and VOLATILITY are reported in decimal terms. OPTIMISM, PESSIMISM, FSI, and EPU are reported as index values.

Source: authors' own creation

Ripple exhibits the highest crisis frequency at 75.34%. The average return is 0.00164 (0.164%) with a standard deviation of 0.0669 (6.69%). Returns are positively skewed (2.05) and strongly leptokurtic (37.29). Volatility is lower on average (0.0051, or 0.51%) but extremely skewed (17.08) and highly leptokurtic (408.35), suggesting rare but severe price swings. Sentiment indicators average 4.12 (OPTIMISM) and 3.27 (PESSIMISM). FSI (100.15) and EPU (199.17) also display strong leptokurtosis. The Jarque-Bera test rejects normality for all variables.

Overall, all three cryptocurrencies exhibit leptokurtic return and volatility distributions, with Bitcoin and Ripple displaying particularly heavy tails – underscoring their vulnerability to extreme market events.

5.3. Estimation results of the probit and logit model explaining cryptocurrency crises and diagnostic checking results

We report the results of simultaneously estimating both probit and logit models to identify the economic and behavioral determinants of cryptocurrency crises, along with relevant diagnostic checks.

5.3.1. Estimation result of probit model explaining cryptocurrency crises

Table no. 6 presents the estimation results of the probit models, which reveal that the explanatory frameworks for Bitcoin, Ethereum, and Ripple crises are both statistically robust and well-specified. Each model demonstrates a strong goodness-of-fit, as evidenced by relatively high McFadden R^2 values and highly significant likelihood ratio (LR) statistics. These indicators support the reliability and validity of the models in capturing the key economic and behavioral determinants of cryptocurrency crises, thereby reinforcing confidence in the empirical findings.

Across all three cryptocurrencies, RETURN is negatively associated with the probability of crises. This indicates that higher returns reduce the likelihood of a crisis, likely because rising returns boost investor confidence and mitigate panic-driven sell-offs. This finding aligns with previous studies by Patel and Sarkar (1998), and Zouaoui *et al.* (2011), which also found a negative relationship between returns and crisis risk.

VOLATILITY emerges as a significant driver of crises across Bitcoin, Ethereum, and Ripple. The positive and significant association suggests that increased price fluctuations raise the probability of a crisis. Higher volatility often signals market uncertainty, instability, and speculative activity, making the market more susceptible to sharp corrections. These results are consistent with the findings of Choudhry (1996); Aggarwal *et al.* (1999); Fang (2001); Ben Yaala and Henchiri (2025b), who showed that elevated volatility increases the likelihood of financial crises.

The role of optimistic sentiment varies across the three assets. For Bitcoin and Ripple, excessive optimism significantly increases the probability of a crisis, implying that overconfidence and speculative behavior may inflate asset prices beyond their fundamentals, thereby increasing vulnerability to sudden reversals. This behavior reflects phenomena such as FOMO (fear of missing out) and momentum trading. These results are consistent with Anamika and Subramaniam (2022); Güler (2023), who found that optimistic sentiment positively affects returns and volatility through speculative trading. They are also supported by Ben Yaala and Henchiri (2024a), who emphasized the role of investor irrationality in

predicting market crashes. However, optimism does not have a statistically significant effect on Ethereum crises, suggesting that Ethereum's investor base may be less influenced by emotional overreactions or speculative surges.

Pessimistic sentiment consistently exhibits a positive and significant effect on crisis probability across all three cryptocurrencies. Heightened pessimism increases risk aversion, often triggering widespread sell-offs and contributing to abrupt market downturns. These results support the findings of Bouri *et al.* (2021), who demonstrated that extreme investor sentiments, whether optimistic or pessimistic, significantly influence market volatility and the likelihood of crises.

The Financial Stress Index is positively associated with crisis occurrence in Bitcoin, Ethereum, and Ripple. Periods of elevated financial stress—characterized by tighter liquidity, credit constraints, and broader financial disruptions—tend to spill over into cryptocurrency markets. In such environments, investors often retreat from risky assets, amplifying the likelihood of sharp price declines. This result is consistent with the research of Bouri *et al.* (2018); Nur and Korkmaz (2022), who found that financial stress can trigger panic selling and increase the risk of cryptocurrency crises.

Economic policy uncertainty also plays a significant role in explaining cryptocurrency crises. The models reveal a strong and positive association between uncertainty and crisis occurrence for all three assets. Political and regulatory unpredictability weakens investor confidence and increases market volatility. While some investors may view cryptocurrencies as safe havens during uncertain periods, the speculative flows they attract can heighten market fragility and crisis susceptibility. These findings are supported by Demir *et al.* (2018); Mokni (2021), who showed that rising economic uncertainty drives both investor reallocation toward alternative assets and an increase in market volatility and crisis risk.

Table no. 6 - Estimation result of probit model explaining cryptocurrency crise

Variables	Coefficient	Prob	Average Marginal Effect	Interpretation of Marginal Effect
Estimation Results of the Probit Model Aiming to Determine the Explanatory Factors of Bitcoin Crises				
RETURN	-1.280543***	0.0010	-0.343804	A one-unit increase in return reduces the probability of a Bitcoin crisis by approximately 34.38 percentage points, suggesting that strong market performance significantly lowers the likelihood of a crisis.
VOLATILITY	1.272397***	0.0000	0.341617	Higher volatility increases crisis probability by 34.16 percentage points, suggesting that market uncertainty and price swings heighten perceived risk.
OPTIMISM	0.083702***	0.0038	0.0022472	Rising investor optimism increases crisis probability by 0.22 percentage points, possibly reflecting overconfidence and speculative behavior.
PESSIMISM	0.015384***	0.0002	0.0041303	Increased pessimism raises crisis probability by 0.41percentage points, reflecting sensitivity to negative investor sentiment.
FSI	0.548133***	0.0001	0.147164	A higher Financial Stress Index raises crisis probability by 14.72 percentage points, highlighting the influence of systemic macro-financial stress on Bitcoin stability.
EPU	0.013790***	0.0000	0.003702	Economic policy uncertainty increases crisis probability by 0.37 percentage points, suggesting that political and policy instability affects investor behavior.
C	7.81031***	0.0000		
R^2 McFadden			0.55	
LR stat (prob)			0.000	

Variables	Coefficient	Prob	Average Marginal Effect	Interpretation of Marginal Effect
Estimation Results of the Probit Model Aiming to Determine the Explanatory Factors of Ethereum Crises				
RETURN	-1.041807*	0.0512	-0.323188	A one-unit increase in return marginally reduces the probability of an Ethereum crisis by approximately 32.32 percentage points. This implies that stronger market performance significantly lowers crisis risk.
VOLATILITY	12.70908***	0.0000	3.94259	A one-unit increase in volatility raises the probability of an Ethereum crisis by approximately 394.26 percentage points, indicating that Ethereum is highly sensitive to market instability.
OPTIMISM	0.0082457	0.2216	0.00255	Not statistically significant — suggests that optimism does not significantly predict Ethereum crises.
PESSIMISM	0.0547422***	0.0032	0.016982	A one-unit increase in pessimism raises the probability of an Ethereum crisis by about 1.70 percentage points, indicating that investor fear heightens vulnerability to crises.
FSI	1.356534***	0.0006	0.420822	A one-unit increase in the Financial Stress Index increases Ethereum crisis probability by 42.08 percentage points, showing that financial stress significantly affects crypto markets.
EPU	0.0091144***	0.0000	0.002827	A one-unit increase in Economic Policy Uncertainty raises the probability of an Ethereum crisis by approximately 0.28 percentage points, suggesting that macroeconomic or regulatory shocks contribute to crisis risk.
C	9.107425***	0.0000		
R^2 McFadden			0.47	
LR stat (prob)			0.0000	
Estimation Results of the Probit Model Aiming to Determine the Explanatory Factors of Ripple Crises				
RETURN	-2.493692***	0.0048	-0.345482	A one-unit increase in return reduces crisis probability by 34.55 percentage points.
VOLATILITY	44.71839***	0.0000	6.195393	Volatility greatly increases crisis risk by 619.54 percentage points, showing Ripple's high sensitivity to market swings
OPTIMISM	0.1678186***	0.0049	0.02325	Optimism raises crisis risk by 2.33 percentage points, suggesting investor overconfidence.
PESSIMISM	0.1413014***	0.0000	0.0195762	Pessimism increases crisis likelihood by 1.96 percentage points, reflecting fear-driven market sentiment.
FSI	0.3974585***	0.0003	0.0550649	Financial stress increases the probability of a Ripple crisis by 5.51 percentage points ,
EPU	0.0327339***	0.0000	0.004535	Economic policy uncertainty raises crisis probability by 0.45 percentage points.
C	08.24941***	0.0000		
R^2 McFadden			0.51	
LR stat (prob)			0.0000	

Notes: *, ** and *** imply significance at the 10, 5 and 1 percent levels. Average Marginal Effects (AMEs) are computed using the Delta-method after estimating the Probit. The command margins, dydx(*) in Stata is used to derive the marginal effect of each explanatory variable on the probability of a crisis.

Source: authors' own creation

5.3.2. Estimation result of Logit model explaining cryptocurrency crises

The estimation results of the logit models in Table no. 7, which aim to identify the determinants of crises in Bitcoin, Ethereum, and Ripple markets, reveal consistent and statistically significant relationships across all three cryptocurrencies. The McFadden R^2 values, ranging from

0.55 to 0.57, indicate a strong model fit, suggesting that the selected explanatory variables account for a substantial proportion of the variation in crisis occurrence. Across all models, return, volatility, pessimistic sentiment, financial stress, and economic policy uncertainty emerge as significant predictors. Specifically, higher returns are associated with a lower probability of crises, while increased volatility, greater pessimism, elevated financial stress, and heightened economic policy uncertainty significantly raise the likelihood of crisis episodes.

However, the effect of investor optimism, measured via Google Trends, appears to be cryptocurrency-specific. While optimism significantly increases crisis risk for Bitcoin and Ripple, it is not statistically significant for Ethereum, suggesting that positive investor sentiment does not play a decisive role in the occurrence of Ethereum crises. This heterogeneity highlights the importance of considering market-specific behavioral dynamics when analyzing the drivers of instability in cryptocurrency markets.

Table no. 7 – Estimation result of Logit model explaining cryptocurrency crise

Variables	Coefficient	Prob	Average marginal effect	Interpretation of Marginal Effect
Estimation Results of the Logit Model Aiming to Determine the Explanatory Factors of Bitcoin Crises				
RETURN	-2.095422***	0.0007	-0.327037	A one-unit increase in return decreases the probability of a Bitcoin crisis by 32.70 percentage points, indicating that stronger market performance reduces crisis risk.
VOLATILITY	1.997939***	0.0000	0.311823	A one-unit increase in volatility raises the likelihood of a Bitcoin crisis by 31.18 percentage points, highlighting that market instability significantly contributes to crisis occurrence.
OPTIMISM	0.144596***	0.0011	0.225675	Greater investor optimism raises the crisis probability by 2.26 percentage points, possibly due to speculative bubbles or overconfidence.
PESSIMISM	0.026001***	0.0001	0.004056	Pessimism increases the probability of a crisis by 0.41 percentage points, reflecting the influence of fear-driven investor reactions on market vulnerability.
FSI	0.934974***	0.0000	0.145923	A 1-unit rise in the Financial Stress Index increases crisis risk by 14.59 percentage points, confirming that systemic financial tension destabilizes Bitcoin markets.
EPU	0.023144***	0.0000	0.003612	A 1-unit increase in Economic Policy Uncertainty raises crisis probability by 0.36 percentage points, highlighting vulnerability to policy shifts.
C	07.55290***	0.0000		
R^2 McFadden			0.57	
LR stat (prob)			0.0000	
Estimation Results of the Logit Model Aiming to Determine the Explanatory Factors of Ethereum Crises				
RETURN	-1.796719*	0.0481	-0.33415	A one-unit increase in return reduces the probability of an Ethereum crisis by approximately 33.42 percentage points indicating that positive performance helps mitigate crisis risk.
VOLATILITY	21.52627***	0.0000	4.00343	A one-unit increase in volatility increases the likelihood of an Ethereum crisis by

Variables	Coefficient	Prob	Average marginal effect	Interpretation of Marginal Effect
				400.34 percentage points, underscoring the strong sensitivity of Ethereum to market instability.
OPTIMISM	0.0141687	0.2089	0.002635	Not significant, — suggests that optimism does not significantly predict Ethereum crises.
PESSIMISM	0.0912276***	0.0016	0.016966	A one-unit increase in pessimism raises the probability of a crisis by 1.70 percentage points, indicating a notable influence of negative investor sentiment on Ethereum's risk profile.
FSI	2.273135***	0.0004	0.422755	A one-unit increase in the Financial Stress Index raises Ethereum crisis probability by 42.28 percentage points.
EPU	0.015182***	0.0000	0.002823	A one-unit increase in Economic Policy Uncertainty increases Ethereum crisis probability by 0.28 percentage points, highlighting the role of macroeconomic and regulatory shocks.
C	8.9946152***	0.0000		
R^2 McFadden			0.55	
LR stat (prob)			0.0000	
Estimation Results of the Logit Model Aiming to Determine the Explanatory Factors of Ripple Crises				
RETURN	-4.934835***	0.0048	-0.3254279	Higher returns reduce the probability of Ripple crises by approximately 32.54 percentage points, indicating a strong stabilizing effect.
VOLATILITY	92.04943***	0.0000	6.070203	An increase in volatility significantly raises the probability of Ripple crises by about 607.02%.
OPTIMISM	0.3360511***	0.0049	0.02216099	A one-unit increase in optimism raises the probability of crisis by 2.22 percentage points, suggesting a modest destabilizing effect.
PESSIMISM	0.2485564***	0.0000	0.0163911	A one-unit increase in pessimism increases crisis probability by 1.64 percentage points, highlighting a significant risk factor.
FSI	1.034878***	0.0003	0.0136738	A one-unit rise in the Financial Stress Index increases the probability of Ripple crises by 1.37 percentage points.
EPU	0.0685409***	0.0000	0.0045199	Economic Policy Uncertainty raises the probability of crisis by 0.45 percentage points, showing a strong link to policy shocks.
C	07.15745***	0.0000		
R^2 McFadden			0.56	
LR stat (prob)			0.0000	

Notes: *, ** and *** imply significance at the 10, 5 and 1 percent levels. Average Marginal Effects (AMEs) are computed using the Delta-method after estimating the Probit. The command margins, dydx(*) in Stata is used to derive the marginal effect of each explanatory variable on the probability of a crisis.

Source: authors' own creation

5.3.3. Diagnostic checking results

The performance analysis results from the double estimation of the Probit and Logit models for the three cryptocurrencies – Bitcoin, Ethereum, and Ripple – indicate that the models achieve high percentages of correctly predicted crisis episodes. At both the 50% and 25% significance thresholds, the false alarm rates (Type B errors) remain low, further confirming the reliability of the predictive frameworks. These findings underscore the robustness and validity of the estimated models in capturing the dynamics of cryptocurrency crises.

Table no. 8 presents the detailed performance results of the estimated models.

Table no. 8 – Performance analysis results

	Forecast error (%) Probit model		
	Probit model for Bitcoin crises explaining	**Probit model for Ethereum crises explaining**	**Probit model for Ripple crises explaining**
50% threshold			
Type A[1]	15.21	16.85	16.49
Type B[2]	09.74	10.01	09.87
25% threshold			
Type A[1]	13.42	14.56	14.13
Type B[2]	07.12	09.64	08.49
	Logit model		
	Logit model for Bitcoin crises explaining	**Logit model for Ethereum crises explaining**	**Logit model for Ripple crises explaining**
50% threshold			
Type A[1]	14.81	16.42	16.05
Type B[2]	09.25	09.78	09.58
25% threshold			
Type A[1]	13.15	14.22	13.89
Type B[2]	06.92	09.31	08.13

Notes: [1] Probability of having a crisis without any signal emitted
[2] Number of false signals among all signals
Source: authors' own creation

6. DISCUSSION AND CONCLUSION

This study investigates the determinants of crises in the cryptocurrency markets – specifically Bitcoin, Ethereum, and Ripple – by integrating economic fundamentals and behavioral factors such as returns, volatility, investor sentiment, financial stress, and policy uncertainty. Utilizing the CMAX method for crisis detection and probit/logit models for estimation, the research offers a comprehensive framework for understanding cryptocurrency market disruptions.

The crisis detection results reveal that Bitcoin experienced three major crises, Ethereum one prolonged crisis, and Ripple a persistent and unresolved crisis. These crises coincided with global financial shocks (e.g., the European sovereign debt crisis, COVID-19 pandemic),

regulatory crackdowns, and exchange-specific events, reflecting the strong sensitivity of these markets to both macroeconomic conditions and internal vulnerabilities.

The estimation results from both the probit and logit models consistently show that returns act as a stabilizing factor across all three cryptocurrencies—Bitcoin, Ethereum, and Ripple. Higher returns are associated with a decreased probability of crisis, indicating that positive market performance enhances investor confidence and mitigates the likelihood of abrupt downturns. This underscores the importance of return trends as key indicators of market sentiment and perceived asset stability.

Conversely, volatility is identified as a significant driver of crises for all three assets. An increase in volatility reflects heightened market uncertainty and leads to amplified information asymmetry. Informed investors may preemptively adjust their portfolios by reducing their positions, while uninformed investors interpret the volatility as a sign of elevated risk. This dual reaction contributes to a collective decline in demand, intensifies panic behaviors, and raises the frequency of crises. Both models confirm that volatility plays a destabilizing role in cryptocurrency markets.

Regarding investor sentiment, the effects differ across assets. For Bitcoin and Ripple, both optimistic and pessimistic sentiments significantly increase the probability of crises. This reflects the speculative nature of these markets, where extreme positive sentiment can lead to overvaluation and bubble formation, while negative sentiment fuels fear-driven sell-offs. These dynamics align with behavioral finance theories, where emotional overreactions play a crucial role in market disruptions.

In contrast, for Ethereum, only pessimistic sentiment has a statistically significant effect on crisis occurrence. Optimistic sentiment does not appear to contribute meaningfully to crisis risk in this case, suggesting that Ethereum's market participants may be more resilient to euphoric speculation, or that its price dynamics are more fundamentally driven. The use of Google Trends to capture direct sentiment indicators further supports the explanatory power of investor behavior in crisis prediction across all three assets.

The Financial Stress Index (FSI) is another robust predictor, showing a positive and significant relationship with crisis risk in Bitcoin, Ethereum, and Ripple. During periods of elevated financial stress, investors tend to react more strongly to economic shocks, amplifying volatility and increasing the likelihood of market breakdowns. Additionally, financial stress reduces overall liquidity, making cryptocurrency markets more fragile and vulnerable to abrupt corrections.

Similarly, Economic Policy Uncertainty (EPU) significantly increases the probability of crises across all three cryptocurrencies. Political and regulatory uncertainty leads to ambiguous economic expectations, prompting disorderly portfolio adjustments and increased market volatility. Heightened EPU can also influence cryptocurrency regulation and investor behavior, exacerbating market instability. The positive association between EPU and crisis risk emphasizes the sensitivity of cryptocurrencies to the broader policy environment.

Finally, the diagnostic results of the probit and logit models confirm their robustness and predictive validity. Both models achieve high rates of correct crisis predictions and maintain relatively low false alarm rates across different threshold levels. These outcomes underscore the reliability of the selected variables—returns, volatility, sentiment, FSI, and EPU—in explaining and anticipating cryptocurrency market crises.

The implications of this study are multifaceted. Theoretically, it advances the understanding of cryptocurrency crises by confirming their presence in Bitcoin, Ethereum,

and Ripple markets, and emphasizes the need to account for asset-specific dynamics in crisis analysis. Methodologically, it demonstrates the utility of advanced techniques—such as the CMAX method, probit and logit models—and highlights the value of integrating non-traditional indicators like Google Trends to capture investor sentiment.

Practically and politically, the findings offer valuable guidance for investors, regulators, and policymakers. Understanding how factors like volatility and sentiment contribute to crises can support more informed investment and regulatory decisions. Investors are encouraged to diversify portfolios and account for political and economic risks. Regulators should monitor sentiment and volatility indicators to detect early warning signs and implement timely interventions. Lastly, the importance of investor sentiment and policy uncertainty highlights the need for transparent communication and proactive regulation to foster stability in cryptocurrency markets.

This study offers valuable insights into cryptocurrency crises but has several limitations. It focuses on three major cryptocurrencies—Bitcoin, Ethereum, and Ripple—limiting generalizability. Future work should include a broader range of assets to verify these findings. While the CMAX method is widely used for crisis identification, it may miss some market distress nuances; combining it with methods like Markov-switching models could improve classification.

The use of probit and logit models assumes linear relationships, which may oversimplify market dynamics. Incorporating machine learning techniques such as random forests or neural networks could capture more complex patterns. Google Trends serves as a useful proxy for investor sentiment but may not capture its full complexity; supplementing it with social media data or surveys would enhance sentiment measurement.

The study does not consider other potentially relevant factors such as technological innovations, cyber-attacks, and governance policies, all of which can significantly influence cryptocurrency markets and their vulnerability to crises.

This analysis focuses on short-term crises, overlooking long-term structural changes. Future studies could apply time-varying or long-horizon models to reveal persistent vulnerabilities. Lastly, the study does not consider regulatory changes or region-specific policies, which can significantly affect markets. Including regulatory indicators would provide a deeper understanding of institutional impacts on crisis risk.

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Globalization of Inflation: Evidence from Balkan, Visegrad and Baltic Countries

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Abstract: Globalization of Inflation (GI) is a recently surged hypothesis that indicate the relatively more importance of foreign dynamics (output slack) in driving the inflation compared to domestic factors. The purpose of this study is to analyze the validity of GI hypothesis for the 16 Eastern European economies over a recent period, 2011-2025. The set of countries include several homogenous groups such as Balkan countries, Visegrad and Baltic countries. The novelty of the paper comes from the fact that GI hypothesis has mostly been unstudied for the transition economies which have experienced a massive liberalization over the last few decades. Also, unlike the existing studies, our dataset represents a very recent period that includes crucial inflationary developments such as Covid-19 outbreak, recent loosening of monetary policy, etc. We take Backward Philips Curve as a theoretical basis and analyze the hypothesis by applying a range of panel methods. We employ domestic and foreign output gaps, lagged inflation, oil prices, Eurozone inflation rate and Covid-19 dummy in terms of regressors. As a result, we find evidence that GI holds for Balkan countries but the evidence on Visegrad and Baltic countries is only partial and weaker. European output gap has been relatively more significant than the domestic output gap in Balkan countries whereas this finding is not true for Visegrad and Baltic countries. This represents a novel finding in the current literature.

Keywords: Globalization of Inflation; Philips Curve; Balkan Economies.

JEL classification: E31; F32.

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1. INTRODUCTION

Globalization of Inflation (GI) is a recently surged hypothesis that indicates the relatively more importance of foreign dynamics in driving the inflation compared to the domestic factors (Borio and Filardo, 2007; Ihrig *et al.*, 2010; Karadam-Yolcu, 2020). Understanding the role played by global components is crucial to shed light onto the change in inflation dynamics and required policies in an extremely open and interdependent environment.

The theoretical literature in this field has put forward several supporting and counter arguments. To start with the supporting ones, increasing trade integration is claimed to bring higher sensitivity of domestic inflation to import prices, not only for consumption goods but also for intermediate and capital goods (Borio and Filardo, 2007; Ihrig *et al.*, 2010; Forbes, 2019; Karadam-Yolcu, 2020). Hence, during the foreign boom periods, elevated import prices are likely to give rise to the domestic prices. Interdependency of Global Value Chains plays a central role in such globalized inflationary movements (Auer *et al.*, 2017; Lovin, 2020). From another perspective, recent increase in the global shocks, such as to energy, food and commodity prices may be regarded as important factors leading to a globalized inflation (Minasyan *et al.*, 2023). Consequently, all these external factors should be taken into account by the monetary policy authorities (Rogoff, 2003; Fisher, 2006; Bernanke, 2007; Ihrig *et al.*, 2010; Karadam-Yolcu, 2020).

On the other side, there exist several counter arguments that still advocate the importance of domestic factors. It is claimed that the even if the import prices increase during the global expansion periods, this will not create additional inflation as long as the domestic currency appreciates under a flexible exchange rate regime (Kohn, 2006; Yellen, 2006; Ihrig *et al.*, 2010; Karadam-Yolcu, 2020). Another view points to the relative importance of other domestic factors such as the success of the domestic monetary/fiscal policy, output smoothing and management of expectations (Buiter, 2000; Ball and Moffitt, 2001; Kamin *et al.*, 2004; Roberts, 2006; Mishkin, 2007, 2009; Zhang, 2015).

Yet, the empirical literature is also far from a clear cut. While some studies provide empirical support of GI Hypothesis for the advanced and emerging economies, there are other controversial findings in the literature. The empirical findings can be found at Tootell (1998); Gamber and Hung (2001); Ball (2006); Helbling *et al.* (2006); Borio and Filardo (2007); Wynne and Kersting (2007); Pain *et al.* (2008); Calza (2009); Ciccarelli and Mojon (2010); Ihrig *et al.* (2010); Milani (2010); Çiçek (2012); Manopimoke (2015); Karadam-Yolcu (2020).

We aim to contribute to the literature in this field in two main directions. First, the existing studies mostly concentrate on advanced countries, while developing countries are relatively ignored. Most importantly, the existing analyses are particularly scarce for the emerging European economies. Indeed, Eastern European Economies (EEE) have experienced a rapid transformation from planned to liberal economy over the last 30 years with increased trade and financial ties with the rest of the world, particularly with the western European economies. Therefore, recent globalization may have significant impact on these economies as well as on the main macroeconomic indicators and policies.

Second, the majority of the studies lack the analysis regarding the most recent period that includes crucial inflationary developments, such as disruptive effect of Covid-19 pandemic on the supply chains, too loose monetary policies after Covid-19 outbreak and a significant tightening afterwards. Hence, providing updated evidence is useful to shed light onto the current status of GI hypothesis and thereby implied new policies.

Thus, the purpose of this study is to analyze the validity of GI hypothesis for the 16 Eastern European (transition economies) for a recent period of 2011-2025. The set of countries include several homogenous groups such as Balkan countries Visegrad and Baltic countries. We provide evidence both for a pool of the countries and for the sub-groups. We adopt a Backward Philips Curve approach as it is a common practice in the literature which we apply on a panel set of countries with an array of empirical (panel) methods.

The paper continues with the literature review (Section 2), data and methods (Section 3), empirical results (Section 4) and conclusion sections (Section 5).

2. LITERATURE REVIEW

2.1. Theoretical literature

The theoretical framework relies on the backward Philips Curve which is conventionally used in the macroeconomics literature, in addition with foreign output gap: (Phillips, 1958; Phelps, 1967; Friedman, 1968; Phelps, 1968; Gordon, 1982; Gordon and Stock, 1998; Ihrig *et al.*, 2010; Karadam-Yolcu, 2020):

$$\pi_t = \tau + \theta\pi_{t-1} + \beta y_t^d + \gamma y_t^f \quad (1)$$

where π denotes the inflation rate, θ represents the degree of inflation persistence (inertia), y_t^d and y_t^f respectively denotes the domestic and foreign (European) output gaps (Phillips, 1958; Phelps, 1967; Friedman, 1968; Phelps, 1968; Gordon, 1982; Gordon and Stock, 1998; Ihrig *et al.*, 2010; Karadam-Yolcu, 2020). β and γ represents the impact of domestic and foreign GDP gap which are theoretically expected as positive. It follows that increasing domestic output gap reflects the elevated aggregate demand which is likely to induce the demand-pull inflation whereas an increase in foreign output gap is possibly translated into domestic prices via increased import prices and other related spillovers (Phillips, 1958; Phelps, 1967; Friedman, 1968; Phelps, 1968; Gordon, 1982; Gordon and Stock, 1998; Borio and Filardo, 2007; Ihrig *et al.*, 2010; Forbes, 2019; Karadam-Yolcu, 2020).

2.2. Empirical Studies

With regard to the empirical literature studies in this field, there exists a number of studies addressing the inflation dynamics but particularly focusing on the Globalization of Inflation hypothesis. However, the findings are far from a clear cut. While some studies provide empirical support of GI Hypothesis for the advanced and emerging economies, there are other controversial findings in the literature.

The early debate has started with the studies on the U.S. For instance, Tootell (1998) finds no evidence of the fact that global capacity has a significant influence on the U.S. inflation for 1973-1996 period whereas Gamber and Hung (2001) finds evidence supporting the role of globalization (and external excess capacity) on the decrease in U.S. inflation. In line with Tootell (1998); Ball (2006) reports little reasons for the significant role of globalization on the U.S. Philips Curve structure and inflation. Finally, Milani (2010) reports the relevance of global slack for the inflation of the US after 1985.

Carrying this debate to the cross-country level, Borio and Filardo (2007) find increasingly supportive evidence of global factors on the inflation for a set of 16 countries

and period between 1980-2005. In support of this finding, Pain *et al.* (2008) find an increasing role of foreign dynamics (i.e. import prices) on the evolution of inflation of countries. In a supportive manner, Ciccarelli and Mojon (2010) show that inflation in 22 OECD countries has largely global component. However, controversially, Ihrig *et al.* (2010), do not report evidence in favor of GI Hypothesis for 11 industrialized countries. Similarly, Karadam-Yolcu (2020) find still the importance of domestic output gap compared to the foreign one for a set of 26 developed countries between 1985-2017.

With regard to the studies on EU, Calza (2009) reports only limited evidence of the role of global capacity constraint on the Eurozone's inflation over the period 1979-2003.

There is a limited number of studies on the Balkan and Eastern European countries in this context. One exceptional study was implemented by Çiçek (2012) on the inflation of Türkiye which reports the fact that the inflation and Philips curve is affected by globalization for a period between 1987-2007. Among the empirical studies on the CEE area, Hałka and Szafrański (2015) finds that inflation in CEE countries is well coupled with the Eurozone, while similarly, Lovin (2020) finds that inflation is highly globalized for CEE countries. In contrast, Minasyan *et al.* (2023) find mostly unsupportive evidence for Western Balkan economies. In a similar vein, Jasova *et al.* (2020) find the relative importance of domestic factors since 2009 for emerging countries.

In summary, the empirical literature is far from a consensus. Although the empirical literature is growing in this field, there is a gap and need for more studies on Eastern European and Balkan economies since these countries have experienced a rapid transition towards liberalization and globalization over the last few decades. Moreover, the countries in this zone have experienced serious inflationary developments in the past.

Globalization should be more focused on as a driver which lacks in the existing empirical literature. Furthermore, the existing study often uses past datasets that are not able to capture the recent developments such as Covid-19 pandemic, digitalization of the economies, recent changes in monetary policies, etc. Indeed, there is a limited number of studies that study the post-covid period in terms of globalization and inflation (some exceptional studies are Binici *et al.* (2022); Chau *et al.* (2024) which we target to focus on. For all these reasons, we find it relevant and novel to pursue our study.

We may hypothesize that the smaller transition economies (i.e. Balkan economies) may have been more exposed to globalized inflation since their input/output markets are yet shallow which may be more heavily affected by the Eurozone's inflation. Moreover, the supply chain of these economies might be more dependent on the Eurozone economies which may ease the transmission of output and inflation. However, all these considerations are subject to an empirical examination which will be carried out in the next section.

3. DATA AND METHODS

The dataset covers a panel of 16 Eastern European emerging economies including Balkan (Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Macedonia, Montenegro, Romania, Serbia), Visegrad (Czech Republic, Hungary, Poland, Slovakia, Slovenia) and Baltic (Estonia, Latvia, Lithuania) countries.

The empirical model is expressed by the regression model in equation (2) that is based on the theoretical model in equation (1).

$$\pi_{i,t} = \tau + \theta\pi_{i,t-1} + \beta y_{i,t}^{d} + \gamma y_{i,t}^{f} + \delta(\pi_{eur,t-1} - \pi_{i,t-1}) + \mu\,(oil_{t-1} - \pi_{i,t-1}) + \aleph covid_t + e_{i,t} \quad (2)$$

t represents the quarters from 2011Q1-2025Q1. The dependent variable ($\pi_{i,t}$) is the annual inflation rate of seasonally adjusted CPI, in natural logs and differenced over the 4-quarters[1]. $y_{i,t}^{d}$ and $y_{i,t}^{f}$ denotes the real GDP gap (GDP seasonally adjusted, in natural logs, constant prices, chain linked volume), estimated by using a Hodrick-Prescott filter, assuming smoothing parameter as 1600 (Hodrick and Prescott, 1997). π_{eur} is the annual inflation rate of the Eurozone calculated using the Harmonized Index of Consumer Prices (ln and 4-quarters differenced). oil represents the global energy prices, brent oil price (in US Dollars, seasonally adjusted, in ln and 4-quarters differenced). Inflation and GDP data ($\pi, y^{d}, y^{f}, \pi_{eur}$) has been obtained from IMF (2025b, 2025a) and Eurostat (2025a, 2025b)'s electronic databases whereas the data for oil is obtained from Eurostat (2025a, 2025b); Investing (2025); OECD (2025). We include a set of control variables (oil prices and Eurozone's inflation) that are considered to be effective on domestic prices.

With regard to the parameters in equation (2), τ is the intercept, θ denotes the first-order autoregressive component of inflation, β and γ are the impact coefficients of domestic and foreign output gaps respectively. Finally, δ and μ show respectively the impact of Eurozone's inflation and oil prices, net of domestic inflation. We add also a dummy ($covid_t$) in order to account for the impact of Covid-19 pandemic. This dummy takes value 0 for the quarters prior to 2020Q1 but takes the value of 1 2020Q1 onwards.

We implement a panel unit root test to the variables in the equation (2). We assume individual unit root processes of the variables in the test implementation that are more compatible with the data generating process. The tests include intercept only. Lag length has been determined by Schwarz (1978) criterion, allowing a maximum lag of 16 quarters. We use 3 different types of tests for the sake of robustness such as IPS (Im *et al.*, 2003), ADF-Fisher and PP-Fisher (Fisher, 1932; Phillips, 1958; Dickey and Fuller, 1979; Phillips and Perron, 1988; Maddala and Wu, 1999; Hadri, 2000; Choi, 2001; Fisher, 2006).

Table no. 1 – Panel Unit Root Test Results

Test Type	$\pi_{i,t}$	$y_{i,t}^{d}$	$y_{i,t}^{f}$	$(oil_{t-1} - \pi_{i,t-1})$	$(\pi_{eur,t-1} - \pi_{i,t-1})$
IPS	-3,76018***	-12,5907***	-12,8458***	-4,77047***	-3,8664***
ADF - Fisher	74,4728***	217,449***	218,536***	71,2574***	90,9023***
PP - Fisher	46,0472*	204,986***	217,408***	92,8713***	69,7801***
lag length	9	2	0	0	9

The results indicate a strong set of evidence that rejects the null hypothesis of panel unit root. In other words, all variables are shown to follow stationary processes that allow us to proceed with the current form of the variables.

The model in the equation (2) is estimated by using Fixed Effect and Random Effect models that are recognized as successful models in handling the possible unobserved heterogeneity and endogeneity in the data (Wooldridge, 2002; Baltagi, 2005). The White diagonal heteroskedasticity robust errors are used (Huber, 1967; White, 1980; Arellano, 1987; Wooldridge, 2002).

Domestic and foreign output gaps are highly correlated with each other as the pairwise correlation coefficient is about 0.77. Therefore, to avoid possible multicollinearity, these variables are separately included in the estimations. Following this, we provide two different robustness analysis. First, we estimate the model for sub-geographical divisions (Balkan, Visegrad and Baltic Groups) by interacting dummy variables representing each group with the variables in the models. Second, we include a dummy variable in the main model for covid-19 period.

A final analysis complements the test of GI hypothesis that we calculate the mean and SD of the correlations of country-level inflations with the Eurozone's inflation in order to explore the tendency of comovements in the inflation patterns. It has been demonstrated graphically for rolling windows of 25 quarters. In this way, one can observe the evolution of inflation's synchronization with the Eurozone, hence, the tendency of globalization.

The methodology of the paper, however, may be subject to several limitations. First, although Fixed Effect and Random Effect models are known as reliable techniques in handling the endogeneity, a robustness analysis may be necessary such as adoption of estimation techniques with relevant instruments. However, due to the lack of such instrumental data, this may be counted as a limitation. Another limitation may be related to the brevity of time period. It could be more precise to pursue an analysis with a longer past trajectory, such as the period covering 1990s or 1980s. However, the sample starts only by 2011 in order to cover a wide array of countries. Despite these limitations, the methodology of the paper can be referred to as reliable since fixed/random effect estimators are standardized techniques, the period of analysis is adequately recent and sample of countries are well-representative of the transition economies.

In terms of software, the analysis in this paper is implemented by using EViews 4 and EViews 10 software (Quantitative Micro Software LLC, 2002; IHS Markit, 2017).

4. EMPIRICAL RESULTS

To start with the empirical results, we initially plot the evolution of the inflation over the period of analysis in Figure no. 1. At a glance, it provides us a visual evidence of highly synchronous inflation patterns although minor idiosyncratic movements are present. It is clearly seen that before the Covid-19 pandemic, the inflation rates were at reasonable levels but elevated rapidly following the pandemic, reaching to even more than 20 % for some countries. Too loose monetary policies during the Pandemic, the uncertainty, expansionary fiscal policies, stimulus fiscal programs, as well as the rise in commodity and food prices, disruptions in global value chains are likely to have given rise to such an aggressive inflation.

As a focus analysis of GI, the regression results (of Philips Curve) are summarized in Tables no. 2a and no. 2b. Table no. 2a shows the estimates of equation (2) for the panel including 16 countries whereas Table no. 2b provides the same estimates for the geographical sub-groups. The results provide several interesting results. First, it is observed that domestic and foreign output gaps have positively significant coefficient for the full country set. However, foreign output gap has relatively higher coefficient. Other control variables have mostly positive and significant coefficient indicating the validity of standard inflation drivers.

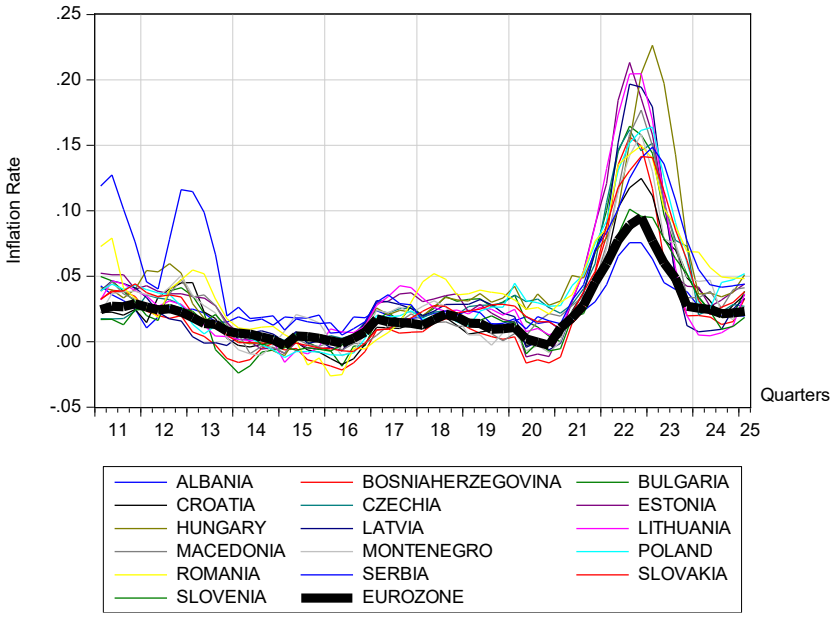

Figure no. 1 – Annual Inflation Rates, ln first difference of quarterly CPI Index

In geographical divisions, when we compare the coefficient size of both variables, the estimated parameter of foreign output gap is larger compared to the domestic one for the full sample and Balkan countries. In contrast, for the Visegrad and Baltic group, although both output gaps are significant, the coefficient is higher for the domestic gap. Consequently, we may state that inflation is more sensitive to the foreign (European) output gap particularly for Balkan group.

The variable $(\pi_{eur,t-1} - \pi_{i,t-1})$ that represents the inflation spillovers (net of domestic inflation) from Eurozone has a positive and significant coefficient for most of the regressions (for the full sample, Balkan and Visegrad groups) but not for Baltic economies. It means that the Eurozone's price movements may spread to the Eastern European economies, possibly, via trade, financial and cost linkages. Similarly, oil price inflation (net of domestic inflation)) has a positive and significant coefficient consistently for the full sample and geographical sub-divisions. The coefficient is higher for Baltic countries followed by Balkan and Visegrad countries. This seems theoretically plausible since energy is one of the main component of production processes and therefore, critical for the inflationary developments.

The regression results are generally consistent when the Covid-19 dummy has been also added. The dummy variable has a positive and significant coefficient as expected since the inflation has risen rapidly after 2019. Inflation persistence degree (θ) is positive and significant for all regressions. The coefficient is highest for the Baltic group followed by Balkan and Visegrad countries.

In sum, the regression results provide a general empirical support for the Globalization of Inflation which is mostly driven by Balkan countries but only partially supported for Visegrad and Baltic countries. Although there is heterogeneity across the geographical groups, Balkan group seems to fit mostly the globalized inflation as foreign output, eurozone inflation and oil price variables are simultaneously significant.

Table no. 2 – Panel Regression Estimates, N=896, Standard Error Type: White Diagonal Heteroskedasticity Robust Errors

2.a – Full Set of (16) Countries

Panel estimator type	τ (constant)	$\pi_{i,t-1}$	$(\pi_{eur,t-1} - \pi_{i,t-1})$	$(oil_{t-1} - \pi_{i,t-1})$	$y^d_{i,t}$	$y^f_{i,t}$	$covid$	R2
Fixed Effect	0,002651***	1,011064***	0,228908***	0,017369***	0,041286**			0,9
Random Effect	0,002843***	0,980724***	0,155265***	0,01773***	0,04252**			0,9
Fixed Effect	0,002836***	1,000229***	0,214075***	0,016957***		0,065453***		0,9
Random Effect	0,003032***	0,970044***	0,141225***	0,017293***		0,067698***		0,9
Fixed Effect	0,001804***	0,929072***	0,156647**	0,017868***	0,083147***		0,00734***	0,9
Random Effect	0,002016***	0,898415***	0,080649	0,018239***	0,083881**		0,007248***	0,9
Fixed Effect	0,002007***	0,885424***	0,106543	0,017124***		0,144708***	0,009119***	0,9
Random Effect	0,002215***	0,854952***	0,031836	0,017471***		0,146489***	0,009056***	0,9

2.b – Geographical Divisions

Country group	Panel estimator type	τ (constant)	$\pi_{i,t-1}$	$(\pi_{eur,t-1} - \pi_{i,t-1})$	$(oil_{t-1} - \pi_{i,t-1})$	$y^d_{i,t}$	$y^f_{i,t}$	R2
Balkan	Fixed Effect	0,001138***	1,017698***	0,271779***	0,015748***	-0,00952		0,92
Balkan	Random Effect	0,000757**	1,027531***	0,226597***	0,014934***	-0,01247		0,92
Balkan	Fixed Effect	0,001225***	1,007553***	0,259053***	0,014602***		0,044346**	0,92
Balkan	Random Effect	0,000809**	1,021282***	0,219541***	0,013704***		0,040796**	0,92
Visegrad	Fixed Effect	0,000301	1,155332***	0,478728***	0,010656***	0,075161***		0,94
Visegrad	Random Effect	0,000216	1,1362***	0,400025***	0,010935***	0,077395***		0,94
Visegrad	Fixed Effect	0,000331	1,148872***	0,46881***	0,011375***		0,0492**	0,94
Visegrad	Random Effect	0,000234	1,132079***	0,393622***	0,011548***		0,052676***	0,94

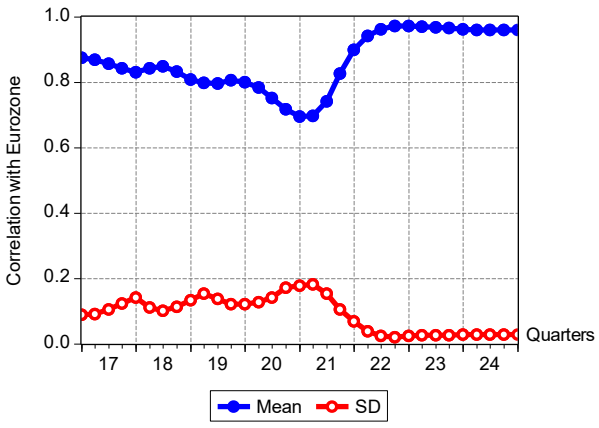

Figure no. 2 – Rolling Windows Correlation between inflations rates of countries and the Eurozone, window length=25 quarters, data points represent the end-point of intervals

As a final complementary analysis, we depict the evolution of correlations (mean and SD) between country level inflations and the Eurozone. It is clearly observed a very high association between domestic inflations and the Eurozone's. The mean correlation coefficient ranges between about 0.7 and 1 which rises rapidly after the Covid-19 pandemic. Consistently, the SD of the correlations tend to fall that indicates the homogeneity of inflation paths.

5. CONCLUSIONS

The current paper reaches to a set of evidence supporting globalized inflation, particularly for Balkan countries but partially for the Visegrad and Baltic countries. European output gap, oil prices and Eurozone inflation is shown to have often positive and significant effects on the domestic inflationary processes.

The obtained results may be argued to differ from the existing findings at two points. First, although the existing studies on CEE (such as Hałka and Szafrański (2015); Lovin (2020) have also found that inflation has a tendency to globalize in Europe and Eastern European economies, we reach to a particular finding that this result is specifically true for Balkan economies rather than for the Visegrad and Baltic countries. The result is theoretically plausible since Balkan economies are relatively small in size and still experience the liberalization and integration process with the EU, which might make their inflation paths more dominated/affected by Europe's business cycle and policies. As a second point, our results represent new and recent evidence from a dataset covering the period 2011-2025. Most of the existing studies fail to include recent inflationary developments in their studies, such as Covid-19 pandemic, the rise in commodity prices, monetary expansionary policies during the pandemic, etc. However, we succeed in incorporating them into our analysis.

The obtained results are also politically important. We argue as a consequence of the analyses that conventional monetary policy rules may not represent the complete dynamics, as the importance of foreign factors may exceed the domestic circumstances from case to case. Global business cycles and common shocks should be followed with a great care in monetary policy conduction as the pass through of these forces to domestic prices are recently strong. One may suggest other preventive policies. For instance, economies small in size should deepen the market size as the shallow market conditions may ease the pronounced fluctuations of the prices. Besides European integration, trade and financial ties with other geographies (Eurasia, etc) should not be neglected in order to provide geographical diversification of trade and other economic relationships. Any other prudential policies are necessary to be developed that will help to mitigate the impact of common shocks.

In sum, globalization of inflation seems as an unignorable phenomenon that is likely to change the conventional paradigm of standard monetary policies. It is necessary to be focused as a further research subject on the mechanisms of how inflation is globalized, determinants and the related forecast of future patterns and policies.

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Notes

[1] Seasonal adjustment of CPI and oil data has been made by using the Ratio to Moving Average Multiplicative method **(**Persons, 1919**)**; Quantitative Micro Software LLC, 2002**)**.

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Competitiveness and Digital Transformation in the Eastern European Countries: A Comparative Analysis of Indicators

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Abstract: The paper's goal is to compare the relationship between competitiveness and digital transformation indicators in the Eastern European countries. The World Competitiveness Index, digital transformation index, government efficiency index, business efficiency index, infrastructure index, World Digital Competitiveness Index, knowledge index, technology index, and future readiness index represent the crucial examined indicators. These indices were chosen in order to thoroughly evaluate the level of digital transformation and how it relates to national competitiveness. The comparative analysis employed different methodologies and actual ratings by using representative data. The relationships between important variables have been examined using Spearman's testing of hypotheses. The competitiveness and digital transformation indicators are shown to be strongly positively correlated. A comparative analysis of the Eastern European countries discovered a strong positive correlation between the analyzed indicators, showing that competitiveness is associated with a higher level of digital transformation. The analysis offers an essential dataset for Eastern European countries' comparisons and indicates suggestions for long-term assessments of the relationship between competitiveness and digital transformation. A higher WCI score, which reflects global competitiveness, is connected with high DTI, GEI, BEI, INF, WDCI, KI, TI, and FRI scores. Policies that improve digital infrastructure, talent development, and innovation frameworks are necessary, as seen by the differences in digital transformation levels among nations. The competitiveness and digital transformation key indicators' rankings and scores can be vital for future cross-national comparisons and provide helpful recommendations for policymakers.

Keywords: competitiveness; digital transformation; comparative analysis; indicators; Eastern European countries.

JEL classification: A10; C80; O30; O57.

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1. INTRODUCTION

The assessment of progressively globalizing countries toward competitiveness and digital transformation has been emphasized as an important topic in modern economic theory and policy. Competitiveness analysis in relation to digital transformation continues to be a top focus worldwide. However, these topics have not been thoroughly examined in the most recent scientific publications due to the diversity of their characteristics and viewpoints. In the past, differentiated products, economies of scale, and cost-effectiveness have all been key components of competitiveness. But as the digital age has progressed, knowledge-based elements such as knowledge capital, employee talent, company image, and innovation capabilities have become important in the competitive environment.

The idea of competitiveness has been significantly redefined by digital transformation (Ashmarina *et al.*, 2020; Enri-Peiró *et al.*, 2025). Businesses must incorporate digital technologies into their fundamental procedures in order to stay competitive. Basically, every aspect of a contemporary, inventive economy and society depends on sophisticated digital infrastructure (Venkatraman, 2017). Digital competitiveness, as a component of the wide-ranging competitiveness approach, is a complex structure that includes different aspects of digital transformation via the capacity to acquire and utilize new technologies that facilitate digital readiness of economies and their citizens.

Considering the range of issues that nations are currently dealing with, a new perspective on analysis would be essential. In order to provide policymakers with more information about the status and direction of competitiveness and digital transformation worldwide, composite analytical indices have become a valuable group of indicators. As an essential tool for decision-makers, the IMD's World Digital Competitiveness Index (WDCI) aims to be a comprehensive, worldwide indicator that monitors the efficiency of digital systems at the national level (IMD, 2025b). The IMD World Competitiveness Index, digital transformation index, government efficiency index, business efficiency index, infrastructure index, and WDCI of the Eastern European countries were examined for certain associations between competitiveness and digital transformation variables.

One of the most important factors influencing a country's economy and potential for sustainability in the future is its competitiveness. However, current publications have not explored the significance of competitiveness for fostering digitalization. This paper provides a comparative analysis of a crucial research issue: Does the Eastern European countries' competitiveness depend on digital transformation? Spearman's investigation of hypotheses has been used for investigation into the associations between significant variables. The study also assessed the significance of Spearman's connections using the rho-p test for hypotheses, which is frequently applied on ordinal parameters. The correlations between the World Competitiveness Index, Digital Transformation Index, Government Efficiency Index, Business Efficiency Index, Infrastructure Index, the World Digital Competitiveness Index, Knowledge Index, Technology Index, and Future Readiness Index were examined using Spearman's rank-order connections.

The study's findings can be useful to governments and significant stakeholders. Future assessments of the competitiveness and the development of appropriate digital transition policies in the Eastern European countries could be possible by variations in the ranking and emphasizing the important indicators. This article is divided into five sections. The introduction is presented in the first section of the article. The theoretical foundations of recent

scientific research on competitiveness and digital transformation are explained in the second section. Data and research methodology are described in the third section of the publication. The fourth section of the article presents the research results. Discussions are presented in the fifth section of the article. Conclusions are presented in the paper's sixth section.

2. LITERATURE REVIEW

Competitiveness and digital transformation have become two of the most popular topics in economic theory and policy in recent years. Despite the growing interest in competitiveness among the scientific community, the field of economics has not definitively demonstrated a coherent definition of competitiveness. This is typically due to the variety of its assessment as well as other related issues. According to Freudenberg (2003); Aghion *et al.* (2005); Snowdon and Stonehouse (2006); Berger and Bristow (2009); Terzić (2017); Bukowski *et al.* (2021) structure convergence and other restrictions that assess the significant interactions between the various aspects of the framework are the primary drivers of competitiveness, inventiveness, and prosperity.

García-Sánchez *et al.* (2019) indicate that the capacity of an economy to maximize the advantages generated by the worldwide transfer of labor and capital is known as its international competitiveness. Garelli (2006) defined competitiveness as a nation's capacity to attain steady growth in GDP per capita, which guarantees its citizens an adequate standard of living, being able to effectively perform specific jobs, and a decrease in unemployment. The scientific literature offers numerous definitions of competitiveness as an economic phenomenon associated with a country's socioeconomic progress (Fagerberg *et al.*, 2007; Aiginger and Schratzenstaller, 2016). Lollar *et al.* (2010) emphasized the role of technology in fostering competitiveness.

Neo-Schumpeterian (Schumpeter, 1934) and neoclassical growth doctrines (Solow, 1956) are two well-known contemporary theories that propose positive connections between technological innovation, technological readiness, technological diffusion, and the overall economic climate. According to Sui *et al.* (2024), digital transformation boosts manufacturing organizations' level of competitiveness by increasing human capital, research and development effectiveness, and efficiency of all factors. Adoption of digital technology and levels of digital competitiveness between European countries are significantly correlated (Martinčević, 2022). Additionally, digitalization is essential for eco-innovation and sustainability (Xu *et al.*, 2024).

The process of reimagining a company in order to fulfill market expectations through the use of digital technologies is known as "digital transformation." The term "digital readiness" describes how ready a company is to embrace and use digital technology, with an emphasis on the fundamental infrastructure, competencies, and resources required to begin digital transformation (Soomro *et al.*, 2020; Verhoef *et al.*, 2021). The International Institute for Management Development (IMD) World Competitiveness Index, which takes into consideration the four main groups of variables that affect an economy's level of competitiveness, applying each category separated into five subdivisions that emphasize different facets of competitiveness, offers a broad overview of the variables that influence an economy's degree of competitiveness. Schwab (2017) asserts that competitiveness has a significant impact on national economies, particularly on their capacity for innovation, finances, institutions, infrastructure, stable macroeconomics, and economic development.

Economists Solow (1956) and Romer (1990) laid the theoretical groundwork for the answers to the problems of why certain nations are more inventive, competitive, and faster-growing than others, but they left out some important details. Competitiveness, innovation, and other national outcomes have drawn the attention of many academics in recent years (Cho and Moon, 2000; Malerba and Brusoni, 2007; Porter, 2008; Carrillo-Hermosilla *et al.*, 2009; Foray, 2009; Atkinson and Ezell, 2012; Edquist, 2016; Terzić, 2017; Bukowski *et al.*, 2021; Hermundsdottir and Aspelund, 2021).

They highlighted various perspectives and elements affecting a nation's ability to compete, innovate, or prosper economically. Rozmahel *et al.* (2014) highlight the infrastructure-based competitiveness assessment of EU member states. The potential to improve one's competitive position is represented by the phenomenon known as national competitiveness. "Competitiveness" has two meanings. Competition has become the primary aspect, and competence – the ability to compete effectively on a national or worldwide scale – is the second aspect.

According to Browne *et al.* (2016), creative and competitive performances affect impressive economic results that impact a particular sector's competitiveness or national competitiveness. The academic and government institutions are becoming increasingly interested in the subject of digital transformation issues. In order to provide policymakers with more information about the status and direction of digital transitions worldwide, composite analytical indices have become a valuable group of indicators.

As an essential tool for decision-makers, the World Digital Competitiveness Index aims to be a comprehensive, worldwide indicator that monitors the efficiency of digital systems at the national level. Additionally, it takes into account knowledge, technology, and future readiness that provide favorable circumstances for a successful digital transition. In this approach, the WDCI makes it possible to comprehend the current and historical conditions of the global digital competitiveness transition, which results in better-informed investment and decisions regarding governmental policy. Higher levels of transparency and a reliable comprehension of the digital transition's development are therefore necessary, as it has become a crucial policy concern and a commercial concern.

In addition to the ambitious goal of thoroughly monitoring the global digital competitiveness and digital transformation, the IMD created the WDCI methodology. An analytical framework that gauges transition as a move toward a digital system that promotes digital competitiveness, sustainability, reliability, and accessibility, as well as toward organizations that facilitate this efficiency, constitutes the core of the Index. There are various definitions and metrics for digital readiness due to the variety of governance systems and mutual dependence across distribution networks and commerce. There is consensus about the wider socio-economic and political aspects of digital transition. However, other studies define it as a change of current technological innovation (Fagerberg and Godinho, 2004; Porter, 2008; Ganotakis and Love, 2011; Castellacci and Natera, 2015; Dorrego *et al.*, 2024).

A rapid transformation to a more economical, viable, and accessible digital system that offers answers to the world's digital transition-associated problems is part of an efficient and knowledge-based competitiveness. Without jeopardizing the equilibrium of the three crucial digital system performance areas that collectively comprise the digital competitiveness framework, it opens possibilities for business and society. The IMD's World Digital Competitiveness Index (IMD, 2025c) is an aggregate measure that combines parameters with identical weights implemented according to hierarchy, covering the most significant elements

across various aspects of three fundamental pillars: knowledge, technology, and future readiness. Table no. 1 presents the definition of the indices used in the study (the World Competitiveness Index, Digital Transformation Index, Government Efficiency Index, Business Efficiency Index, Infrastructure Index, World Digital Competitiveness Index, Knowledge Index, Technology Index, and Future Readiness Index).

Table no. 1 - Definition of competitiveness and digital transformation indices used in the study

Indices	Definition
WCI	The World Competitiveness Index (WCI) evaluates a country's capacity to establish and preserve a sustainable business environment. WCI includes four pillars: economic performance, government efficiency, business efficiency, and infrastructure.
DTI	The digital transformation index (DTI) demonstrates how the economy's major economic sectors are addressing the issue of digitization, highlighting advancements, obstacles, and possibilities. It also shows how digitalization has developed into a strategic force that can change organizational cultures and ways of doing business.
GEI	Government efficiency index (GEI): the degree to which competitiveness initiatives are supported by the government policies including public spending, tax legislation, organizational framework, enterprise legislation, and social systems.
BEI	Business efficiency index (BEI): the degree to which the national environment promotes innovative, profitable, and ethical business practices. BEI includes the following: labor market conditions, created values, management skills, standards, and ethics.
INF	Infrastructure index (INF): how well the company's requests are fulfilled by its essential, technology-related, scientific, and human resources. INF includes fundamental infrastructure, technological infrastructure, infrastructure for knowledge creation, health protection, environment, and learning systems.
WDCI	The World Digital Competitiveness Index (WDCI) emphasizes innovation, human capital, and future readiness, focusing on knowledge-driven competitiveness.
KI	The knowledge index (KI) includes intangible infrastructure necessary for discovering, comprehending, and creating new technologies (talent, training and education, and scientific concentration).
TI	Technology index (TI): the broader framework associated with dimensions of technology that ensures development of digital technologies (regulatory environment, capital, and technological skills).
FRI	The future readiness index (FRI) is examining the level of preparedness of the economy for the digital transformation (flexible viewpoints, business agility, and integration of the IT sector).

Source: Derived from IMD World Competitiveness Booklet 2025 (IMD, 2025b), IMD World Digital Competitiveness Rankings 2025 (IMD, 2025c).

The significance of digital infrastructure, environments for innovation, and technological adaptability as crucial factors influencing socioeconomic and financial outcomes is being emphasized in increasing numbers by academics and organizations. The indices examined in this research, which together offer a multifaceted view of digital competitiveness, also represent these elements: WCI, DTI, BEI, INF, WDCI, KI, TI, and FRI. The aforementioned indices constitute some of the most popular metrics for assessing a nation's digital competitiveness, which is why they were selected for this study.

Complex scientific, economic, and sociopolitical variables are driving the digital competitiveness in the Eastern European countries. The connection between initiatives to conduct digital transformation, especially in the industrial sector, should be taken into

consideration in a cohesive policy strategy. Reliable governing circumstances and efficient use of EU funding should be given top priority under the comprehensive policy regulations. In the past, product differentiation, economies of scale, and cost effectiveness have all been key components of competitiveness. Nevertheless, as the digital economy has developed, the competitive environment has changed by putting more emphasis on knowledge-based elements, including human resources, intellectual capital, the image of the company, and the ability to innovate. The idea of competitiveness has been progressively extended by digital transformation. Companies must incorporate digital technologies throughout their fundamental operations in order to stay competitive. It is difficult to compete in the modern world without utilizing new digital technology. Global digital competitiveness is increased by the digital economy and cutting-edge technology that accelerate social and economic change.

Numerous well-established indices that gauge various aspects of a country's preparedness and capacity to use digital technology can be used to evaluate a nation's digital competitiveness. Every one of the parameters is divided into four categories: infrastructure, business efficiency, government efficiency, and economic performance. Every factor is divided into five sub-factors. These sub-factors do not always have an identical set of factors, as, for example, evaluating the education sub-factor requires more criteria than evaluating the prices sub-factor. Each sub-factor has a weight of 5% (20 x 5 = 100) in the overall aggregation of findings, regardless of how many criteria they comprise. Knowledge, technology, and future readiness are the three primary components of digital competitiveness, according to the World Digital Competitiveness Rankings (WDCR) methodology. Each one of those components is subsequently separated down into three components; each one of them highlights a different aspect of the areas under analysis.

3. RESEARCH METHODOLOGY AND DATA

The International Institute for Management Development (IMD) developed the World Competitiveness Index (WCI), which provides a data-driven evaluation of overall competitiveness. The IMD World Competitiveness Index includes four dimensions of national competitiveness: the economic performance index, the government efficiency index, the business efficiency index, and the infrastructure index (IMD, 2025b). The IMD World Competitiveness Yearbook is a thorough yearly report that serves as a global standard for evaluating national competitiveness. In addition to metrics and research findings derived from in-depth study, it offers comparative analysis and overall patterns. In order to accomplish generating value over time, it assesses and ranks nations based on how they effectively govern their capabilities.

The model was based on an integrated theory of both technology-driven and endogenous growth (Romer, 1990). Such concepts have been used in the study to emphasize the importance of national rankings based on competitiveness, technological effectiveness, and knowledge. Effective companies should produce final goods that could be used to create intermediate goods or goods of higher quality with a new technology application.

Thus, a new technology indicator could be presented using the following equation:

$$Indicator = \int_0^g X_i^{\alpha} \left(Y_i^{\alpha} Y^{1-\alpha} \frac{Sd^{\beta} \mathrm{Re}^{1-\beta}}{g^{1-\delta}}\right)^{1-\delta} x_i \qquad 0<\alpha, \beta; \delta<1 \tag{1}$$

Where: g is the indicator of intermediate goods, Sd indicates digital skills, and Re represents efficient resources. The indicators for observed countries could be calculated using the formula below:

$$i = DTI_i C_i^{\alpha} Sd_i^{\beta} \mathrm{Re}_i^{1-\alpha-\beta} \quad 0<\alpha<1;0<\beta<1 \tag{2}$$

$$DTI_i = DTI^{\beta} C_{DTI}^{\beta} Sd_{DTI}^{\beta} \mathrm{Re}_{DTI}^{1-\beta-\delta} \quad 0<\beta<1;\delta<1 \tag{3}$$

where:

- The quantity of metrics utilized in knowledge creation is represented by the variable i.
- C displays the capital used to create knowledge,
- Sd signifies digital skills,
- Re refers to efficient resources, and
- Digital Transformation Index (DTI) denotes the set of indicators regarding the digital transformation initiatives developed in the R&D sector of companies in Eastern European countries.

In order to verify the indicators' aggregation with many dimensions, each DTI-monitored parameter has been transformed into "grades of achievement", which categorize countries from 0 to 10 (with the highest conceivable and the lowest tolerable digital transformation performance scores). Therefore, each parameter is typically scaled again using the following formula to determine the total WDCI score:

$$Normalized\ score = \frac{Country\ value - Minimum}{Sample\ maximum - Sample\ minimum} * 100 \tag{4}$$

Based on an extensive study of economic publications from international, national, and local databases, as well as input from the business sector, government organizations, and economists, 334 competitiveness parameters were chosen to create the World Competitiveness Ranking. As new theories, investigations, and data become available, as well as the world economy changes, the criteria are routinely evaluated and revised (Garelli, 2006; Tusińska, 2016; Terzić, 2017). To increase the uniformity and impartiality of the WCR Index structure, the IMD is making modifications. Globally, policymakers and scholars will be able to extract more relevant and important suggestions to improve or fully disclose the competitive advantages of the states under observation. Spearman's analysis of hypotheses has been employed to investigate the associations between significant variables.

The comparative analysis also examined the significance of Spearman's relationships using the rho-p test for hypotheses, which is frequently conducted on ordinal variables. The relationships between the World Competitiveness Index, Digital Transformation Index, Government Efficiency Index, Business Efficiency Index, Infrastructure Index, World Digital Competitiveness Index, Knowledge Index, Technology Index, and Future Readiness Index were investigated employing Spearman's rank-order correlations. Knowledge, technology,

and future readiness are the three primary components of digital competitiveness according to the WDCR methodology. Each of these elements is subsequently divided into three sub-factors, each of which highlights a different aspect of the areas under analysis. Every sub-factor has the same relevance in the total aggregation of findings. Three sub-indices are weighted and averaged to determine the WDCI score. The numerous parameters of the index serve as the foundation for each sub-index, which is the arithmetic average across its constituent dimensions.

The most recent data available at the time of collection is reflected in the WDCI 2025 results. The WDCI score is measured on a scale of 0 to 100, with 100 being the highest attainable score and 0 being the lowest. Each indicator, except the indicator of digital transformation in companies, is standardized to the 0–100 scale, employing a minimum-maximum approach to enable comparison and aggregation. The indicator of digital transformation in companies is standardized to the 0–10 scale, employing a minimum-maximum approach to assure aggregation.

The lowest and greatest values for nations covered by the WDCI are represented by the sample's minimum and sample maximum. The analysis uses a normalizing procedure that not only converts the series to 0-100 and 0-10 but also modifies it so that 0 and 100, and 0 to 10, still represent the worst and best, correspondingly, for those parameters for which a larger raw value suggests a less favorable result. Data sources that were implemented to aggregate the indicators include the IMD World Competitiveness Report (IMD, 2025b), World Digital Competitiveness Report (IMD, 2025c), and IMD countries database (IMD, 2025a). This study benchmarks associations between competitiveness and digital transformation across Eastern European countries in 2025. Spearman's rank correlations on a longitudinal dataset and actual 2025 scores were employed in the analysis. The comparative analysis is restricted to descriptive associations but provides essential information for Eastern European comparisons and formulating hypotheses for future analyses on the relationship between competitiveness and digital transformation. Given the annual snapshot, results should not be interpreted as patterns or causal impacts. To be supplemented with a content analysis of the results obtained when applying statistical methods.

4. RESEARCH RESULTS

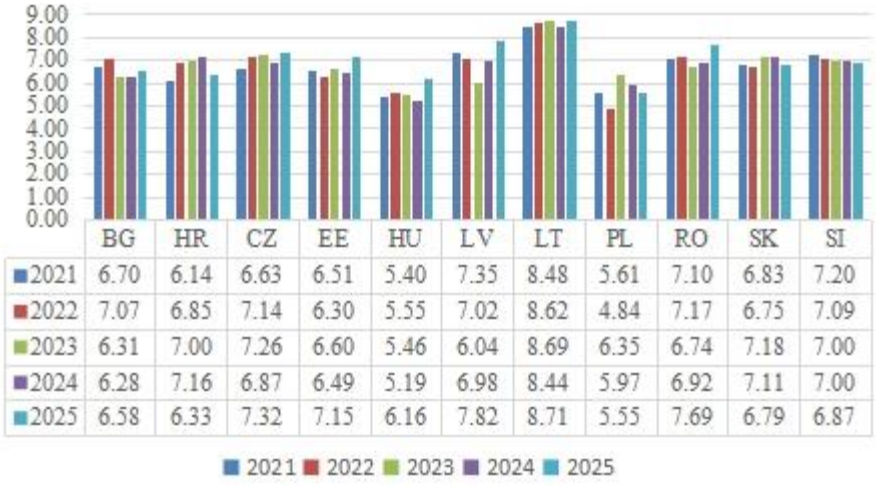
The research study was carried out in the following Eastern European countries: Czech Republic (CZ), Slovenia (SI), Estonia (EE), Latvia (LV), Lithuania (LT), Slovakia (SK), Croatia (HR), Romania (RO), Poland (PL), Hungary (HU), and Bulgaria (BG). The aggregated data for the Eastern European countries covers the period 2024–2025. Table no. 2 presents scores and ranks in the Eastern European countries based on the World Competitiveness Index (WCI), Digital Transformation Index (DTI), Government Efficiency Index (GEI), Business Efficiency Index (BEI), and Infrastructure Index (INF).

Table no. 2 - Scores and rankings of the Eastern European countries based on indicators of competitiveness and digital transformation for the 2024-2025 period

Country	WCI		DTI		GEI		BEI		INF	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
PL	53.91	8	5.09	7	36.88	10	17.41	8	46.83	7
CZ	73.66	2	6.24	3	63.28	1	57.25	3	60.42	2
SK	42.79	11	3.76	11	25.59	11	9.87	11	38.27	10
HU	56.71	6	5.04	8	44.09	6	21.81	7	53.19	5
LT	77.68	1	7.33	1	63.14	2	74.19	1	63.99	1
LV	67.03	4	6.59	2	56.54	4	54.87	4	58.32	4
EE	69.65	3	6.00	4	62.19	3	57.92	2	59.20	3
RO	56.64	7	5.91	5	44.78	5	38.46	5	43.63	8
SI	59.14	5	5.16	6	42.82	7	33.09	6	50.89	6
HR	51.19	9	4.81	9	38.39	9	16.50	9	39.43	9
BG	47.96	10	4.43	10	41.13	8	14.50	10	33.37	11

Source: Data from IMD (2025b), (IMD, 2025a), and the author's own calculations.

On the basis of the competitiveness and digital transformation scores and rankings compared to other analyzed economies for the studied period, Lithuania has achieved the best results. According to the World Competitiveness Index, Digital Transformation Index, Business Efficiency Index, and Infrastructure Index, Lithuania is the best-ranked economy. Slovakia is the worst-ranked economy according to the WCI, DTCI, GEI, and BEI compared to the observed Eastern European economies, while Bulgaria is the worst-positioned economy on the Infrastructure Index. The Czech Republic is the highest-ranked Eastern European country according to the Government Efficiency Index (GEI). Figure no. 1 below shows digital/ technological skills scores in Eastern European countries in the observed period (2021-2025).

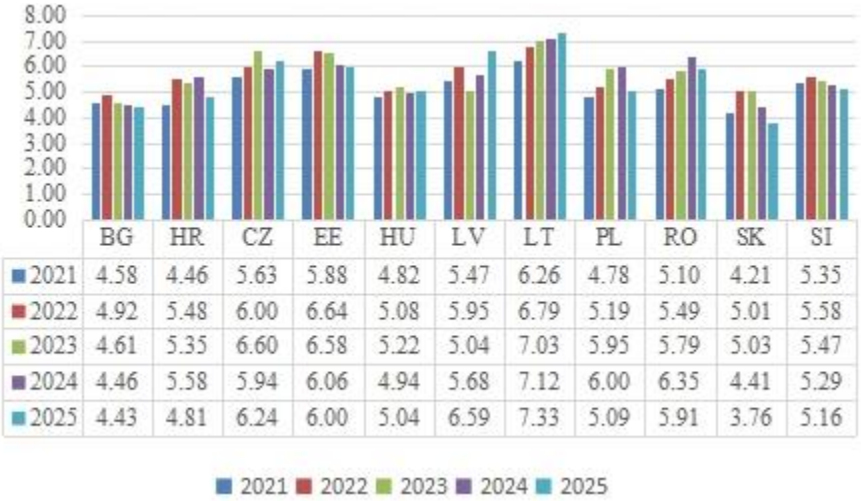


	BG	HR	CZ	EE	HU	LV	LT	PL	RO	SK	SI
2021	6.70	6.14	6.63	6.51	5.40	7.35	8.48	5.61	7.10	6.83	7.20
2022	7.07	6.85	7.14	6.30	5.55	7.02	8.62	4.84	7.17	6.75	7.09
2023	6.31	7.00	7.26	6.60	5.46	6.04	8.69	6.35	6.74	7.18	7.00
2024	6.28	7.16	6.87	6.49	5.19	6.98	8.44	5.97	6.92	7.11	7.00
2025	6.58	6.33	7.32	7.15	6.16	7.82	8.71	5.55	7.69	6.79	6.87

Source: author's own creation from the IMD country database, 2021-2025.

Figure no. 1 – Digital/Technological skills Index scores in Eastern European countries for the 2021-2025 period

As shown in Figure no. 1, Lithuania achieved the highest Digital/Technological Skills Index (DTSI) scores from 2021 to 2025. In 2021, and 2023, Hungary was the nation with the lowest DTSI index score. According to DTSI, Poland obtained the lowest score in 2022 and 2025. After Lithuania, Latvia has achieved the second-highest DTSI score (7.82) in 2025. A mix of government efforts, strategic infrastructure investments, and a dedication to digital transformation are responsible for Lithuania's accomplishments in digital/technological skills. The scores of the Eastern European countries based on digital transformation index scores for the years 2021–2025 are shown in Figure no. 2.



	BG	HR	CZ	EE	HU	LV	LT	PL	RO	SK	SI
2021	4.58	4.46	5.63	5.88	4.82	5.47	6.26	4.78	5.10	4.21	5.35
2022	4.92	5.48	6.00	6.64	5.08	5.95	6.79	5.19	5.49	5.01	5.58
2023	4.61	5.35	6.60	6.58	5.22	5.04	7.03	5.95	5.79	5.03	5.47
2024	4.46	5.58	5.94	6.06	4.94	5.68	7.12	6.00	6.35	4.41	5.29
2025	4.43	4.81	6.24	6.00	5.04	6.59	7.33	5.09	5.91	3.76	5.16

Source: author's own creation from the IMD country database, 2021-2025

Figure no. 2 – Digital Transformation Index scores in Eastern European countries for the 2021-2025 period

Lithuania achieved the highest Digital Transformations Index scores from 2021 to 2025 (6.26, 6.79, 7.03, 7.12, 7.33). According to the DTI index, Latvia had the second-highest score in 2025 (6.59). In 2021, 2024, and 2025, the Slovak Republic was the country with the lowest DTI index score. According to DTI, Bulgaria obtained the lowest score in 2022 and 2023. In addition to Lithuania, the Czech Republic and Estonia also scored highly in terms of corporate digital transformation. After Lithuania, Romania has the second-highest DTI score (6.35) in 2024. Through the assistance of a legal system that prioritizes transparency and stakeholder involvement, Lithuania has achieved notable progress in developing its digital transformation.

Regulatory impact evaluations, which are required to assess the possible social, environmental, and economic implications of new regulations, are part of the systematic process for establishing or eliminating restrictions. This guarantees that new rules are supported by knowledge and harmonized with national interests. During the process of creating regulations, the Lithuanian government frequently uses working groups and open discussions to interact with the commercial sector and other interested parties. The scores and rankings of the Eastern European nations based on digital competitiveness indicators for the years 2024–2025 are shown in Table no. 3.

Table no. 3 – Scores and rankings of the Eastern European countries based on indicators of digital competitiveness in 2024-2025

Country	WDCI		Knowledge Index		Technology Index		Future Readiness Index	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank
PL	60.22	6	58.10	6	54.34	8	50.07	7
CZ	71.06	4	65.40	4	64.82	5	64.82	4
SK	50.72	10	49.01	10	44.15	11	40.86	8
HU	60.14	7	55.88	7	65.65	4	40.75	10
LT	84.30	1	74.62	1	75.41	1	84.74	1
LV	74.87	3	62.62	5	70.50	2	73.35	3
EE	77.84	2	68.70	2	70.12	3	76.57	2
RO	59.39	8	50.71	9	57.76	7	51.56	6
SI	65.06	5	66.15	3	58.74	6	52.15	5
HR	55.18	9	52.51	8	54.04	9	40.84	9
BG	49.53	11	44.86	11	52.28	10	33.29	11

Source: data from IMD (2025c), IMD (2025a), and the author's own calculations

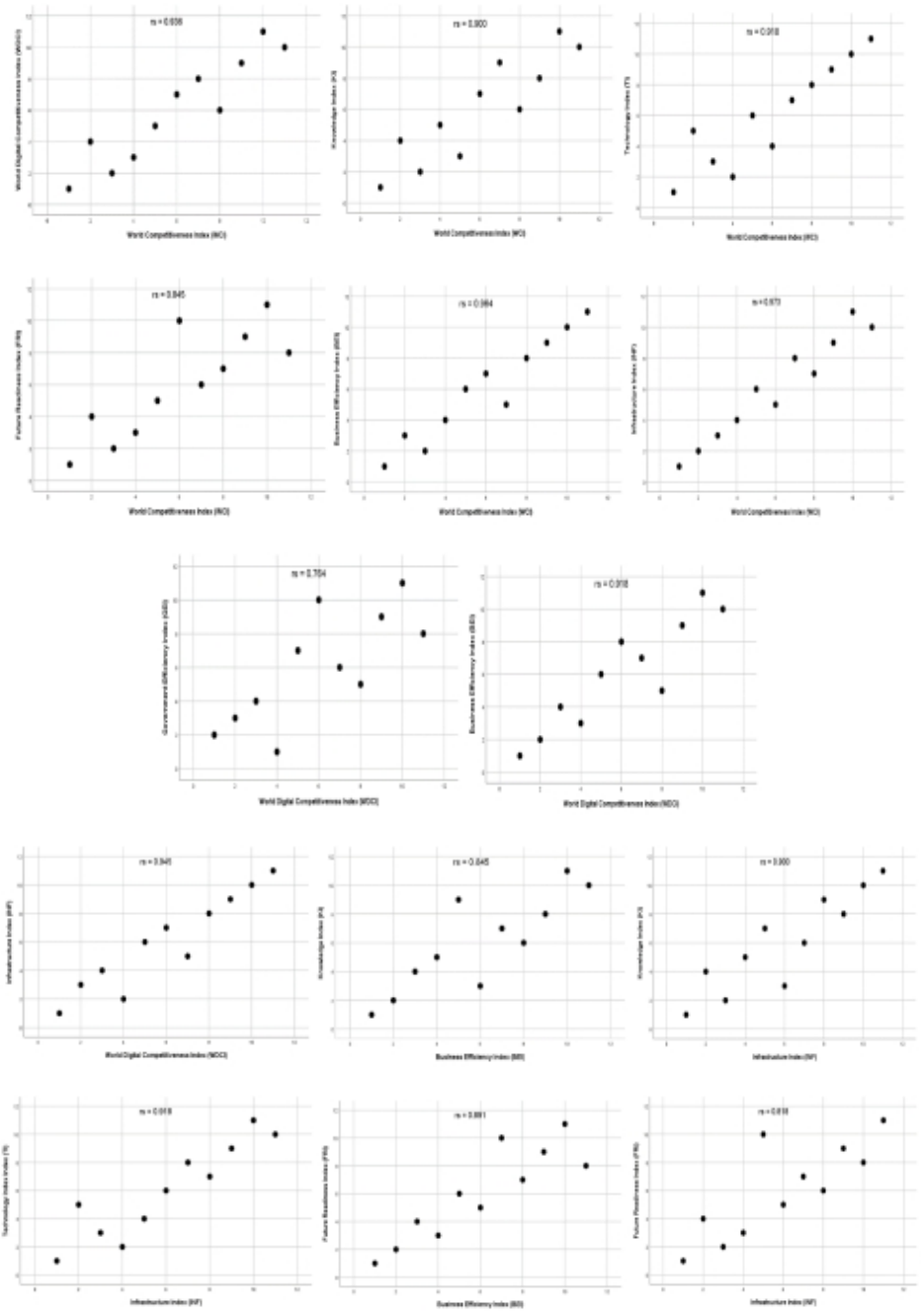
In the observed period, Lithuania achieved the highest position (1st ranked Eastern European country) in the following innovation indices: World Digital Competitiveness Index (WDCI), Knowledge Index (KI), Technology Index (TI), and Future Readiness Index (FRI). Estonia positioned as the second highest ranked Eastern European countries according to WDCI, KI, and FRI. Behind Lithuania, Latvia is the second ranked country according to the Technology Index. The correlations between the competitiveness and digital transformation variables in the observed Eastern European economies are displayed in Table no. 4. The statistical software program (SPSS 25) was used to carry out the empirical investigation.

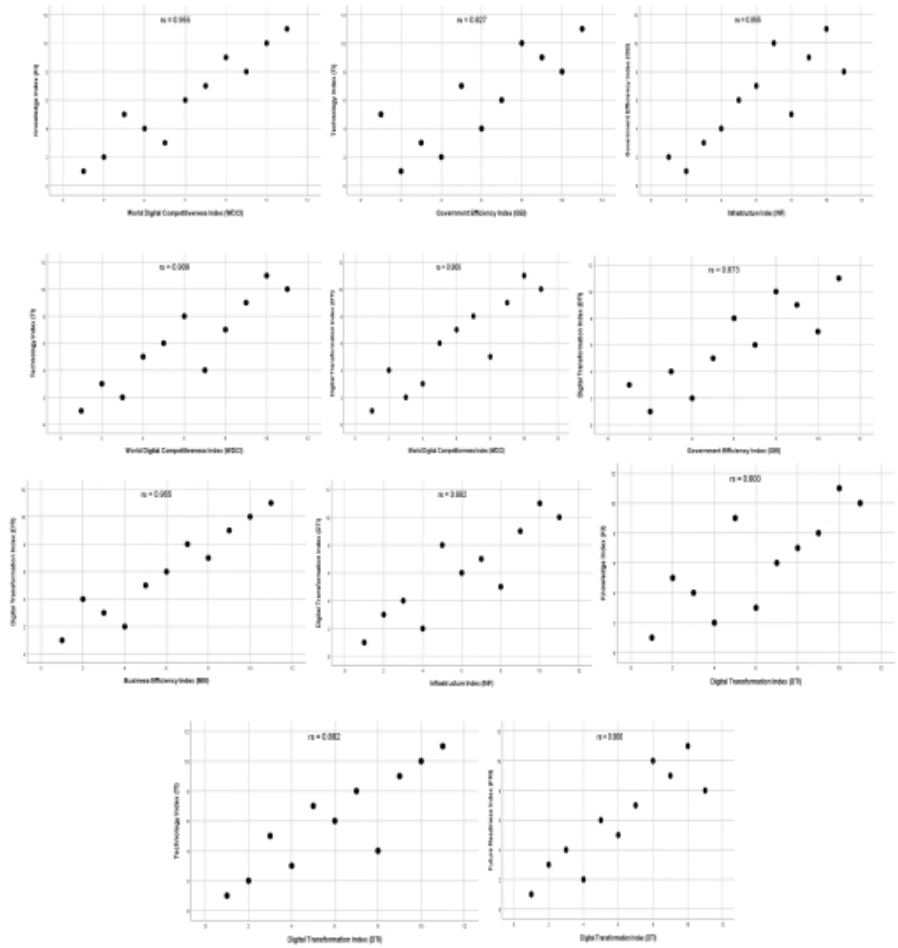
Table no. 4 – Correlation matrix of the competitiveness and digital transformation variables

	WCI	DTI	GEI	BEI	INF	WDCI	KI	TI	FRI
WCI	1.000	.927**	.918**	.964**	.973**	.936**	.900**	.918**	.845**
DTI	.927**	1.000	.873**	.955**	.882**	.909**	.800**	.882**	.900**
GEI	.918**	.873**	1.000	.927**	.855**	.764**	.673*	.827**	.727*
BEI	.964**	.955**	.927**	1.000	.918**	.918**	.845**	.900**	.891**
INF	.973**	.882**	.855**	.918**	1.000	.945**	.900**	.918**	.818**
WDCI	.936**	.909**	.764**	.918**	.945**	1.000	.955**	.909**	.918**
KI	.900**	.800**	.673*	.845**	.900**	.955	1.000	.818**	.855**
TI	.918**	.882**	.827**	.900**	.918**	.909	.818	1.000	.764**
FRI	.845**	.900**	.727*	.891**	.818**	.918	.855	.764	1.000

Note: **Correlation is significant at p<0.001 level. *Correlation is significant at p<0.005 level.
Source: author's own calculation

The following scatter plots show the Spearman's correlation coefficient results for Eastern European countries in 2024-2025.





Source: created by the author using SPSS 25

Figure no. 3 – Scatterplots presenting the relationships between the competitiveness and digital transformation indicators for Eastern European countries in 2024-2025

The Spearman's rank-order correlations were run to examine the relationship between WCI, DTI, GEI, BEI, INF, WDCI, KI, TI, and FRI. There are positive and significant correlations between WCI and WDCI, rs=.936 p<0.001; WCI and KI, rs=.900 p<0.001; WCI and TI, rs=.918 p<0.001; WCI and FRI, rs=.845 p<0.001; WCI and BEI, rs=.964 p<0.001; WCI and INF, rs=.973 p<0.001; WDCI and GEI, rs=.764 p<0.001; WDCI and BEI, rs=.918 p<0.001; WDCI and INF, rs=.945 p<0.001; BEI and KI, rs=.845 p<0.001; KI and INF, rs=.900 p<0.001; TI and INF, rs=.918 p<0.001; FRI and BEI, rs=.891 p<0.001; FRI and INF, rs=.818 p<0.001; WDCI and KI, rs=.955 p<0.001; GEI and TI, rs=.827 p<0.001; INF and GEI, rs=.855 p<0.001; WDCI and TI, rs=.909 p<0.001; DTI and WDCI, rs=.909 p<0.001; DTI and GEI, rs=.873 p<0.001; BEI and DTI, rs=.955 p<0.001; INF and DTI, rs=.882 p<0.001; DTI and KI, rs=.800 p<0.001; DTI and TI, rs=.882 p<0.001; DTI and FRI, rs=.900 p<0.001.

5. DISCUSSIONS

The study's findings represent substantial evidence of consistency as well as reliability of the rankings obtained from the chosen competitiveness, digital competitiveness and digital transformation indices. According to the investigation, rankings based on the WCI, DTI, GEI, BEI, INF, WDCI, KI, TI, and FRI show a high degree of compatibility. This is especially evident in the scores and Spearman's coefficient values. According to Spearman's rank-order correlation coefficient, rs=.936, p<0.001, the first scatter diagram in Figure 3 demonstrates a very strong positive and significant relationship between WCI and WDCI. The positive correlation coefficient (0.936**) between WCI and WDCI shows that infrastructure, corporate efficiency, and government efficiency all reflect national competitiveness, which is crucial for digital competitiveness.

The second scatter diagram in Figure 3 shows a very high positive interlinkage between WCI and KI (0.900**). The development, dissemination, and use of knowledge are crucial for increasing national competitiveness and digitalization, according to a positive correlation between WCI and KI. The correlation coefficient rs=.918, p<0.001, as shown in the third scatter plot in Figure 3, indicates a very strong positive link between WCI and TI. The regulatory framework, capital, and technological skills all reflect the importance of digital technologies for national competitiveness, as evidenced by the positive correlation coefficient between WCI and TI (0.918**).

The competitiveness based on government efficiency, corporate efficiency, and infrastructure is crucial for future digital readiness, evidenced by the positive correlation coefficient between WCI and FRI (0.845**). According to Spearman's rank-order correlation coefficient (rs=.964, p<0.001), there was a very high positive relationship between WCI and BEI. The significance of business efficiency for boosting national competitiveness is demonstrated by the positive correlation coefficient (0.964**) between WCI and BEI. Spearman's rank-order correlation coefficient (rs=.973, p<0.001) indicated that WCI and INF had a very strong positive association. Infrastructure, as determined by basic infrastructure, technological infrastructure, infrastructure for knowledge creation, health protection, the environment, and learning systems, is crucial for national competitiveness, according to the positive correlation coefficient between WCI and INF (0.973**).

The significance of government efficiency for digital competitiveness is demonstrated by the positive correlation coefficient (0.764**) between WDCI and GEI. Spearman's rank-order correlation coefficient (rs=.918, p<0.001) indicated the very high positive interlinkage between WDCI and BEI. Business efficiency is essential for digital competitiveness, according to the positive correlation coefficient (0.918**) between WDCI and BEI. Spearman's rank-order correlation coefficient (rs=.945, p<0.001) indicated the very high positive interlinkage between WDCI and INF. The significance of infrastructure development for digital competitiveness is demonstrated by the positive correlation coefficient (0.945**) between WDCI and INF.

The significance of knowledge for business efficiency is demonstrated by the positive correlation coefficient (0.845**) between BEI and KI. The significance of digital infrastructure for knowledge creation, dissemination, and application is indicated by a substantial positive correlation (0.900**) between KI and INF. The significance of technology for the development of digital infrastructure is indicated by the positive correlation coefficient

(0.918**) between TI and INF. FRI and BEI showed a very strong positive correlation (0.891**), indicating the importance of company efficiency for future digital readiness.

Spearman's rank-order correlation coefficient, rs=.818, p<0.001, confirmed the very strong positive association between FRI and INF. The significance of digital infrastructure for national economies' future digital preparedness is indicated by the positive correlation coefficient between FRI and INF (0.818**). Spearman's rank-order correlation coefficient (rs=.955, p<0.001) indicated a very strong positive association between WDCI and KI. The significance of knowledge generation, dissemination, and application for digital competitiveness is indicated by a substantial positive correlation (0.955**) between WDCI and KI. The significance of technology for government efficiency is demonstrated by the positive correlation coefficient (0.827**) between GEI and TI. Spearman's rank-order correlation coefficient (rs=.855, p<0.001) indicated a very strong positive association between INF and GEI**.**

Digital infrastructure is essential for government efficiency, according to the positive correlation coefficient (0.855**) between INF and GEI. The significance of technology for digital competitiveness is demonstrated by the very significant positive interlinkage between WDCI and TI (0.909**). The significance of digital transformation for digital competitiveness is demonstrated by the substantial positive correlation coefficient (0.909**) between DTI and WDCI. Spearman's rank-order correlation coefficient, rs=.873, p<0.001, indicated a very significant positive interlinkage between DTI and GEI, indicating that governance efficiency is critical for digital transformation.

Spearman's rank-order correlation coefficient, rs=.955, p<0.001, revealed that BEI and DTI had a very strong positive association. The significance of business efficiency for digital transformation is indicated by the strong positive correlation (0.955**) between BEI and DTI. The significance of digital infrastructure for digital transformation is indicated by the positive correlation coefficient (0.882**) between INF and DTI. According to Spearman's rank-order correlation coefficient, rs=.800, p<0.001, there was a very substantial positive association between DTI and KI. The significance of knowledge production, dissemination, and application for digital transformation is indicated by the substantial positive correlation between WDCI and KI (0.800**). The significance of technology for digital transformation is demonstrated by the substantial positive correlation coefficient (0.882**) between DTI and TI. Spearman's rank-order correlation coefficient, rs=.900, p<0.001, indicated that there was a very strong positive association between DTI and FRI. The significance of digital transformation for future digital preparedness is indicated by the substantial positive correlation (0.900**) between DTI and FRI.

These results support the claim that the relative positions of nations in an environment of digital competition, particularly between the highest-ranked and lowest-ranked nations, remain surprisingly consistent regardless of methodological variations. The findings are consistent with a deeper understanding of the role that digital skills play in boosting national competitiveness. For example, Sui *et al.* (2024) and Martinčević (2022) noted that industrial companies' competitiveness is positively impacted by digital transformation and that digitalization-driven competitiveness has become a tool to boost resilient economies, lower costs, and increase productivity.

The integration of country rankings across different indices supports the claim that adequate digital infrastructure, future readiness, and digital quality based on sufficient knowledge are essential elements of competitiveness, as acknowledged by various international governing bodies. According to this, nations like Lithuania, Latvia, and Estonia

are among the top-ranked in every index, which is indicative of their acknowledged capabilities in digital infrastructure, environments for innovation, and strategic approach toward digital technology.

These findings are consistent with those of Venkatraman (2017), who recognized certain nations as digital innovators because of their capacity for innovation and development of digital infrastructure. Ashmarina *et al.* (2020) results, which emphasize the importance of institutional encouragement and adequately developed digital infrastructures in attaining high competitiveness rankings, reinforce this concept. However, according to the study findings, nations like Bulgaria and Slovakia routinely score lower on almost every index. In general, by offering an analysis of indicators and confirming their dependability, this investigation contributes to the continuing discussion on digital competitiveness. A significant degree of consensus regarding the relative digital competitiveness of nations is suggested by the consistent results across the majority of indicators. Nonetheless, the differences observed in particular indices emphasize how crucial it is to have a multifaceted strategy in order to fully assess and comprehend digital competitiveness.

6. CONCLUSIONS

The primary objective of this article was to examine the influence of digital transformation on the competitiveness of the Eastern European countries. Different methodological approaches have been used in regard to the stated goal of investigating the relationships between competitiveness and digital transformation indicators. The research results have indicated very strong positive and significant correlations between the WCI, DTI, GEI, BEI, INF, WDCI, KI, TI, and FRI. Designating the determined significant correlations, it could be concluded that Eastern European countries' competitiveness is influenced by digital transformation that relies upon the WDCI pillars as follows: knowledge, technology, and future readiness. The research results also indicate that the digital competitiveness of observed countries is influenced by the following WDC pillars: digital transformation in companies, government efficiency, business efficiency, and infrastructure.

The competitiveness and digital transformation scores and rankings provided by the key indicators can be crucial for comparative analysis between countries and offer useful suggestions to policy creators in order to achieve a prosperous future and the objectives of the digital competitiveness policies of Eastern European countries. Eastern European countries and their companies are well-positioned to adopt the new technology solutions needed to sustain digital competitiveness throughout Europe as well as worldwide. This paper contributes by assuring new theoretical perception and empirical research on the relationship between competitiveness and digital transformation indicators in Eastern European countries. Additionally, the conducted comparative analysis guarantees a newly collected, comprehensive dataset that may be utilized for additional empirical research on countries' competitiveness, digital competitiveness, and digital transformation. The study provides insights into the literature that aims to gauge economies' competitiveness and digital transformation. The findings of the study have significant policy ramifications. In addition, improving the expected theoretical foundation for appropriate new economic policy in the Eastern European countries' investigations could be beneficial to provide an essential framework for acknowledging the significance of competitiveness and digital transformation variables in fostering digital transition.

The paper offers a new perspective by adapting Paul Romer's theory to the contemporary digital landscape of Eastern Europe, providing distinct theoretical insights and empirical research on the relationship between competitiveness and digitalization. Core originality lies in the adapted formula of the technological indicator, which integrates digital skills and efficient resources. Competitiveness and digital transformation indicators could provide valuable insights into business and government efficiency at the national level, accompanied by qualitative data or national policy recommendations. A more comprehensive look of industrial sector, government administration, health services, and educational opportunities could advance future knowledge of digital transformation and resource efficiency, as well as formulation of evidence-driven competitiveness policies. Future studies can also include the regular evaluation of the long-term viability and dependability of national rankings throughout indices. The data collected variability from year to year in certain rankings indicates that benchmark-based assessments could be influenced by methodological adjustments, indicator weights changes, or additional policy alterations, even if results show a high level of consistency.

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The Knowledge Structure, Emerging Trends, and Future Directions of Stock Market Volatility Research: A Bibliometric Review

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Abstract: This bibliometric review examines the evolution of stock market volatility (SMV) research by analyzing 1,949 publications indexed in Scopus between 1980 and 2025. The study provides valuable insights into major research trends, influential contributions, and emerging themes, while highlighting potential directions for future research in the field. The research aimed to identify influential elements within the literature and perform a comprehensive analysis. The study investigated two direct research streams through a systematic review approach and conducted a network analysis of keywords and documents supported by content analysis. The findings suggested several areas for future research, including Islamic stock markets, structural breaks, cryptocurrency, economic policy uncertainty, and futures. Notably, hybrid models like ANN-GARCH, Wavelet-GARCH, and Copula-GARCH were found to have received limited attention, limited work is available on emotional and behavioural dimensions in the context of stock market volatility, which needs to be addressed through sentiment-driven modelling using NLP and social media indicators. Moreover, few studies are available related to comparative analysis across market segments & require panel Data-based Studies. The study covered various aspects of stock market volatility, encompassing models, applications, and empirical properties. The study comprehensively covers models, applications, and empirical properties of stock market volatility. Additionally, the study offered practical implications and recommendations for regulators (to make informed decisions regarding policy development and implementation) and portfolio managers (understanding of influential elements in stock market volatility). Overall, this bibliometric review

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contributes valuable insights to the field, providing a comprehensive knowledge of stock market volatility and paving the way for further research.

Keywords: bibliometric analysis; biblioshiny; literature review; stock market volatility; VosViewer; volatility spillovers.

JEL classification: G10; C55.

1. INTRODUCTION

Volatility, a pivotal characteristic of capital markets, remains a pressing concern in the realm of financial economics research (Ahmed, 2021; Apostolakis *et al.*, 2021). Volatility, characterised by the extent of variation in financial time-series data, serves as a crucial metric for assessing the risk associated with the unpredictability of underlying asset returns. Following the profound impact of the international financial crisis, global stock markets experienced unprecedented and tumultuous fluctuations (Bhowmik and Wang, 2020). It has created challenges for the stock market's functioning and raises risk and uncertainty. Therefore, the precise measurement of stock index return volatility is crucial for lowering this uncertainty. In the 1960s, Eugene Fama introduced the efficient market hypothesis (EMH), which posits that financial markets are informationally efficient. According to this theory, current prices fully reflect all relevant and available Information regarding the intrinsic value of underlying securities. However, viewpoints among investors and academics regarding the actual efficiency of markets diverge, as evidenced by the strong, semi-strong, and weak versions of the EMH. Empirical testing of market efficiency hypotheses has been conducted in both developed and developing countries, yielding diverse outcomes.

The existing literature on Stock Market Volatility (SMV) highlights that, in addition to market efficiency, volatility profoundly affects investment yields (Mamtha and Srinivasan, 2016). Stock prices have proven to be "too volatile" to be explained by efficient market hypotheses, and therefore, volatility has emerged as a distinct and increasingly surprising fact (Campbell and Shiller, 1988). Financial market volatility plays a crucial role in determining the risk of financial assets (Ji *et al.*, 2022) and is a significant determinant in the pricing of financial derivatives and asset allocation (Zhu and Ling, 2015), as well as in portfolio management. However, predicting volatility is difficult because it is an unknown latent variable with intricate properties such as heavy tails and non-stationarity. Despite the accessibility of numerous techniques to estimate volatility, not all perform significantly in all markets (Matar *et al.*, 2013). Many univariate, multivariate, and hybrid models have been used to model and quantify SMV (Kashyap, 2023). Recently, numerous forecasting methodologies have improved the forecasting accuracy of SMV by fully utilising the forecasted data from a large number of possible determinants (Li *et al.*, 2021). In recent years, Stock Market Volatility (SMV) has become a high-profile area of research due to increased global uncertainties, advancements in trading technology, and changing geopolitical and macroeconomic conditions (Xu *et al.*, 2024) . The COVID-19 pandemic aftermath, coupled with the Russia–Ukraine war, long-term inflation, and central bank interest rate increases globally, has heightened the degree of uncertainty in global equity markets (Papadamou *et al.*, 2023; Insaidoo *et al.*, 2024). All these have reflected the urgency for sophisticated volatility forecasting models that can handle real-time data and respond to structural shifts in market

behaviour. Artificial intelligence (AI), machine learning (ML), and deep learning (DL) models are gaining popularity for modelling and forecasting volatility more accurately (Salisu *et al.*, 2023; Saraf and Kayal, 2023; Chatziantoniou *et al.*, 2025). The models are capable of processing high-frequency data and extracting sophisticated nonlinear patterns lost by conventional econometric models. In addition, the complementarity of large datasets, including social media sentiment, news analysis, and Google Trends, has been effective in improving volatility prediction. A second new thread of literature concerns spillover effects and volatility transmissions between markets, particularly under financial crises, geopolitical conflicts, and times of international economic integration (Naeem, 2024; Chatziantoniou *et al.*, 2025). Analysts are now studying volatility in terms of networks and contagion with a view to deepening systemic risk. In addition, the inclusion of ESG factors, green finance metrics, and crypto market dynamics in SMV research is creating new research opportunities (Yang, 2025; Zhang *et al.*, 2025). As the financial system grows more interdependent, the proper modelling and forecasting of SMV continues to be a bedrock of well-informed investment decision-making, policymaking, and risk assessment.

1.1. Volatility modelling, measurement, and theoretical background

Volatility is a fundamental metric for capturing the extent of fluctuations in security or asset prices, providing insight into their dynamic nature. This key measure is derived through the calculation of the standard deviation of price returns, offering a quantitative representation of the magnitude of price changes (Hou *et al.*, 2024). The definition of the price return r (N, Δ_t) at a time scale of Δ_n is derived from.

$$P(N) = e^{r\,(N,\Delta_t)} P(N - \Delta_t) \quad (1)$$

where P(N) is the price level of the asset.

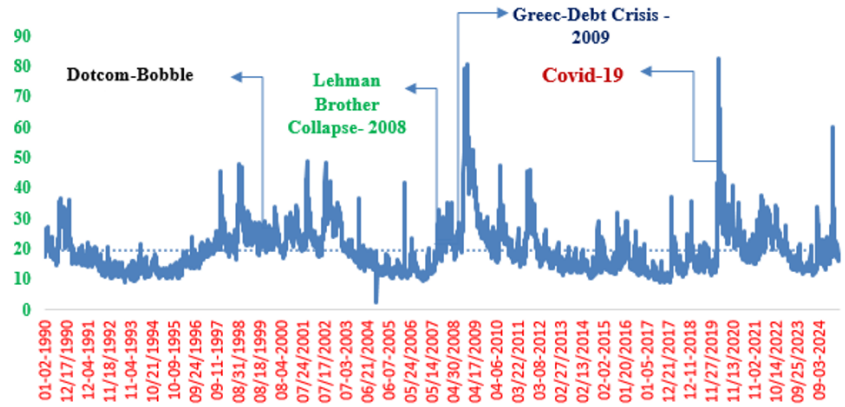
Hence:

$$r\,(N, \Delta_t) = \ln\left(\frac{P_N}{P(N-\Delta_t)}\right) \quad (2)$$

It can be calculated by applying traditional and emerging methods, and a wealth of financial economics literature on volatility forecasting has recently been developed. The influential ARCH model was given by (Engle, 1982), followed by the GARCH model (Bollerslev, 1986). Subsequently, a multitude of researchers have identified and developed various analytical volatility models, including EGARCH, GJRGARCH, QGARCH, SWARCH, M-GARCH, DCC-GARCH, BEKK-GARCH, ANN-GARCH, and others. These models have been devised to address the evolving challenges encountered in stock markets, such as volatility persistence, leverage effect, spillover effect, structural breaks, and the impact of macroeconomic variables.

Knowledge of the changing facets of volatility is essential for asset valuation, estimation, and risk management. For illustrative purposes, Figure no. 1 depicts the Chicago Board Options Exchange's (CBOE) Volatility Index's (VIX) yearly data based on the S&P 500 index from 1990 to 2025. A perceptive analysis of the data reveals intriguing insights about volatility returns in the United States. In 2018, the highest positive return of +130.25 per cent

was observed, while the lowest negative return of -45.80 per cent followed in 2019. These findings indicate the cyclical nature of volatility, with fluctuations occurring over time (Kashyap, 2023). Further, it also shows some other stylised facts about the stock market. It is affected by sudden changes or structural breaks due to several economic factors, like speculation, financial bubbles, and major catastrophic events like the early 1990s recession, the Dot-Com bubble, the 2008 Lehman collapse, the Greek debt crisis (2010), the European debt crisis (2011), and the COVID-19 pandemic (Simitis, 2016). It is due to the stock market's distinct characteristics, as depicted in Figure no. 1, that modelling volatility has become challenging. It seems that there is an inherent necessity to review volatility patterns. It also includes the movement of the data post-COVID.



Source: author's calculations

Figure no. 1 – CBOE Volatility Index (S&P returns: 1990-2025)

This paper reviews historical research developments in volatility, including interfaces in models and their extensions. It summarises and categorises the existing literature on SMV and can be used as a roadmap for future research (Raghuram *et al.*, 2010). As Winston Churchill once said, the farther back you look, the farther forward you can go. This study's analysis of previous literature on SMV since 1980 may be useful for estimating trends in the twenty-first century. It is believed to provide useful inputs for carrying out investigations in multiple emerging areas of stock markets and will aid the structure for subsequent studies (Tranfield *et al.*, 2003). This study has mapped the intellectual structure of SMV research based on the frequency of occurrence and co-occurrence of keywords and documents. This study also offers an overview of the forecasting models and their properties. SMV themes have further been reflected as crisis-specific and market-specific spillovers. Therefore, the current work, building on the previous research, provides a comprehensive bibliometric record of scientific contributions to the field of SMV to elicit a response to the ensuing questions:

1. How has the literature on stock market volatility (SMV) evolved, and what are the projected areas for future research advancements?
2. What are the key findings and trends identified through bibliometric and content analysis approaches?

3. How do methodological practices and contexts affect our understanding of stock market volatility?

4. What are the implications of the COVID-19 pandemic on stock market volatility and its differences between emerging and developed economies?

5. What are the dominant themes and niche areas in studying stock market volatility?

The remainder of this research is presented as follows: Section 2 demonstrates the methodology, encompassing data collection and examination scheme; Section 3 depicts the bibliometric and content analysis; Section 4 gives the discussion, and lastly, Section 5 provides implications and limitations of the study.

2. RESEARCH METHODOLOGY

This research applied a two-tiered investigative methodology, incorporating bibliometric analysis (Bhowmik and Wang, 2020) and content analysis (Kashyap, 2023; Insaidoo *et al.*, 2024). As a method for conducting systematic reviews, the bibliography framework of highlighting keywords, modelling, and synthesising the literature has been proposed. Researchers in the past have attempted to review the literature on SMV, but the conventional and customary literature assessments were constrained by the ability of investigators to manually handle data, resulting in a limited number of documents that could be reviewed (Ineichen, 2000; Hussain *et al.*, 2019; Seth and Sidhu, 2020; Kashyap, 2023). To statistically measure the vast, transparent, and reliable volume of Information, bibliometrics may be able to offer a systematised, fine, and regenerable investigative technique. However, the informational content of text-based records can be analysed using a series of organised, rule-based approaches known as "content analysis." In the social sciences, content analysis is a frequently employed technique that evaluates text data by condensing it into more easily understood clusters of facts (Kim and So, 2022). Figure no. 2 describes the entire research design and the procedures utilised for sampling, data collection, evaluation, and conclusion.

2.1. Sampling procedure

The study incorporates literature published from 1980 to 2025, dealing with SMV characteristics and patterns. The method of searching has been designed in such a manner as to ensure coverage of a broad spectrum of records. Documents have been sought, filtered, and assembled from the Scopus database (Khiste and Paithankar, 2017). This forum has been preferred for current academic work because it contains extensive peer-reviewed studies closely linked to the subjects of study (Anglada-Tort and Sanfilippo, 2019). For this article, we have taken the Scopus database for the literature review with the following strings; "Stock-Market" AND "volatility,"*TITLE("Stock-Market" AND "volatility") AND PUBYEAR > 1979 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"cp") OR LIMIT-TO (DOCTYPE,"ch") OR LIMIT-TO (DOCTYPE,"re")) AND (LIMIT-TO (LANGUAGE,"English")))*. Additional filters were added to make the study concise and focused, such as publication stage (Final or AIP (Article in Press), Document type (Article (AR), Review (RE), Conference Paper (CP), Book Chapter (CH), or Book (BK)), source type (journal), and finally, language (to English). We defined academic produce broadly to include books, book chapters, and conference proceedings, even though Lisée *et al.* (2008) demonstrated that published scientific articles constitute the primary research source for

bibliometric investigations. Authors like Glänzel *et al.* (2006) showed that adding conference records to bibliometric research results in a more thorough and accurate representation of a certain discipline's scientific productivity and can measure the potential to invent and present novel notions. Furthermore, while citations for specific book chapters are lower, the intricacies of idea transmission would likely be lost without them. However, review publications that lack conceptual and empirical applications have been eliminated from the scope of this study. Furthermore, because of either honest scientific errors or scientific malfeasance, retracted documents that were defective or deceptive were not considered (Schneider, 2021). Finally, regarding the inclusion and exclusion criteria, various academic outputs, including journal articles, books, book chapters, and conference proceedings, whether published or available in the press, were evaluated for this review. Excluding non-English publications, 2176 documents have been embedded. Further, the review articles (19) which are excluded from the search strings have themes covering exchange rate volatility, oil price volatility, volatility spillover or contagion, SMV (specific to Granger causality), investment risk in securities, financial crisis effect and calendar anomalies are a few of them (Jones *et al.*, 2004; Guo and Savickas, 2006; Kamstra *et al.*, 2010; Brancaccio *et al.*, 2020; Zhong and Liu, 2021; Sreenu, 2022, 2023). Afterward, a thorough review was done, and it was observed that there are various review articles (17) published in the context of the individual country or regional blocks, such as in India, China, China, Pakistan, Southeast Asian countries, and European Unions, (Ahmed *et al.*, 2005; Chancharoenchai and Dibooglu, 2006; Harrison and Moore, 2012; Alikhanov, 2013; Zhang and Jaffry, 2015; Khan *et al.*, 2017; Singh, 2018). Further, review article (1) examined the SMV specifically to oil price and volatility spillover. Another study which are similar to our research work restricts its bibliometric analysis from the period of 2008 to 2019 (Bhowmik and Wang, 2020). Our research extended this work up to more than four decades, and apart from the bibliometric analysis, we considered content analysis to fill the research gap. Additionally, a manual elimination of 116 articles was done based on title, abstract and keywords specific to the other channels of volatility, say, import-export oil price volatility, commodity price volatility, exchange rate volatility, and some other macro-economic variables' volatility. The final sample of 1949 research articles has been taken for bibliometric and content analysis.

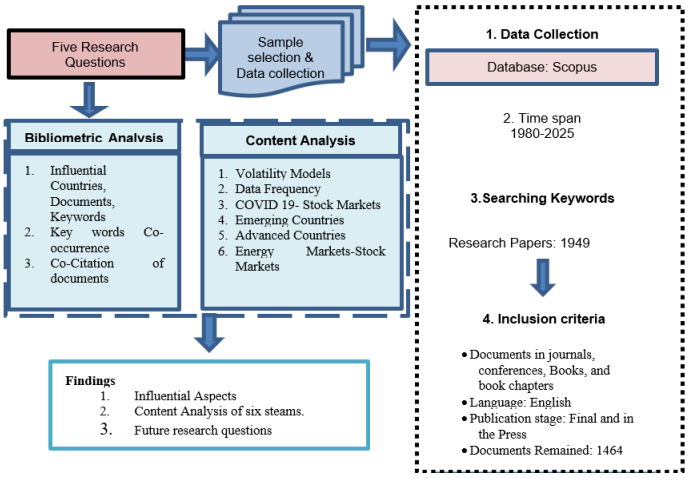


Figure no. 2 – Search parameters for document retrieval

2.2. Data analysis

There are two steps to the analysis of this research: bibliometric and content analysis. In the bibliometric stage, trends in publications and citations, as well as the co-occurrence of keywords and co-citation of documents, have been examined. To process the data statistically and visually, we used Biblioshiny and the VOS Viewer apps. In the second step of the project, we carried out a content analysis and were able to separate two independent research streams using subject keywords and a comprehensive review of abstracts.

3. BIBLIOMETRIC AND CONTENT ANALYSIS

3.1. Preliminary facts relating to data

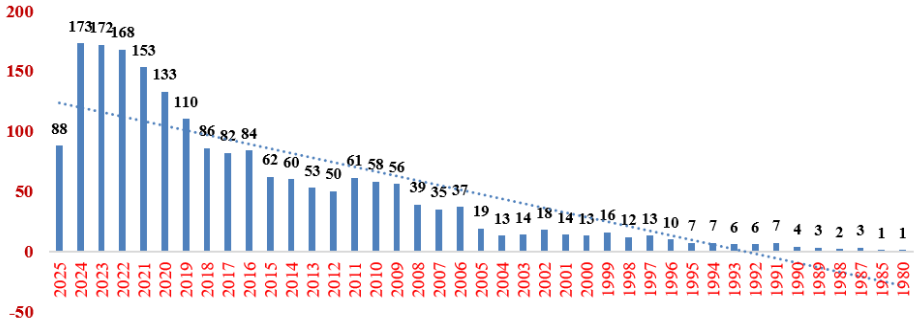
Table no. 1 presents a panoramic view of the database, wherein it can be seen that 3509 authors have made contributions in the field, applying 3562 non-identical keywords for classifying their work. Additionally, the mean citations per document equalled 26.91. The outcome stipulates that there are ample numbers of papers with huge citation counts, while a small number of papers have few citations. Moreover, the dataset included 328 single-authored studies on SMV. The average score of co-authors against each document is 2.61, indicating that SMV publications have been collectively explored.

Table no. 1 – Summary description of data

Description	Results	Description	Reseults
Main Information About Data		Authors	3509
Timespan	1980:2025	Authors of single-authored docs	284
Sources (Journals, Books, etc)	667	Authors Collaboration	
Documents	1949	Single-authored docs	328
Annual Growth Rate %	10.46	Co-Authors per Doc	2.61
Document Average Age	8.8	International co-authorships %	22.88
Average citations per doc	26.91	Document Types	
References	61860	Article	1684
Document Contents		book chapter	57
Keywords Plus (ID)	2442	conference paper	184
Author's Keywords (DE)	3562	Review	24

Source: authors' compilation

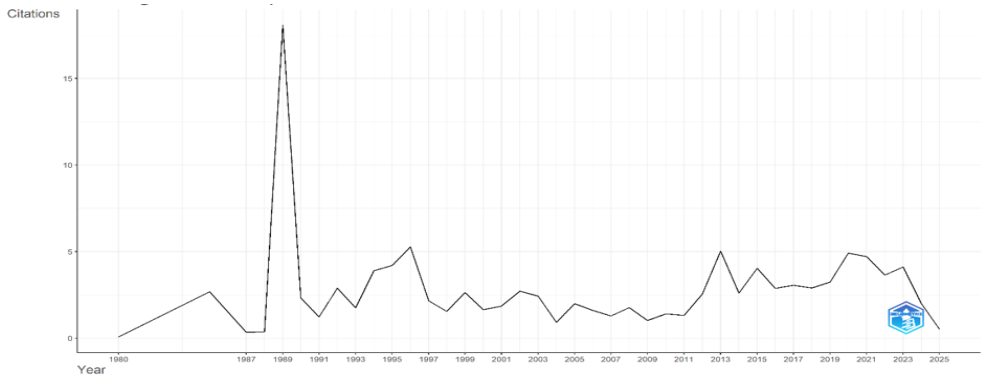
Figure no. 3 demonstrates the full order of publications in SMV during the time under consideration, from 1980 to 2025. The research concerns the notions of SMV and appeared in the year 1980 through the publication of a single document. Thereafter, 56 documents were issued during the year 2009, 104 documents in 2019, and 133 articles in 2020. As of December 15, 2022, 165 documents have been issued. Further, it depicts the annual growth rate of 12.93% and reveals that scholars are showing great interest in SMV. The annual Production has continuously increased as in the year 2024 it reached to 173 and is expected to continuously increase in the coming years as per the trend line.



Source: biblioshiny output

Figure no. 3 – Annual scientific production of SMV documents (1980-2025)

Figure no. 4 offers an appraisal of the citations, which permits the assessment of the superiority of the published documents. The only article published by Mankiw *et al.* (1985) has 110 citations. The article makes an unbiased reappraisal of SMV and offers impartial tests for small samples with no stationary hypotheses, avoiding the requirement to detrend. In 1989, only 3 articles were produced, and the mean number of citations per article was 582. Schwert (1989) has received 1710 citations so far. In the year 2013, 52 documents were produced, with the greatest number of 2401 citations, with an average of above 46 citations per article and 5 citations per year. The year 2015 witnessed 61 documents with 1840 citations and 30 citations on average per document. These findings disclose that research on SMV began several years ago, and 87 per cent of the publications have obtained citations.



Source: biblioshiny output

Figure no. 4 – Average article citations per year

3.2. Influential facets of the literature

We determined the influential countries, documents, and keywords in the SMV literature.

3.2.1. Influential countries

Table no. 2 portrays the prolific countries ascertained by the number of documents released. The studies on SMV are based in 60 different countries, with China having the most documents (484). However, surprisingly, the USA, which seems too small to see as compared to China in terms of publication counts, became the first-ranked country in total citations with 14637. On analysing the citations, it is established that the USA is producing quality work, as it gained the most citations. As a result, both developed nations like the United States and the United Kingdom and developing nations like India, China, and Malaysia have been trying to investigate SMV. It is evident from the table that other countries are also putting efforts in the same area to benefit domestic as well as Global stakeholders.

Table no. 2 – The leading publishing Nations in the SMV

Country	Documents	Citations	Country	Documents	Citations
China	484	10033	Jordan	16	198
United States	261	14637	Oman	16	532
India	223	3307	Czech Republic	15	615
United Kingdom	137	5617	Brazil	14	528
Australia	82	2484	Indonesia	14	118
Taiwan	80	1209	Netherlands	14	755
South Korea	79	2619	Poland	14	376
Turkey	73	1576	Bangladesh	13	195
Malaysia	69	1068	Egypt	13	205
France	63	2708	Ghana	12	102
Pakistan	61	1955	Iran	12	85
Tunisia	58	2053	Ireland	12	331
South Africa	55	825	Russian Federation	12	162
Germany	53	2487	Bahrain	11	69
Italy	47	1486	Denmark	11	276
Saudi Arabia	44	862	Qatar	10	181
Greece	43	1122	Sweden	10	100
Spain	39	1432	Switzerland	10	378
Canada	38	1494	Finland	9	350
Nigeria	35	431	Morocco	9	108
Viet Nam	35	772	Peru	8	52
Hong Kong	26	690	Slovakia	8	197
Japan	26	1145	Belgium	7	91
New Zealand	26	923	Kuwait	7	287
United Arab Emirates	26	640	Macao	7	283
Lebanon	25	988	Singapore	7	127
Portugal	23	746	Chile	6	45
Romania	23	178	Colombia	6	182
Thailand	22	184	Israel	6	448

Source: authors' compilation

3.2.2. Influential documents

Table no. 3 provides information about the top 10 documents that researchers most frequently cite. First is the local citation, depicting a document getting citations in each 1949-

node network, and second is the global citation, which speaks about the entire Scopus citations owing to the document. It is demonstrated that a noteworthy disparity prevails across the globally cited and locally cited documents. A leading document in global citations signifies that the paper has drawn the attention of the scholarly community from other domains as well. Schwert (1989) has the highest global citations (1,969) but the lowest Lc/Gc ratio of 6.70%, which implies wider influence outside the main research area. Conrad and Conrad and Loch (2015) and Paye (2012) have the highest Lc/Gc ratios of 22.62% and 22.06% respectively, reflecting strong contextual significance with lower global citation rates. Early classics by Engle *et al.* (2013), Bollerslev and Ole Mikkelsen (1996) and Hamilton (1996) retain high levels of international visibility, highlighting the impact their findings have had on econometrics and volatility modelling, although their reduced Lc/Gc ratios indicate they are today more referenced for theoretical foundation than recent empirical use. Later publications between 2012–2015 tend to have higher Lc/Gc ratios, indicating their methodological consistency with contemporary research directions.

Table no. 3 – The top 10 Most-cited Papers

Document	Year	Local Citations	Global citations	Lc/Gc Ratio (%)
(Schwert, 1989), j finance	1989	132	1969	6.70
(Engle *et al.*, 2013), rev econ stat	2013	104	760	13.68
(Paye, 2012), j financ econ	2012	75	340	22.06
(Koutmos and Booth, 1995) j int money financ	1995	62	450	13.78
(Liu and Zhang, 2015), finan res lett	2015	56	411	13.63
(Bollerslev *et al.*, 1988), j econom	1996	49	723	6.78
(Aggarwal *et al.*, 1999), j financ quant anal	1999	44	451	9.76
(Lee *et al.*, 2002), j bank finance	2002	40	487	8.21
(Conrad and Loch, 2015), j appl econom	2015	38	168	22.62
(Hamilton, 1996), j appl econom	1996	38	428	8.88

Source: authors' compilation

3.2.3. Influential keywords

The word cloud depicted in Figure no. 5 is a graphical representation of the frequency of occurrence of keywords in documents, as indicated by the size of the word in the graph. This may exhibit the significance of the keyword in scientific literature. When the authors' keywords were examined, it was discovered that the term "volatility" appeared the most (322 times), followed by words describing theoretical, methodological, contextual, and typical characteristics of volatility such as "GARCH" (224), "volatility spillover" (180), "realized volatility" (108), "volatility forecasting" (82), "emerging markets" (61), "EGARCH" (53), "COVID-19" (48), "long memory" (42) and others (50). Apart from these, psychological or behavioral variables like investor sentiments, variables depicting the structure of the data like "high-frequency data" and "idiosyncratic volatility," as most of the results lose reliability due to inappropriate collection of the data, and variables explaining some properties or effects of volatility like implied volatility, leverage effect, volatility persistence, etc. were noticed to be dominant. Internationally, numerous researchers have examined how investor sentiments influence stock markets. There is a strong relationship between investor sentiment and market

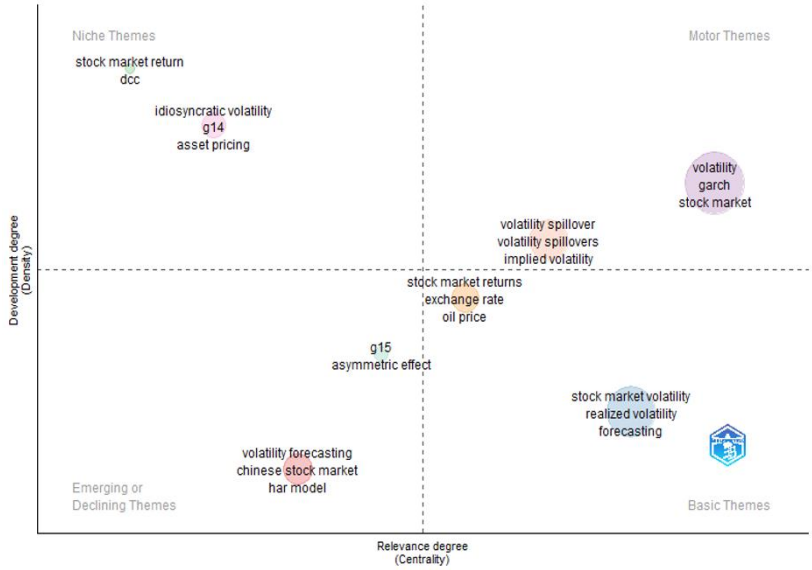
anomalies (Chen *et al.*, 2020; Ferreira *et al.*, 2021; Zhang *et al.*, 2021). It can be inferred from this word cloud that the existing literature on SMV has been exploring its various properties, effects, and mathematical and econometric models, which are of great significance to address the theme.

Source: biblioshiny output

Figure no. 5 – Word Cloud

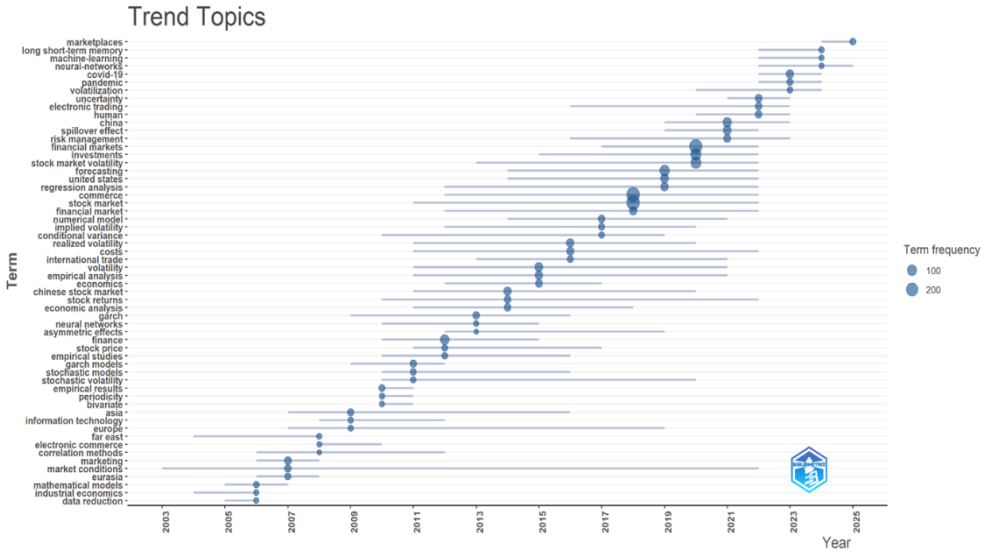
3.2.4. Influential themes

Figure no. 6 presents a thematic analysis that provides the potential for further developments in the domain. The themes of GARCH and spillover in Q1 (upper-right quadrant) are the leading themes. GARCH models have been extensively used to forecast volatility (Zhang and Zhang, 2022). The studies on volatility spillover have encompassed the evolving process of volatility spillover across the world (Charfeddine and Al Refai, 2019). Q2 (upper left) comprises idiosyncratic volatility and the DCC model, both of which are very high in density but low in centrality. Idiosyncratic volatility calculates the part of the variance in returns that a particular asset-pricing model fails to explain (Hoang Van *et al.*, 2020). The DCC-GARCH model is perceived as a powerful model since it accounts for time-varying volatility spillovers. Both the DCC-GARCH model and idiosyncratic volatility are extremely established, focused, and niche themes that need to form bonds with the leading theme of SMV. Q3 (lower left) shows asymmetric market interactions as the emerging theme, exhibiting how the oil market and stock markets have asymmetrical spillover effects and how bad volatility spillovers outweigh favourable volatility spillovers. Lastly, Q4 constitutes SMV, an underlying theme that is continuing with several experiments and explorations across the world. This theme is central and important for the research field.



Source: biblioshiny output

Figure no. 6 – Thematic map



Source: biblioshiny output

Figure no. 6.1 – Trending topics

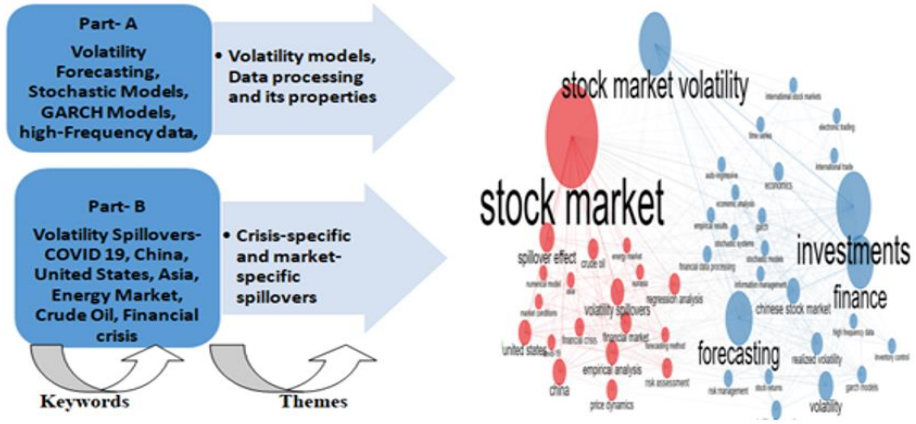
Figure no. 6.1 shows in these years how some topics became popular, along with the density of their popularity some of the trends started from 2004 to 2006 topics like industrial

economics, mathematical models and data reduction were in trend whereas from 2010 to 2015 topics like bivariate analysis, empirical studies, Stock Movement, Garch Models and Technological issues were in focus and from 2020 to 2025 Themes like machine learning, Neural- Networking, Spillover and Similar Themes are more frequently used and Focused. Over the past five years, stock market volatility has been increasingly influenced by global uncertainties, geopolitical tensions, and macroeconomic shocks such as the COVID-19 pandemic. Technological advancements and algorithmic trading have further amplified short-term market fluctuations. Additionally, investor sentiment shaped by social media, news flows, and behavioural biases has emerged as a critical driver of volatility trends.

3.3. Network analysis

3.3.1. Keywords co-occurrence network extended with content analysis

Co-occurrence Network, Categorisation, and Classification of Constructs on the basis of the keywords plus is the next analysis produced by Biblioshiny. It is a means to broadly comprehend the conceptual structure of this scientific work. Keyword co-occurrences in Figure no. 7 show that the whole literature on SMV revolves around two main categories identified in two parts.



Source: authors' compilation and biblioshiny output

Figure no. 7 – Themes based on the keywords

Part A: It displays the methodological practices implemented for the achievement of SMV. It covers Information about types of volatility models, data preprocessing, and properties of volatility models.

Volatility models and data pre-processing: The keywords "forecasting," "stochastic models," "financial data processing," "risk management," "conditional volatility," "GARCH models," "auto-regressive," and "high-frequency data" suggest that, given the econometric advances, SMV is predictable and that too with greater certainty (Pagan and Schwert, 1990).

Volatility modelling has been a rising area of investigation ever since the initiation of ARCH and stochastic volatility (SV) models. Table no. 4 exhibits Information about volatility models and authors who have used the respective volatility models to forecast volatility.

Table no. 4 – Volatility models and authors' information

S. No	Volatility Model	Model features	Author's Information
1.	Benchmark (GARCH)	The GARCH model posits that conditional volatility is a linear combination of prior volatility and errors, making it suitable for forecasting short-term volatility.	(Kiymaz and Berument, 2003; Hammoudeh and Li, 2008; Bouri, 2015; Boldanov *et al.*, 2016; Ewing and Malik, 2016)
2.	Integrated GARCH (IGARCH)	The IGARCH model (unit-root GARCH models) exhibits long memory in volatility, and the sum of the variance equation coefficients is close to unity.	(Horng *et al.*, 2012; Bentes, 2014)
3.	Fractionally Integrated GARCH (FIGARCH)	It is a non-linear model appropriate for capturing long-memory shocks.	(Zhang, 2014; Kyriakou *et al.*, 2021; Tripathy, 2022)
4.	Golsten, Jagannathan, and Runkle (GJR-GARCH) & Threshold GARCH (TGARCH) model	These models are used to analyse asymmetrical behaviour in volatility, and they add another residual term to the benchmark GARCH.	(Bakry *et al.*, 2022)
5.	GARCH-MIDAS	It is suitable to link the observations with macroeconomic variables and can be used to examine its impact on stock volatility.	(Bai *et al.*, 2021; Su and Liu, 2021; Song *et al.*, 2023)
6.	GARCH-in-Mean (GARCH-M), SWARCH	It permits the mean of the security returns to be a function of the conditional volatility. On the other hand, SWARCH is a regime-switching model designed to capture the high persistence of variance in returns.	(Natarajan *et al.*, 2014; Coffie, 2015)
7.	Exponential GARCH (EGARCH), AGARCH, QGARCH	It is suitable to capture the asymmetric behaviour of volatility, and it does not have the restriction that the coefficients be positive.	(Walid *et al.*, 2011)
8.	Multivariate GARCH	Their models are used to compute volatility at the same time for multiple securities.	(van Dieijen *et al.*, 2020; Yu *et al.*, 2020)
9.	Component GARCH(CGARCH)	It captures long-term effects by breaking the model down into long-run and short-run components.	(Chen *et al.*, 2015)
10.	Dynamic Conditional Correlation (DCC) model	It is a nonlinear model that has the versatility of standard GARCH models and can be approximated using univariate or two-step methods depending on the likelihood function.	(Gamba-Santamaria *et al.*, 2019; Luo and Wang, 2019; Tang and Aruga, 2021)

S. No	Volatility Model	Model features	Author's Information
11.	BEKK-GARCH	It is a benchmark GARCH model extension that allows interaction between conditional variances and covariance with limited parameters.	(Sarwar *et al.*, 2019; Zhang *et al.*, 2020; Ahmed and Huo, 2021)
12.	Hybrid models-ANN-GARCH, Neural Network GARCH, Fuzzy/SVM/ GARCH, COPULA, Wavelet	These are useful for capturing extreme values, structural breaks, and chaotic Information better than others.	(Chen *et al.*, 2022; Kashyap, 2023; Katoch and Peer, 2026)

Source: authors' compilation

Furthermore, the frequency of data also impacts the accuracy of the analysis of volatile time series. Table no. 5 provides Information about the frequencies of the data used to understand and estimate volatility. The majority of the existing volatility forecasting literature relied on a data set of equivalent frequencies that are easily accessible on a monthly, weekly, and daily basis. Since shock impacts are thought to be swift and short-lived, daily data is contended to be more revealing than weekly or monthly data (Madaleno and Pinho, 2014). However, with the availability of high-frequency data, researchers have found that these data are even more insightful on volatility, which has led to the development of the idea of realised volatility. High-frequency data has entered the literature on volatility modelling and forecasting quite rapidly (Andersen *et al.*, 2007) and has gained popularity in price forecasting as well as volatility models (Degiannakis *et al.*, 2018). It has been proved that extreme value models, structural break models, etc., fail to provide good volatility forecasts because of the low-frequency data being used (Bali and Weinbaum, 2007; Taylor, 2008).

Table no. 5 – Type of data and author information

S No.	Authors' Information	Type of data
1	(Ashwani and Sheera, 2018; Finta *et al.*, 2019)	High-frequency data
2	(Khalfaoui *et al.*, 2019; Belhassine and Karamti, 2021)	Daily data
3	(Abbas and Satti, 2019; Haritha and Rishad, 2020; Ma *et al.*, 2024)	Monthly data
4	(Wang and Moore, 2009; Cevik *et al.*, 2020; Kartsonakis-Mademlis and Dritsakis, 2020)	Weekly data

Source: authors' compilation

3.3.2. Properties of volatility model

Volatility Persistence Including Innovations: Empirical Evidence: The autocorrelation of absolute returns, known as persistent behaviour, is used to examine volatility clustering, and this level of persistence varies from market to market. The effects of shocks typically take a long time to return to the normal mean level, and the return series exhibits volatility persistence. It is influenced by innovations, public news, and trading volume (Hammoudeh and Li, 2008). Many scholars have also analysed the long-term persistence in SMV, proving that volatility exhibits long memory behaviour (Corsi, 2009;

Chkili and Hamdi, 2021; Lahmiri and Bekiros, 2021). During the COVID-19 pandemic, all markets exhibited a significant level of volatility persistence.

Volatility and Leverage Effect: Empirical Evidence: Volatility is frequently associated with asymmetric reactions (ups and downs), implying that negative Information generates more volatility than positive Information and increases financial leverage (Zhou *et al.*, 2012; Hussain *et al.*, 2019). The leverage effect describes how negative shocks increase conditional covariance, while positive shocks respond differently to conditional covariance. Many academicians have debated this asymmetric phenomenon, and it has been observed that global equity markets are usually assumed to be asymmetric with negatively correlated conditional variance returns (Dash and Mahakud, 2013; Bagchi, 2017). On the other hand, some scholars have given contradictory conclusions about the asymmetric phenomenon and are sceptical about whether negative conclusions generate more volatility than positive ones do (Chiang and Doong, 2001; Coffie, 2018; Kashyap, 2023). During the COVID pandemic, various researchers depicted the dominance of asymmetric phenomena in emerging market economies and proved that negative shocks generated more volatility than positive shocks (Bhattacharjee and De, 2022; Jindal and Kumar Gupta, 2022).

Structural breaks: It is a radical shift in the time series that affects the volatility model's persistence (Lamoureux and Lastrapes, 1990). The global stock markets have become more chaotic due to sudden changes in recent years, such as political or crisis news, or casualties like the COVID-19 pandemic. Scholars have utilised numerous methodological tools such as Chow tests, Iterated Cumulative Sum of Squares (ICSS), Bai & Perron (BP) tests, etc., to capture structural breaks (Kashyap, 2023). Various studies have concluded that if structural breaks are ignored, it may affect the volatility persistence and lead to forecasting errors (Ewing and Malik, 2016; Cevik *et al.*, 2020; Kartsonakis and Charitidis, 2020; Dabwor *et al.*, 2022). As a result, when analysing volatility and spillover effects, practitioners should consider structural breaks or run models that account for these changes.

Part B: It covers the dynamics of volatility spillovers in global financial markets. Spillover effects are influenced by crisis-specific and market-specific factors (Lien *et al.*, 2018). Li (2021) found that risk is transmitted by economically developed regions and received by economically undeveloped areas. Moreover, several studies discovered volatility spillovers to be crisis-sensitive during the coronavirus recession (Apostolakis *et al.*, 2021; Bahloul and Khemakhem, 2021; Li, 2021). Table no. 6 exhibits the summary table of crisis-specific and market-specific spillovers.

3.3.3. Crisis-specific (COVID-19) Spillovers on SMV

The connection between SMV and COVID-19 has garnered significant attention since the onset of the pandemic. Due to the pandemic's contagious effect, the whole globe changed drastically, and the stock markets were no exception. The conclusions are:

i) Spillover Effects between Thailand and Indian Stock Markets: There are significant spillovers from Thailand to Indian Stock Markets and vice versa, and further revealed the impact of negative shocks than positive shocks on these markets (Jindal and Kumar Gupta, 2022).

ii) Overconfidence Bias and Volatility Spillovers in Ghana: Overconfidence bias and volatility spillovers exist during the COVID-19 pandemic in Ghana.

(iii) Strengthened Connections across Continents: Cheng *et al.* (2022) observed that the pandemic period led to stronger connections among stock markets across different continents, highlighting the global nature of the crisis.

(iv) Unprecedented Volatility Spillovers across International Stock Market Indices: There is an unprecedented increase in volatility spillovers across international stock market indices in Brazil, China, Italy, India, Germany, Russia, Spain, the United Kingdom, and the United States of America (Basuony *et al.*, 2021).

(v) Currency Volatility and Stock Market Returns: Currency volatility has influenced the market returns of Brazil (BOVESPA), Chile (S&P CLX IPSA), India (SENSEX), Mexico (S&P BMV IPC), and Russia (MOEX) significantly, and significant volatility spillover between stock and currency markets was found in emerging economies.

The other studies depict a similar influence of COVID-19 on SMV (Lahmiri and Bekiros, 2021; Gupta *et al.*, 2022). These collective findings demonstrate the wide-ranging effects of the pandemic on stock market volatility, revealing important insights into the interconnectedness of global markets and the influence of various factors on investment dynamics during times of crisis.

3.3.4. Market-specific spillovers

Evidence from Emerging Countries

The intriguing research by Kambouroudis (2016) suggests that risk transmission in emerging markets is a recent phenomenon, rendering these markets susceptible to external shocks. These emerging markets have 25 developing nations, some of which fall under economic blocs such as BRICS, CIVETS, and MENA (Jeris *et al.*, 2022). The forthcoming information highlights the interconnectedness between the stock market and other markets within these emerging countries.

BRICS: BRICS is a block of five major countries (Brazil, Russia, India, China, and South Africa). The conclusions are:

(i) Long-term Dependencies and Energy Commodities: Long-term dependencies exist between energy commodities and the stock markets of the BRICS countries.

(ii) Volatility Spillovers during Major International Events: There is an increase in time-varying volatility spillovers in BRICS nations during major international happenings (Mensi *et al.*, 2021).

(iii) Heterogeneous Spillovers and Positive/Negative Shocks: Stock and oil market volatility exhibits heterogeneous spillovers, indicating positive and negative shocks (Salisu and Gupta, 2021).

(iv) Market-Specific Volatility and Persistence: Significant volatility spillovers are found in all markets and further, Chinese market is the most volatile, whereas the Brazilian market is the least volatile, and the Chinese market has the highest volatility persistence, followed by South Africa, Russia, India, and Brazil, respectively (Mukhodobwane *et al.*, 2020).

(v) Bi-Directional Volatility Spillover between Currency and Stock Markets: There is a bi-directional volatility spillover between currency and stock markets of India, China, and South Africa.

(vi) Risk Exporters and Risk Receivers: G7 is the exporter of risk, and BRICS is the receiver of risk (Zhang *et al.*, 2021).

(vii) Significant Spillover Effects and Volatility Shocks Persistence: There is evidence of significant spillover effects and persistence in volatility shocks in all BRICS stock markets. To sum up, it is concluded that most scholars have demonstrated the impact of stock market volatility in BRICS nations, and significant persistence and spillover effects have been observed.

North Africa (MENA), Middle East, and CIVETS: The findings are as follows:

(i) Influence of Macroeconomic Variables on SMV: The SMV is not fully influenced by spillovers and fluctuations in macroeconomic variables (Mechri *et al.*, 2021).

(ii) Impact of Political Events on SMV in MENA: Significant volatility spillovers are found, but political events have a greater impact on MENA's SMV than the financial crisis (Talbi *et al.*, 2022).

(iii) Economic Freedom Index and SMV: There is an association between the economic freedom index and SMV, and it proven that spillover effects can be lessened when economic freedom is linked with efficient regulations (Touny *et al.*, 2021).

(iv) Time-Varying Volatility Spillovers and Market Regimes: There are time-varying volatility spillovers in markets, and three regimes, as low, turmoil, and high volatility regimes, are found (Bahloul and Abid, 2014).

(v) Interlinkages of African and Middle East Stock Markets: The interlinkages of the African and Middle East region's stock markets are not uniform across all the region's countries.

vi) Volatility Spillovers between Chinese and African Stock Markets: There are significant volatility spillovers between the Chinese and African stock markets.

There are some other emerging nations (Thailand, Poland, Croatia, Hong Kong, South Korea, Malaysia, India, Philippines, and Singapore) where the scholars analyzed SMV and all markets depicted significant volatility persistence, spillover, and leverage effects (Spulbar *et al.*, 2020; Toe and Ouedraogo, 2022).

SMV in the Islamic stock market (ISM): Over the years, several studies have been conducted to analyse SMV in the Islamic market. Unfortunately, the ISM was not given much importance and was not considered a regular stock market. The conclusions are:

(i) Risk and Spillovers: There are investment risks in the Muscat securities market due to SMV spillovers in ISM (Alam *et al.*, 2020).

(ii) Political Uncertainty and Spillovers: The political uncertainty influenced the spillover effects (Li *et al.*, 2023).

(iii) Return-Volatility Relationship: There is a strong association between return and volatility spillovers of the global ISM as well as the conventional stock markets (Shahzad *et al.*, 2017).

(iv) Bonds and Volatility Spillovers: There is a significant dependence of bond returns on volatility spillovers in ISM (Naifar, 2016).

(v) Forex Market Spillovers: There are volatility spillovers from the ISM to the forex market of Turkey.

(vi) Oil Volatility and Market Returns: There is a negative spillover effect of the oil volatility on ISM returns (Karim and Masih, 2021).

(vii) Regional Volatility Dynamics: The volatilities depend upon their own short, mid, and long-term volatilities, which differ significantly between the Malaysian and global ISM indices. These themes collectively provide insights into the dynamics and implications of SMV in the Islamic stock market, emphasising the importance of considering the ISM as a regular and significant stock market.

3.3.5. SMV and advanced countries

This section covered the SMV and its interconnection in emerging as well as advanced economies. The conclusions are: (i) The bidirectional volatility spillovers and the structural breaks influenced the dynamic conditional correlations between Shanghai's and S&P trading return (Pan and Mishra, 2022); (ii) different markets (Hong Kong, and United States) have different reactions to the same events (Hou *et al.*, 2024); (iii) Share markets in USA, Germany, Hungary, India, and Canada depicted high positive volatility during the global financial crisis and also influence each other (Spulbar *et al.*, 2020); (iv) Economic policy uncertainty (EPU) connectedness significantly influences the partner country's SMV ; (v) There are crisis specific spillovers depicting shock transmission from the US to Latin America during the Lehman Brothers crisis, significant interactions between the European markets SMV during the Brexit crisis (Li, 2020), existence of financial contagion in US, Central and Eastern European stock markets (Horváth *et al.*, 2018).

3.3.6 SMV and Energy Markets

The scope and development of connections between stock markets and energy markets, including electricity, natural gas, coal, oil, and carbon, have also been reviewed in the study. The main conclusions are: (i) strong spillover relations exist between crude oil and stock markets (Wen *et al.*, 2019; Ashfaq *et al.*, 2020); (ii) Natural gas provides better hedging effectiveness to stock markets than crude oil (Jebabli *et al.*, 2022); (iii) spillovers became intense following the fall of Lehman Brothers (Wen *et al.*, 2020) and the COVID-19 pandemic (Hernandez *et al.*, 2022); (vi) There are reciprocal spillover effects between the coal market and the stock market for emerging energy companies (Lin *et al.*, 2019) (vii) The carbon and stock market correlation is strengthened by the financialization of the carbon market, policies governing carbon market performance, and investor behavior (Wen *et al.*, 2020).

Table no. 6 – Summary table crisis-specific and market-specific spillovers

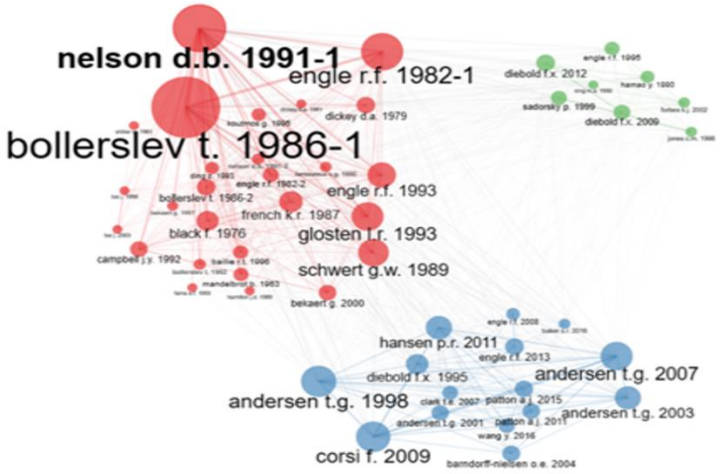
Spillover		Key Findings
Crisis-Specific Spillovers on SMV	COVID-19	Significant spillovers during the crisis, Existence of overconfidence bias, China is not the main carrier of volatility spillover, Connections across different continents became stronger, Significant volatility spillover between stock and currency markets was found.
Market-Specific Spillovers on SMV	BRICS	Long-term dependencies exist between energy commodities and the stock markets. Heterogeneous spillovers are found between the stock and oil markets, Bi-directional volatility spillover between currency and stock markets, G7 is the exporter of risk, and BRICS is the receiver of risk.

Spillover		Key Findings
	North Africa (MENA), Middle East, & CIVETS	No uniformity in African and Middle East regions, significant volatility spillovers between Chinese and African stock markets, Significant volatility spillovers between the Chinese and African stock markets.
	Islamic Stock Market (ISM)	Political uncertainty influenced the SMV spillovers. Strong association between return and volatility spillovers of the global ISM, Significant dependence of bond returns on SMV, Negative spillover effect of oil volatility on ISM returns.
	Advanced Countries	Different markets (China, Hong Kong, and the United States) have different reactions to the same events; Economic policy uncertainty (EPU) connectedness significantly influences the partner country's market spillover. Existence of financial contagion in the US, Central and Eastern European stock markets.
	Energy Markets	Strong spillover relations exist between crude oil and stock markets. Spillovers became intense after the crisis, such as the Lehman collapse and the pandemic.

Source: authors' compilation

3.4. Co-Citation network of documents

Figure no. 8 gives Information about the co-citation network of documents. It exhibits fresh papers of highly cited articles based on the citation indexes and offers a list of more significant "core" publications of former materials for a specific field (Small, 1973). In the red cluster, Bollerslev (1986) (GARCH-1986), Engle (1982) (ARCH-1982), Nelson (1991) (E-GARCH-1991), and Glosten *et al.* (1993) (GJR-GARCH-1993) models have been covered (Refer Table no. 4). In the blue cluster, Andersen *et al.* (2007) discovered the difference between the volatility jump component and continuous component and proved that the former is less persistent than the latter, yet an important predictor of future volatility. Andersen and Bollerslev (1998) proposed a realised volatility model, and relying on that, Andersen *et al.* (2007) gained the attention of many scholars. Later, others worked on realising volatility using high-frequency data, like Corsi (2009), Patton and Sheppard (2015). The green cluster gives Information about the authors who highlighted volatility spillovers between the markets (Engle, 1990; Hamao *et al.*, 1990; Sadorsky, 2009). The contributory work was done by Diebold and Yilmaz (2009), who analysed the volatility spillover across the markets, i.e., from one market to the other. They concluded that the markets have different behaviour in terms of the dynamics of return and volatility spillovers. Extending their previous work, Diebold and Yilmaz (2012) analysed the volatility spillovers across different assets, considering US stock, bond, currency, and commodity markets. The results showed significant volatility variations in all markets, limited cross-market volatility spillovers until the 2007 global financial crisis, and significant volatility spillovers after the crisis.



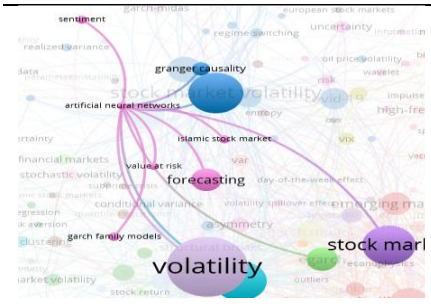
Source: biblioshiny output

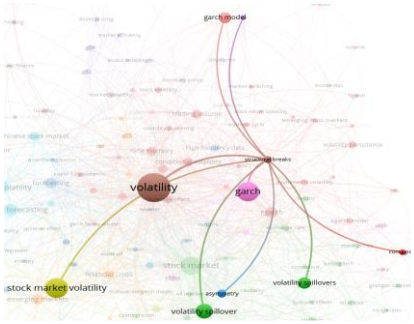
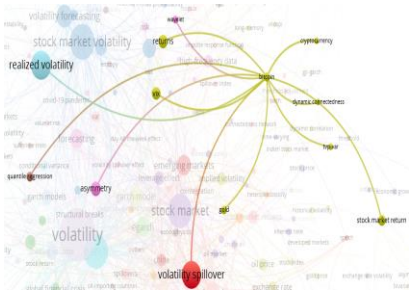
Figure no. 8 – Co-citation network of documents

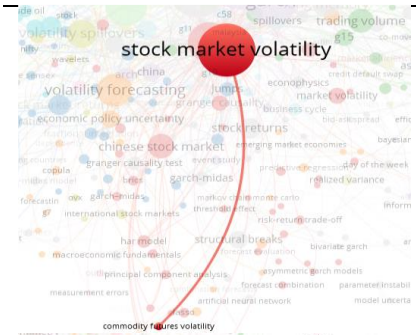
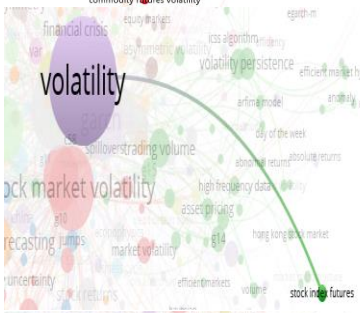
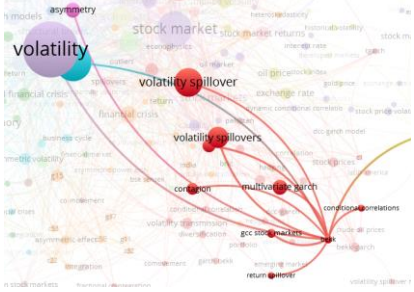
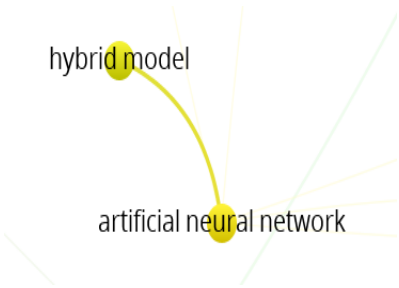
3.5. Future research gaps

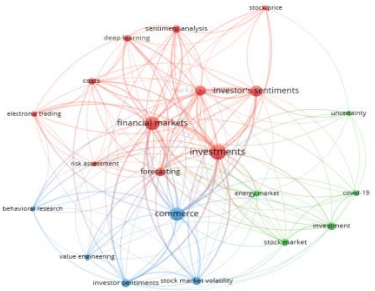
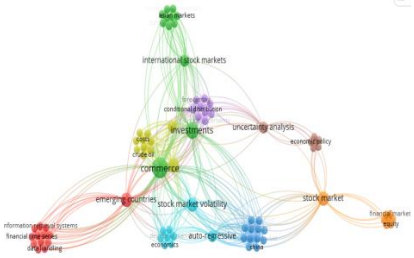
This section is significant as it highlights the research gaps, network gaps, and future research directions. The body of knowledge on SMV is growing quickly, but there are still crucial aspects that need to be addressed. Firstly, the bibliometric analysis helped us suggest various areas of research for additional investigation; subsequently, we developed the relevant research questions from future study agendas. We have used VOS viewer software, which is highly advised in this context since it assesses the importance of a particular subject in the literature by automatically counting the frequency of keywords in the sampled documents (José de Oliveira *et al.*, 2019). The potential research questions for upcoming studies are presented in Table no. 7.

Table no. 7 – Research Gaps & Future Research directions

Network Gaps	Keywords frequency in the identified network	Current State and Research Gap	Future Research Direction
	Volatility (280), Granger casualty Forecasting (21) GARCH (118). Sentimental analysis (24)	Few researchers have examined market-to-market effect (e.g. Islamic stock market and other markets) applying Granger causality. It has also been confirmed that hybrid volatility	a) What is the relationship between stock price movements and public sentiments? b) Does the Artificial Intelligence technique

Network Gaps	Keywords frequency in the identified network	Current State and Research Gap	Future Research Direction
	Islamic stock market (7), Hybrid models (3)	models are the emerging tools in measuring stock market volatility and sentiment analysis.	predict stock market volatility better than benchmark GARCH models?
	Volatility (280), GARCH (118) Volatility spillover (73) Asymmetry (61) Structural Breaks (15),	Though the majority of researchers have analysed volatility, structural breaks and spillover effects, few scholars have analysed volatility and spillovers simultaneously with structural breaks.	What are the emerging techniques to examine the volatility spillovers, and do they take into consideration the structural breaks?
	Volatility spillover (73) Quantile regression (8) Bitcoin (7) Wavelet (5) Cryptocurrenc y (3)	Concerning stock market volatility and cryptocurrency market, research is still at its infancy stage and that to apply quantile regression and wavelet techniques.	What are the spill-over effects from stock to the cryptocurrency market and vice versa?
	Stock market volatility (280) Economic policy uncertainty (15)	Few scholars have explored the relationship between economic policy uncertainty and stock market volatility.	a) How does stock market volatility react to economic policy uncertainty in different market conditions? b) What are the spillover effects from economic policy uncertainty to the stock market?

Network Gaps	Keywords frequency in the identified network	Current State and Research Gap	Future Research Direction
	Stock market volatility (280) commodity futures volatility (4)	Concerning stock market volatility and commodity futures market, research is still in its infancy, and the insights need to be explored.	Can commodity future volatility help in forecasting stock market volatility or vice versa?
	Stock market volatility (280) Stock index futures (4)	Few researchers have analysed the relationship between stock market volatility and stock index futures, and it needs to be explored.	Is there any risk transmission or risk spillover effect from stock market to stock index futures and vice versa?
	Volatility (282) volatility spillover (73) Multivariate GARCH (18) DCC (7) BEKK (5)	Few studies have examined volatility and its spillover effects by applying multivariate GARCH, DCC-GARCH and BEKK-GARCH models.	What are the emerging techniques to examine the volatility effects depicting marketwise, countrywide unidirectional, bidirectional, and multidirectional spill overs?
	Artificial Neural Network (5), Hybrid Model (3)	Few scholars have analysed SMV by applying a hybrid model approach. It has also been confirmed that hybrid volatility models (ANN-GARCH, Wavelet-GARCH, Copula GARCH	Do hybrid models take care of the non-linearity, structural breaks, chaotic Information of the data.

Network Gaps	Keywords frequency in the identified network	Current State and Research Gap	Future Research Direction
		etc) are emerging tools in measuring volatility spillovers.	
	Investors' Sentiments (13), Sentiment Analysis (11), Behavioural Research (5).	Only limited research is available in this area. Volatility studies often ignore the role of emotions and behavioural finance variables.	Develop sentiment-volatility models using NLP and social media indicators.
	Emerging Countries (4), Relationship Stock market Volatility (6), Developed Countries and Comparative Analysis (8).	Only Frew researchers have focused on Comparative analysis in the same Context.	Conduct comparative studies using panel data across market segments.

Source: Vosviewer output and authors' compilation

4. CONCLUSION

The landscape of stock market volatility (SMV) literature continues to evolve, presenting abundant opportunities for future research advancements. By employing a comprehensive bibliometric and content analysis approach, this study delved into the ongoing discourse surrounding SMV. The rigorous examination of 1,949 publications sourced from selected sources between 1980, and July 2025 shed light on the "how" and "what" of existing SMV research, encompassing methodological practices, contextualization within emerging and developed economies, and key properties like spillover effects. Notably, SMV has sustained the interest of researchers, particularly during the unprecedented circumstances of the global pandemic in 2020. Contributions to the SMV literature have emerged from scholars in both developed and developing countries, with notable prominence from China, the USA, and India. The study discovered that volatility exhibited higher levels in emerging markets compared to developed economies, and all markets exhibited significant volatility persistence during the COVID-19 period. Mixed conclusions regarding volatility and the leverage effect were observed in these countries simultaneously. Citation analysis highlighted the impact and significance of various publications, with Bollerslev's GARCH model (1986) and Engle's ARCH model (1982) identified as valuable "core" contributions. Thematic analysis revealed

GARCH and volatility spillover as dominant themes, while DCC-GARCH and the idiosyncratic volatility model emerged as niche areas. Content analysis exposed substantial persistence and spillover effects of SMV in emerging countries (e.g., BRICS, MENA) and advanced economies. The study identified emerging topics for further exploration in SMV research, emphasising the nascent stage of understanding the relationship between SMV and cryptocurrency, economic policy uncertainty, and derivatives such as commodity futures and stock index futures. Additionally, the utilisation of hybrid models represents a growing concern, warranting future investigation. In addition, behavioural and sentiment-based models of volatility are underdeveloped, particularly to the extent that they relate to social media and algorithmic trading's impact on investor responses. The use of machine learning and artificial intelligence in volatility prediction is becoming a revolutionary but methodologically disjointed field. Cross-country and sectoral analyses also require further panel-data-based investigations to reveal structural asymmetries in spillovers. Future studies are also required to work towards improving model robustness and interpretability to maintain viability in quickly changing financial environments. Overall, this study provides valuable insights, signalling the dynamic nature of SMV research and outlining promising avenues for scholars to delve deeper into the intricacies of volatility phenomena.

5. IMPLICATIONS AND LIMITATIONS

Volatility, a phenomenon and a concept remains central to both contemporary financial markets and academic research. The past few decades saw an explosion of literature on testing the stock market's efficiency. The assertion about the validity of the SMV and its determinants has remained the subject of several investigations. These frequently expressed assertions about "SMV" have implications for stock market investigators, market professionals, practitioners, and regulators. A thorough understanding of SMV can form the basis for efficient price discoveries, implying predictability, which is embraced by both traders and investors. Portfolio managers, risk arbitrageurs, and corporate treasurers can closely watch these trends because price fluctuations may have a significant impact on their decision-making about investments and risk management. This study aims to provide a comprehensive understanding of stock market volatility (SMV) to financiers and stock market enthusiasts. The study covers the underlying philosophies, historical developments, and empirical findings related to SMV. It seeks to attract the attention of both academics and practitioners. Additionally, the study emphasises the need for regulators to play a responsible role in reducing stock market volatility. Although the paper has contributed scientifically to the recognition of wider stock market forces, researchers' bias in the selection of databases and inclusion-exclusion checks can limit its use. The study is restricted to the SCOPUS repository, but it does not cover all journals in any discipline. Hence, the biggest shortcoming of this paper is limiting the coverage. To identify the most accurate issues in SMV, this study could furthermore extend to encompass more nonspecific keywords from social sciences journals, such as equity volatility, market shocks, stock mis valuation, and Market instability (Buldyrev *et al.*, 2021). Further different diagnosis-deductive reasoning approaches for qualitative content analysis can illuminate many hidden or less explored dimensions of the domain. Though it is believed that the aggregation of the conceptual essence of the SMV presented through this study remains comparable for subsequent investigations as well.

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The Impact of Aid for Trade on Income Inequality: The Case of Developing Countries

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Abstract: AfT (Aid for Trade) in developing and less developed countries can help reduce income inequality while promoting exports. The present study analyses the effect of AfT on income inequality for 32 countries using the Driscoll-Kraay estimator for fixed effect and random effect models over the period 2003-2021. The results indicated that total Aft has negative impact on income inequality. Regarding specific AfT components, AfT inflows to built production and develop trade policies had no significant effect on income inequality. However, AfT funds for the improvement of infrastructure significantly reduced income inequality. This suggests that directing AfT funds related with transport and storage, communications, and energy generation and supply can also make the income distribution more equitable in middle-income and low income countries. The panel quantile regression method was also applied. The results demonstrated that infrastructure-oriented AfT or total AfT contributes to a reduction in income inequality, and this effect is stronger in countries with high income inequality.

Keywords: Aid for Trade; Income Inequality; Foreign Aid.

JEL classification: O10; F35; P45.

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1. INTRODUCTION

Developing countries seeking to achieve sustainable development and reduce poverty rely significantly on foreign aid (Garrett and Wanner, 2017). To rebuild their economies in the aftermath of World War II, Western European countries received foreign aid, termed Official Development Assistance (ODA), via the Marshall Plan. Since then, similar forms of support have been extended to developing and less developed countries facing economic crises or natural disasters. During the 1990s, however, the effectiveness of foreign aid was increasingly called into question, given the continued high poverty rates in many of these countries. Meanwhile, there was also increasing recognition that economic growth also depended on openness and exports. Hence, donor countries began requiring aid-receiving countries to reduce import restrictions and liberalize their trade policies. Meanwhile, to maximize the benefits of foreign trade for these countries, donors introduced aid for trade (AfT) initiatives, which combined foreign aid and trade strategies with the aim of raising living standards (Van Der Sluis and Durowah, 2018; Lee and Oh, 2022; Sardar *et al.*, 2022). As Gnangnon (2020b) puts it, AfT refers to foreign aid that aims to expand developing countries' participation in international trade.

AfT was launched in 2005 at the World Trade Organization's (WTO) Hong Kong Ministerial Conference, although the WTO had already noted that trade is an important, but neglected, economic development tool. For example, the WTO argued during the 1986-93 Uruguay WTO negotiations that developing countries' needs were being ignored. Likewise, the WTO claimed during the 2001 Doha Development Round that developing countries were not gaining much from international trade. The AfT initiative is thus a response to these debates, which aims to reshape foreign aid to focus on international trade. Currently, this approach is supported by many developed countries, such as the USA, Australia, Germany, and Japan (European Commission, 2020).

Developing and less developed countries can particularly benefit from AfT given their inadequate production capacity and the difficulties and costs they face in integrating into international markets due to long procedures and insufficient infrastructure and institutions. These factors hinder their ability to compete internationally (Berrittella and Zhang, 2014; Alonso, 2016). AfT enables these countries to eliminate trade barriers, improve infrastructure, and negotiate bilateral commercial agreements. AfT also promotes private sector participation in international trade (Ghimire *et al.*, 2016; European Commission, 2020), thereby supporting sustainable economic development (Garrett and Wanner, 2017). Although the United Nations' 2030 sustainable development goals lack an explicit trade target, a number of other targets interrelate with trade (Lammersen and Hynes, 2016).

Total AfT has grown from 556.4 billion dollars in 2006 to 48.7 billion dollars in 2020, to become a key financial resource for low- and middle-income countries (OECD/WTO, 2022). At $30 billion annually, AfT currently represents about 30% of developing countries' financial ODA, although the level is rising (de Melo and Wagner, 2015). The leading donors are European Union (EU) member states, which together provided 13.5 billion Euros in 2018, or about 30% of total AfT funding (European Commission, 2020). African, Asian, and South American countries are the largest AfT recipients (Berrittella and Zhang, 2014).

A number of studies have evaluated whether AfT inflows achieve their aim of increasing developing and less developed countries' foreign trade volume (Mowlaei, 2017; Gnangnon, 2019; Nathoo *et al.*, 2021) and reducing poverty (Menon and Meléndez, 2020; Gnangnon,

2020a). However, to the best of our knowledge, only one study (Gnangnon, 2020b), has directly assessed whether AfT inflows reduce income inequality. For 65 countries, Gnangnon (2020b) found that AfT inflows were associated with lower wage inequality. Furthermore, this reduction was associated with higher exports of labour-intensive manufacturing products. Given that, for many people, wages represent either their total income or most of it, one can assume that wage inequality can closely proxy for income inequality (Urata and Narjoko, 2017; Siddique, 2021). Indeed, empirical studies generally measure income inequality using either the Gini coefficient or wage inequality. Unlike Gnangnon's (2020b) study, which addresses AfT-income inequality and consider wage inequality as an indicator of income inequality, the present study applies the Gini coefficient to examine the effect of AfT on income inequality. Therefore, to our knowledge, this study is the first to investigate the issue of AfT-income inequality using the Gini coefficient. This study aims to fill this gap in the literature from this perspective. On the other hand, various studies investigating the causes of income inequality can be cited in the literature e.g. (Jauch and Watzka, 2016; Siami-Namini and Hudson, 2019; Gimba *et al.*, 2021; Roy-Mukherjee and Udeogu, 2021; Villanthenkodath *et al.*, 2024). These studies generally focus on the relationship between income inequality and macroeconomic variables such as economic growth, financial development, globalisation, inflation, unemployment, and financial development. This study, however, investigates the impact of AfT on income inequality and differs from the aforementioned studies in this respect. Income inequality is a significant problem, particularly in developing countries. Therefore, identifying factors that will reduce income inequality could also serve as a guide for the policies to be implemented (Uche *et al.*, 2024). In this context, determining that AfT reduces income inequality could be an important policy tool for policymakers.

High income inequality has many negative effects, including societal disruption and conflict, political and economic instability, poor governance, limited access to healthcare, rising criminality, and lower economic growth and labour productivity (Fang and Qamruzzaman, 2021; Siddique, 2021; Levin *et al.*, 2022). Hence, a critical goal of sustainable development is addressing income inequality (Urata and Narjoko, 2017), which in turn requires identification of its causes, as reflected in the large amount of empirical research in this area. According to the 10th goal, 'reducing income disparities between and within countries' is important by 2030 (Cojocaru *et al.*, 2022). In order to be successful in reducing inequalities, it is important to involve all political, social and economic units in the process (Uche *et al.*, 2024). Moreover, reducing inequalities will contribute not only to Goal 10 but also to the achievement of other sustainable development goals (Szymańska, 2021). Identifying the income-reducing effect of AfT could guide policymakers in their policy choices. If AfT can reduce income inequality, this will indicate an additional benefit beyond its main function of raising export volumes in recipient countries. This in turn could suggest that donor countries aiming to support developing countries should provide foreign aid mostly as AfT. On the other hand, one of the world's major problems is the current increase in income inequality in both developing and developed countries (Huang *et al.*, 2022).

Income inequality is a multifactorial problem, including demographic, political and institutional, economic and financial, globalization and technological elements. Some argue that the quadrupling of international trade since 2000 is a key cause of growing income inequality (Huang *et al.*, 2022), which in turn raises the question of the effect of AfT on income inequality. According to Berrittella and Zhang (2014), AfT can help reduce both poverty and inequality through its main function of increasing developing and less developed

countries' human, institutional, and physical capacity so that they can participate in foreign trade. That is, despite not directly aiming to reduce income inequality, AfT can help do so by helping these countries to expand exports specifically and grow the economy more generally. Our study tests this claim by analysing middle-income and low income countries using the Driscoll and Kraay (1998) estimator for fixed effect and random effect models. The analysed period covers 2003 to 2021.

The rest of this paper is organized as follows. Section 2 discusses the relationship between AfT, foreign trade, and income inequality while Section 3 reviews the relevant literature. Section 4 presents the method and data set while Section 5 reports the analysis results. Section 6 concludes the paper.

2. THEORETICAL FRAMEWORK: AFT, FOREIGN TRADE, AND INCOME INEQUALITY

As already outlined, by addressing poverty, AfT can potentially reduce income inequality via several direct or indirect channels. For example, OECD statistics for 2009 showed that AfT can bring poor people into the market system by minimizing supply-side restrictions and trade costs while increasing exports (de Melo and Wagner, 2015; Gnangnon, 2020a; Sardar *et al.*, 2022). That is, growth in foreign trade and the economy can decrease poverty and inequality. However, while there is broad agreement that developing and less developed countries with inadequate domestic markets can grow their economies more quickly by liberalizing foreign trade, there is disagreement regarding international trade's effects on income inequality in these countries. More specifically, AfT will not do this unless trade-led growth occurs in those sectors that have the most low-income employees. When it does, it can indeed reduce income inequality (de Melo and Wagner, 2015; Durowah, 2017).

The relationship between foreign trade and income inequality is usually explained in terms of the Heckscher-Ohlin and Stolper-Samuelson theories. According to the Heckscher-Ohlin theory, each country has a comparative advantage in certain products, so it should specialize in exporting these. According to the Stolper-Samuelson theory, developing and less developed countries should also consider both product and factor prices. In particular, because these countries have more labour, their export efforts should be focused on labour-intensive products. The resulting international trade will then raise labour employment and wages, thereby reducing income inequality within the country.

As already noted, the integration of developing countries into the global market through trade reforms has helped increase their economic growth. Yet, it has also worsened income inequality in many cases (United Nations (UN), 2019), particularly since 1990. This simultaneous increase in income inequality and trade needs explanation because it contradicts the predictions of the Stolper-Samuelson model (Lin and Fu, 2016). Gnangnon (2020b), for example, suggests that the wage gap between skilled and unskilled workers is widening because the growing trade in technologically advanced products has increased demand for skilled workers. Similarly, Borrs and Knauth (2021) conclude that the demand for skilled labour, and hence wage inequality, has grown since China and Eastern Europe countries joined the international market system. They suggest that trade can explain about 15% of this rise in wage inequality.

Another explanation for growing income inequality is that the large companies that currently dominate international trade have successfully kept profits to themselves (United

Nations (UN), 2019). A further factor may be that skills and technology development have become increasingly important, thereby reducing subcontracted, unskilled workers' bargaining power and wages (Dorn *et al.*, 2021).

A more recent approach to theorizing these relationships is the Kuznets (1955) inverted U curve hypothesis. This predicts that participating in international trade will initially increase income inequality in less developed countries due to the focus on high-income sectors. Later, however, income inequality will fall as these societies become more equal, democratic, and economically advanced (Huang *et al.*, 2022). In short, foreign trade may have unexpected effects on income inequality that may occur via various channels (United Nations (UN), 2019). In general, even if foreign trade does not decrease poverty directly, it may do so indirectly by reducing poverty through the higher employment and wages resulting from economic growth (Page, 2007; Lammersen and Hynes, 2016; Fang and Qamruzzaman, 2021). Another indirect influence may occur through beneficial structural changes, such as the shift in many East Asian countries from predominantly agricultural to manufacturing economies. This has led to a burgeoning middle-income class (United Nations (UN), 2019). AfT can also reduce income inequality indirectly by funding the development of productive capacities, particularly in agriculture, such as for training, irrigation, energy sources, and fertilizers (de Melo and Wagner, 2015). Such initiatives can have significant effects on family incomes given the importance of agriculture to developing countries' GDP (Lammersen and Hynes, 2016).

Another poverty-alleviating effect of AfT in developing countries occurs through its support for small and medium-sized enterprises to make them more competitive internationally. These enterprises can provide new income streams for otherwise underemployed or unemployed workers (Gnangnon, 2020b). Given that women tend to own smaller businesses than men, this focus of AfT can also reduce gender-based income inequality specifically by empowering women to increase their incomes by participating in international markets (Lammersen and Hynes, 2016; OECD/WTO, 2022). In short, AfT can indirectly alleviate poverty by encouraging foreign trade strategies supportive of women and young people (Gnangnon, 2020a).

Gnangnon (2020a) demonstrated that AfT can also reduce poverty by increasing the diversity of a country's exports. AfT funding can enable these countries to develop the necessary economic infrastructure to easily access up-to-date technology and global communication networks. This is important because countries with more diversified exports tend to have more sustainable growth and create more employment opportunities (UNCTAD, 2018). Furthermore, products tend to be more complex in those countries with more advanced institutions and a skilled, well-unionized workforce that consequently has strong collective bargaining power. However, the diversity of export products may have varying effects on income inequality depending on whether it differentially affects skilled and unskilled workers' wages (Gnangnon, 2020b). Le *et al.* (2020), for instance, reported an inverted-U relationship between export product diversity and income inequality for 90 countries between 2002 and -2014.

Finally, AfT can attract more foreign direct investment (FDI) to less developed countries (Nguyen *et al.*, 2023), particularly for infrastructure projects. By stimulating economic growth and technology and knowledge transfers, FDI can help these countries' local companies become more productive and internationally competitive. This in turn, can help reduce income inequality (Hayashikawa, 2009).

In conclusion, although the direction of AfT's impact on income inequality is uncertain, we can formulate the following hypothesis (de Melo and Wagner, 2015; Gnangnon, 2020a, 2020b; Sardar *et al.*, 2022):

***H**: Higher levels of AfT are expected to reduce income inequality.*

3. LITERATURE REVIEW

There has been extensive research into the effect of foreign aid on poverty and income inequality (Younsi *et al.*, 2019; Maqbool and Ali, 2022; Wang *et al.*, 2024). In contrast, research regarding the specific effect of AfT on poverty is rare. Van Der Sluis and Durowah (2018), for example, reported that AfT reduced poverty in 91 countries, although the effects varied as a result of regression analysis covering the 2000-2014 period. Specifically, they were largest in less developed countries; they were larger if AfT was used for infrastructure or new trade policies; and were larger if the recipient country's economy relied less on agriculture. For Rwanda, Diop *et al.* (2005) found that reducing transportation costs was associated with rising export product prices and lower poverty. From their literature review, de Melo and Wagner (2015) concluded that AfT can increase productivity in agriculture, which is a major employer of poorer people. More specifically, such people can increase their incomes if AfT is used for road construction and other infrastructure to connect rural regions to major markets. Analyzing countries in South and East Asia, Africa, and the Pacific, Ashenafi and Dong (2023) concluded in their fixed-effects method based study covering the period 2006-2020 that reducing tariffs stimulates agricultural production, which in turn raises unskilled workers' incomes. Finally, focusing on six South Asian countries (Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka) and the 2005-2019-time period, Sardar *et al.* (2022) conducted an analysis using the pooled mean group-autoregressive distributed lag (PMG-ARDL) model. The analysis found that AfT has improved human development.

Several other studies have investigated how AfT influences international trade volumes. Vijil and Wagner (2012), for example, reported that AfT that is focused on infrastructure, trade policies, and regulations was associated with higher total exports. The author's study covered the period 2002-2008 and is based on ordinary least squares (OLS) and 2SLS methods. Lee and Oh (2022) analysed a sample of 143 countries between the years 2003 to 2018 by employing fixed effect and two stage least squares methods. From their analysis, Lee and Oh (2022) found that AfT to reform foreign trade policies and regulations had a positive effect on exports in Asian countries. The researchers suggested that this was due to government support for liberalizing trade in this region. Finally, Ghimire *et al.* (2016) who analysed 121 developing countries over the period 1995-2010 by applying system-GMM technique, also found a positive association between AfT and export volumes.

Despite the large number of studies into the relationship between foreign trade and income inequality, there is still no consensus. Some studies conclude that international trade reduces income inequality (Calderon and Chong, 2001; Goldberg and Pavcnik, 2007; Jaumotte *et al.*, 2013; Berrittella and Zhang, 2014; Nguyen, 2020; Dorn *et al.*, 2021), whereas others conclude the opposite (Wagle, 2007; Roser and Cuaresma, 2016; Khan *et al.*, 2021) and a third group find no significant relationship (Dabla-Norris *et al.*, 2015; Beaton *et al.*, 2017; Agusalim and Pohan, 2018). The findings can also vary between countries. For instance, from their analysis of 100 countries using 2SLS-IV and OLS models Zhu *et al.* (2023) reported that trade in digital services was associated with income inequality in middle-

and upper-income countries but not in lower-income countries. Another factor is the theoretical model used. Thus, Urata and Narjoko (2017) found that applying certain models indicated that trade liberalization reduced wage inequality whereas other models indicated the opposite. The authors argued that these results critically depended on each country's specific characteristics regarding the labour market, capital inflows, and trade policies. Another factor is system of government, with Lin and Fu (2016) reporting that foreign trade reduces income inequality in autocracies but increases it in democracies. They explained this in terms of export focus, with autocracies focusing on primary goods whereas democracies focus on manufacturing. The authors preferred the OLS and instrumental variables methods and considered the period between 1985 and 2012. Finally, Mumuni and Abille (2023) analyzed the period 2000-2018 using Driscoll and Kraay (1998) augmented fixed and random effects model. They found that trade liberalization in 30 African countries ultimately reduced income inequality, although it initially made it worse.

When we consider the studies focusing on the determinants of income inequality, for example, Bahmani-Oskooee *et al.* (2008) examined 15 least developed countries and the United States and questioned the effect of openness on income inequality using time series analysis. Findings from the error correction model indicate that results vary across countries. Furthermore, very limited evidence was found regarding the validity of the Kuznets inverted-U hypothesis. Siami-Namini and Hudson (2019) observed 24 developed countries and 66 developing countries over the period 1990–2014. Using the Vector Error Correction Model (VECM) approach, the authors found evidence of a U-shaped relationship between inflation and income inequality. Roy-Mukherjee and Udeogu (2021) employed the Feasible Generalized Least Squares method and analyzed OECD and Western Balkan countries for the period 1991 to 2017. The findings provide evidence that globalization has a positive relationship with income inequality. Gimba *et al.* (2021) focused on sub-Saharan African countries and preferred the ARDL method. The analysis results found that unemployment increases income inequality in both the short and long term. Trade globalization is significant in the long term and heightens income inequality. Seabela *et al.* (2024), who focused on South Africa and analyzed the period from 1975 to 2017 using the Vector Error Correction Model (VECM), concluded that economic growth is negatively related to income inequality. In another study, Ahmed and Shadmani (2024) focused on the US economy and analyzed the period 1962-2019 using the SVAR method. The findings show that shocks to male unemployment briefly increase income inequality, whereas shocks to female unemployment reduce it. Villanthenkodath *et al.* (2024) focused on the impact of the components of globalization (economic, trade, and financial globalization) on income inequality. The study preferred the PMG-ARDL method and examined low, middle, and high-income countries, reaching differing conclusions. Simionescu (2025) investigated income inequality for 27 EU countries. Analyzing the 1990–2023-time period using mean group estimators and system generalized method of moments estimators, the author observed that inflation increases income inequality while reducing wealth inequality. Another finding of the study is that trade reduces income inequality. Financial development and government spending, on the other hand, exacerbate income inequality. Abdi *et al.* (2025) investigated the determinants of income inequality in the Somali economy. According to the analysis, which covers the period 1990-2020 and is based on the ARDL method, economic growth and income inequality initially increase, but this effect diminishes as income levels rise. Globalization, unemployment, and inflation increase income inequality in the short and long term.

4. DATA AND MODELS

The present study investigated the effect of AfT on income distribution in countries classified by the World (2024) as middle-income countries and low income countries, i.e., countries with a per capita Gross National Income (GNI) of 1,135 dollars or less for low income countries and 1,136 - 13,845 dollars as middle income countries in 2022. Based on the available data, the following 32 countries were analysed for 2003-2021: Burkina Faso, Mali, Niger, Bangladesh, Benin, Bolivia, India, Egypt, Honduras, Kenya, Kyrgyzstan, Mongolia, Nepal, Philippines, Senegal, Tunisia, Brazil, Vietnam, China, Colombia, Costa Rica, Dominic Republic, Ecuador, El Salvador, Guatamala, Indonesia, Malaysia, Kazakhstan, Moldova, Peru, Thailand and Türkiye. Model (1) was constructed to evaluate the impact of AfT on income inequality. Model (1) is:

$$GINI_{it} = \beta_0 + \beta_1 AfTTOT_{it} + \beta_2 GDP_{it} + \beta_3 ENF_{it} + \beta_4 KOF_{it} + \beta_5 UNEMP_{it} + \varepsilon_{it} \quad (1)$$

Here, income inequality was represented by Gini coefficients ($GINI_{it}$) obtained from Standardized World Income Inequality Database (SWIID) while the OECD database provided data for the AfT disbursements. β , β_0 and ε_{it} denote parameters of the variables, constant term, and error term, respectively. Total AfT disbursements (in terms of per capita) is represented by the variable $AfTTOT_{it}$. $GDP_{it}, ENF_{it}, KOF_{it}, UNEMP_{it}$ were included in the model as control variables representing economic growth, inflation, globalisation and unemployment rate, respectively. Real GDP per capita (constant US $ in 2015) was preferred to represent economic growth, and inflation rate in CPI was preferred to represent inflation. The global KOF index which covers three main components: economic, social and political dimensions was used to reflect globalisation and retrieved from KOF Economic Institute (2024). Data of economic growth, inflation and unemployment data were taken from WB's WDI database. Data for the AfT disbursements were obtained from Creditor Reporting System (CRS) from the OECD database. Information on the variables is summarized in Table no. 1. All variables were transformed into their natural logarithmic forms before being used in the models. (Multicollinearity was checked and not found to be present, results are therefore not reported).

Table no. 1 – Definition of Variables

Variables	Definitions	Sources
GINI	GINI index	Standardized World Income Inequality Database (SWIID)
AfTTOT	Total AfT disbursements(per capita US$)	OECD Creditor Reporting System
AfTINF	AfT for infrastruction (per capita US$)	OECD Creditor Reporting System
AfTPROD	AfT for building productive capacity (per capita US$)	OECD Creditor Reporting System
AfTPOL	AfT for trade policies and regulations (per capita US$)	OECD Creditor Reporting System
GDP	GDP per capita (constant 2015 US$)	World Bank
ENF	Inflation, consumer prices (annual %)	World Bank
KOF	KOF globalisation index	KOF Economic Institute (2024)
UNEMP	Unemployment, total (% of total labor force)	World Bank

The present study also tested whether the components of AfT can explain income inequality, namely infrastructure-focused AfT, production capacity-focused AfT and trade policy-focused AfT. For this purpose we formed Model (2), Model (3) and Model (4). Following Nguyen *et al.* (2023), in Model (2) below, AfT infrastructural funding for improving communication, energy production and supply, storage facilities, and transportation networks is represented by $AfTINF$. In Model (3) below, AfT production capacity funding for improving agriculture, forestry, and fishing, industry, mining, tourism, banking, and financial services are represented by $AfTPROD$. In Model (4), we investigated whether AfT for trade policies and regulations had an effect on income inequality.

$$GINI_{it} = \beta_0 + \beta_1 AfTINF_{it} + \beta_2 GDP_{it} + \beta_3 ENF_{it} + \beta_5 KOF_{it} + \beta_4 UNEMP_{it} + \varepsilon_{it} \quad (2)$$

$$GINI_{it} = \beta_0 + \beta_1 AfTPROD_{it} + \beta_2 GDP_{it} + \beta_3 ENF_{it} + \beta_5 KOF_{it} + \beta_4 UNEMP_{it} + \varepsilon_{it} \quad (3)$$

$$GINI_{it} = \beta_0 + \beta_1 AfTPOL_{it} + \beta_2 GDP_{it} + \beta_3 ENF_{it} + \beta_5 KOF_{it} + \beta_4 UNEMP_{it} + \varepsilon_{it} \quad (4)$$

5. EMPİRİCAL RESULTS

In the study, we firstly investigated the effect of AfT on income inequality with fixed effect and random effect models. According to the F test, the fixed effect model is more appropriate than the classical model (Pooled OLS). On the other hand, the random effects model is preferred over the classical model since the probability values of the Breusch and Pagan Lagrangian multiplier test (LM) for random effects are less than 0.05. Later, Hausman (1978) test can enable us to make a choice between random effect and fixed effect models. As a result of the Hausman test of all the four models, the fxed effect estimator is more efficient than the random effect estimator since the probability value is less than 0.05. In summary, F test, LM test and Hausman test results show that the suitable model is the fixed effect model. However, random effect model results are also reported in the tables for comparison and robustness check purposes. The RE models support the coefficients and significanse levels indicated by the FE models and thus serve a robustness check purpose.

It is necessary to test the validity of the assumptions in the fixed and random effect models. For this purpose, the presence of heteroskedasticity, autocorrelation and cross-sectional dependence problems were investigated. Modified Wald test was employed to test heteroskedasticity and heteroskedasticity in the fixed effects model. For the autocorrelation test, the Durbin-Watson test developed by Bhargava *et al.* (1982) and the LBI test developed by Baltagi and Wu (1999) were applied. According to these tests, if the test statistic results are less than 2, it is concluded that there is autocorrelation. In relation with the random effect model, the heteroscedasticity problem was investigated with the Levene-Brown-Forsthe test (Levene, 1960; Brown and Forsythe, 1974). For the autocorrelation test, Baltagi and Wu (1999) and the Durbin Watson test were employed (Given that our results are convincing, we did not apply further tests like Wooldridge and White). The testing of the cross section dependency in the models was carried out with the Pesaran (2004) test since this test provides consistent estimates so long as the cross-sectional dimension greater than the time dimension.

According to the findings obtained from Model (1), Model (2), Model (3) and Model (4), the test statistics of Baltagi and Wu (1999) and Durbin Watson test are less than 2 indicating the existence of the autocorrelation problem in all of the models. Similarly, the heteroscedasticity test results suggests the acceptance of alternative hypothesis, which denotes that there is heteroscedasticity. In addition, according to the results of Pesaran CD test, the basic hypothesis of no cross-section dependency is rejected indicating that the model is characterized by cross-sectional dependency.

As a result, it was determined that fixed effect and random effect models contain all three problems of autocorrelation, heteroscedasticity and cross-sectional dependence. Therefore, the estimation of the fixed effect and random effect models will be inconsistent suggesting the usage of robust estimators.

If the model consists of both heteroscedasticity and autocorrelation Newey and West (1987) estimator can be used as robust estimator. However, if there exists cross-sectional dependence in addition to heteroskedasticity and autocorrelation, Driscoll and Kraay (1998) should be preferred as a robust estimator for fixed and random effects models. Parks's (2009) study, can be considered as the first study that considers heteroscedasticity, autocorrelation and cross-sectional dependence. Kmenta (1986) later contributed to this study. However, Parks-Kmenta method is valid in the case of T>N. As a robust estimator, the panel-corrected standard errors (PCSE) estimator proposed by Beck and Katz (1995) can also be preferred. However, if cross-sectional dimension is larger than the time dimension, the estimates of this method are rather poor (Driscoll and Kraay, 1998; Hoechle, 2007).

The Driscoll and Kraay estimator was developed as an alternative to the Parks-Kmenta or PCSE approaches. Driscoll and Kraay estimator performs standard heteroskedasticity and autocorrelation consistent covariance matrix estimation, similar to the Newey and West (1987) or Andrews (1991) method, and the results are consistent to any value of N (Driscoll and Kraay, 1998; Hoechle, 2007).

In summary, since the results of fixed and random effects models for Model (1), Model (2), Model (3) and Model (4) will be biased, it is appropriate to use the Driscoll and Kraay estimator. Therefore, the estimates for these 4 models were performed utilizing the Driscoll and Kraay estimator. The results of Model (1) from Driscoll-Kraay (fixed effects) standard error estimator in Table no. 2 show that the effect of total AfTTOT disbursements on income inequality is negative and statistically significant. This result coincides with the results of Driscoll-Kraay(random effects) estimator. Thus, we can conclude that total AfT provided to developing countries makes income distribution more equitable. These findings can also be interpreted as being in line with previous studies reporting that AfT reduces poverty (Van Der Sluis and Durowah, 2018; Ashenafi and Dong, 2023). Because poverty and income distribution are closely related. The distribution of resources in the country is the fundamental determinant of poverty (Cojocaru *et al.*, 2022). The advantages of AfT may stem from its ability to reduce income inequality, lower foreign trade costs, facilitate foreign trade and, in particular, ease access to international markets for sectors employing low-income workers, stimulate economic growth, and enhance the international competitiveness of small and medium-sized enterprises (de Melo and Wagner, 2015; Gnangnon, 2020a, 2020b; Sardar *et al.*, 2022).

Table no. 2 – Driscoll-Kraay Regression Results for Model (1) and Model (2)

	Model (1)		Model (2)	
	Fixed Effects	**Random Effects**	**Fixed Effects**	**Random Effects**
AfTTOT	-.0065305 (0.018)	-.0081247 (0.014)		
AfTINF			-.0080842 (0.003)	-.0090238 (0.008)
GDP	-.1040644 (0.000)	-.0860537 (0.000)	-.1009964 (0.000)	-.083663 (0.000)
ENF	.0012856 (0.001)	.001427 (0.003)	.0011749 (0.001)	.0013025 (0.002)
KOF	-.0798608 (0.000)	-.0948386 (0.022)	-.066838 (0.000)	-.0820915 (0.077)
UNEMP	.0036905 (0.666)	.0064511 (0.408)	.003008 (0.721)	.0056244 (0.467)
C	4.856872 (0.000)	4.773685 (0.000)	4.777422 (0.000)	4.69898 (0.000)
Diagnostic tests				
	F test: 238.56 (0.000) Hausman: 30.76 (0.000) Modified Wald : 26259.93 (0.000)	LM test: 4097.55 (0.000) W0: 17.069229 (0.0000) W50: 11.190392 (0.0000) W10: 16.555437 (0.0000)	F test: 232.34 (0.000) Hausman: 28.05 (0.000) Modified Wald: 16655.42 (0.000)	LM: 4072.35 (0.000) W0: 17.069229 (0.0000) W50: 11.190392 (0.0000) W10: 16.555437 (0.0000)
	Durbin–Watson: .10764448 Baltagi–Wu LBI: .32532366 Pesaran CD:2.696 (0.0070)	Durbin–Watson : .10764448 Baltagi–Wu LBI: .32532366 Pesaran CD: 3.542 (0.0004)	Durbin–Watson: .12869066 Baltagi–Wu LBI: .3472836 Pesaran CD:2.554 (0.0107)	Durbin–Watson: .12869066 Baltagi–Wu LBI: .3472836 Pesaran CD: 3.472(0.0005)

According to Model (1), both economic growth and globalization affect income inequality at the 5 % significance level, with negative coefficients. This result indicates that as global integration and per capita income increases, income inequality falls. Our finding about economic growth in line with Akpa *et al.* (2024) and, Seabela *et al.* (2024). On the other hand Paweenawat and McNown (2014), Wu *et al.* (2024) and Dossou (2023) determined an inverted U shaped relationship between economic growth and income inequality. The findings showing a negative relationship between globalization and income inequality supports the findings of Tabash *et al.* (2024) and Sethi *et al.* (2021). However, the increase in inflation have a detrimental effect on inequality due to the positive relationship between inflation and income inequality coincide with the study of Beck *et al.* (2007). On the other hand, the effect of unemployment on income inequality is statistically insignificant.

Table no. 2 also presents the results of the Driscoll-Kraay regression results for Model (2). According to these findings, the effect of AfT for infrastructure on income inequality is negative and significant at the 5% significance level. Therefore this implies that that AfT related with transport and storage, communications, and energy generation and supply contributes to reducing income inequality. Regarding infrastructure-focused AfT funding, our findings consistent with de Melo and Wagner (2015), and Van Der Sluis and Durowah (2018)

conclusion that such funding can reduce poverty. This result indicates that particularly poor people may benefit from development of infrastructural sectors such as transportation, communication, energy and informatics due to connecting rural areas to international markets through road constructions and global communication networks. Beside, building infrastructure makes easy to reach new technology which in turn enabling economic growth and thus employment. In addition, AfT may attract mostly foreign direct investment for infrastructural sectors leading to new job opportunities as denoted by Nguyen *et al.* (2023). Infrastructure sectors have become increasingly prominent in recent years and represent areas where investment and employment are expanding. In particular, the energy, communication, and transportation sectors can be considered key drivers of economic growth. The influence of economic growth, inflation, globalization and unemployment on income inequality are coincide with the findings in Model (1).

Table no. 3 – Driscoll-Kraay Regression Results for Model 3 and Model 4

	Model 3		**Model 4**	
	Fixed Effects	**Random Effects**	**Fixed Effects**	**Random Effects**
AfTPROD	.0030319 (0.237)	.0018071 (0.521)		
AfTPOL			.0008071 (0.374)	.0008745 (0.374)
GDP	-.1036713 (0.000)	-.0847299 (0.000)	-.1029868 (0.000)	-.0830865 (0.000)
ENF	.0013187 (0.003)	.0014937 (0.007)	.0013665 (0.002)	.0015387 (0.004)
KOF	-.1131092 (0.000)	-.1313704 (0.002)	-.1102612 (0.000)	-.1336308 (0.000)
UNEMP	.003814 (0.648)	.006953 (0.367)	.0046467 (0.570)	.0077856 (0.306)
C	4.97348 (0.000)	4.893737 (0.000)	4.9603 (0.000)	4.892802 (0.000)
Diagnostic tests				
	F test: 244.35 (0.000) Hausman:38.37 (0.000) Modified Wald : 120442.97(0.000)	LM: 3985.73 (0.000) W0: 17.069229 (0.0000) W50: 11.190392 (0.0000) W10: 16.555437 (0.0000)	F test: 238.26 (0.000) Hausman:36.94 (0.000) Modified Wald :58693.97(0.000)	LM: 3814.73 (0.000) W0:17.069229 (0.000) W50:11.190392 (0.000) W10:16.555437 (0.000)
	Durbin–Watson: .10575283 Baltagi–Wu LBI : .31898834 Pesaran CD: 3.213 (0.0013)	Durbin–Watson: .10575283 Baltagi–Wu LBI: .31898834 Pesaran CD: 4.145(0.000)	Durbin–Watson: .10721488 Baltagi–Wu LBI: .3237646 Pesaran CD: 3.088(.0020)	Durbin–Watson: .10721488 Baltagi–Wu LBI: .3237646 Pesaran CD: 4.057(0.000)

Table no. 3 summarizes the results of Driscoll-Kraay regressions for Model (3). According to the findings here, AfT inflows for building productive capacity have no impact on income inequality. Therefore we expect no impact of Aft disbursements for agriculture,

forestry, fishing, industry, mineral resources and mining, tourism, banking and financial services, business and other services on income inequality in developing and less developed countries. Regarding the impact of AfT for production capacity, we may contradict with de Melo and Wagner (2015), who reported that poverty can be reduced by focusing AfT funding on agriculture. AfT inflows for building productive capacity have no impact on income inequality, which may be due to the fact that the production activities in question do not account for a significant share of GDP in developing countries. Therefore, AfT to these sectors may be relatively small. On the other hand, in recipient countries, such inflows may not be used for its intended purpose due to the reasons mentioned above or political preferences, and may be diverted to other sectors. Moreover, the impact of production-oriented activities is likely to materialize only in the long run, whereas the relatively short time horizon considered in this study may be insufficient to capture their distributional effects. According to the findings of Calì and te Velde (2011), AfT reduces trade costs and generally has a positive effect on exports. However, this effect is entirely driven by aid directed toward economic infrastructure, while aid aimed at productive capacity does not have a significant impact on exports. This may be due to the fact that AfT is disproportionately allocated to well-performing sectors. Furthermore, in developing or less-developed countries, infrastructure often constitutes a major constraint. Therefore improvements in infrastructure can substantially promote economic growth, enhance trade, and ultimately benefit individuals.

Driscoll-Kraay results for Model (4) are also reported in Table no. 3. The focus here is on the impact of AfT for policy regulations and trade-related adjustment on income inequality. According to the findings, AfT related with trade policies and regulations have no impact on income. This can be related with the same reasons mentioned for AfT for production. As with the first 3 models, there is an negative relationship between economic growth and income inequality. Similarly globalization and income inequality has negative relationship. Beside there is no impact of unemployment on income inequality.

Table no. 4 reports the results obtained from the estimation of Model (1), Model (2), Model (3) and Model (4) without control variables. In other words, the effect of total AfT, AfT for infrastructure investments, AfT for production, and AfT for trade policies on income inequality was tested without control variables. According to these results, the effect of total AfT and AfT for infrastructure on income inequality is negative and statistically significant. Thus, AfT for infrastructure investments and total AfT have a reducing effect on income inequality. The effect of AfT for production and trade policies on income inequality is statistically insignificant. These results are consistent with those reported in Tables no. 2 and no. 3, which include control variables in Models (1), (2), (3) and (4). Thus, we can conclude that the AfT-income inequality relationship is robust.

Finally, the panel quantile regression method developed by Koenker (2004) was applied. Quentile regressions firstly developed by Koenker and Bassett (1978) and aim to estimate the conditional median functions and minimize asymmetrically weighted absolute residuals. Quantile regression estimates yield more effective results when outliers are present (Buhai, 2005). We applied to the panel quantile regression to test the robustness of the results obtained. Additionally, it will be possible to examine how AfT affects countries with different levels of income inequality. The results obtained from the panel quantile regression models are presented in Table no. 5.

Table no. 4 – Driscoll-Kraay Regression Results for Model (1), Model (2), Model (3) and Model (4)

	Model 1		Model 2		Model 3		Model 4	
	Fixed Effects	Random Effects	Fixed Effects	Random Effects	Fixed Effects	Random Effects	Fixed Effects	Random Effects
AfTTOT	-.020247 (0.001)	-.020330 (0.002)						
AfTINF			-.016362 (0.000)	-.016536 (0.001)				
AfTPROD					-.004253 (0.393)	-.004454 (0.383)		
AfTPOL							-.001124 (0.737)	-.001258 (0.679)
Constant	3.74685 (0.000)	3.74701 (0.000)	3.72598 (0.000)	3.72617 (0.000)	3.71270 (0.000)	3.71289 (0.000)	3.70533 (0.000)	3.70494 (0.000)

Table no. 5 – Quantile Regression Results for Model (1), Model (2), Model (3) and Model (4)

Variables	0.1	0.3	0.5	0.7	0.9
AfTTOT	-.0151486 (0.002)	-.0171261 (0.000)	-.0202681 (0.000)	-.0231417 (0.000)	-.0259077 (0.000)
AfTINF	-.0126577 (0.000)	-.014244 (0.000)	-.0164167 (0.000)	-.0182281 (0.000)	-.0203766 (0.000)
AfTPROD	.0030282 (0.612)	.0004407 (0.922)	-.0037629 (0.390)	-.0082945 (0.244)	-.012452 (0.235)
AfTPOL	.0040573 (0.944)	.0020738 (0.790)	-.000821 (0.994)	-.0039902 (0.984)	-.0067514 (0.982)

According to the estimates in Table no. 5, total AfT and AfT for infrastructure have a negative and statistically significant effect on income inequality. This effect is greater at higher quantiles. In this case, we can denote that infrastructure-oriented AfT or total AfT contributes to a reduction in income inequality, and that this effect is stronger in countries with high income inequality. In other words, the income inequality-reducing effect of AfT is larger in countries with high income inequality. The coefficients of AfTPROD and AfTPOL are statistically insignificant. Therefore, it can be claimed that AfT targeting production and trade policies has no effect on income inequality. In conclusion, the results of Driscoll-Kraay and panel quantile regression are consistent. AfT aimed at infrastructure benefits the poor and helps reduce income inequality.

6. CONCLUSION

While foreign aid primarily aims to promote economic development in developing and less developed countries, ultimately, it also aims to reduce poverty. Given research showing that such aid in the form of ODA has not been so effective in achieving this latter aim, it has been suggested that the promotion of foreign trade in these countries could be more effective. Proponents argue that by combining foreign aid and trade policies, AfT can better stimulate recipient countries' economic growth through exports. In particular, increasing exports can create new job opportunities and raise wages. Hence, AfT may be an important financial tool for reducing poverty and income inequality.

Using Driscoll-Kraay fixed effect and random effect models the present study analysed the impact of AfT on income inequality for middle-income and low income countries between

2003 and 2021. The analysis indicated that total AfT disbursements had statistically significant effect on income inequality in these countries. However, three specific AfT components (infrastructural-focused, productive capacity-focused and trade policy- focused) had differential effects on income inequality. More specifically, the former component significantly reduced income inequality whereas the latters had no significant impact on income inequality. The results also supported a negative relationship between economic growth and income inequality, and globalization and income inequality.

The panel quantile regression method was also utilized in the study. The findings here support the results obtained through the Driscoll-Kraay method. In other words, while total AfT and AfT for infrastructure reduces income inequality, AfT for production and trade policy has no statistically significant effect on income inequality. Furthermore, according to the panel quantile regression method, in countries with high income inequality, total AfT and AfT for infrastructure has a stronger income inequality-reducing effect. In other words, as countries' income distribution becomes more equitable, the impact of AFT on income inequality diminishes.

In conclusion, the present findings show that AfT inflows can reduce income inequality in developing and less developed countries, but only if they aim to improve infrastructure. In another word, infrastructure-focused AfT funding (e.g., for energy production, transportation and communication) will have noticeable effect on income inequality. This situation can be explained by ensuring that the poor have access to infrastructure, as stated by Nguyen *et al.* (2023). As is well known, in developing countries, the technology, energy, and transportation sectors are underdeveloped, and regional disparities exist. The poor, when they have access to infrastructure such as technology, energy, and transportation, are better able to improve their skills and seize improved employment opportunities. In sum, countries should increase AfT disbursements for infrastructure so that the poor or women living in rural areas can benefit. AfT's ability to reduce income inequality in addition to trade is emerging as an extra tool that policymakers in developing and less developed countries can use to reduce income inequality. Thus, with increased AfT for infrastructure, reducing income inequality could facilitate the achievement of the United Nations development goals, particularly Goal 10.

Overall, our analysis indicates that policymakers should aim to accelerate economic growth and integrate into international markets in developing and less developed countries in order to make income distribution more equitable. Additionally, the proper monetary and fiscal policies should be preferred to ensure a low inflation. Meanwhile, donor countries should increase AfT funding for projects related to recipient countries' infrastructure investments.

The availability of AfT data only from 2002 onwards does not allow for the use of panel cointegration or time series analyses in examining the impact of AfT on income inequality. Consequently, only a limited number of methods can be employed in the analyses. In the coming years, an increase in the time span of AfT data will remove this constraint and allow for the use of different methods. Studies investigating AfT and income inequality can investigate the transmission channels in detail, or the effect of the interaction of various macroeconomic variables with AfT on income inequality can be examined. While the Driscoll–Kraay estimator addresses certain econometric concerns, the potential endogeneity between AfT and inequality is not fully explored. This limitation is acknowledged in the paper. Accordingly, future research may consider employing instrumental variable approaches to address this issue.

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The Macroeconomic Effects of Tariffs Through the Exchange Rate and Migration

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Abstract: This paper uses a new open-economy macroeconomic model that considers worker migration to analyze the effects of tariffs. The model shows that an increase in tariffs in the domestic country leads to a higher level of relative consumption in that country when the elasticity of substitution between the two goods is low or the rate of time preference is small. However, when the elasticity of substitution between the two goods is high, the relative consumption level in the domestic country is unaffected by the tariff increase. Additionally, the paper shows that a tariff increase in the domestic country appreciates the exchange rate if the rate of time preference is relatively small. Furthermore, the paper shows that, when the rate of time preference is relatively small, an increase in tariffs causes workers to migrate from the foreign country to the domestic country in both the short and long runs. Finally, the paper shows that an increase in a country's tariff rate worsens world welfare because it causes market distortions.

Keywords: tariffs; migration; exchange rate; consumption; welfare.

JEL classification: E21; F16; F22; J61; O24.

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1. INTRODUCTION

The Great Depression of the late 1920s and the prolonged global economic stagnation that followed gave rise to exclusive economic blocs. The isolation of each economic bloc and the conflicts of interest between economic blocs based on protectionism are said to have been one of the indirect causes of the outbreak of World War II. In light of this, the General Agreement on Tariffs and Trade (GATT) was established in 1947 to promote free trade, and since then, GATT member countries have begun to move toward global economic integration by reducing tariffs and eliminating non-tariff barriers. In 1995, the GATT was transformed into the World Trade Organization (WTO), and economic integration has continued to be promoted through higher-level multilateral trade negotiations among several countries. However, since the Doha Round in 2001, the economic rise of emerging economies and the resulting conflicts of interest between North and South have made multilateral negotiations more difficult, and the focus has shifted from multilateral to bilateral Economic Partnership Agreements (EPAs). Thus, economic integration is currently proceeding in a distorted manner, moving from multilateral economic integration to bilateral EPAs. What is overlooked, however, is that the liberalization of labor mobility (labor market integration) within each economic zone, such as the EPAs and the EU, has been promoted at the same time.

On the other hand, the impact of tariffs on the global economy has received considerable attention from researchers around the world in recent years, as evidenced by the intensifying tariff competition between the U.S. and China, the U.S. and Canada, and the U.S. and the EU[1]. However, although there have been numerous empirical studies on trade wars, particularly the tariff competition between the U.S. and China, only a few studies in the new open economy macroeconomics (NOEM) literature have examined the effects of a tariff increase[2]. Examples include the works of Fender and Yip (2000), Reitz and Slopek (2005), Lai (2016), and Johdo (2019). These studies examine the effects of a tariff on a NOEM model with a fixed distribution of migrant workers across borders[3]. For example, Fender and Yip (2000) are the first to use the NOEM model of Obstfeld and Rogoff (1995) to study the effects of tariff increases[4]. In this study, they divide tariffs into two types: temporary tariffs and future tariffs, and analyze the output effects of tariffs in each case. They show that a tariff increase in the domestic country always reduces output in the domestic economy, but has both positive and negative effects on foreign output. They also conduct a welfare analysis using a permanent tariff, which combines temporary and future tariffs, and show that it always has a negative effect on global welfare. Reitz and Slopek (2005) incorporate a bond market into the model, which Fender and Yip (2000) deliberately exclude from the Obstfeld and Rogoff (1995) model to simplify the analysis, and clarify the effects of permanent tariff policies on the output of each country's economy and global welfare, taking into account current account imbalances and wealth redistribution. Their analysis shows that, when current account imbalances are considered, an increase in tariffs in the home country reduces short-term output and creates a short-term deficit in the home country's current account, but results in an increase in long-term output in the home country. However, the global welfare effects are always shown to be negative, similar to Fender and Yip (2000). Lai (2016) uses a simulation analysis of the impact of permanent tariffs on macroeconomic variables (consumption, production, price index, terms of trade, etc.) based on the model of Warnock (1998), which takes into account the consumption home bias in the model of Obstfeld and Rogoff (1995). In Lai (2016), it is shown that undershooting or overshooting occurs in the dynamic adjustment

process of each macroeconomic variable in response to a tariff shock, depending on the degree of consumption home bias of consumers in both countries. Finally, Johdo (2019) uses a model that incorporates industrial location into the Obstfeld and Rogoff (1995) model to theoretically analyze the impact of tariff shocks on consumption in each country, the exchange rate, and the relocation of firms. Although this study did not conduct a welfare analysis, it showed that a tariff shock in the home country increases relative consumption in the home country and appreciates the home country's currency. In addition, the effect of the tariff shock on the international relocation of firms consists of a direct effect of the tariff policy through the international transfer of income and an indirect effect through an appreciation of the home currency, but in the model the home currency appreciation effect always dominates the international income redistribution effect, and as a result it shows that a tariff shock always causes firms to move out of the country that raised the tariff. As can be seen from the model structure of the above literature, there are no studies that have used the NOEM model to analyze the effects of tariff increases that take into account international migration of workers[5]. In recent years, many researchers have analyzed the macroeconomic effects of protectionist policies, such as tariffs, using dynamic stochastic general equilibrium (DSGE) or New Keynesian models that account for price stickiness. For example, Barattieri *et al.* (2021) used an open-economy DSGE model to demonstrate the effects of temporary trade barriers on exchange rates, trade balances, production, and inflation rates over time. Bianchi and Coulibaly (2025) and Monacelli (2025), on the other hand, used an open-economy New Keynesian DSGE model to determine the most effective monetary policy in response to tariffs. Auclert *et al.* (2025) examined the temporary effects of tariffs on GDP and the trade balance using an open-economy New Keynesian DSGE model. Auray *et al.* (2022, 2025) used a New Keynesian open-economy macroeconomic model with endogenously determined tariff rates to demonstrate quantitatively the impact of various monetary policy regimes on countries' motivations to raise tariffs. Erceg *et al.* (2023) used a New Keynesian DSGE model of an open economy to examine the macroeconomic effects of uniformly increasing import tariffs and export subsidies. However, despite employing the latest analytical tools, these studies, like NOEM models, only examine the macroeconomic effects of tariff policies under the constraint of ignoring the existence of cross-border immigrants. As previously mentioned, the strength of NOEM lies in its capacity to illustrate the theoretical underpinnings of economic shocks. However, its limitations stem from its tendency to oversimplify complex concepts. Conversely, DSGE models offer the advantage of enabling the construction of sophisticated models that more closely reflect the real economy and estimate parameters that reflect the country's real economy. However, DSGE models are contingent upon economic data from individual countries when examining the impact of shocks, and the theoretical mechanisms underlying the estimated results of economic shocks are not always clearly demonstrated. Consequently, the previous NOEM model, which is a simple model but has a clear theoretical mechanism for economic shocks, and the DSGE model, which has a sophisticated theoretical structure and focuses on being able to predict the impact of shocks from actual estimated parameters, can be said to complement each other. However, of these two representative approaches, no research has examined the macroeconomic effects of tariff hike shocks using a model that incorporates endogenous international worker migration. The aim of this paper is to fill this research gap through the NOEM model.

Unfortunately, while there are no empirical studies showing a direct relationship between the exchange rate and international migration of workers, there are a number of

empirical studies on the relationship between the exchange rate and remittances to the home country, which affect the destinations of workers' migration (Faini, 1994; Higgins *et al.*, 2004; Yang, 2008; Shin, 2021). All of the above empirical studies show that exchange rate shocks have a nontrivial impact on workers' remittances abroad, suggesting that exchange rate shocks affect workers' cross-border mobility in the long run. Moreover, there is evidence that in the real world, cross-border worker migration has a significant impact on international trade in differentiated goods[6]. Given that the modern global economy is one in which international migration of workers is increasingly active, the close relationship between cross-border migration of workers, exchange rates, and international trade in differentiated goods is a perspective that cannot be ignored when considering the macroeconomic effects of tariffs. The purpose of this paper is to introduce international migration of workers into the NOEM and to show the macroeconomic effects of tariff increases through international migration of workers, which have been overlooked in this area. This model has one notable feature: cross-border migration of workers responds not only to the tariff increase itself, but also to exchange rate changes caused by the increase. Thus, an additional international transmission effect is generated by our model that operates through the cross-border migration of workers, an effect that has been overlooked in the NOEM literature that considers tariffs.

This paper shows that an increase in domestic tariffs leads to higher relative consumption in that country when the elasticity of substitution between two goods is low or the time preference rate is low. However, when the elasticity of substitution between two goods is high, the tariff increase has no effect on the relative consumption level in the domestic country. Additionally, the paper shows that a tariff increase in the domestic country appreciates the exchange rate if the rate of time preference is relatively small. Furthermore, the paper shows that, when the rate of time preference is relatively small, an increase in tariffs causes workers to migrate from the foreign country to the domestic country in both the short and long runs. Lastly, the paper shows that raising a country's tariff rate always worsens world welfare due to resulting market distortions. In this paper, we would like to emphasize the welfare analysis results in particular among the above results. In our model, a tariff increase in one country causes market distortions and creates asymmetric effects on domestic and foreign production activity. These effects are due to exchange rate fluctuations and cross-border labor migration. In turn, these effects affect consumption and labor supply between the two countries. In our model, however, the effects of a tariff increase on consumption and labor supply cancel each other out between countries when aggregated globally. Ultimately, only the market distortion caused by the tariff increase remains, leading to a deterioration in global economic welfare. Therefore, the imposition of unilateral tariffs gives rise to inefficiencies and a decline in global welfare, even when accounting for the adjustment of cross-border worker migration.

The rest of this paper is organized as follows: Section 2 outlines the model. Section 3 presents the steady state with flexible wages. Section 4 explains how exchange rates affect migration. Section 5 examines how a tariff imposed by the domestic country affects migration, the exchange rate, and relative consumption. Section 6 examines the welfare effects of an increase in the domestic tariff. The final section of the paper offers a conclusion.

2. MODEL

This paper uses a two-country model that integrates Obstfeld and Rogoff (1995)'s Redux model with cross-border worker migration[7]. Households (or workers) in each country engage in intertemporal optimization to maximize utility, consisting of three components: consumption of differentiated goods, real money, and labor effort. On the supply side, households provide differentiated labor services to firms in their region. Producers input these services and produce differentiated goods that contribute to the consumption index. Because the labor market is imperfectly competitive, the zero-shock symmetric equilibrium results in labor supply being less than the level that would be achieved under perfect competition. To examine the impact of a permanent tariff hike in one country, we use an analytical solution that approximates the log-linear values of our model variables compared to a distortion-free, symmetric steady state with zero tariffs. We define the short-run equilibrium as the period during which nominal wage rigidity occurs and the long-run equilibrium as the period following this period during which nominal wages are flexible. Thus, a tariff hike will substantially impact both the short- and long-run equilibria through bilateral current account surpluses (or deficits). A key feature of our model is that cross-border worker migration, which responds to real wage differentials between the two countries, is an important channel for the international spillover effects of a permanent domestic tariff hike shock, in addition to the exchange rate channel.

In this model, the workers in the interval $[0, n_t]$ are located in the domestic country, while the remaining workers, $(n_t, 1]$, are located in the foreign country. We normalize the size of the world population to unity. There are manufactures continuously in the world in the range [0, 1]. We further assume that, manufactures in $[0, s]$ are located in the domestic country, and the remaining $(s, 1]$ manufactures are located in the foreign country, where s is exogenous. The lifetime utility of household $i \in [0, n_t]$ in the domestic country is defined as follows:

$$U_0(i) = \sum_{t=0}^{\infty} \beta^t \left(\log C_t(i) + \chi \log(M_t(i)/P_t) - (\kappa/2)\left(L_t^s(i)\right)^2 \right) \quad (1)$$

where the subjective discount factor, β, remains constant ($0 < \beta < 1$), $L_t^s(i)$ is the supply of labor, and $C_t(i) = (\int_0^1 C_t(i,j)^{(\sigma-1)/\sigma} dj)^{\sigma/(\sigma-1)}$, $\sigma > 1$, where $C_t(i,j)$ is the consumption of good j and σ is the elasticity of substitution between any two differentiated goods. In addition, $M_t(i)$ denotes nominal money balances, and $P_t = (\int_0^1 P_t(j)^{1-\sigma} dj)^{1/(1-\sigma)}$, where $P_t(j)$ is the price of good j. The foreign price index is $P_t^* = (\int_0^1 P_t^*(j)^{1-\sigma} dj)^{1/(1-\sigma)}$. In accordance with the principle of the law of one price, it can be demonstrated that $P_t(j) = \varepsilon_t P_t^*(j)$. In this equation, ε_t is defined as the nominal exchange rate, which is expressed as the domestic currency price per unit of foreign currency. For simplicity, we will assume that tariffs are levied only in the domestic country. If τ_t is the domestic country's tariff rate, then the price indices can be rewritten as, respectively, $P_t = (\int_0^s P_t(j)^{1-\sigma} dj + \int_s^1 \left((1+\tau_t)\varepsilon_t P_t^*(j)\right)^{1-\sigma} dj)^{1/(1-\sigma)}$ and $P_t^* = (\int_0^s (P_t(j)/\varepsilon_t)^{1-\sigma} dj + \int_s^1 P_t^*(j)^{1-\sigma} dj)^{1/(1-\sigma)}$. We make two assumptions: first, that there is an international risk-free real bond market, and second, that real bonds are denominated in units of the composite consumption good. Thus, the budget constraint for a typical domestic household is as follows, measured in per capita terms: $P_t B_{t+1}(i) + M_t(i) = P_t(1 +$

$r_t)B_t(i) + M_{t-1}(i) + W_t(i)L_t^s(i) + \int_0^s \Pi_t(j)\,dj + \int_s^1 \varepsilon_t \Pi_t^*(j)dj - P_tC_t(i) + P_tT_t(i)$, where $B_{t+1}(i)$ denotes real bonds, r_t is the real interest rate, $W_t(i)$ is the nominal wage rate, $\int_0^s \Pi_t(j)\,dj$ ($\int_s^1 \varepsilon_t \Pi_t^*(j)dj$) represents the total nominal profit flows of firms located in the domestic (foreign) country from sales of products, and $T_t(i)$ denotes real lump-sum transfers. We assume that government spending is zero and that the government rebates all seignorage and all tariff revenue to the public in the form of lump-sum transfers. Therefore, the fiscal budget constraint in the domestic country is $P_tT_t = \tau_t \int_0^{n_t} \int_s^1 \varepsilon_t P_t^*(j)C_t(i,j)\,dj\,di + M_t - M_{t-1}$, where M_t is money supply, and $T_t = \int_0^{n_t} T_t(i)\,di$ and $M_t = \int_0^{n_t} M_t(i)\,di$. In the production sector, manufacture $j \in [0, s]$ produces a unique product according to $y_t(j) = (n_t{}^{-1/\phi} \int_0^{n_t} \left(L_t^d(i,j)\right)^{(\phi-1)/\phi} di)^{\phi/(\phi-1)}$, where $y_t(j)$ is the amount of production, $L_t^d(i,j)$ is the manufacture j's input of labor from household i, and $\phi > 1$. From the cost minimization, manufacture j's labor demand is:

$$L_t^d(i,j) = n_t{}^{-1}(W_t(i)/W_t)^{-\phi} y_t(j), \tag{2}$$

where $W_t \equiv (n_t{}^{-1} \int_0^{n_t} W_t(i)^{(1-\phi)} di)^{1/(1-\phi)}$. In the first stage, households in the domestic (foreign) country maximize $C_t(i)$ ($C_t^*(i)$) subject to $P_tC_t(i) = \int_0^1 P_t(j)\,C_t(i,j)dj$ ($P_t^*C_t^*(i) = \int_0^1 P_t^*(j)\,C_t^*(i,j)dj$) by allocating $C_t(i,j)$ and $C_t^*(i,j)$ optimally. This yields:

$$C_t(i,j) = (P_t(j)/P_t)^{-\sigma} C_t(i), \;\; C_t^*(i,j) = (P_t^*(j)/P_t^*)^{-\sigma} C_t^*(i) \tag{3}$$

By summing the demands in equation (3) for globally, the market clearing condition for $y_t(j)$ is derived:

$$y_t(j) = \int_0^{n_t} C_t(i,j)\,di + \int_{n_t}^1 C_t^*(i,j)\,di = (P_t(j)/P_t)^{-\sigma} C_t^w \tag{4}$$

where $C_t^w \equiv \left(\int_0^{n_t} C_t(i)\,di + \int_{n_t}^1 C_t^*(i)\,di\right)$ is the world consumption. Similarly, $y_t^*(j) = (P_t^*(j)/P_t^*)^{-\sigma} C_t^w$. Next, a typical household maximizes (1) subject to the intertemporal budget constraint. The following are the first-order conditions with respect to $B_{t+1}(i)$ and $M_t(i)$:

$$1/C_t(i) = \beta[(1 + r_{t+1})/C_{t+1}(i)] \tag{5}$$

$$M_t(i)/P_t = \chi C_t(i)((1 + R_{t+1})/R_{t+1}), \tag{6}$$

where R_{t+1} is defined as the nominal rate of interest and $1 + R_{t+1} = (1 + r_{t+1})[(P_{t+1}/P_t)]$. Finally, the transversality condition is $\lim_{T\to\infty}\left(1/\Pi_{v=1}^{t+T}(1 + r_v)\right)[B_{t+T+1} + M_{t+T}/P_{t+T}] = 0$.

In the production sector, given W_t, P_t, C_t^w, n_t, (2), and (4), manufacture j faces the profit maximization problem: $\max_{P_t(j)} \Pi_t(j) = (P_t(j) - W_t)y_t(j)$. The following price markup is obtained by substituting $y_t(j)$ from equation (4) into $\Pi_t(j)$ and subsequently differentiating $\Pi_t(j)$ with respect to $P_t(j)$:

$$P_t(j) = (\sigma/\sigma - 1)W_t. \tag{7}$$

From (7), $P_t(j) = P_t(h)$, $j \in [0, s]$, and hence all manufactures require $L_t^d(i,j) = L_t^d(i,h)$, $j \in [0,s]$. Similarly, $P_t^*(j) = P_t^*(f)$, $j \in (s,1]$. Substituting equations (4) and (7) into $\Pi_t(h)/P_t$ and $\Pi_t^*(f)/P_t^*$, respectively, gives

$$\Pi_t(h)/P_t = (1/\sigma)(P_t(h)/P_t)^{1-\sigma}C_t^w,\ \Pi_t^*(f)/P_t^* = (1/\sigma)(P_t^*(f)/P_t^*)^{1-\sigma}C_t^w. \tag{8}$$

In accordance with Corsetti and Pesenti (2001)'s conceptual framework, our model incorporates nominal rigidity manifested as a one-period wage contract. In this contract, the nominal wage for period t is predetermined at time $t-1$ by the monopolistically competitive labor supplier, who wields its superior bargaining position over each firm. The labor-market equilibrium conditions imply that $L_t^s(i) = \int_0^s L_t^d(i,j)dj$, $i \in (0, n_t)$ and $L_t^{s*}(i) = \int_s^1 L_t^{d*}(i,j)dj$, $i \in (n_t, 1]$, where the left-hand sides represent the supply of labor and the right-hand sides represent firms' total demand. By substituting equation (2) and $L_t^s(i) = \int_0^s L_t^d(i,j)dj$ into the intertemporal budget constraint, and maximizing (1) with respect to $W_t(i)$, we obtain:

$$\phi(W_t(i)/P_t)^{-1}\left[\kappa\left(L_t^s(i)\right)^2\right] = (\phi - 1)[L_t^s(i)/C_t(i)] \tag{9}$$

The key feature of our model is its allowance of border-crossing migration by workers. Additionally, we assume that the driving force behind workers migrating to another country is the difference in real wages between the two countries. For simplicity, we ignore factors that are important in real-world migration decisions, such as moving costs, immigration policies, network effects, and expectations about future wages and policies. The above adjustment process for the cross-border migration of workers is defined as follows:

$$(n_t - n_{t-1})/n_{t-1} = \gamma[(W_t(i)/P_t)/(W_t^*(i)/P_t^*) - 1], \tag{10}$$

where γ ($0 \le \gamma < \infty$) is the degree to which worker migration responds to the wage differential: a larger value of γ implies a higher degree of cross-border worker migration responding to the real wage differential between two countries.

3. SYMMETRIC STEADY STATE

From now on, we will use the subscript *ss* to denote the steady-state values. The solution for a symmetric steady state is derived under the following conditions: all exogenous variables are constant, initial net foreign assets are zero ($B_{ss,0} = 0$) and $\tau_{ss,0} = 0$. In the steady state,

the Euler equation (5) gives that the constant real interest rate is $r_{ss} = (1 - \beta)/\beta \equiv \delta$. Here, δ is the rate of time preference. In the steady state, $W_{ss}(h)/P_{ss} = W_{ss}^*(f)/P_{ss}^*$ must hold. From $P_t = \varepsilon_t P_t^*$ and equation (7), we obtain $P_{ss}(h) = \varepsilon_{ss} P_{ss}^*(f)$. Therefore, the real goods prices are as follows:

$$P_t(h)/P_t = (P_t(h)/\varepsilon_t)/P_t^* = \left[s + (1-s)\left(\left(\varepsilon_t P_t^*(f)\right)/P_t(h)\right)^{1-\sigma}\right]^{-1/(1-\sigma)} \tag{11}$$

$$\varepsilon_t P_t^*(f)/P_t = P_t^*(f)/P_t^* = \left[s\left(\left(\varepsilon_t P_t^*(f)\right)/P_t(h)\right)^{\sigma-1} + (1-s)\right]^{-1/(1-\sigma)}, \tag{12}$$

The steady-state real prices can be found by substituting $P_{ss}(h) = \varepsilon_{ss} P_{ss}^*(f)$ into equations (11) and (12):

$$P_{ss}(h)/P_{ss} = (P_{ss}(h)/\varepsilon_{ss})/P_{ss}^* = 1,\ \varepsilon_{ss} P_{ss}^*(f)/P_{ss} = P_{ss}^*(f)/P_{ss}^* = 1. \tag{13}$$

From $W_t \equiv (n_t^{-1}\int_0^{n_t} W_t(i)^{(1-\phi)}di)^{1/(1-\phi)}$, $W_t^* \equiv ((1-n_t)^{-1}\int_{n_t}^{1} W_t^*(i)^{(1-\phi)}di)^{1/(1-\phi)}$, (7) and (13), real wages in the steady state are given as follows:

$$W_{ss}/P_{ss} = W_{ss}^*/P_{ss}^* = (\sigma - 1)/\sigma. \tag{14}$$

The steady-state allocation of workers is given by the symmetry condition $n_{ss} = 1 - n_{ss}$:

$$n_{ss} = 1/2. \tag{15}$$

Finally, from (7) and (9), we obtain:

$$L_{ss}^s = L_{ss}^{*s} = C_{ss} = C_{ss}^* = C_{ss}^w = ((\phi-1)/\phi)^{1/2}((\sigma-1)/\sigma)^{1/2}(1/\kappa)^{1/2}. \tag{16}$$

4. MIGRARION AND EXCHANGE RARE

It is assumed that the economy commences in a zero-shock steady state in period 0 and that nominal wage rigidities emerge in period 1. This suggests that nominal wages are unable to instantaneously adjust to an unanticipated permanent tariff in period 1. This temporal span is referred to as the short run. In periods 2 and beyond, nominal wages undergo a perfect adjustment to their new steady-state values. We refer to the time from period 2 onwards as the long run. The short-run deviations from the initial steady-state of any variable X are denoted by $\hat{X}$. That is to say, $\hat{X} = dX_1/X_{ss,0}$, where $X_{ss,0}$ is the initial steady-state value in the absence of any shocks and subscript 1 denotes the period in which the shock takes place. The short-run percentage deviations align with the duration of nominal wage rigidities. Thus, $\widehat{W} = \widehat{W}^* = \hat{P}(h) = \hat{P}^*(f) = 0$. We also use $\bar{X}$ to represent long-term percentage changes from the initial steady-state value. That is, $\bar{X} = dX_2/X_{ss,0} = dX_{ss}/X_{ss,0}$, which aligns with flexible

nominal wages. The following expression is obtained for the migration of workers in the short run by log linearizing equation (10) and setting $\widehat{W} = \widehat{W}^* = \hat{P}(h) = \hat{P}^*(f) = 0$:

$$\hat{n} = -\gamma(\hat{\varepsilon} + (1/2)d\tau), \tag{17}$$

where $d\tau$ is the permanent increase in domestic tariffs. Equation (17) shows that for a given level of a tariff, an appreciation of the domestic currency ($\hat{\varepsilon} < 0$) induces workers to migrate to the domestic country ($\hat{n} > 0$) (and vice versa). Moreover, from equation (17), it can be seen that the imposition of a tariff by the domestic country ($d\tau > 0$) at a given level of the exchange rate induces workers to migrate to the foreign country, resulting in $\hat{n} < 0$. Similarly, in the long run, by log-linearizing equation (10), the following expression is obtained for the migration of workers:

$$\bar{n} = -\gamma\left(\hat{\varepsilon} + (1/2)d\tau - (\bar{W} - \bar{W}^*)\right). \tag{18}$$

According to equation (18), the long-term shift in the international distribution of workers is positively impacted by the difference in wages between two countries, but negatively impacted by the exchange rate, which affects the difference in price levels between the two countries. Additionally, given a certain exchange rate and wage disparity between two countries, an increase in tariffs by the domestic country ($d\tau > 0$) will, in the long run, lead to workers migrating from the domestic country to the foreign country. As stated above, the tariff rate and the exchange rate are both important factors affecting the cross-border migration of workers, as shown by equations (17) and (18).

5. TARIFFS POLICIES

5.1. Short-Run Migration Effects of Tariffs

We are now examining the consequences of a sudden permanent tariff imposed by the domestic country. The short-run changes in the migration of workers are as follows (see Annex 2 for the derivation of equation (19)):

$$\hat{n} = \frac{1}{2}\left(\frac{\gamma A[1+\delta((\sigma-1)/\sigma)]}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right)d\tau, \tag{19}$$

where:

$$A \equiv \left(1+\left(\frac{\sigma-1}{\sigma}\right)\left(\frac{\sigma-1+2\gamma}{\sigma+1+2\gamma}\right)\right)^{-1} > 0,\ D \equiv \left(1-2\gamma\left(\frac{\delta}{1+\delta}\right)\right)\left(1+\left(\frac{1}{1+\delta}\right)\left(\frac{2\gamma}{\sigma+1+2\gamma}\right)\right)^{-1}.$$

Here, the composite parameter D in the above equation is a decreasing function of γ and an increasing function of σ. Therefore, D can be regarded as a term that is decreasing in the elasticity of cross-border worker mobility and increasing in the elasticity of substitution between the two goods. However, equation (19) shows that the short-run effect of tariffs on the direction of international migration is ambiguous. Note here that in equation (17), the effect of a tariff increase in the domestic country on the direction of international worker

migration in the short run consists of two effects, the first and second terms in parentheses on the right-hand side. The first term in parentheses on the right-hand side of equation (17) is the effect of an increase in tariff revenue from a tariff increase, which increases consumption in the domestic country and thus appreciates the value of the domestic currency due to the money market equilibrium condition. This is because in this paper, since the money supply is constant, when the demand for money increases due to increased consumption, an imbalance occurs in the money market, and in order to balance it, it is necessary to lower the price level in the domestic country by increasing the value of the domestic currency. And the appreciation of the domestic currency means an increase in real wages in the domestic country by lowering the price level in the domestic country, and the increasing gap in real wages between the domestic country and foreign countries increases the motivation of foreign workers to move to the domestic country. This paper defines this term as the tariff revenue effect. The second term in parentheses on the right-hand side of equation (17) represents the effect of a direct increase in the price level in the domestic country due to an increase in tariffs (i.e., indirect taxes), which causes the real wage of the domestic country to fall relative to that of the foreign country. As a result, in contrast to the tariff revenue effect, this effect creates an incentive for workers in the domestic country to migrate to the foreign country. This paper defines this effect as the terms of trade effect. The two effects of raising tariffs in the domestic country – the tariff revenue effect and the terms of trade effect – can be illustrated as Figure no. 1.

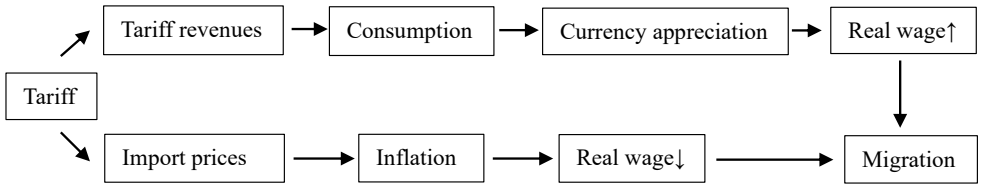

Figure no. 1 – Tariff revenue effect and terms of trade effect

As demonstrated above, the tariff revenue effect is a factor that engenders an influx of workers from the foreign country to the domestic country, while the terms of trade effect is a factor that engenders an outflow of workers from the domestic country to the foreign country. Ultimately, depending on the relative size of the tariff revenue effect and the terms of trade effect, a permanent tariff increase in the domestic country will determine the direction of international migration of workers between two countries. However, with equation (19) as it is, the mathematical formula is too complicated to immediately determine the sign of the effect of the domestic tariff increase on the direction of worker migration. Therefore, in this paper, we focus on the value of δ to determine the sign of equation (19). In this paper's model, if the time preference rate (equal to the steady-state real interest rate) δ is relatively small, or if $1 > 2\gamma(\delta/(1+\delta))$, households have less incentive to smooth their consumption (or to save more). In this case, the effect of increasing tariff revenues through tariff hikes on boosting consumption becomes greater. Therefore, if δ is relatively small and tariffs are raised in the domestic country, the tariff revenue effect outweighs the terms of trade effect, causing workers to leave the foreign country and migrate to the domestic country:

$$\hat{n} > 0, \text{ if } 1 > 2\gamma\left(\frac{\delta}{1+\delta}\right) \text{ or } \delta \text{ is small.} \quad (20)$$

Furthermore, if σ is sufficiently large, $\hat{n} = 0$. This is because, when σ is sufficiently large, the change in the real wage gap between the domestic country and foreign countries becomes negligible, even when the domestic country raises tariffs.

5.2. Plausible Parameter Values for δ and γ

Here, let us explain the economic meaning of $1 > 2\gamma(\delta/(1+\delta))$. This condition requires either low cross-border worker mobility or a low time preference rate. Therefore, under this condition, our model indicates that high time preference and high cross-border worker mobility are not permitted. A high time preference rate renders consumption smoothing improbable as a mechanism to curtail consumption in response to an escalation in the real interest rate. Additionally, cases of high cross-border worker mobility are typically confined to economically integrated countries, such as those within the European Union. Conversely, a low time preference rate indicates that consumption is likely to decline instantaneously in response to an increase in the real interest rate. Furthermore, cases in which cross-border worker mobility is low apply to bilateral relationships in which cross-border labor is difficult due to physical, linguistic, or institutional constraints (e.g., between the United States and Russia or China). This paper's assumption of $1 > 2\gamma(\delta/(1+\delta))$ suggests a scenario in which global consumption is sensitive to increases in real interest rates or cross-border worker between two countries is difficult due to physical, linguistic, or institutional constraints. Figure no. 2 shows the allowable range of γ and δ that satisfies the condition $1 > 2\gamma(\delta/(1+\delta))$, with $\gamma = (1+\delta)/2\delta$ as its boundary. Figure no. 2 also shows that, for $1 > 2\gamma(\delta/(1+\delta))$, at least one of γ and δ must be small. The specific values of γ and δ at the $\gamma = (1+\delta)/2\delta$ boundary are listed in Table no. 1. Table no. 1, second row, shows the elasticity of worker migration with respect to the exchange rate. Although no empirical studies have estimated the value of γ in Table no. 1, many studies have estimated the time preference rate of each country. First, Kula (2004) calculated India's time preference rate at 1.3%, based on average mortality rates. Evans and Sezer (2004) estimated time preference rates at 1.5% for Australia, Japan, and the United States and at 1% for France, Germany, and the United Kingdom. Furthermore, Evans (2005) estimated the time preference rates for France, Germany, Japan, the United Kingdom, and the United States to be 1% based on mortality rates. Azar (2007) and Moore Moore *et al.* (2013) estimated the time preference rate for the United States to be between 1% and 1.5%. Lopez (2008) estimated the time preference rates for nine South American countries and found a value of 1% for each. Percoco (2008) proposed that Italy's time preference rate ranged from 0.98% to 1%. Akbulut and Seçilmiş (2019) estimated Turkey's time preference rate to be 0.99%. Nesticò and Maselli (2020) estimated Italy's and the United States' time preference rates to be 1.3% and 1.1%, respectively. Based on these empirical evidence, it is reasonable to assign a time preference rate between 1% and 1.5% to any country, whether developed or developing[8]. Based on the above, if the time preference rate is between 1% and 1.5% in our model, then the value of γ that satisfies $\gamma = (1+\delta)/2\delta$ lies within the range of 33.833 and 50.5. The elasticity of cross-border worker mobility with respect to exchange rates is γ in our model. Therefore, Table no. 1 and Figure no. 2 show that the acceptable range of γ for time preference rates between 1%

and 1.5% is between 33.833 and 50.5. This range suggests that our model is applicable to a wide variety of countries.

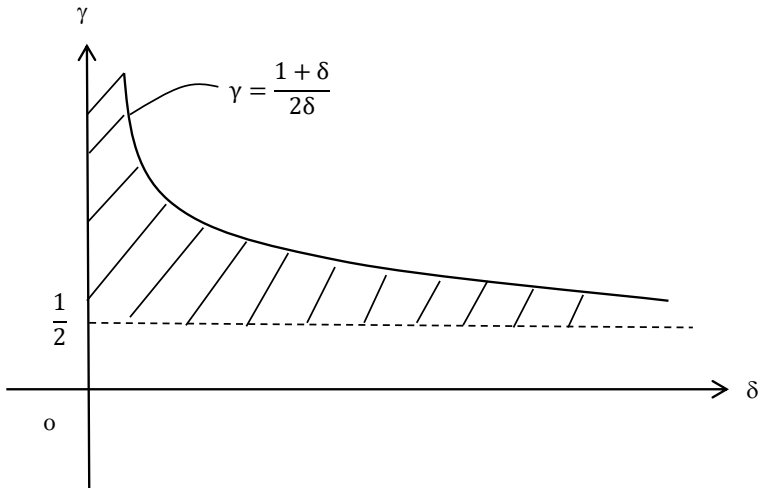

Figure no. 2 – Range of $\mathbf{1 > 2\gamma(\delta/(1+\delta))}$

Table no. 1 – Numerical examples on the boundary line in Figure no. 2

δ	0.001	0.005	0.01	0.015	0.02
γ	500.5	100.5	50.5	33.833	25.5

5.3. Consumption and Exchange Rate Effects

Next, we analyze how the tariff affects the exchange rate and short- and long-run relative consumption. The effects on these variables are as follows:

$$\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* = \frac{1}{2}\left\{\frac{AD[1+\delta((\sigma-1)/\sigma)]}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right\} d\tau, \tag{21}$$

$$\hat{\varepsilon} = -\frac{1}{2}\left(\frac{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma+2\gamma)+A}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right) d\tau. \tag{22}$$

Equation (21) shows the effect of an unanticipated permanent tariff increase in the domestic country on the consumption of the domestic country compared to the foreign country. In order to determine the sign of equation (21), this paper focuses on four effects of a tariff increase in the domestic country on the relative consumption of the domestic country. The first is the effect of the increase in the domestic country's tariff revenue due to a tariff increase in the domestic country, which increases the domestic country's consumption. The second is the effect of the increase in the domestic country's import prices due to a tariff increase in the domestic country, which leads to an increase in the production of the domestic country's products, which in turn increases the domestic country's labor supply and increases

the domestic country's consumption. The third is the effect of an inflow of workers from the foreign country to the domestic country. This increase in the labor force leads to an increase in production in the domestic country and a decrease in production in the foreign country. Consequently, this leads to an increase in the domestic country's exports and an increase in the foreign country's imports. This phenomenon leads to an increase in the domestic country's short-term current account surplus and the net foreign assets, as well as an increase in the domestic country's relative consumption. The fourth is the impact that causes the value of the currency in the domestic country to appreciate by raising tariffs in the domestic country, through the money market equilibrium condition. This, in turn, leads to a reduction in production within the domestic country and an increase in production within the foreign country. Consequently, this results in a decrease in the short-run current account surplus and the long-run net foreign assets in the domestic country, and thus a reduction in the relative consumption of the domestic country. Table no. 2 and Figure no. 3 below summarize the impact of an increase in domestic tariffs on a country's relative consumption.

Table no. 2 – Four effects of tariffs on $\widehat{C} - \widehat{C}^*$

Four effects of a unilateral domestic tariff increase on relative domestic consumption
1 The effect of the increase in the domestic country's tariff revenue
2 The effect of the increase in the domestic country's import prices
3 The effect of migration of workers from the foreign country to the domestic country
4 The effect of domestic currency appreciation

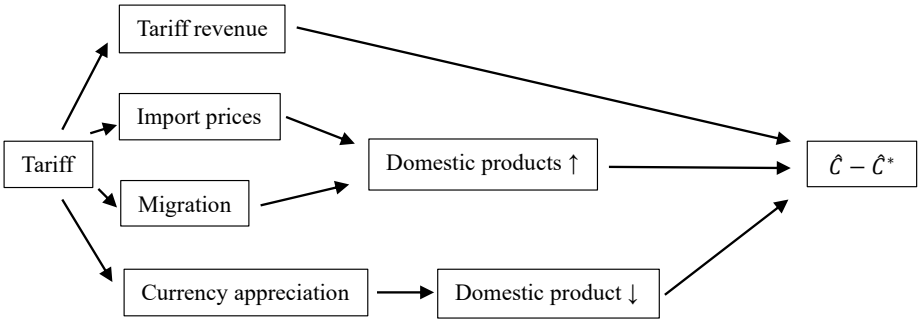

Figure no. 3 – A simple diagram that shows the channels of transmission of tariffs on $\widehat{C} - \widehat{C}^*$

Since the above four effects are not all in the same direction, the effect of raising tariffs in the domestic country on the relative consumption of the domestic country is indeterminate. In this paper, to determine the sign of equation (21), we will determine the magnitude relationship between the above four effects by focusing on the values of σ, δ, and γ. First, when σ is sufficiently close to 1, the markup price of differentiated goods becomes higher, so the tariff revenue, which is determined proportionally, becomes larger. Therefore, when σ is sufficiently close to 1, among the four effects previously mentioned, the first effect through the tariff revenue becomes larger, and therefore, the imposition of a tariff in the domestic country leads to an increase in relative consumption in the domestic country: $\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* > 0$ (see Annex 1). Next, if the rate of time preference δ is sufficiently small and therefore

close to 0, the effect of raising tariffs in the domestic country through the current account balance or net foreign assets becomes relatively small. In other words, if δ is sufficiently small and therefore close to 0, among the four effects mentioned above, the fourth effect through the terms of trade become small. Therefore, if δ is sufficiently small and therefore close to 0, raising tariffs in the domestic country will instead accentuate the first three effects, which have a positive impact on the domestic country's relative consumption, and as a result, the domestic country's relative consumption will increase: $\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* > 0$ (see Annex 1). On the other hand, when σ is large, the markup price of the differentiated goods is low, so the proportionally determined tariff revenue is small, and the first effect through the tariff revenue among the four effects mentioned above becomes smaller; consequently, the positive effects on the relative domestic consumption are smaller in total. As a result, in our model, when σ is sufficiently large, the first three effects that increase the relative domestic consumption are offset by the fourth effect that decreases it, resulting in the relative domestic consumption level remaining unaffected by the tariff increase: $\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* = 0$ (see Annex 1). The above results can be summarized as follows:

$$\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* > 0, \text{ if } \sigma \text{ is small or } \delta \text{ is small,} \tag{23}$$

$$\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* = 0, \text{ if } \sigma \text{ is large.} \tag{24}$$

On the other hand, as with the results in (21), equation (22) also shows that the effect of a tariff increase on the nominal exchange rate is ambiguous. Therefore, to assess the effect of a tariff increase on the nominal exchange rate, we must first consider how a tariff increase in the domestic country affects the value of its currency in detail. First, according to equations (23) and (24), an increase in tariffs in the domestic country increases (or decreases) domestic consumption, thereby increasing (or decreasing) the demand for money. Therefore, given a constant supply of money, the domestic currency must appreciate (or depreciate), and the price level in the domestic country must fall (or rise) to balance supply and demand in the money market. The second is that a tariff increase in the domestic country as an indirect tax causes the domestic price level to rise and the real money supply to fall. Therefore, even if the demand for money is constant, the domestic currency must appreciate and the price level must fall in order to achieve equilibrium between supply and demand in the money market. The third effect is that if an increase in tariffs in the domestic country causes workers to move from the foreign country to the domestic country, the relative consumption in the domestic country is increased by a current account surplus. This increases demand for money, causing the nominal exchange rate to appreciate according to the equilibrium conditions of the money market. In fact, as equation (20) shows, raising tariffs in the domestic country causes workers to move from the foreign country to the domestic country, under the assumption that $1 > 2\gamma(\delta/(1+\delta))$. Therefore, under the assumption that $1 > 2\gamma(\delta/(1+\delta))$, the third effect certainly becomes a factor that appreciates the domestic currency. From the above, in equation (22), if a tariff increase is implemented in the domestic country under the assumption that either $1 > 2\gamma(\delta/(1+\delta))$ or δ is small, then the domestic currency appreciates ($\hat{\varepsilon} < 0$) (see Annex 1)[9]. Figure no. 4 summarizes the impact of a country's domestic tariff increase on the nominal exchange rate.

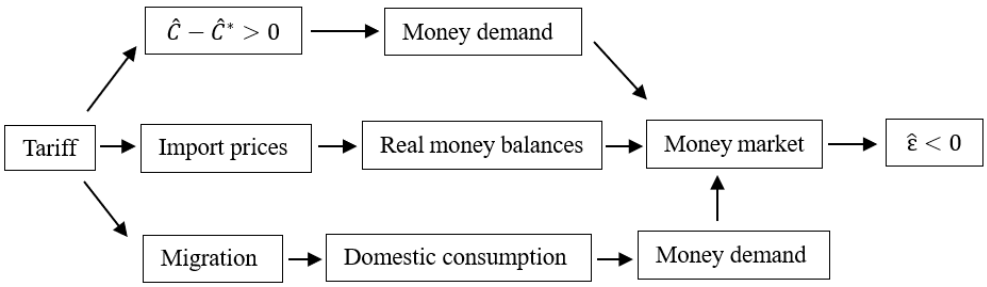

Figure no. 4 – A simple diagram that shows the channels of transmission of tariffs on $\hat{\varepsilon}$

5.4. Long-Run Migration Effects of Tariffs

Similar to the short-run results in (20), the long-run effect of a tariff increase in the domestic country on the direction of migration is as follows:

$$\bar{n} = \frac{1}{2}\left(\frac{\gamma}{\sigma+1+2\gamma}\right)\left(\frac{AD}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right)\left(1+\delta\left(\frac{\sigma-1}{\sigma}\right)\right)d\tau. \quad (25)$$

From equation (25), the effect of a tariff increase on the international migration of workers in the long run is ambiguous. In order to assess the effect of a tariff increase on the international migration of workers in the long run, we must pay attention to equations (9) and (18), which have meaning in the long-run equilibrium. From equations (9) and (18), the effect of tariff increases on the direction of international migration of workers in the long run can be divided into three effects. The first, as shown in equations (18) and (22), is a decrease in the price level in the domestic country and an increase in the price level in the foreign country through the appreciation of the domestic currency due to the tariff increase in the domestic country under the assumption of $1 > 2\gamma(\delta/(1+\delta))$. As a result, the real wage in the domestic country becomes higher than the real wage in the foreign country, which induces foreign workers to migrate to the domestic country. This effect corresponds to the tariff revenue effect shown in the short-run effect. The second effect is the terms of trade effect, as in the short run, where a tariff increase in the domestic country causes prices in the domestic country to rise and real wages in the domestic country to fall. This terms of trade effect gives workers an incentive to migrate from the domestic country to the foreign country. The third effect is an effect through a kind of labor-leisure trade-off condition, as shown in equation (9). Here, as shown in equation (21), especially when the value of δ is small and the relative domestic consumption increases ($\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* > 0$), the marginal utility of consumption associated with the labor supply on the right side of equation (9) decreases. Therefore, in this case, workers in the domestic country will increase their nominal wage to satisfy equation (9) and take actions to further reduce their labor supply. This will increase the real wage in the domestic country relative to the foreign country, providing an incentive for workers to migrate from the foreign country to the domestic country. In this paper, this effect is called the consumption effect. From the above, as shown in equation (18), the net effect of a tariff increase on the international migration of workers in the long run is determined by the relative magnitudes of the tariff revenue effect, the terms of trade effect, and the consumption effect.

In other words, the tariff revenue effect and consumption effect are factors that cause workers to move from the foreign country to the domestic country, while the terms of trade effect is a factor that causes workers to move from the domestic country to the foreign country. Table no. 3 and Figure no. 5 summarize the effects of home country tariff increases on long-run cross-border worker migration.

Table no. 3 – Three effects of tariffs on $\bar{n}$

Three effects of a domestic tariff increase on the long-run migration of workers
1 The appreciation effect of the domestic currency through domestic tariff revenues
2 The effect of an increase in domestic import prices on a relative decline in domestic real wages
3 The effect through the labor-leisure trade-off condition

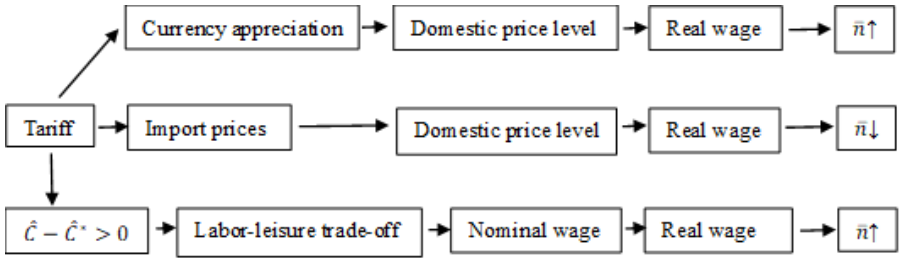

Figure no. 5 – A simple diagram that shows the channels of transmission of tariffs on $\bar{n}$

Here we focus on the case where the value of δ, which is the result of equation (23), is small and the consumption effect is positive: $\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* > 0$. In this case, the tariff revenue effect becomes larger, so that the sum of the consumption effect and the tariff revenue effect exceeds the terms of trade effect, and as a result, real wages in the domestic country exceed real wages in the foreign country. Therefore, if the value of δ is small, in the long run, an increase in the domestic country's tariff will cause workers to migrate from the foreign country to the domestic country ($\bar{n} > 0$). Moreover, similar to the short-run changes in worker migration, if σ is sufficiently large, $\bar{n} = 0$. This is because, when σ is sufficiently large, the change in the real wage gap between the domestic country and foreign countries becomes negligible, even when the domestic country raises tariffs and has no effect on the direction of international worker migration. Table no. 4 summarizes the effects of raising tariffs in the domestic country on changes in the direction of international migration of workers and the domestic country's relative consumption level, focusing particularly on σ and δ.

Table no. 4 – The migration effect and the relative consumption effect

	Worker migration	Relative consumption
σ is small or δ is small	$\hat{n} > 0, \bar{n} > 0$	$\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* > 0$
σ is large	$\hat{n} = 0, \bar{n} = 0$	$\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* = 0$

6. WELFARE

Following the NOEM literature, we focus on the real component of an agent's utility. The definition of this real component as U_0^R enables the rewriting of equation (1) as $U_0^R = \sum_{t=0}^{\infty} \beta^t \left(\log C_t(i) - (\kappa/2)\left(L_t^s(i)\right)^2\right)$. The welfare of the domestic country is impacted by unanticipated tariff policy shocks in the following ways:

$$dU_0^R = -(1/4)d\tau + (1/2)\left(\hat{C} - \hat{C}^*\right) - ((\phi-1)/\phi)((\sigma-1)/\sigma)\{(1/4)(\sigma-1)d\tau + (1/2)\left(\hat{L}^s - \hat{L}^{s*}\right)\} - (1/8\delta)d\tau + (1/2\delta)(\bar{C} - \bar{C}^*) + (1/\delta)((\phi-1)/\phi)((\sigma-1)/\sigma)\{(1/8)d\tau - (1/2)(\bar{L}^s - \bar{L}^{s*})\}. \quad (26)$$

Similarly, the impact on the welfare of the foreign country is:

$$dU_0^{R*} = -(1/4)d\tau - (1/2)\left(\hat{C} - \hat{C}^*\right) - ((\phi-1)/\phi)((\sigma-1)/\sigma)\{(1/4)(\sigma-1)d\tau - (1/2)\left(\hat{L}^s - \hat{L}^{s*}\right)\} - (1/8\delta)d\tau - (1/2\delta)(\bar{C} - \bar{C}^*) + (1/\delta)((\phi-1)/\phi)((\sigma-1)/\sigma)\{(1/8)d\tau + (1/2)(\bar{L}^s - \bar{L}^{s*})\}. \quad (27)$$

Here, we can calculate the effect of a rise in the domestic tariff on the world's welfare. For the purpose of this study, the term world welfare is hereby defined as $U_t^W = n_t U_t^R + (1 - n_t)U_t^{R*}$, where $n_{ss,0} = 1/2$ and $U_{ss,0}^R = U_{ss,0}^{R*}$. According to Equations (26) and (27), the impact of an increase in the domestic tariff rate on global welfare can be calculated as follows:

$$dU_0^W = dn(U_0^R - U_0^{R*}) + (1/2)(dU_0^R + dU_0^{R*}) = (1/2)(dU_0^R + dU_0^{R*}) = -(1/4)\{1 + ((\phi-1)/\phi)((\sigma-1)/\sigma)(\sigma-1) + 1/2\delta\,[1 - ((\phi-1)/\phi)((\sigma-1)/\sigma)]\}d\tau < 0. \quad (28)$$

It is shown by equation (28) that the welfare of the world economy is worsened by a tariff increase in the domestic country. The intuitive explanation for this result is as follows: First, it should be noted that world welfare is unaffected by the international movement of workers or the redistribution of income through tariff revenues. This is because the impact of these two factors on world welfare is exactly offset between the domestic country and the foreign country. Therefore, world welfare is only affected by the utility of consumption and the disutility of labor via exchange rate fluctuations. It should be recalled here that in this paper, the starting point is an initial steady state where no market distortions exist and tariffs are zero, and the effects of a tariff hike are analyzed from there. Moreover, as already shown in this paper, a tariff increase is found to reduce production in the domestic country and increase production in the foreign country through the consumption switching effect caused by the appreciation of the domestic country's currency, as shown in the fourth of the four effects that determine the sign of (21). Therefore, equation (28) demonstrates that exchange rate fluctuations resulting from a tariff increase impact relative prices between the two countries, adversely affecting global welfare by increasing consumption and production distortions. Indeed, equation (28) shows that as in the conventional NOEM model, the larger the value of σ, the larger the consumption switching effect through exchange rate fluctuations, and therefore, the negative effect of a tariff hike on

world welfare is proportionately larger, too. Figure no. 6 summarizes the impact of a country's domestic tariff increase on global welfare.

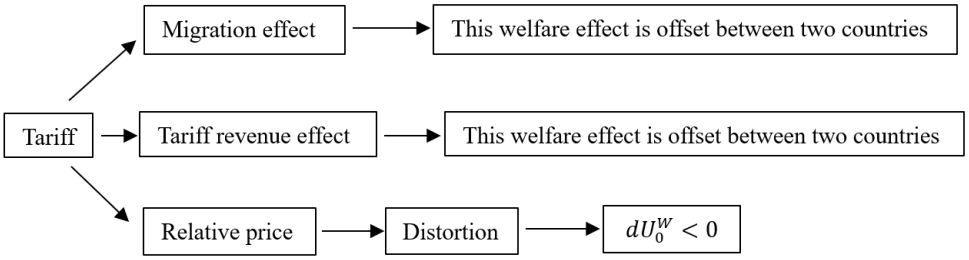

Figure no. 6 – A simple diagram that shows the channels of transmission of tariffs on dU^W

7. CONCLUSION

The impact of tariff shocks on consumption, exchange rates, and global welfare has been examined in this paper. The examination was conducted using a two-country intertemporal model with international migration of workers. The following are the main results of our analysis: i) when the elasticity of substitution between the two goods is small, or the rate of time preference is small, a tariff increase in the domestic country increases the relative domestic consumption level, but when the elasticity of substitution between the two goods is large, the relative domestic consumption level remains unaffected by the tariff increase; ii) if the rate of time preference is relatively small, the exchange rate is appreciated by the tariff increase in the domestic country, iii) if the rate of time preference is small, an increase in the tariff rate in the domestic country will cause workers to migrate from the foreign country to the domestic country, both in the short and long runs, finally, iv) an increase in the domestic tariff rate worsens world welfare due to the resulting market distortions. In this paper, we would like to emphasize the welfare analysis results in particular among the above results. In our model, a tariff increase in one country not only causes market distortions but also creates asymmetric effects on domestic and foreign production activity due to exchange rate fluctuations and cross-border worker migration, which in turn affect consumption and labor supply between the two countries. Therefore, the impact of a tariff increase in one country on global welfare is not trivial. However, in our model, when aggregated globally, the effects of a tariff hike in one country on consumption and labor supply cancel each other out between one country and another, and in the end, only the market distortion caused by the tariff hike remains, which leads to a deterioration in global economic welfare. Therefore, the imposition of unilateral tariffs gives rise to inefficiencies and a decline in global welfare, even when accounting for the adjustment of cross-border worker migration. This result suggests theoretical future consequences for global economic welfare from US tariff hikes in the context of the recent trend toward economic integration, which has seen an increase in international labor mobility.

In this paper, an open economy model with cross-border labor migration was employed to analyze the effects of a unilateral tariff hike on consumption, exchange rates, cross-border labor migration, and global welfare. Despite the simplicity of the model presented here, it offers numerous avenues for future research. The primary objective of this paper was to

analyze the effects of a fixed tariff increase in an open economy using a general equilibrium model. Therefore, we did not remain to consider interactions between bilateral governments, including retaliatory tariff competition, as in Gros (1987). Consequently, it would be advantageous to extend this model to analyses that treat tariff rates as strategic variables. In addition, for simplicity, our model assumed that worker migration is influenced only by the real wage gap between two countries. This allowed worker migration to be influenced by both nominal wage gaps and exchange rate changes. The resulting model structure more closely reflects the real economy. This is because international remittances, which affect worker mobility internationally, are influenced by exchange rates, which ultimately affect workers' destination choices. However, real wage gaps and exchange rates are not the only factors influencing actual worker migration. Our formulation ignores important real-world migration decision factors, such as moving costs, immigration policies, network effects, and expectations about future wages and policies. For instance, when choosing a destination, workers are more likely to select a country with a large number of compatriots because they can utilize information networks. Therefore, incorporating these factors into our model would be useful for more accurately predicting the economic effects of tariff hikes. Furthermore, this analysis assumes a single risk-free real bond and ignores the effect of financial market imperfections on the transmission of tariff shocks. However, empirical evidence has shown that uncertainty about tariff policy affects the real economy through various financial markets (He *et al.*, 2021; Hoque *et al.*, 2023; Huynh *et al.*, 2023; Hajilee *et al.*, 2025; Yilmazkuday, 2025). Therefore, it is important to consider how tariff shocks affect exchange rates, consumption, and cross-border worker migration through their impact on imperfect financial markets. These issues are to be addressed in future research.

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ANNEXES

Annex 1

First, in our model, when we evaluate the impact of an increase in tariffs in the domestic country on the nominal exchange rate when σ is as close to 1 as possible, we find the following:

$$\hat{\varepsilon}|_{\sigma\approx 1} = -\frac{1}{2}\left(\frac{D(1+\delta A)+A}{D(1+\delta A)}\right) d\tau,. \tag{A.1}$$

where

$$\mathrm{A}|_{\sigma\approx 1} = 1,$$

$$D|_{\sigma\approx 1} = \left(1 - 2\gamma\left(\frac{\delta}{1+\delta}\right)\right)\left(1 + (1/(1+\delta))\left(\frac{\gamma}{1+\gamma}\right)\right)^{-1}.$$

Here, if $1 > 2\gamma(\delta/(1+\delta))$, then $D|_{\sigma\approx 1} > 0$ and $(D(1+\delta A)+A)|_{\sigma\approx 1} > 0$. Thus, when $1 > 2\gamma(\delta/(1+\delta))$, the following result is obtained:

$$\hat{\varepsilon}|_{\sigma\approx 1} = -\frac{1}{2}\left(\frac{D(1+\delta A)+A}{D(1+\delta A)}\right) d\tau < 0. \tag{A.2}$$

On the other hand, if σ is sufficiently large and $1 > 2\gamma(\delta/(1+\delta))$, then, from $A \equiv \left(1 + ((\sigma-1)/\sigma)\left(\frac{\sigma-1+2\gamma}{\sigma+1+2\gamma}\right)\right)^{-1} > 0$ and $D \equiv \left(1 - 2\gamma(\delta/(1+\delta))\right)\left(1 + (1/(1+\delta))\left(\frac{2\gamma}{\sigma+1+2\gamma}\right)\right)^{-1} > 0$, the following result is obtained:

$$\hat{\varepsilon}|_{\sigma\approx\infty} = -\frac{1}{2}\left(\frac{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma+2\gamma)+A}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right) d\tau < 0. \tag{A.3}$$

Therefore, from (A.2) and (A.3), regardless of the value of σ, under the condition of $1 > 2\gamma(\delta/(1+\delta))$, $\hat{\varepsilon} < 0$ holds. Next, in our model, if we evaluate the impact of raising tariffs in the domestic country on the domestic country's relative consumption at a point where σ is as close to 1 as possible, we get the following:

$$\hat{C} - \hat{C}^*\big|_{\sigma\approx 1} = \frac{1}{2}\left\{\frac{AD[1+\delta((\sigma-1)/\sigma)]}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right\} d\tau = \frac{1}{2(1+\delta)} d\tau > 0. \tag{A.4}$$

Next, in our model, if we evaluate the impact of raising tariffs in the domestic country on the domestic country's relative consumption at a point where δ is as close to 0 as possible, we get the following:

$$\hat{C} - \hat{C}^*\big|_{\delta\approx 0} = \frac{1}{2}\left\{\frac{AD[1+\delta((\sigma-1)/\sigma)]}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right\} d\tau = \frac{1}{2} A > 0. \tag{A.5}$$

Finally, in our model, if we evaluate the impact of raising tariffs in the domestic country on the domestic country's relative consumption at a point where σ is sufficiently large, we get the following:

$$\hat{C} - \hat{C}^*\big|_{\sigma\approx\infty} = \frac{1}{2}\left\{\frac{AD[1+\delta((\sigma-1)/\sigma)]}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right\} d\tau = 0. \quad \text{(A.6)}$$

Annex 2

In what follows, the derivation process of equation (19) is presented. The linearized short-run current account equations for domestic and foreign countries are:

$$\bar{B} = -\left(\frac{\sigma-1}{\sigma}\right)\hat{P} + \left(\frac{\sigma-1}{\sigma}\right)\left(\hat{n} + \hat{L}^d\right) + \frac{1}{2\sigma}\left[\hat{\Pi}(h) + \hat{\Pi}(f)^* + \hat{\varepsilon} - 2\hat{P}\right] - \hat{C} + \frac{1}{2}d\tau, \quad \text{(B.1)}$$

$$-\bar{B} = -\left(\frac{\sigma-1}{\sigma}\right)\hat{P}^* + \left(\frac{\sigma-1}{\sigma}\right)\left(-\hat{n} + \hat{L}^{d^*}\right) + \frac{1}{2\sigma}\left[\hat{\Pi}(h) - \hat{\varepsilon} + \hat{\Pi}(f)^* - 2\hat{P}^*\right] - \hat{C}^*. \quad \text{(B.2)}$$

Subtracting (B.2) from (B.1) yields:

$$2\bar{B} = -\left(\frac{\sigma-1}{\sigma}\right)\left(\hat{P} - \hat{P}^*\right) + \left(\frac{\sigma-1}{\sigma}\right)\left(\hat{L}^s - \hat{L}^{s^*}\right) + \frac{1}{\sigma}\left[\hat{\varepsilon} - \left(\hat{P} - \hat{P}^*\right)\right] - \left(\hat{C} - \hat{C}^*\right) + \frac{1}{2}d\tau. \quad \text{(B.3)}$$

The following schedules show the linearized short-run world demand for representative domestic and foreign products:

$$\hat{y} = \sigma\hat{P} + \hat{C}^W, \hat{y}^* = \sigma\hat{P}^* + \hat{C}^W. \quad \text{(B.4)}$$

We obtain the following equations from the linearized short-run production functions for both domestic and foreign countries:

$$\hat{L}^d = -\hat{n} + \hat{y}, \hat{L}^{d^*} = \hat{n} + \hat{y}^*. \quad \text{(B.5)}$$

The linearized short-run price index equations for both domestic and foreign countries are as follows:

$$\hat{P} = \frac{1}{2}\hat{\varepsilon} + \frac{1}{2}d\tau, \quad \hat{P}^* = -\frac{1}{2}\hat{\varepsilon}. \quad \text{(B.6)}$$

From equations (B.4), (B.5), and (B.6), the short-run relative labor demand is as follows:

$$\hat{L}^s - \hat{L}^{s^*} = -2\hat{n} + \sigma\left(\hat{P} - \hat{P}^*\right). \quad \text{(B.7)}$$

Substituting equations (B.6), (B.7), and (17) into (B.3) yields:

$$\bar{B} = \frac{1}{2}\left(\frac{\sigma-1}{\sigma}\right)(\sigma - 1 + 2\gamma)\hat{\varepsilon} - \frac{1}{2}\left(\hat{C} - \hat{C}^*\right) + \frac{1}{4}\left(\frac{\sigma-1}{\sigma}\right)(\sigma + 2\gamma)d\tau. \quad \text{(B.8)}$$

The linearized Euler equations for domestic and foreign countries are as follows:

$$\bar{C} = \hat{C} + (\delta/(1+\delta))\bar{r},\ \bar{C}^* = \hat{C}^* + (\delta/(1+\delta))\bar{r}. \tag{B.9}$$

From equations in (B.9), subtracting the foreign Euler equation from the domestic country's counterpart yields the following relative per capita consumption dynamics:

$$\bar{C} - \bar{C}^* = \hat{C} - \hat{C}^*. \tag{B.10}$$

The linearized short-run money demand equations for both domestic and foreign countries are as follows:

$$\widehat{M} - \hat{P} = \hat{C} + \hat{n} - \bar{r}/(1+\delta) - \left(\bar{P} - \hat{P}\right)/\delta,\ \widehat{M}^* - \hat{P}^* = \hat{C}^* - \hat{n} - \bar{r}/(1+\delta) - \left(\bar{P}^* - \hat{P}^*\right)/\delta. \tag{B.11}$$

Subtracting the foreign money-demand equation from the domestic counterpart in (B.11) yields:

$$\widehat{M} - \widehat{M}^* - \hat{\varepsilon} - (1/2)d\tau = \hat{C} - \hat{C}^* + 2\hat{n} - (\bar{\varepsilon} - \hat{\varepsilon})/\delta. \tag{B.12}$$

We assume that the nominal money supply is held constant in both countries, so $\widehat{M} = \bar{M} = \widehat{M}^* = \bar{M}^* = 0$. The linearized long-run world demand schedules for domestic and foreign products are as follows:

$$\bar{y} = \sigma\left(\bar{P} - \bar{P}(h)\right) + \bar{C}^W,\ \bar{y}^* = \sigma\left(\bar{P}^* - \bar{P}^*(f)\right) + \bar{C}^W. \tag{B.13}$$

The linearized long-run production functions for both domestic and foreign countries are as follows:

$$\bar{y} = \bar{n} + \bar{L}^d,\ \bar{y}^* = -\bar{n} + \bar{L}^{d^*}. \tag{B.14}$$

The linearized long-run labor market clearing conditions for both countries are as follows:

$$\bar{L}^s = \bar{L}^d,\quad \bar{L}^{s^*} = \bar{L}^{d^*}. \tag{B.15}$$

The linearized long-run optimal pricing equations for firms in each country are as follows:

$$\bar{P}(h) = \bar{W},\quad \bar{P}^*(f) = \bar{W}^*. \tag{B.16}$$

From equations (B.13), (B.14), (B.15) and (B.16), we obtain the following equation:

$$\bar{L}^s - \bar{L}^{*s} = -2\bar{n} + \sigma\left[\bar{\varepsilon} - (\bar{W} - \bar{W}^*) + \frac{1}{2}d\tau\right]. \tag{B.17}$$

By substituting equation (18) into equation (B.17), we obtain the following:

$$\bar{L}^s - \bar{L}^{*s} = (2\gamma + \sigma)\left(\bar{\varepsilon} - (\bar{W} - \bar{W}^*) + \frac{1}{2}d\tau\right). \tag{B.18}$$

The linearized long-run purchasing power parity equation is as follows:

$$\bar{\varepsilon} = \bar{P} - \bar{P}^* - \frac{1}{2}d\tau. \tag{B.19}$$

The linearized long-run first-order conditions for optimal wage setting are as follows:

$$\bar{L}^s = \bar{W} - \bar{P} - \bar{C}, \quad \bar{L}^{s^*} = \bar{W}^* - \bar{P}^* - \bar{C}^*. \tag{B.20}$$

From equations (B.19) and (B.20), we obtain the following equations:

$$\bar{L}^s - \bar{L}^{*s} + \bar{C} - \bar{C}^* = \bar{W} - \bar{W}^* - \bar{\varepsilon} - \frac{1}{2}d\tau. \tag{B.21}$$

Substituting (B.21) into (B.18) yields:

$$\bar{L}^s - \bar{L}^{*s} = \left(\frac{\sigma + 2\gamma}{\sigma + 1 + 2\gamma}\right)(\bar{C} - \bar{C}^*) \tag{B.22}$$

The linearized long-run response of relative per capita consumption levels is as follows:

$$\bar{C} - \bar{C}^* = 2\delta\bar{B} + \left(\frac{\sigma-1}{\sigma}\right)(\bar{W} - \bar{W}^* - (\bar{P} - \bar{P}^*) + \bar{L}^s - \bar{L}^{s*}) + \frac{1}{2}d\tau. \tag{B.23}$$

By substituting equation (B.19) into equation (B.23), we obtain the following:

$$\bar{C} - \bar{C}^* = 2\delta\bar{B} + \left(\frac{\sigma-1}{\sigma}\right)(\bar{W} - \bar{W}^* - \bar{\varepsilon} + \bar{L}^s - \bar{L}^{*s}) + \frac{1}{2}d\tau. \tag{B.24}$$

Substituting (B.21) into (B.24) yields:

$$\bar{C} - \bar{C}^* = 2\delta\bar{B} + \left(\frac{\sigma-1}{\sigma}\right)(2(\bar{L}^s - \bar{L}^{*s}) + \bar{C} - \bar{C}^*) + \frac{1}{2}d\tau. \tag{B.25}$$

Substituting (B.22) into (B.25) yields the linearized long-run response of the relative consumption level.

$$\bar{C} - \bar{C}^* = 2\delta\left\{1 + \left(\frac{\sigma-1}{\sigma}\right)\left(\frac{\sigma-1+2\gamma}{\sigma+1+2\gamma}\right)\right\}^{-1}\bar{B} + \frac{1}{2}\left\{1 + \left(\frac{\sigma-1}{\sigma}\right)\left(\frac{\sigma-1+2\gamma}{\sigma+1+2\gamma}\right)\right\}^{-1}d\tau = 2\delta A\bar{B} + \frac{1}{2}Ad\tau, \tag{B.26}$$

where $A \equiv \left\{1 + \left(\frac{\sigma-1}{\sigma}\right)\left(\frac{\sigma-1+2\gamma}{\sigma+1+2\gamma}\right)\right\}^{-1} > 0$. Substituting (B.21) into equation (18) yields the following:

$$\bar{n} = \gamma[(\bar{L}^s - \bar{L}^{*s}) + (\bar{C} - \bar{C}^*)]. \tag{B.27}$$

Substituting (B.22) into (B.27) yields:

$$\bar{n} = \left(\frac{\gamma}{\sigma+1+2\gamma}\right)(\bar{C} - \bar{C}^*). \tag{B.28}$$

By linearizing the long-run money demand equations and subtracting the foreign money demand equation from its domestic counterpart, we obtain the following equation:

$$\bar{\varepsilon} = \bar{M} - \bar{M}^* - (\bar{C} - \bar{C}^*) - \frac{1}{2}d\tau. \tag{B.29}$$

When $\bar{M} - \bar{M}^* = 0$ and (B.28) are substituted into (B.29), the following is yielded:

$$\bar{\varepsilon} = -\left(\frac{\sigma+1+4\gamma}{\sigma+1+2\gamma}\right)(\bar{C} - \bar{C}^*) - \frac{1}{2}d\tau. \tag{B.30}$$

From equation (17), equation (B.12) can be rewritten as follows:

$$\bar{\varepsilon} = (1+\delta)\hat{\varepsilon} + \delta\left(\hat{C} - \hat{C}^*\right) - 2\delta\gamma\hat{\varepsilon} - \delta\gamma d\tau + \frac{1}{2}\delta d\tau. \tag{B.31}$$

Eliminating $\bar{\varepsilon}$ from equations (B.30) and (B.31) yields the following equation:

$$\left\{1 - 2\gamma\left(\frac{\delta}{1+\delta}\right)\right\}\hat{\varepsilon} = -\left\{1 + \left(\frac{1}{1+\delta}\right)\left(\frac{2\gamma}{\sigma+1+2\gamma}\right)\right\}\left(\hat{C} - \hat{C}^*\right) - \frac{1}{2}\left\{1 - 2\gamma\left(\frac{\delta}{1+\delta}\right)\right\}d\tau. \tag{B.32}$$

Substituting equation (B.10) into equation (B.26) yields

$$\hat{C} - \hat{C}^* = 2\delta A\bar{B} + \frac{1}{2}Ad\tau. \tag{B.33}$$

From equations (B.8) and (B.33), we obtain the following relationship between the exchange rate change and the relative consumption change:

$$\delta A\left(\frac{\sigma-1}{\sigma}\right)(\sigma - 1 + 2\gamma)\hat{\varepsilon} = (1+\delta A)\left(\hat{C} - \hat{C}^*\right) - A\left\{\frac{1}{2}\delta\left(\frac{\sigma-1}{\sigma}\right)(\sigma + 2\gamma) + \frac{1}{2}\right\}d\tau. \tag{B.34}$$

Equation (B.32) can be rewritten as follows:

$$\hat{C} - \hat{C}^* = -D\hat{\varepsilon} - \frac{1}{2}Dd\tau, \tag{B.35}$$

where $D \equiv \frac{1-2\gamma\left(\frac{\delta}{1+\delta}\right)}{1+\left(\frac{1}{1+\delta}\right)\left(\frac{2\gamma}{\sigma+1+2\gamma}\right)}$. Substituting (B.35) into (B.34) yields the following equation:

$$\hat{\varepsilon} = -\frac{1}{2}\left(\frac{D(1+\delta A) + \delta A((\sigma-1)/\sigma)(\sigma+2\gamma) + A}{D(1+\delta A) + \delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right)d\tau \tag{B.36}$$

Substitution of (B.36) into (17) yields the following short-run change in the international migration of workers:

$$\hat{n} = \frac{1}{2}\left(\frac{\gamma A[1+\delta((\sigma-1)/\sigma)]}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right)d\tau \tag{B.37}$$

Equation (B.37) corresponds to equation (19) in the main text.

Notes

[1]For a comprehensive review of empirical studies on the impact of a U.S.-China trade war, see Fajgelbaum and Khandelwal (2022) and Caliendo and Parro (2023).

[2]For an analysis of the various NOEM models, please refer to the studies conducted by Lane (2001) and Sarno (2001).

[3]Furthermore, Ganelli and Tervala (2015a, 2015b) analysis examines the impact of a tariff reduction, employing a New Keynesian model as the analytical framework.

[4]Obstfeld and Rogoff (1995)'s benchmark model shows that monetary expansion leads to an increase in global output and welfare by increasing global spending, assuming a constant distribution of workers across borders.

[5]One exception is Johdo (2022), who developed a *Redux* model incorporating worker migration and examining the effects of unanticipated domestic monetary expansion. However, this research focuses on the macroeconomic effects of unanticipated domestic monetary expansion and therefore does not consider the effects of tariffs. Furthermore, House *et al.* (2025) use a DSGE model that accounts for migration to quantitatively examine whether labor migration can substitute for independent monetary policy in the event of a supply shock between currency union countries. However, this study does not consider the relationship between labor migration and tariffs, despite considering supply shocks.

[6]Poot and Strutt (2010) provide a comprehensive discussion of the two-way interaction between international trade and migration using New Zealand as a case study.

[7]For a detailed explanation of the model structure of the Redux model of Obstfeld and Rogoff (1995), see VanHoose (2004).

[8]However, a survey paper by Frederick *et al.* (2002) on empirical research on time preference rates shows that, although estimates of time preference rates worldwide range from 0% to infinity and some are negative, most are concentrated between 0% and 10%.

[9]For empirical studies demonstrating that tariff increases appreciate the currency of the country where the tariff is implemented, see Furceri *et al.* (2019), Jeanne and Son (2024), and Matveev and Ruge-Murcia (2024).

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GDP per Capita for West-Balkan Countries: Evidence from Linear and Nonlinear Unit Root Tests

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Abstract: The purpose of the paper is to investigate whether the economic trends of the Western Balkans are characterized by stationarity, long-term stability or permanent structural disruptions. Furthermore, the purpose of the work is to analyze institutional impacts on development and identify sustainable development pathways, as well as to assess economic resilience after crises. For this purpose, we examine the stationarity of GDP per capita (adjusted for purchasing power parity-PPP) during the period 1990-2023. To achieve this goal, we apply both linear and nonlinear unit root tests, after first evaluating the series in linear and nonlinear terms. The results of the linear tests showed that the GDP per capita series at the variable levels have a unit root. Linear tests with structural breaks find evidence of stationarity in the levels of the variables in some of the Western Balkan countries. When nonlinear unit root tests are used (with and without structural breaks) we find stationarity in some of the countries we examine.

Keywords: GDP per capita; West-Balkan countries; Linear and Nonlinear Unit Root Tests; Fourier unit root tests.

JEL classification: C12; C22; O40.

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1. INTRODUCTION

Modeling real GDP per capita has attracted the interest of researchers since the work of Nelson and Plosser (1982). In the macroeconomic literature, both Neo-Keynesian and Monetarist economists believe that business cycles are transitory phenomena and that output returns to its natural rate in the long run. Nelson and Plosser (1982) argue that a unit root in real output is inconsistent with the idea that business cycles are a transitory phenomenon. Furthermore, they note that shocks to real output create permanent effects in the system. This means that shocks to real output that have permanent effects (global financial, climate, pandemic and war) will have uncontrolled effects on the economy.

If real output contains a unit root, the structural reform that a government might pursue will be of limited value, because the impact of that reform in the long run will be offset by other shocks. Conversely, if real output is stagnant, only a large shock will have permanent effects on the country's growth trajectory. Therefore, it is important to assess the validity of the unit root hypothesis in real output. Stationarity of real GDP per capita in an economy suggests that business cycles have stable fluctuations around a defining trend. Since real GDP per capita is an important macroeconomic variable for economic policy analysis, it is essential to statistically determine whether real GDP per capita is stationary or contains a unit root. Furthermore, choosing the right control is important for drawing conclusions such as forecasting and making decisions for planning and formulating economic policy.

The empirical literature has concluded that real GDP, at the level form of the series, is non-stationary, using either univariate unit root tests or unit root tests on panel data. The key characteristic of all these tests is that they assume a symmetric adjustment process. In contrast, Enders and Granger (1998) test the null hypothesis of a unit root against the alternative of stationarity with asymmetric adjustment. They demonstrate that movements toward the long-run equilibrium relationship are better modeled as an asymmetric process. Therefore, they show that standard linear unit root tests have lower power in the presence of misspecified dynamics. Moreover, Enders and Granger (1998) relax the assumption of linearity in standard unit root tests by developing tests capable of distinguishing between linear non-stationary processes and nonlinear stationary processes. That is, the null hypothesis tested is that of a unit root, against the alternative of a nonlinear stationary process. Based on these assumptions, the literature identifies two sources of nonlinearity: Regime-dependent nonlinearity, meaning nonlinearity in the speed of mean reversion depending on the regime; and time-dependent nonlinearity, where structural breaks occur-that is, nonlinearity in the deterministic components.

The power of standard unit root tests depends on the specification of the alternative hypothesis. Structural breaks and nonlinear data in standard unit root tests cause erroneous results, resulting in a reduction in the statistical power of these standard tests. Perron (1989) first notes that stationary processes with structural breaks are very often mistakenly interpreted as unit root processes.

Recent empirical literature allows for nonlinear dynamics for unit root testing procedures. Kapetanios *et al.* (2003) argue that standard unit root tests suffer from a strong problem when applied to Data Generating Process (DGP) data. Kapetanios *et al.* (2003), Kruse (2009), and Sollis (2009) apply regime-dependent, nonlinear unit root tests. The above tests differ in the speed of adjustment towards equilibrium. Kapetanios *et al.* (2003), and Kruse (2009), use the exponential smooth transition autoregressive model (ESTAR), while Sollis (2009) uses the asymmetric exponential smooth transition autoregressive model

(AESTAR). Christopoulos and Leon-Ledesma (2010) apply tests that incorporate two structural breaks and nonlinearity simultaneously.

The main problem encountered in studies based on unit root tests is the selection of the correct test. Different tests that are chosen produce different results. Therefore, the primary goal is to first select a unit root test that is appropriate for the data structure in order to avoid any results with deviations. To achieve this, we develop the Harvey *et al.* (2008) linearity test which is used to investigate whether the series is linear or not. The reason why the Harvey *et al.* (2008) test is used is that the variables are not affected by the levels of stationarity. That is, the variables under investigation can be either zero-order integrals I(0), or first-order integrals I(1).

The countries of the Western Balkans have close ties with the EU and their goal is to ensure stable, prosperous and well-functioning democratic societies for a path towards the EU. Reforms are essential for their European path, but the most important and vital thing is the improvement of political and economic governance, the rule of law, media freedom and conditions for civil society. The EU also provides political and economic support to the countries of the region to strengthen good neighbourly relations and build shared prosperity through regional integration. In addition to its strong political support for the Western Balkans, the EU supports regional cooperation organizations to stimulate economic development, improve connectivity and strengthen security across the region (European Bank for Reconstruction and Development, 2024).

The standard of living in the Western Balkans lags far behind that of the EU. All six Western Balkan countries have a per capita gross domestic product (GDP) (adjusted for purchasing power parity (PPP)) that is less than half the EU average. The underlying problem is low productivity due to lack of investment, weak institutions, unfavorable demographics and a difficult business environment. The GDP gap between the Western Balkans and the EU has narrowed over the last two decades, but the pace of convergence has slowed since the global financial crisis of 2008-2009. The key question is: what can be done to speed up the rate of convergence? (European Bank for Reconstruction and Development, 2024).

The aim of the paper is to provide direct evidence for the stationarity of real GDP per capita using unit root methods with linear and nonlinear dynamics. There are several important differences between this work and previous ones that tested the properties of stationarity in per capita GDP. First, the paper uses the Harvey *et al.* (2008) test to investigate whether the series of GDP per capita for the Western Balkan countries is linear or not. Second, it uses linear tests as well as tests with a structural break. Third, it detects the stationarity of GDP per capita with a nonlinear ESTAR model around a nonlinear symmetric equilibrium with the tests of Kapetanios *et al.* (2003), and Kruse (2009). Fourth, it analyzes the test of Sollis (2009) that examines the asymmetric adjustment of countries' GDP per capita with a nonlinear ESTAR model depending on the direction of deviation. Fifth, with the Fourier ADF test of Enders and Lee (2012a), it examines the stationarity of GDP per capita with nonlinear structural breaks through cyclical changes without specifying time points.

The rest of this paper is organized as follow: Section 2 presents the literature review. Data and methodology are provided in Section 3 and Section 4 respectively. Section 5 reports the empirical results and discussion. Finally, Section 6 presents conclusions and policy implications.

2. LITERATURE REVIEW

In the context of time series analysis, and following the influential study "Trend and Random Walk in Macroeconomic Time Series" by Nelson and Plosser (1982), GDP per capita is often examined for the presence of a unit root, which indicates that the series is non-stationary. In this way, the stationarity of real per capita GDP has been analyzed, aiming to determine whether the effects of shocks are temporary or permanent. Moreover, it has been observed that the findings of studies on the stationarity of per capita GDP vary depending on the country, the time period covered, and the econometric methods applied. In this regard, this section of the literature review focuses on studies that investigate the stationarity of per capita GDP.

Table no. 1 presents a literature review of some empirical works that analyze the stationary property of GDP per capita. The grouping of the papers was done according to linear and nonlinear unit root tests with and without structural breaks as well as unit root tests on panel data.

Table1 no. 1 – Literature Summary on Stationarity of GDP

Studies	Countries	Time Period	Method	Results
Studies that used traditional unit root and structural breaks tests				
Narayan (2007)	G7 Countries	1870-2001	Lee and Strazicich (2003)	Italy and Germany Stationary
Chang *et al.* (2009)	24 OECD countries	1970-2006	Carrion-i-Silvestre *et al.* (2009)	Stationary for 22 Countries
Narayan and Narayan (2010)	79 developing countries	1970-2005	Zivot and Andrews (1992) unit root test with one structural break & Lumsdaine and Papell (1997) unit root test with two structural breaks.	Stationary for 40 Countries
Chapsa *et al.* (2015)	14 EU countries	1950-2010	Zivot and Andrews (1992) unit root test with one structural break	Stationary for 6 Countries
Stanisic *et al.* (2018)	Western Balkan (WB) and the Central and Eastern European	1993-2015	Augmented Dickey-Fuller (ADF) test and Zivot-Andrews (ZA)	Stationary Slovenia Latvia, Bosnia, Herzegovina (ADF) Bulgaria, Hungary, Lithuania (Z-A)
Dritsaki and Dritsaki (2021)	Bulgaria, Croatia, Greece, Romania, Slovenia	1990-2020.	Zivot and Andrews (1992) unit root test with one structural break	Unit Root
Studies that used unit root tests on panel data				
Ozturk and Kalyoncu (2007)	27 OECD countries	1950-2004.	Im *et al.* (2003) test to panel data	Unit Root
Genç *et al.* (2011)	The Gulf Cooperation Council (GCC) Countries	1950-2004	Levin *et al.* (2002), Im *et al.* (2003), Hadri (2000), Maddala and Wu (1999)	Unit Root

Studies	Countries	Time Period	Method	Results
Furuoka (2011)	9 Asian Countries	1970-2007	Pesaran (2007), Choi (2001), Panel Unit Root	Unit Root
Oskooe and Akbari (2015)	27 OPEC Countries	2000-2012	Im *et al.* (2003) Panel unit root test	Unit Root
Zeren and İşlek (2019)	D8 countries	1960-2014	BCIPS Lee *et al.* (2016) Fourier functions	Stationary
Hacıimamoğlu (2021)	G-7 countries	1970-2019	BCIPS Lee *et al.* (2016)	Stationary
Radulović and Kostic (2024)	5 Western Balkan countries (Serbia, Albania, Bosnia and Herzegovina, Montenegro, and North Macedonia)	1998-2020	(CIPS) panel unit root test.	Stationary
Studies that used nonlinear unit root tests				
Cuestas and Garratt (2011)	Selection of countries	1960-2008	Nonlinear (ESTAR) KSS (2003)	Stationary
Su and Chang (2011)	7 Eastern European countries	1969-2009	Enders and Lee (2012a, 2012b) Fourier Unit Root Test	Stationary Bulgaria, Latvia, and Romania
Shen *et al.* (2013)	9 Central-Eastern European Countries	1969-2009	Panel KSS with Fourier Unit Root Test	Unit Root for 6 Countries
Solarin and Anoruo (2015)	52 African Countries	1960-2011	KSS (2003) Non-Linear Unit Root Test	Stationary for 23 Countries
Omay *et al.* (2017)	USA	1875:1-2015:2	Fractional Frequency Flexible Fourier Form (FFFFF) Dickey-Fuller (Omay, 2015)	trend-stationary
Zeren and İşlek (2019)	D8 countries	1960-2014	Lee *et al.* (2016) and using Fourier functions.	Stationary
Canarella *et al.* (2020)	U.K.	1270-2016 1700-2016.	Omay *et al.* (2018)	Nonlinear stationary asymmetric process
Alancıoğlu (2025)	Turkey	1960-2022	RALS-LM και RALS-ADF, Fourier KPSS, Fourier ADF, and Fourier GLS (Meng *et al.*, 2017)	Stationary

GDP per capita is usually tested for stationarity to determine whether economic shocks have temporary or permanent effects. Traditional unit root tests, such as Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS), often find that real GDP per capita series contain a unit root (non-stationary), suggesting that shocks have long-run effects. In many papers and for many countries, GDP per capita is found to be non-stationary, meaning it follows a random path rather than returning to a trend. This suggests that shocks to the economy can have permanent effects on the path of growth.

The papers that test GDP per capita for unit roots assume either that there are no structural breaks, or that there is a structural break. These papers support the unit root or stationarity hypothesis. With multiple structural breaks, the empirical results point against the unit root or in others the results are mixed. Therefore, traditional tests may lack power and

sometimes may fail to distinguish between a true unit root and a stationary series with structural break, leading to conflicting results depending on the data set and the test method. The choice of control and the presence of structural changes in the data (such as financial crises or wars) significantly affect whether unit roots are found.

Studies using panel techniques (LLC, IPS, Hadri) suggest that GDP per capita is non-stationary. Unit root tests in panels exploit both cross-sectional and longitudinal information. Panel unit root tests, or nonlinear tests, are often applied to GDP per capita to determine whether it is stationary or contains a unit root. These tests enhance statistical power over individual time series tests, often revealing that real GDP per capita is mean-reverting (stationary) or trend-stationary for many countries. Studies often show that while each country's GDP data may appear non-stationary, panel-level analysis often shows that real GDP per capita is stationary.

Nonlinear unit root tests, such as those of KSS, Kruse, and Sollis, or approaches based on Fourier functions, are more powerful than traditional linear tests for analyzing real GDP per capita. Nonlinear tests often reveal that apparently nonstationary data actually follow a nonlinear, mean-reverting (stationary) process. While linear tests often fail to reject the unit root hypothesis for GDP per capita (implying that shocks have permanent effects), nonlinear tests often reject it, suggesting that economies adjust to shocks in a nonlinear manner. Nonlinear controls often take into account state-dependent behavior (e.g., different rates of adaptation during recessions versus booms) using methods such as the Exponential Smooth Transition (ESTAR) model.

Research work with structural changes and nonlinear trends suggests that the use of Fourier approximations can take into account complex, nonlinear determinant trends that could otherwise be misinterpreted as a unit root. Studies have found evidence of nonlinear stagnation in real GDP per capita of OECD countries, Europe, and some African countries, in contrast to findings of non-stationarity from linear tests.

The empirical results of the work in the above table are unclear and the issue of the stationarity property of per capita GDP is still not clear, so further research is required on the issue we are examining.

3. DATA

For the analysis of the paper, we use annual data for the period 1990-2023 for the six Western Balkan countries. The GDP per capita variable is given based on purchasing power parity (PPP) in US dollars at constant 2021 prices and is taken from the World Development Indicators databases from the World Bank. The gap of missing observations, for some countries, has been filled using a simple average or trend fitting.

Figure no. 1 presents the graphs of GDP per capita of the Western Balkan countries from1990 to 2023.

From Figure no. 1 we observe that the GDP per capita of all countries shows an increasing trend except for the year 2020 when all countries show a decrease in GDP with Montenegro showing the largest. Like Europe and the rest of the world, the Western Balkans went through a recession in 2020 due to the Covid-19 pandemic. The Covid-19 crisis brought containment measures, business closures, and a decline in household income and consumption. The decline in employment was greatest in Montenegro (75%), while in the remaining countries the decline was 50% (World Bank, 2020). The summary statistics of West Balkan countries are provided in Table no. 2.

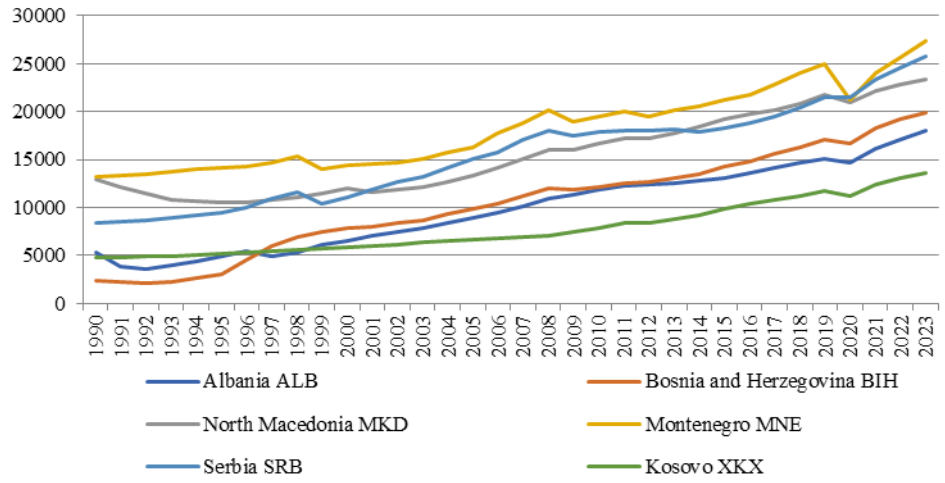

Figure no. 1 – Evolution of the GDP per capita, PPP (constant 2021 international $)

Table no. 2 – Descriptive statistics of the GDP per capita PPP (constant 2021 international $)

Country	Mean	Max.	Min.	Std.Div	Skew.	Kurt.	J-B
Albania	9,820.8	17,975.8	3,603.4	4,282.5	0.136	1.780	2.212 (0.330)
Bosnia and Herzegovina	10,379.5	19,829.2	2,148.3	5,273.2	-0.048	2.025	1.358 (0.506)
North Macedonia	15,445.6	23,323.9	10,491.6	4,212.5	0.415	1.753	3.179 (0.204)
Montenegro	18,216.8	2,7342	13,145.4	4,148.1	0.482	2.060	2.568 (0.276)
Serbia	15,466.2	25,718.4	8,345.3	5,010.1	0.187	2.003	1.607 (0.447)
Kosovo	7,780.4	13,642.6	4,736.7	2,650.3	0.713	2.279	3.623 (0.163)

Note: Std. dev denotes standard deviation and J-B denotes the Jarque-Bera test normality.

Descriptive statistics of GDP per capita in the Western Balkan countries highlight significant variations in the level of economic well-being in the region. The highest average level is recorded in Montenegro at $18,216.8, indicating that this country is the best performing country in the group. On the contrary, Kosovo has the lowest GDP per capita with $7,780.4, reflecting the most limited productive potential and the lowest level of development compared to other countries.

The largest variation in GDP per capita is observed in Bosnia and Herzegovina, which has a standard deviation of $5,273.2. This suggests that its economic activity is characterized by more pronounced fluctuations over time, possibly due to political, institutional, and productive instabilities. In contrast, Kosovo presents the smallest standard deviation of 2,650.3, indicating a more stable but lower level of economic performance.

Regarding distribution characteristics, the asymmetry is positive in all countries except Bosnia and Herzegovina, which indicates that high values of GDP per capita have a greater impact on shaping the distribution than low ones. In most countries, therefore, periods of relatively higher economic growth "pull" the average value upwards. Bosnia and Herzegovina, with negative asymmetry, appears to have a distribution that is more burdened by lower growth rates.

The kurtosis is less than 3 in all countries, which indicates a flat distribution, i.e. a distribution with more "spread out" values than the normal one. This finding, combined with the asymmetry, confirms that the evolution of GDP per capita is not characterized by extreme values but follows a relatively smooth dynamic.

Finally, the Jarque-Bera test demonstrates that the normality assumption is not rejected for any of the Western Balkan countries. This result strengthens the statistical reliability of subsequent tests, given that many methods are subject to assumptions related to the normality of the underlying distributions.

Overall, the findings depict a region with strong economic heterogeneity, differing levels of development, and variations in the stability of GDP per capita over time. These elements are crucial for interpreting the results of unit root tests and formulating economic convergence strategies.

4. METHODOLOGY

As we have mentioned, the purpose of our work is to examine the stationarity of the per capita GDP of the Western Balkan countries in the period 1990-2023. To this end, we apply various linear and nonlinear unit root techniques in order to check the order of integration of real GDP per capita in the countries we study. The unit root tests to be applied in the work require examining the series for linearity and their structural breaks. Specifically, before applying individual unit root tests, we begin by testing the null hypothesis of linearity against a nonlinear alternative. Also, to investigate whether the series we examine remain stable over time or exhibit abrupt structural breaks, we apply the structural breaks test. Therefore, linearity and structural breaks are among the basic diagnostic checks that a researcher should investigate before performing data analysis (Dritsaki and Dritsaki, 2025).

To test the linearity of the series, we use the Harvey *et al.* (2008) test, which is currently one of the most popular. The Harvey *et al.* (2008) test can be applied to either I(0) or I(1) processes. Also, when the order of integration is unknown, Harvey *et al.* (2008) suggest constructing a weighted average Wald test statistic. Furthermore, the test is not affected strongly by structural breaks.

For linear unit root tests, we use the Phillips and Perron (1988) test mainly for the way it deals with serial correlation and heteroscedasticity in the errors. Also, in linear unit root tests we use the test of Eliott *et al.* (1996), who propose a modified Dickey-Fuller test using the generalized least squares (GLS) method who argue that their test has greater power than that of Dickey-Fuller when we do not know the mean and trend in the series (Enders, 1995).

Because ignoring structural breaks (financial crises, policy changes, wars) in per capita GDP data leads to the incorrect acceptance of the null hypothesis of the unit root, we used in our work the tests of Zivot and Andrews (1992), and Perron and Vogelsang (1992). Both tests provide more evidence of stationarity, showing that shocks are often temporary. The Zivot and Andrews test allows for an endogenous break that can be at the intercept, the trend, or both. The test is repeated for all possible time points and the one that gives the most negative t-statistic is selected. The null hypothesis states that the series has a unit root with no structural break. The alternative shows that the series is stationary with a structural break. The Perron and Vogelsang test allows for a break that can be an Additive Outlier (abrupt break) or an Innovation Outlier (gradual break). The null hypothesis states that the series has a unit root with a structural break. The alternative shows that the series is stationary with a structural break.

Nonlinear unit root tests determine whether a time series is stationary, allowing for nonlinear, flexible adjustments toward equilibrium rather than assuming a linear process. For nonlinear unit root tests, we use the tests of Kapetanios *et al.* (2003), Kruse (2009), Sollis (2009), as well as the Enders and Lee Fourier Unit Root Test (Enders and Lee, 2012a). The KSS test controls a nonlinear ESTAR-type adjustment, i.e. near zero it behaves like a random walk, and far from zero it exhibits strong regression. The null hypothesis states that the series has a unit root (linear random walk) and the alternative nonlinear stationary process ESTAR. The Kruse test is an extension of KSS that allows for a non-zero threshold. The assumptions are the same as for KSS. The Sollis test tests for asymmetric adaptation, i.e. different behavior on rise/fall. The test is based on the AESTAR model. The null hypothesis states that the series has a unit root and the alternative states that the series has asymmetric nonlinear stationarity. The Enders and Lee Fourier Unit Root test is based on Fourier series. The Fourier terms approximate smooth, unknown structural breaks, without defining breaks. The null hypothesis states that the series has a unit root while the alternative is that it is stationary with smooth breaks (Dritsaki and Dritsaki, 2025).

4.1. Linear and nonlinear time series test

Linear and nonlinear tests of time series determine whether the data follows a linear process or a complex, non-stationary, or chaotic structure. Basic methods include testing surrogate data to test a linear relationship under the null hypothesis. Linear time series assume a fixed structure. The residuals of these models should be independent and distributed in the same way (white noise). If the residuals in a fitted linear model still show autocorrelation in their squares, this is a strong indication of nonlinear dependencies. Nonlinear time series are characterized by asymmetric cycles, time-varying variation (variability), or changes that cannot be captured by simple linear regressions.

One of the fundamental properties that researchers look for in time series data is stationarity. The presence of stationarity in a time series is the cornerstone for applying econometric techniques to data analysis. It is therefore important to investigate, before testing the stationarity of the series, whether the series are linear or nonlinear (Dritsaki *et al.*, 2024). Linear models have the advantage of being simple and intuitive. However, they have some limitations such as:

- They cannot allow for strong asymmetries in the data (Enders and Granger, 1998).
- They are not suitable for data characterized by sudden and irregular jumps (Guris *et al.*, 2017).
- They are not suitable for series that are not time reversible (Bisaglia and Gerolimetto, 2014).

The linearity tests developed by Harvey and Leybourne (2007) and Harvey *et al.* (2008) were used to test the time series under consideration. The Harvey *et al.* (2008) test can be applied to either I(0) or I(1) processes. Furthermore, when the order of integration is unknown, Harvey *et al.* (2008) suggest constructing a weighted average Wald test statistic which can be written as follows:

$$W_{\lambda} = (1-\lambda)W_0 + \lambda W_1 \tag{1}$$

where W_0 and W_1 denote the Wald tests when the variable is I(0) and I(1), respectively. Both tests follow the standard X^2 distribution. The parameter λ in the above formula indicates the

weight and is calculated by the following formula according to Harvey *et al.* (2008); Harvey and Leybourne (2007).

$$\lambda(U,S) = \exp\left[-g\left(\frac{U}{S}\right)^2\right]$$

where g represents a finite positive constant. U is the Dickey-Fuller unit root test statistic and S is the nonparametric stationarity test statistic of Harris *et al.* (2003). If the series being tested for linearity is stationary, the ratio $\left(\frac{U}{S}\right)^2$ will diverge, causing λ to converge to zero. On the contrary, if the series contains a unit root, the ratio $\left(\frac{U}{S}\right)^2$ will converge to zero, resulting in λ converging to one (Harvey *et al.*, 2008).

Harvey *et al.* (2008) examine the linearity of a series starting from a nonlinear first-order autoregressive model AR(1) for a time series y_t stationary in the levels (integrated zero-order I(0), with $t=1, \ldots, T$ where T is the sample size. The series y_t is estimated as:

$$y_t = \mu + u_t \tag{2}$$

$$u_t = \rho u_{t-1} + \delta f(u_{t-1}, \vartheta) u_{t-1} + \varepsilon_t \tag{3}$$

where ρ, δ are used in the function $f(.\vartheta)$ and are chosen so that u_t is stationary. In the above function ε_t is a white noise process with mean zero iid. The function $f(.\vartheta)$ is assumed to allow a Taylor series expansion with $\vartheta = 0$ so that model (3) is approximated to the second order by Guris *et al.* (2017).

$$u_t = \delta_1 u_{t-1} + \delta_2 u_{t-2}^2 + \delta_3 u_{t-3}^3 + \varepsilon_t \tag{4}$$

According to function (4) the null hypothesis and the alternative can be formulated as follows:

$$H_{0,I(0)} : \delta_2 = \delta_3 = 0 \quad \text{(linearity)}$$

and the alternative

$$H_{1,I(0)} : \delta_2 \neq 0, \ \ and \ \ / or \ \ \delta_3 \neq 0 \ \text{(nonlinearity)}$$

where $H_{1,I(0)}$ indicates a hypothesis under the assumption of y_t being I(0). Under these conditions, the following happens:

$$y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-2}^2 + \beta_3 y_{t-3}^3 + e_t \quad (5)$$

According to function (5) the null hypothesis and the alternative can be formulated as follows:

$$H_{0,I(0)} : \beta_2 = \beta_3 = 0 \quad \text{(linearity)}$$

and the alternative

$$H_{1,I(0)} : \beta_2 \neq 0, \quad and \quad / or \quad \beta_3 \neq 0 \quad \text{(nonlinearity)}$$

The standard Wald statistic for testing these limitations is given by the following formula:

$$W_0 = T\left(\frac{RSS_0^r}{RSS_0^u} - 1\right) \quad (6)$$

where T is the number of observations, RSS_0^u denotes the residual sum of squares from the unrestricted OLS regression in (5) and RSS_0^r is a restricted ordinary least square(OLS) regression imposing $\beta_2 = \beta_3 = 0$ in (5). It W_0 follows the asymptotic $X^2(2)$ distribution under the null $H_{0,I(0)}$.

Harvey *et al.* (2008) also examine the linearity of a series starting from a nonlinear first-order autoregressive model AR(1) for a time series y_t stationary in first differences (first-order integrated I(1).

$$y_t = \mu + u_t \quad (7)$$

$$\Delta u_t = \phi \Delta u_{t-1} + \lambda f(\Delta u_{t-1}, \vartheta)\Delta u_{t-1} + \varepsilon_t \quad (8)$$

where ϕ, λ are used in the function $f(.\vartheta)$ and are chosen so that Δu_t is stationary. In the above function ε_t is a white noise process with mean zero iid . The function $f(.\vartheta)$ is assumed to allow a Taylor series expansion with $\vartheta = 0$ so that the model (8) is approximated to the second order by:

$$\Delta u_t = \lambda_1 \Delta u_{t-1} + \lambda_2 (\Delta u_{t-1})^2 + \lambda_3 (\Delta u_{t-1})^3 + \varepsilon_t \quad (9)$$

According to the above, the null hypothesis and the alternative can be formulated as follows:

$$H_{0,I(0)} : \lambda_2 = \lambda_3 = 0 \quad \text{(linearity)}$$

and the alternative

$$H_{1,I(1)}: \lambda_2 \neq 0, \quad and \quad / or \quad \lambda_3 \neq 0 \quad \text{(nonlinearity)}$$

where $H_{1,I(1)}$ indicates a hypothesis under the assumption of y_t being I(1). Under these conditions with $\Delta y_t = \Delta u_t$ η y_t becomes:

$$\Delta y_t = \lambda_1 \Delta y_{t-1} + \lambda_2 (\Delta y_{t-1})^2 + \lambda_3 (\Delta y_{t-1})^3 + \varepsilon_t \tag{10}$$

Therefore, according to function (10) the null hypothesis and the alternative can be formulated as follows:

$$H_{0,I(1)}: \lambda_2 = \lambda_3 = 0 \quad \text{(linearity)}$$

and the alternative

$$H_{1,I(1)}: \lambda_2 \neq 0, \quad or \quad \lambda_3 \neq 0 \quad \text{(nonlinearity)}$$

The corresponding Wald statistic based on function (10) to control these restrictions is given by the following formula:

$$W_1 = T\left(\frac{RSS_0^r}{RSS_0^u} - 1\right) \tag{11}$$

where T is the number of observations, RSS_0^u denotes the residual sum of squares from the unrestricted OLS regression in (10) and RSS_0^r is a restricted OLS regression imposing $\lambda_2 = \lambda_3 = 0$ in (10). The W_1 follows the asymptotic $X^2(2)$ distribution under the null $H_{0,I(1)}$.

4.2. Unit root linear test

The methodology for testing a linear unit root assumes that the series moves towards equilibrium, despite the fact that the deviation process is linear and the adjustment rate is constant. If these conditions hold, linear unit root tests are valuable tools for determining whether economic time series follow a consistent pattern or not. To test for a linear unit root, we use the Phillips and Perron (1988), the Eliott *et al.* (1996) test, as well as unit root tests with a single structural break, specifically those of Zivot and Andrews (1992) and Perron and Vogelsang (1992).

4.2.1. Phillips-Perron test

Phillips and Perron (1988) proposed a methodology to test the existence of stationarity in a time series in which the well-known hypotheses about the disruptive term, such as the autocorrelation hypothesis, are not met. Phillips and Perron (1988) proposed a nonparametric test

for estimating the model coefficients, that is, they make a correction to the t-statistic. This test differs from the augmented Dickey and Fuller (1979, 1981) test mainly in how it examines autocorrelation and heteroscedasticity in the errors. The Phillips-Perron regression test is the following:

$$\Delta y_t = \beta' D_t + \pi y_{t-1} + u_t \tag{12}$$

where u_t is the term is integral of order zero I(0) and may be heteroscedastic.

4.2.2. Eliot, Rothenberg and Stock test

Eliott *et al.* (1996), proposed a test modifying the Dickey and Fuller (1979, 1981) test using the generalized least squares (GLS) method. Eliott *et al.* (1996), claim that the DF-GLS test has significantly improved power when we do not know the mean and trend in the series – see p. 813 from Eliott *et al.* (1996).

The DF-GLS test proposed by Eliott *et al.* (1996), is based on the following regression without the determinant variables:

$$\Delta Y_t^d = \delta_2 Y_{t-1}^d + \beta_1 \Delta Y_{t-1}^d + \beta_2 \Delta Y_{t-2}^d + ... + \beta_p \Delta Y_{t-p}^d + u_t \tag{13}$$

where Y_t^d is the time series (detrended) free from trends.

4.3. Unit root tests with one structural break

One of the hypotheses we make in linear unit root testing is that time series evolve smoothly over time. However, there are some cases where time series exhibit abrupt changes in their course due to various events. In this case the well-known unit root tests are not reliable. In this paper we present two tests with a structural change due to the small number of observations that deal with the nonlinearity due to structural breaks.

4.3.1. Zivot-Andrews test

Zivot and Andrews (1992) following the form of Perron (1989), models and considering that the structural point (TB) is an endogenous phenomenon, propose three models for unit root tests, which are the following:

A. Model with Intercept

$$y_t = \hat{\mu}^A + \hat{\vartheta}^A DU_t(\hat{\lambda}) + \hat{\beta}^A t + \hat{\alpha}^A y_{t-1} + \sum_{j=1}^{k} \hat{\gamma}_j^A \Delta y_{t-j} + \hat{e}_t \tag{14}$$

B. Model with Trend

$$y_t = \hat{\mu}^B + \hat{\beta}^B t + \hat{\rho}^B DT_t^*(\hat{\lambda}) + \hat{\alpha}^B y_{t-1} + \sum_{j=1}^{k} \hat{\gamma}_j^B \Delta y_{t-j} + \hat{e}_t \tag{15}$$

C. Model with Both Intercept and Trend

$$y_t = \hat{\mu}^C + \hat{\vartheta}^C DU_t(\hat{\lambda}) + \hat{\beta}^C t + \hat{\rho}^C DT_t^*(\hat{\lambda}) + \hat{\alpha}^C y_{t-1} + \sum_{j=1}^{k} \hat{\gamma}_j^C \Delta y_{t-j} + \hat{e}_t \quad (16)$$

where DU_t is a dummy variable for the mean shift and appears in every possible change, whereas DT_t^* is the corresponding variable for mean shift and trend.

$$DU_t(\lambda) = \begin{cases} 1, & \alpha\nu \ \ t > \mathrm{T}\lambda \\ 0 & otherwise \end{cases} \text{ and } DT_\tau^*(\lambda) = \begin{cases} t - T\lambda, & \alpha\nu \ \ t > \mathrm{T}\lambda \\ 0 & otherwise \end{cases}$$

The above models are based on Perron (1989) models, as a data-dependent algorithm is used as a proxy for Perron to determine the structural points.

4.3.2. Perron and Vogelsang test

Perron and Vogelsang (1992), proposed a class of statistical tests that allows for two different forms of structural changes. The Additive Outlier model (AOM) and the Innovative Outlier model (IOM). The forms of these models are given below:

The Innovative Outlier model (IOM):

$$y_t = \mu + \delta DU_t + \vartheta D(T_b)_t + \alpha y_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta y_{t-i} + e_t \quad (17)$$

The Additive Outlier model (AOM) which is performed in two stages, is formulated as follows:

$$y_t = \mu + \delta DU_t + \hat{y}_t \quad \text{(first stage)} \quad (18)$$

$$\hat{y}_t = \sum_{i=0}^{k} w_i D(T_b)_{t-i} + \alpha \hat{y}_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta \hat{y}_{t-i} + e_t \quad \text{(second stage)} \quad (19)$$

where $\hat{y}_t$ in equation (19) represents the time series data free from trends.

Perron and Vogelsang (1992) argue that the tests in the above models are made with the minimum value of the t-statistic in the sum of the autoregressive coefficients over all possible structural points of the appropriate autoregression.

4.4. Nonlinear unit root test

A nonlinear form that can be used to control for the nonlinear unit root is the nonlinear exponential smooth transition autoregressive process (ESTAR) model. The ESTAR model is suitable for cases where deviations from equilibrium decrease smoothly as we move away from the equilibrium point. The univariate model of the first-order nonlinear exponential smoothing transitional autoregressive process (ESTAR) has the following form:

$$y_t = \beta y_{t-1} + \gamma y_{t-1}\left[1 - \exp\left\{-\vartheta\left(s_t - c\right)^2\right\}\right] + e_t \tag{20}$$

where y_t is the series under analysis β is the linear coefficient and γ is the degree of nonlinearity c is the center of the regime, usually taken to be 0 for weighted series, $\vartheta \geq 0$ is the slope parameter and provides the speed of transition to the mean inversion, is the transition variable and $e_t \to iid(0,\sigma^2)$. Therefore, we can assume that model (20) is a mean zero stochastic process. Furthermore, in model (20) a joint hypothesis is considered where one parameter is one-sided, while the others are two-sided under the alternative is considered and we propose a modified Wald test for a unit root against an alternative nonlinear ESTAR procedure (Hu and Chen, 2016).

4.3.1. Kapetanios, Shin, Snell (KSS) Unit Root Test

Kapetanios *et al.* (2003) developed a procedure for detecting the presence of non-stationarity, against nonlinear but globally stationary exponential smooth transition autoregressive ESTAR processes. For this purpose, they use the following ESTAR model.

$$\Delta y_t = \gamma y_{t-1}\left[1 - \exp\left\{-\vartheta y_{t-1}^2\right\}\right] + e_t \tag{21}$$

Furthermore, Kapetanios *et al.* (2003) used the first-order Taylor series in model (21) to obtain the following auxiliary regression:

$$\Delta y_t = \rho y_{t-1}^3 + \sum_{i=1}^{k} \lambda_i \Delta y_{t-i} + e_t \tag{22}$$

The two hypotheses of equation (22) are written as follows:

$H_0 : \rho = 0$ (the series follows a unit root process).

$H_1 : \rho < 0$ (the series follows a nonlinear stationary process of the form ESTAR).

The above hypotheses are tested by statistics $t_{NL} = \dfrac{\hat{\rho}}{s.e.(\hat{\rho})}$, where $\hat{\rho}$ is its estimate from the auxiliary regression (22).

Under the null hypothesis the statistic has the following asymptotic distribution (see Kapetanios *et al.* (2003).

$$t_{NL} \Rightarrow \frac{\left\{\frac{1}{4}W(1)^4 - \frac{3}{2}\int_0^1 W(r)^2 dr\right\}}{\sqrt{\int W(r)^6 dr}}$$

όπου $W(r)$ is the standard Brownian motion defined on $r \in [0;1]$.

Here, Kapetanios *et al.* (2003) assume that y_t is a mean zero stochastic process. When the process has nonzero mean and/or linear time trend, Kapetanios *et al.* (2003) suggest demean or detrend the data.

4.3.2. Kruse Unit Root Test

Kruse (2009) extends the unit root test of Kapetanios *et al.* (2003) by allowing for the exponential smooth transition autoregressive (ESTAR) model:

$$y_t = \beta y_{t-1} + \gamma y_{t-1}\left[1 - \exp\left\{-\vartheta(s_t - c)^2\right\}\right] + e_t \tag{23}$$

the parameter $c \neq 0$ as non-zero. Based on this, using the Taylor approximation, the above function is transformed into the following form:

$$\Delta y_t = \delta_1 y_{t-1}^3 + \delta_2 y_{t-1}^2 + \sum_{j=1}^{p} \varphi_j \Delta y_{t-j} + e_t \tag{24}$$

Kruse (2009) test examines the nonlinear stationary exponential smooth transition autoregressive (ESTAR) against the null hypothesis of a unit root.

The two hypotheses of equation (24) are written as follows:

$H_0 : \delta_1 = \delta_2 = 0$ (the series follows a unit root process)

$H_1 : \delta_1 < 0, \delta_2 \neq 0$ (the series follows a nonlinear stationary process of the form ESTAR).

For the above hypothesis testing, Kruse (2009) proposed the Abadir and Distaso (2007) test, which is a modified Wald statistic and is formulated as follows:

$$\tau = t^2_{\delta_2^+=0} + 1\left(\hat{\delta}_1 < 0\right) t^2_{\delta_1=0}$$

Kruse (2009) shows that the statistic follows the asymptotic distribution which is free from nuisance parameters.

$$\tau \Rightarrow A\left(W(r)\right) + B\left(W(r)\right)$$

where A and B are functions of Brownian motion $W(r)$ – see Kruse (2009).

4.3.3. Sollis Unit Root Test

The tests developed by Kapetanios *et al.* (2003) and Kruse (2009) are based on the assumption that mean reversion is symmetrical at every point. This assumption implies that negative and positive deviations have the same effect. Sollis (2009), extended this assumption and developed a new test that allows for both symmetric and asymmetric nonlinear adjustments. In other words, it permits differentiation in the impact of negative and positive shocks on the series. In this test, the speed of mean reversion depends on the sign of the shock, not just its magnitude (Cuestas and Ramlogan-Dobson, 2013). The asymmetric exponential

smoothing transitional autoregressive model (AESTAR) developed by Sollis (2009) is formulated as follows:

$$\Delta y_t = \left[1-\exp\left(-\theta_1 y_{t-1}^2\right)\right]\left[1+\exp\left(-\theta_2 y_{t-1}\right)\right]^{-1} p_1 + \left\{1-\left[1+\exp\left(-\theta_2 y_{t-1}\right)\right]^{-1} p_2\right\} y_{t-1} + \sum_{i=1}^{k} k_i \Delta y_{t-i} + e_t \quad (25)$$

where $\theta_1 \geq 0$ and $\theta_2 \geq 0$.

The model (25) with Taylor approximations can be formulated as follows:

$$\Delta y_t = \alpha\left(p_2^* - p_1^*\right)\theta_1\theta_2 y_{t-1}^4 + p_2^*\theta_1 y_{t-1}^3 + \varepsilon_t \quad (26)$$

where p_1^* and p_2^* is a linear function of p_1 and p_2. If $\alpha = 1/4$ then the above function can be written as:

$$\Delta y_t = \varphi_1 y_{t-1}^4 + \varphi_2 y_{t-1}^3 + \varepsilon_t \quad (27)$$

where $\varphi_1 = p_2^*\theta_1$ and $\varphi_1 = \alpha\left(p_2^* - p_1^*\right)\theta_1\theta_2$

Function (27) can be written as:

$$\Delta y_t = \varphi_1 y_{t-1}^4 + \varphi_2 y_{t-1}^3 + \sum_{i=1}^{k} k_i \Delta y_{t-i} + \varepsilon_t \quad (28)$$

The null hypothesis of equation (28) is written as follows:

$$H_0 : \varphi_1 = \varphi_2 = 0 \text{ (unit root or non-stationarity)}$$

Note: While the above hypothesis H_0 indicates the non-stationarity of the series, the alternative hypothesis represents the symmetric or asymmetric stationarity ESTAR. In case of rejection of the null hypothesis, to decide whether the series exhibits symmetric or asymmetric stationarity ESTAR, we make the following hypotheses:

$$H_0 : \varphi_2 = 0 \text{ (symmetric stationarity ESTAR)}$$

$$H_1 : \varphi_2 \neq 0 \text{ (asymmetric stationarity ESTAR)}$$

The above hypotheses are tested with the F statistic and the critical values are listed on Table no. 1 of the article by Sollis (2009).

4.3.4. Enders and Lee Fourier Unit Root Test (Fourier ADF unit root test)

The Fourier ADF test belongs to the linear class of unit root tests with the incorporation of nonlinear determinants. That is, the Fourier terms are nonlinear in time but the model

remains linear in the parameters. Enders and Lee (2012a) propose a unit root test with the Fourier function following the Dickey Fuller unit root test where the deterministic term is a time- dependent function denoted by $\alpha(t)$:

$$y_t = \alpha(t) + \rho y_{t-1} + \gamma t + \varepsilon_t \tag{29}$$

where $\alpha(t)$ is a determinant of t, and ε_t is a stationary disturbance with variance σ_ε^2. The null hypothesis for the unit root test is $\rho = 1$.

In the case where the form of the determinant is not known, Enders and Lee (2012a) proposed the Fourier approach for unknown determinants, which is defined as follows:

$$\alpha(t) = \alpha_0 + \sum_{k=1}^{n} \alpha_k \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{n} \beta_k \cos\left(\frac{2\pi kt}{T}\right) \quad for \quad n \le \frac{T}{2} \tag{30}$$

where n represents the number of frequencies, k represents the optimal frequency, t is the trend, and T is the number of observations. It should be mentioned here that if the coefficients of the trigonometric terms are not statistically significant that is, $\alpha_k = \beta_k = 0$ then the function (30) is linear, so the unit root test is done with the traditional tests. In order to use the above functional form, a large value of n should not be used in the regression (30). Furthermore, the use of many component frequencies uses degrees of freedom which may lead to over-fitting. Therefore, instead of setting its specific form according to Enders and Lee (2012b) we should select the appropriate frequencies to be included in the regression (30). Suppose we use only one frequency k to examine the following regression: (Enders and Lee, 2012a).

$$\Delta y_t = \rho y_{t-1} + c_1 + c_2 t + c_3 \sin\left(\frac{2\pi kt}{T}\right) + c_4 \cos\left(\frac{2\pi kt}{T}\right) + e_t \tag{31}$$

In the above equation, t represents the trend, T represents the number of observations, $\sin\left(\frac{2\pi kt}{T}\right)$ and $\cos\left(\frac{2\pi kt}{T}\right)$ represent the trigonometric terms of the Fourier function.

To estimate the above regression, we create a three-step procedure:

In the first step, all models are estimated for 1<k <5 and the model with the smallest residual squares (SSR) is selected as the appropriate model. If the residuals exhibit serial correlation, we increase the regression (31) with lags of the variable. Secondly, we test the linearity or not of the most appropriate model by testing the coefficients c_3 and c_4. If the coefficients, that is $c_3 = c_4 = 0$, are not statistically significant, then the function (31) is linear, so the unit root test is performed using traditional tests. The hypothesis of linearity or not is examined by testing the F test. If the coefficients $c_3 \neq c_4 \neq 0$ i.e. are statistically significant then the Fourier function is significant and can be used to test for the unit root with

the Fourier ADF unit root test (FADF). The critical values for the above hypothesis are presented at the bottom of Table 1a of Enders and Lee (2012a).

In the third step, the FADF test statistics are calculated using the best-fit model and the unit root hypothesis is tested against the critical values. The critical values depend only on the frequency k and the sample size T – Table no. 1a of Enders and Lee (2012a). The unit root test is performed using the significance of the coefficient ρ of y_{t-1}. If the calculated statistic is less than the critical value of Enders and Lee (2012a), the null hypothesis of the unit root is rejected, so we say that the series is stationary.

5. EMPIRICAL RESULTS AND DISCUSSION

5.1. Linear and nonlinear tests

In theoretical and empirical econometric studies, the investigation of linearity is one of the crucial issues. Classical tests of linearity are based on the assumption that the variables are zero I(0) or first-order I(1) integrated. In empirical studies, this issue is particularly problematic. Harvey *et al.* (2008), proposed a new linearity test that can be applied whether the variables are I(0) or I(1). In their paper they propose a Wald test when the order of integration is unknown which is a weighted Wald mean and tests the null hypothesis of linearity when the variable is known to have a unit root and when it is known to be stationary (Cuestas *et al.*, 2012). Given the importance of this issue in theoretical and empirical econometrics, the linear or nonlinear structure of each time series must be investigated. The table below presents the results of the Harvey *et al.* (2008) test regarding the linearity (or nonlinearity) of per capita GDP.

The results of Harvey *et al.* (2008) linearity test for GDP per capita in the Western Balkan countries highlight significant differences in the dynamics of economic growth among the countries in the region. Specifically, it is found that the countries of Bosnia and Herzegovina, North Macedonia, and Serbia follow a linear economic path, while on the contrary the countries of Albania, Montenegro, and Kosovo display nonlinear dynamics.

Table no. 3 – Harvey *et al.* (2008) linearity test results

Country	Wλ	Result
Albania	25.043***	Nonlinear
Bosnia and Herzegovina	0.903	linear
North Macedonia	5.086	linear
Montenegro	13.597***	Nonlinear
Serbia	3.596	linear
Kosovo	20.889***	Nonlinear

Notes: The Wλ statistic follows the $\chi^2(2)$ distribution and the relevant critical values are 9.21 (%1), 5.99 (%5) and 4.60 (%10). *** and ** denote the rejection of the null of linearity at the %1 and 5% significance level, respectively.
Source: author's calculations

Countries that exhibit linearity seem to be characterized by a stable and smooth evolution of GDP per capita over time. This suggests that the economic growth process in these economies may be driven by relatively stable, time-consistent trends without strong regimes of change, abrupt changes or non-linear structural relationships. Linear behavior is compatible

with more mature or stabilized economic processes, possibly due to more stable institutions, lower volatility in the productive base, or limited exposure to severe economic shocks.

In contrast, the countries Albania, Montenegro, and Kosovo exhibit nonlinearity, which suggests that their GDP per capita is affected by nonlinear phenomena, such as periodic structural changes, regimes with different growth rates, external shocks, or changes in economic policy. The existence of nonlinearity is compatible with economies in transition, with frequent adjustments of their production structure and higher uncertainty. Also, such dynamics are often associated with economies that seek convergence but with an uneven, wavy or interrupted growth path.

The differentiation between linear and nonlinear countries reinforces the position that the Western Balkans do not constitute a homogeneous economic unit but instead exhibit significant differences in terms of their stability and pattern of economic growth. Understanding these differences is crucial for choosing the appropriate methodology for subsequent unit root tests. For linear countries, classical linear tests are more appropriate, while for nonlinear countries, nonlinear or regime-oriented tests oriented to the data structure are required.

Overall, the results indicate that countries with nonlinear behavior are likely to be in a more unstable or transitional economic trajectory while those with linearity exhibit more stable and predictable developments in GDP per capita. The findings constitute an important basis for the correct interpretation of subsequent unit root tests and for drawing conclusions regarding the long-term sustainability and convergence of the region's economies.

5.2. Unit root linear test

The validity of the GDP per capita of countries with the linearity characteristic was analyzed with the linear unit root tests of Phillips and Perron (1988), and Eliott *et al.* (1996) as well as with tests with a structural change, such as the tests of Zivot and Andrews (1992) and Perron and Vogelsang (1992). Table no. 4 gives the results of linear unit root tests at the series levels.

Table no. 4 – Linear unit root test results

Country	Level			
	Phillips-Perron		DF-GLS	
	Intercept	Intercept and Trend	Intercept	Intercept and Trend
Bosnia and Herzegovina	0.654[1]	-2.344[2]	2.015(0)	-1.913(0)
North Macedonia	1.493[3]	-4.763[1]*	-1.918(8)	-1.821(0)
Serbia	1.333[2]	-1.561[3]	2.258(0)	-1.361(0)

Note: 1. *, **, *** for significance levels 1, 5 and 10 respectively.
2. The numbers in brackets refer to the bandwidth of the autocorrelation for the Phillips-Perron (PP) test equations based on the Newey and West (1994) estimator using the Bartlett kernel (correcting for heteroscedasticity and autocorrelation of the residuals).
3. To reject the unit root hypothesis we use the tables of MacKinnon (1996).
4. The numbers in parentheses represent the number of time lags of the dependent variable used for white noise errors (autocorrelation correction).
5. The number of time lags for the ADF equation was selected using the Modified Akaike (MAIC).
6. To reject the unit root hypothesis, we use the tables of MacKinnon (1996), when the equation has only a constant, and the tables of Eliott *et al.* (1996),when the equation presents a constant and a trend.

The results of the above table show that the Phillips and Perron (1988) linear test showed that only North Macedonia exhibits stationarity and only in the model that includes a constant and a trend. This finding suggests that the country's GDP per capita may follow a long-term downward or upward trajectory around a defining linear path, without exhibiting permanent stochastic deviations.

In contrast, the Eliott *et al.* (1996) test, which is generally considered more robust in small samples, does not reject the null hypothesis of a unit root for any of the countries Bosnia and Herzegovina, North Macedonia, and Serbia. This suggests that the growth process in these countries likely follows a stochastic path and the long-term deviations are not temporary.

This result, combined with the linearity test of Harvey *et al.* (2008), reinforces the view that while North Macedonia exhibits linear dynamics, its stationarity is not strongly confirmed under all linear tests.

5.3. Unit root tests with one structural break

Common unit root tests (Dickey and Fuller, 1979, 1981; Phillips and Perron, 1988) have low power to reject the null hypothesis and are affected by the presence of structural break. In particular, Enders (1995) argues that if the Dickey Fuller test rejects the null hypothesis of a unit root, there is no need to continue. Furthermore, Perron (1989) noted that if the data series is subject to structural changes, traditional linear tests are not robust and do not reject the null hypothesis of a unit root.

Linear controls with an endogenous structural breaks provide a more realistic picture for economies such as those of the Western Balkans, which have undergone significant transformations in the last 25 years (transition economies, political changes, 2008 global crisis, 2020 pandemic, etc.).

The results of the above table show that only North Macedonia exhibits stationarity (model with constant) with endogenously localized structural break in 2006. This year coincides with a period of stabilization and intensification of relations with the EU, as well as with the country's pre-accession institutional adjustments. The existence of such a change reinforces the view that North Macedonia's growth curve underwent a significant turning point that likely affected the level (or even the trend) of GDP per capita.

Table no. 5 – Unit root test with structural breaks results

Country	Zivot-Andrews Level					
	Intercept	Break	Trend	Break	Intercept and Trend	Break
Bosnia and Herzegovina			-3.302	1998		
North Macedonia	-4.702**	2006	-3.976	2018	-3.819	2018
Serbia	-1.677	2011	-2.069	2018	-2.609	2014

Note: *, **, *** for significance levels 1, 5 and 10 respectively.

The results of the Perron and Vogelsang (1992) test provide clear indications that per capita GDP for the two Western Balkan countries, North Macedonia and Serbia, is stationary when possible structural breaks in the time course of the series are taken into account.

More specifically, in the Innovation model with constant and trend, North Macedonia exhibits stationarity with a localized structural break in 2016, while Serbia exhibits similar behavior with a turning point in 2020. These findings suggest that significant economic events

or reform interventions in the respective periods likely influenced the course of GDP per capita, creating one-off or gradual changes in the long-term trend.

Table no. 6 – Unit root test with structural breaks results

Country	Perron and Vogelsang Level							
	Innovation				Additive			
	Intercept	Break	Intercept and Trend	Break	Intercept	Break	Intercept and Trend	Break
Bosnia and Herzegovina	-0.871	1995	-3.283	1995	-1.570	2021	-3.413	2020
North Macedonia	-1.377	2021	-5.369*	2016	-2.651	2012	-3.868	2006
Serbia	-0.341	2017	-7.266*	2020	-0.812	2015	-5.833*	2000

Note: *, **, *** for significance levels 1, 5 and 10 respectively.

Furthermore, for Serbia, the Additive model with constant and trend also detects stationarity with a structural break identified in 2000, a year associated with the profound political and economic changes following the end of the conflict period and the beginning of gradual normalization and economic restructuring. The fact that Serbia exhibits stationarity in two different approaches to the Perron and Vogelsang (1992) test with different points of change reinforces the hypothesis that its economic course was shaped by multiple and temporally differentiated structural breaks.

Overall, the results of the Perron and Vogelsang (1992) test emphasize that, unlike linear unit root tests, the incorporation of structural breaks allows the emergence of stationarity in series that would otherwise be characterized as non-stationary. This suggests that the dynamics of GDP per capita in these countries are not smooth and linear, but are influenced by significant historical and political economic events that alter the trajectory of long-term economic growth.

5.4. Nonlinear unit root test

The nonlinear unit root tests developed by Kapetanios *et al.* (2003) and Kruse (2009) examine the implications of a specific type of nonlinear dynamics. In addition, they provide an alternative framework for testing the null hypothesis of a unit root process against the alternative of a stationary nonlinear exponential smooth transition autoregressive (ESTAR) process. The estimated results of the KSS, Kruse, and Sollis tests from the nonlinear unit root analysis for Albania, Montenegro, and Kosovo are presented on Table no. 7.

Table no. 7 – Nonlinear unit root tests results

	KSS(t_{NL})		Kruse(τ)		Sollis(F)		
	k	Stat	k	Stat	k	$H_0 : \varphi_1 = \varphi_2 = 0$	$H_0 : \varphi_2 = 0$
Albania	0	-4.276*	0	11.501**	1	5.654**	4.089
Montenegro	0	-2.016	0	2.793	1	3.675	2.379
Kosovo	0	-5.621*	1	18.026*	1	18.219*	16.305*

Notes: The symbols *, ** and *** mean rejection of the null hypothesis of unit root at the 1%, 5% and 10% respectively. KSS: −3.48, −2.93, −2.66; Kruse: 13.75, 10.17, 8.6; Sollis: 6.883, 4.954, 4.157.

The results of the nonlinear unit root tests on Table no. 7 show that the economic series of GDP per capita for the three Western Balkan countries Albania, Montenegro, and Kosovo exhibit dynamics that cannot be satisfactorily described by linear models. The existence of nonlinearity, as also identified by the Harvey test, is verified and reinforced by the three nonlinear tests (KSS, Kruse, and Sollis) which capture different forms of nonlinear self-regression.

The KSS test (Kapetanios *et al.*, 2003) which checks for symmetric ESTAR-type nonlinearity shows that:

- Albania and Kosovo exhibit stationarity.
- Montenegro does not show statistically significant evidence of a return to long-run equilibrium.

These findings suggest that for Albania and Kosovo, GDP per capita follows a nonlinear adjustment mechanism where deviations from the long-term path are corrected when they become large enough, which is characteristic of economic variables that react slowly to small changes but more strongly to large ones.

The Kruse test, which controls for more flexible forms of nonlinearity through quadratic and cubic terms, confirms stationarity for Albania and Kosovo and at the same time captures a more complex form of nonlinear adjustment than the KSS. The convergence of the KSS-Kruse results for these two countries strengthens the credibility of the finding of nonlinear stationarity. In contrast, Montenegro shows no signs of stationarity in this test either, suggesting that it may be following either a higher-order nonlinear process or a truly non-stationary path.

The Sollis test distinguishes between symmetric and asymmetric nonlinear adjustment. The results show that:

- Albania and Kosovo exhibit stationarity in the symmetric version of the test.
- However, Albania does not exhibit stationarity in the asymmetric version of Sollis.

The non-stationarity in the asymmetric form suggests that the adjustment process of GDP per capita in Albania is symmetric. That is, positive or negative deviations from the long-term trend are handled by the economy in a similar way, without a stronger or slower adjustment in one direction or the other. In Kosovo, on the other hand, the results are consistent in both Sollis test approaches, suggesting a pure form of symmetric nonlinear stationarity. Montenegro, once again, does not show evidence of stationarity in either the symmetric or the asymmetric version.

Overall, the results show that:

- Albania and Kosovo: The existence of nonlinear stationarity is recognized in all nonlinear tests (with minor exceptions regarding symmetry). This suggests that their economies, despite experiencing fluctuations, maintain a long-term path to which they return, but the adjustment process is not linear.
- Montenegro: It shows no sign of stationarity in any of the nonlinear tests, which is consistent with the high volatility and structural instability that characterizes its economic system. The absence of stagnation suggests that GDP per capita may follow a prolonged non-stationary path, likely influenced by external factors (tourism, fiscal imbalances, small economic size).

The above tests have made an invaluable contribution to unit root testing by taking nonlinearity into account. Although these tests consider the asymmetric speed of mean reversion (as in the Sollis (2009) test), they do not address nonlinearity in the deterministic components. However, according to Becker *et al.* (2004); Becker *et al.* (2006), in nonlinear unit root tests, the form of the structural breaks is assumed to be known, which in reality is not feasible-neither the form of the breaks nor the exact break dates are usually known. From

this perspective, the Fourier approach offers a valuable solution to the question of how structural breaks should be modelled.

In their study, Enders and Lee (2012b) showed that one or more structural breaks can be captured using low-frequency Fourier functions. It is not necessary to know the number or location of the breaks when applying the test. The appropriate frequency value in the Fourier function must be estimated in equation (31).

The following table presents the results of the FADF (Fourier Augmented Dickey-Fuller) unit root test.

Table no. 8 – Fourier ADF unit root test results

Countries	$\hat{k}$	Min SSR	F($\hat{k}$)	k^*	FADF
Albania	1	3570139	9.314[b]	1	−4.6519**
Montenegro	1	2928702	7.936[c]	1	−1.7250
Kosovo	1	2159487	13.97[a]	2	−7.1869*

Notes: 1. All unit root tests include an intercept and trend,
2. a, b, and c show that the trigonometric terms are statistically significant at the 1%, 5%, and 10% significance levels, respectively.
3. k* indicates the optimal frequency.
4. *,**Indicates that the series is stationary at the 1% and 5% significance level.
5. The critical values for the F($\hat{k}$) statistics are 12.21, 9.14 and 7.78 for 100 observations and the 1%, 5% and 10% significance levels, respectively (Enders and Lee, 2012a).
6. The critical values for the FADF statistics are -4.95, -4.35 and -4.05 for 100 observations and the 1%, 5% and 10% significance levels, respectively (Enders and Lee, 2012a).

The statistical significance of the Fourier terms on Table no. 8 across all countries Albania, Montenegro, Kosovo shows that:

1. The GDP per capita series do not follow a linear path.
2. There are smooth but non-linear structural breaks in the long-term trend, which cannot be detected by traditional linear tests or tests with abrupt structural breaks (such as Z-A, PV).

This means that the economies of these countries are characterized by gradual, cyclical or periodic changes, possibly due to:

- Recurrent economic cycles.
- Gradual reforms.
- Alignment with the EU.
- Structural breaks in production and employment.

Finding statistical significance verifies that the nonlinearity identified by Harvey and the nonlinearity tests (KSS, Kruse, Sollis) is substantial and present in the model and not a chance finding.

The results of the FADF (Fourier ADF) test show that Albania and Kosovo exhibit stationarity, while Montenegro exhibits a unit root.

In detail for each country we can report the following:

Albania

The existence of stationarity when smooth structural breaks are allowed for suggests that GDP per capita follows a non-linear but stable long-term path, which is not fully captured by

linear or abrupt tests. The agreement of the FADF results, with KSS and Kruse, reinforces the conclusion that Albania exhibits nonlinear stationarity.

Kosovo

Similar to Albania, Kosovo exhibits stationarity, confirming that GDP per capita returns to long-run equilibrium, but in a non-linear and cyclical manner, due to the significant influence of Fourier terms. The consistency with KSS, Kruse and Sollis makes the finding stable and robust.

Montenegro

The failure to reject the unit root even when smooth changes are allowed means that Montenegro's GDP per capita does not return to long-run equilibrium, even when the method is highly flexible and captures gradual economic changes. This reinforces the findings of the other tests (linear and nonlinear) which showed a consistent absence of stationarity in Montenegro.

Possible reasons:

- High dependence on tourism.
- Strong volatility in the balance of payments.
- Small and vulnerable economy.
- Delayed structural adjustments.

6. CONCLUSIONS AND POLICY IMPLICATIONS

This paper examines the dynamics of GDP per capita in the Western Balkan countries, utilizing a wide range of linear, nonlinear and structural unit root tests, in order to investigate whether their economic trajectories are characterized by stationarity, long-term stabilization or permanent disturbances. The results demonstrate significant heterogeneity across countries, but also some common patterns that reflect their economic structure and degree of integration into European markets.

The linear PP and DF-GLS tests generally failed to detect stationarity in most countries, with the exception of North Macedonia for which the PP test in the constant-trend combination shows a stabilizing process. This suggests that for most economies in the sample, economic shocks have a long-term and permanent effect on income.

However, when endogenous structural cuts (Zivot-Andrews) are introduced, the results change. North Macedonia shows stationarity with a cut in 2006, which is associated with significant economic reforms. Even more encouraging are the results of Perron-Vogelsang, where North Macedonia and Serbia show stationarity in the Innovation and Additive models, with intercepts in 2016, 2020 and 2000. This means that much of the non-stationarity in linear tests was due to the failure to incorporate important economic events, such as crises, reforms, and entry into new European frameworks.

The importance of these results is crucial because they show that the disruptions in the economies of these countries are not necessarily permanent when taking into account major economic events, such as the global financial crisis, the debt crisis in Europe, and reform periods in the face of European adjustment.

Nonlinear tests (KSS, Kruse, and Sollis) provide a complementary picture. The countries of Albania and Kosovo show clear signs of nonlinear stationarity, confirming nonlinear recovery mechanisms, which are common in emerging economies where growth phases and

recessions do not follow a linear path. In the Sollis test, Albania shows stationarity but without asymmetry, while Kosovo shows a clear return to a symmetric trend.

The Enders-Lee test shows a statistically significant presence of trigonometric terms in all countries, so the fluctuations of GDP per capita follow cyclical or periodic nonlinear forms. The FADF test shows stationarity in Albania and Kosovo, but a unit root in Montenegro.

The overall picture from the nonlinear controls shows that the economies of Albania and Kosovo have nonlinear recovery mechanisms, while Montenegro shows greater vulnerability to permanent shocks.

Overall, the results of the checks reveal three groups of countries:

A. Countries with stabilization trends (Albania, Kosovo, North Macedonia, Serbia).

These economies show a return to a long-term trend, either linear or non-linear. Policy should focus on strengthening infrastructure, institutional reforms, and diversification of production.

B. Countries with permanent shock effects (Montenegro).

GDP is permanently affected by external shocks due to high dependence on tourism. The policy priority is to diversify the economy, strengthen fiscal reserves and develop sustainable sectors.

C. Countries with a mixed picture (Bosnia and Herzegovina).

No stationarity has been observed and the disruptions appear to have lasting effects. Institutional, administrative and financial reforms are needed.

In conclusion, we can say that the Western Balkan countries are not moving along a single development trajectory. The different dynamics that emerged indicate that the process of convergence with the EU requires individualized policies per country, aiming to enhance stability, resilience and productivity.

Policy Proposals

For the countries Albania, Kosovo, North Macedonia, Serbia.

- Strengthening infrastructure and productivity.
- Improving institutions, transparency and administrative capacity.
- Promoting export orientation.
- Investments in education, digital economy and innovation.
- Supporting export orientation and diversification of the production base

For Montenegro

- Reducing over-reliance on tourism.
- Developing sustainable sectors (energy, logistics, agri-food).
- Strong fiscal discipline and building reserves.
- Deepening financial supervision.

For Bosnia and Herzegovina

- Improving institutional functioning and governance.
- Political stabilization and strengthening investment confidence.
- Improving competitiveness and exports.
- Regional economic integration.

GDP per capita in the Western Balkan countries does not follow a uniform path. Most economies show signs of gradual convergence and a return to the long-term trend, especially when non-linearities and structural breaks are taken into account. However, some economies

remain vulnerable to permanent shocks. The prospect of economic convergence with the EU requires targeted differentiated and institutionally stable policies adapted to the findings of empirical tests.

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Taxation and Sustainability: How does Green Innovation Influence the Impact of Taxation on Firm Performance in China and the U.S.

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Abstract: This study examines the impact of corporate taxation on financial performance, with a focus on the moderating role of green innovation. Using panel data from 35 U.S. and 25 Chinese listed technology companies between 2010 and 2022, econometric models are employed to capture both direct and interaction effects, with robustness checks ensuring reliability. Findings indicate that high tax rates constrain firms' financial performance by limiting resources available for strategic investment, including sustainability initiatives. In the United States, tax incentives such as credits mitigate these effects, supporting green innovation and improving firms' ability to balance fiscal pressure with long-term growth. In contrast, Chinese firms benefit from green innovation in the long run, but the high upfront costs combined with less developed fiscal support systems intensify short-term financial pressures. These results highlight the crucial role of tax policy design in encouraging sustainable business practices without undermining competitiveness. Incentive-based fiscal measures can foster green innovation, strengthen firm performance, and contribute to a more sustainable economic model. The comparative U.S.–China perspective represents an important contribution of this research, while the inclusion of robustness tests, particularly during the COVID-19 period, enhances the empirical validity of the findings across different contexts.

Keywords: taxation; firm performance; green innovation; R&D investment; comparative analysis.

JEL classification: M41; H20; C23; L25.

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1. INTRODUCTION

Taxation plays a crucial dual role in sustainable development and corporate finance. While well-designed tax policies drive economic growth and government revenue, supporting the achievement of Sustainable Development Goals (SDGs), they also reduce businesses' cash flow, limiting resources for reinvestment, innovation, and strategic growth. Companies must balance contributing to public revenue with maintaining profitability and competitiveness, particularly in capital-intensive sectors where taxation significantly influences investment decisions (Djankov *et al.*, 2010).

To adapt, firms are increasingly adopting tax optimization strategies, such as leveraging credits and incentives, lowering their tax burden, free up capital, and fund innovation projects. These strategies are critical in today's financial environment, where businesses are also expected to meet high environmental and social standards. Governments play a pivotal role by offering tax incentives to encourage sustainable practices, particularly green innovation. These incentives make eco-friendly investments more financially viable, enabling firms to align their financial and environmental objectives (Nguyen *et al.*, 2021). By incorporating green innovation into their strategies, companies not only enhance their environmental performance but also strengthen their competitive position and meet growing stakeholder demands for responsibility.

Corporate Social Responsibility (CSR) further expands companies' commitments to society and the environment. CSR practices build trust with stakeholders, including customers, investors, and regulators, while fostering customer loyalty, reducing reputational risks, and ensuring long-term financial stability (Freeman, 2010). Integrating green innovation within CSR strategies allows firms to meet societal expectations while maintaining profitability and competitiveness in an evolving market landscape.

This paper addresses the following question: *How does green innovation moderate the impact of taxation on firm performance in the American and Chinese contexts?*

While existing research has explored taxation's direct impact on profitability and the advantages of innovation, little attention has been given to their interaction, particularly involving green innovation. This study bridges this gap by examining the interplay between taxation, green innovation, and financial performance, providing insights into the moderating role of green innovation.

By incorporating this dimension, the study offers a more nuanced and realistic interpretation of contemporary financial dynamics. It provides insight into the conditions under which taxation can become a lever for performance rather than a simple cost, and how green innovation can amplify or moderate this effect. This perspective not only enriches the debate on taxation and performance, but also enlightens public decision-makers and managers on the importance of designing policies and strategies that simultaneously integrate fiscal imperatives, environmental requirements and financial objectives.

The comparative approach of this research focuses on two major economies: the United States and China. The choice of the U.S. and China is based on their global economic prominence and their growing influence on sustainability initiatives. The U.S. represents a mature financial market with well-established regulatory policies that have historically incentivized corporate engagement in CSR and sustainability practices, making it an ideal context to study how CSR strategies impact financial performance in a stable and advanced economy. Moreover, the U.S., a mature economy, offers competitive tax policies and well-established incentives such as research

and development (R&D) tax credits, supported by a strong legal framework that promotes sustainability. In contrast, China provides a compelling perspective as an emerging market characterized by rapid economic growth and evolving regulatory frameworks that are increasingly prioritizing environmental and social issues. China has implemented progressive tax reforms to encourage sustainability and industrial growth. However, Chinese firms often face challenges like uneven application of tax incentives and the high costs of green innovation.

By comparing these distinct regulatory and economic environments, this study sheds light on how green innovation moderate taxation's impact on financial performance, addressing a critical gap in the literature and providing practical insights for policymakers and business leaders. The comparison between these two distinct contexts is crucial, because it allows to investigate whether CSR strategies yield consistent financial benefits across different economic systems, or if their effectiveness is shaped by the maturity and regulatory environment of the market. This cross-contextual analysis provides a deeper understanding of how companies can tailor CSR initiatives to optimize financial performance under varying economic and regulatory conditions, offering practical insights for both global and local business strategies. The technology sector was chosen for our study because it plays a central role in both economies and is heavily impacted by challenges related to innovation and sustainability. In the United States, the technology ecosystem is characterized by a strong capacity for innovation, supported by the interaction between businesses, academic institutions, and financial players. In China, the sector benefits from public policies aimed at strengthening technological autonomy and accelerating the energy transition. In both cases, technology companies simultaneously face imperatives of rapid innovation, environmental sustainability, and operational efficiency. Thus, studying this sector in both countries allows us to understand how national strategies influence organizations' ability to reconcile performance, innovation, and sustainability, making the technology sector a particularly relevant area of analysis for understanding contemporary economic transformations.

The paper is structured as follows: Section 2 reviews the literature and hypotheses. Section 3 details the data and methodology. Section 4 presents empirical results and robustness tests, followed by conclusions and implications in Section 5.

2. LITERATURE REVIEW

2.1. Theoretical background

To understand the interactions between taxation, green innovation, and firm performance, it is essential to consider the theoretical frameworks that provide a foundation for these dynamics.

2.1.1. Taxation and firm performance

Taxation is a critical factor shaping financial performance. Stakeholder theory (Freeman, 2010) highlights that ethical and transparent tax practices build trust with stakeholders, enhancing corporate reputation and financial stability (Schoenmaker and Schramade, 2023). Similarly, legitimacy theory (Suchman, 1995) suggests that fulfilling tax obligations strengthens a company's social legitimacy, fostering customer loyalty and stakeholder confidence (Nguyen *et al.*, 2021). From a strategic perspective, transaction cost theory

(Williamson, 1985) considers taxes as operational expenses affecting financial flexibility. Efficient tax management allows firms to allocate resources to sustainability initiatives, achieving both financial and environmental goals. Meanwhile, tax avoidance theory emphasizes that minimizing tax burdens can enhance post-tax profits, enabling firms to invest in green innovation and drive long-term growth (Desai and Dharmapala, 2006). Li *et al.* (2021) show that when U.S. states implement addback statutes to limit tax avoidance, firms significantly reduce their patent activity. This suggests that restricting tax avoidance can hinder innovation, thereby reinforcing the theory.

2.1.2. Green innovation and firm performance

Green innovation is a crucial driver of financial performance. According to stakeholder theory, aligning with societal expectations for environmental sustainability improves corporate reputation, stakeholder loyalty, and profitability (Homayoun *et al.*, 2023). Supporting this theory, Liu *et al.* (2024) provide empirical evidence that green innovation guided by stakeholder expectations significantly enhances both environmental and financial performance. Their study reinforces the idea that stakeholder engagement plays a critical role in driving sustainable business success. The Natural Resource-Based View (Hart, 1995) emphasizes that firms can enhance their competitive advantage by developing environmental capabilities that are strategic and difficult to replicate. Green innovation, as part of these capabilities, strengthens firms' positioning in increasingly sustainability-driven markets. This theoretical perspective is reinforced by recent contributions such as Achmad and Wiratmadja (2025). Furthermore, CSR theory emphasizes that integrating green innovation within corporate strategies not only fulfills societal expectations but also enhances resource utilization and financial outcomes (Nguyen *et al.*, 2021; Nureen *et al.*, 2023).

2.1.3. Green innovation and taxation

Taxation influences the adoption of green innovation, which in turn shapes financial performance. Stakeholder theory highlights that tax incentives encourage eco-friendly practices, aligning companies with societal norms and improving their reputation (Homayoun *et al.*, 2023). Additionally, institutional theory (Dimaggio and Powell, 2021) explains how regulatory pressures, in the form of tax incentives, drive firms toward sustainable practices, enhancing legitimacy. The Natural Resource-Based View (Hart, 1995) highlights that environmental capabilities can drive sustainable competitive advantage.

2.2. Empirical background and hypotheses development

Empirical studies provide further evidence on the interactions between taxation, green innovation, and financial performance, revealing important insights that support the formulation of hypotheses.

2.2.1. Taxation and firm performance

Taxation has a profound effect on corporate financial performance, with its influence varying depending on tax policies and firms' strategies. Elevated tax rates often restrict

companies' capacity to invest and grow. Djankov *et al.* (2010) found that high tax burdens reduce investment, particularly for small and medium enterprises, by limiting resources available for long-term projects. Similarly, Gadzo *et al.* (2013) identified a negative relationship between tax rates and financial metrics such as ROA and ROE, underscoring how taxes can diminish shareholder returns and reinvestment opportunities.

Strategic tax planning can mitigate these constraints. Zimmerman (1983) showed that firms leverage techniques such as intra-group debt structuring and transfer pricing to optimize their tax burden and improve financial outcomes. Tax incentives, including reduced corporate tax rates and credits, further enhance firms' ability to allocate resources effectively. For example, Chen and Frank (2022) demonstrated that lower tax rates encourage investment, particularly in capital-intensive sectors, by freeing up cash flow for innovation and expansion. Fang *et al.* (2022) provided compelling evidence from China's 2002 tax reform, where a 1% reduction in the effective tax rate increased ROA by 1.7%, driven by greater investments in fixed assets and reduced financial constraints.

In addition to direct effects, taxation shapes firms' financial structures, Nwaorgu and Abiahu (2020) observed that firms facing higher tax liabilities often resort to debt financing, altering their debt-to-equity ratios. Alkurdi *et al.* (2023) further explored the moderating role of governance mechanisms, finding that board gender diversity helps mitigate the negative impacts of elevated tax rates, illustrating how internal governance can influence firms' responses to taxation.

2.2.2. Green innovation and firm performance

The relationship between green innovation and financial performance is complex, shaped by regulatory contexts and firms' strategic priorities. Ghisetti and Rennings (2014) highlighted that innovations focused on energy and resource efficiency enhance profitability, while those targeting pollution reduction may incur high initial costs, potentially impacting competitiveness. Liu *et al.* (2024) supported this by showing that high-quality green innovations, such as cleaner production technologies, significantly boost financial performance by increasing competitiveness rather than solely through direct environmental improvements.

In the context of small and medium enterprises, Ji *et al.* (2024) revealed that green process innovation positively influences financial performance, while product innovations yield mixed results. Their findings suggest that government economic support moderates these outcomes, though predefined objectives tied to subsidies may limit financial gains. Similarly, Borsatto and Bazani (2022), in their review of 66 studies, found that 55% reported a positive relationship between green innovation and financial performance, often driven by improved resource efficiency and competitiveness. However, compliance costs can reduce short-term profitability, as noted by Cegarra-Navarro *et al.* (2016).

Institutional context also plays a critical role. Aguilera-Caracuel and Ortiz-de-Mandojana (2013) showed that firms in highly regulated environments achieve better returns from green innovation, while Duque-Grisales *et al.* (2020) emphasized that substantial R&D investments are necessary to maximize its financial benefits. For large U.S. firms, Liu (2024) demonstrated that green innovation enhances financial stability by reducing volatility and credit risk, aligning firms with regulatory and market expectations.

2.2.3. Taxation, firm performance and green innovation

The interaction between taxation, firm performance, and green innovation is particularly important for understanding how fiscal policies influence sustainability. Indeed, favorable tax policies, such as R&D credits, reduce financial constraints and encourage green innovation. However, existing research on tax performance and green innovation is still limited, with most researchers exploring these aspects two by two separately (Song *et al.*, 2020). Furthermore, most previous work has focused on a specific aspect of taxation or innovation, such as environmental taxation, green taxation, tax incentives, technological innovation, or others. Stucki *et al.* (2018) show that tax incentives can stimulate innovation in green products. According to Pan *et al.* (2021), tax incentives improve companies' net cash flow, providing them with sufficient funds to invest in R&D and improve the efficiency of their production in terms of innovation. In the Canadian context Griffith *et al.* (1995) found that tax policy has considerable benefits for research and development. According to Pénard and Poussing (2010), tax incentives have a positive communication effect. As they send a positive signal to financial institutions and private investors, companies can attract more social capital investment.

According to Lei *et al.* (2022), environmental taxes can encourage companies to reduce their emissions, strengthen their capacity to control pollution, and improve the technological level of environmentally friendly products by transforming their production processes and increasing their investments in green innovation, which will increase the market share of their products and eventually improve their performance. This means that technological innovation is undoubtedly the best practice for companies to promote green development and protect public interests, enabling them to ensure both environmental protection and business development. While many studies have focused on the mediating role of green innovation, particularly in the relationship between environmental taxation and environmental responsibility (Amoh *et al.*, 2025), or between CSR and sustainable performance (Tran and Le, 2025), few studies have explored its moderating role, thus leaving a gray area in the understanding of its contingent influence.

To our knowledge, no study has explored the relationship between these three concepts simultaneously and using the same definitions as in our work. However, we can cite a few related articles, such as Xiaowei and Petrovskaya (2022). They found that environmental taxes contribute directly and significantly to improved financial performance and that technological innovation, to a certain extent, produces a mediating effect.

Xiong *et al.* (2023) found that high-tech enterprises in China benefiting from a 15% tax rate incentive achieved significant improvements in innovation performance, which positively impacted financial metrics. Similarly, Huang and Liu (2024) highlighted that tax incentives enhance innovation efficiency by easing financing constraints, enabling firms to allocate resources toward sustainable initiatives. Consistently with prior findings, Sang *et al.* (2024) demonstrated that reductions in corporate income tax rates significantly foster innovation, especially among highly productive firms operating in competitive markets. Using a quasi-natural experiment based on China's tax reform, their findings revealed that tax increases discourage innovation, emphasizing the importance of well-designed tax policies to stimulate innovation-led growth.

Green innovation plays a moderating role in translating tax savings into financial gains. Abdelhakim and Lamia (2022) found that Tunisian firms investing in green innovation reduced their tax liabilities, strengthening their financial structures and growth potential.

Porter and van der Linde (1995) argued that green innovation reduces long-term costs while attracting environmentally conscious consumers, enhancing profitability. However, the extent of these benefits depends on firms' capacity to innovate and the scale of tax incentives offered. Based on this evidence, the following hypotheses are proposed:

H1*: Taxation negatively impacts corporate financial performance.*

H2*: Green innovation positively moderates the relationship between taxation and financial performance.*

3. METHODOLOGY

3.1. Data and sample

To achieve the objectives of this study, we use panel data econometrics by exploiting a sample of American and Chinese companies observed over a period of thirteen years, covering the years 2010 to 2022. This study uses data extracted from the Datastream database. This timeframe captures significant global tax reforms and the increasing emphasis on green innovation. The sample includes 35 American and 25 Chinese publicly traded technology companies. The selection reflects the study's comparative focus on two economies with distinct regulatory frameworks: the United States, a mature economy with competitive tax policies, and China, a rapidly developing economy prioritizing sustainable industrial growth.

American technology firms are more numerous and have a well-established presence in global markets, justifying the slightly larger sample size. Meanwhile, Chinese technology companies, though fewer in number, have experienced remarkable growth and are increasingly important players in the global technology landscape. Limiting the sample to 35 American and 25 Chinese companies allows for a deep analysis while ensuring that the data is consistent, manageable, and representative of broader trends in CSR practices within the industry. This distribution ensures a robust comparative analysis while acknowledging the differences in the corporate ecosystems of the two countries. The technology sector was chosen for our study because it plays a central role in both economies and is heavily impacted by challenges related to innovation and sustainability. Firms in this sector are particularly responsive to tax incentives, making them ideal for analyzing the intersection of taxation, innovation, and financial performance.

3.2. Variable's definition

The study examines the impact of corporate taxation on financial performance, moderated by green innovation. Financial performance is measured by Return on Assets (ROA), a widely accepted indicator of profitability and operational efficiency (Lajmi *et al.*, 2025a; Lajmi and Shiri, 2025; Ben Flah *et al.*, 2026). Corporate taxation is calculated as the ratio of total taxes paid to pre-tax income, noted Cash ETR, captures firms' effective tax burden and financial flexibility (Alkurdi *et al.*, 2023). Green innovation is proxied by annual R&D expenditures, reflecting broader innovation efforts, including sustainability initiatives. In fact, research and development (R&D) is commonly used as an indicator of green innovation, as it reflects companies' investment efforts in developing technologies, processes, and products aimed at reducing environmental impacts. R&D expenditures focused on energy

efficiency, reducing polluting emissions, or the sustainable use of resources demonstrate companies' capacity for environmental innovation. As such, R&D constitutes an indirect but relevant measure of green innovation, widely used in the empirical literature (Makpotche *et al.*, 2024; Lajmi *et al.*, 2025a).

Control variables include firm size (ln of total assets), which reflects resource availability and economies of scale (Lajmi *et al.*, 2021; Lajmi and Yab, 2022; Eche *et al.*, 2023); board size, capturing governance structure and strategic oversight (Shamil *et al.*, 2024; Lajmi *et al.*, 2025a; Lajmi *et al.*, 2025b); and gender diversity, representing the proportion of female directors, linked to improved decision-making and financial stability (Alkurdi *et al.*, 2023; Lajmi *et al.*, 2025a). The ratio of tax expense to pre-tax income, noted GAAP ETR, accounts for direct impacts on cash flow and reinvestment capacity (Eche *et al.*, 2023). This framework provides a comprehensive basis for analyzing the interaction between taxation, green innovation, and financial performance.

3.3. Models' specification

To examine the relationship between taxation, financial performance, and the moderating role of green innovation, we employ econometric models incorporating direct and interaction effects with robustness checks for validation. The baseline model assesses the direct impact of taxation on performance, using Ln ROA as the dependent variable, with tax rate, income taxes, firm size, board size, and gender diversity as predictors:

$$\text{Ln ROA}_{it} = \beta0 + \beta1 \text{ Ln Cash ETR}_{it} + \beta2 \text{ Ln GAAP ETR}_{it} + \beta3 \text{ Gender Diversity}_{it} + \beta4 \text{ Board Size}_{it} + \beta5 \text{ Firm Size}_{it} + \varepsilon_{it} \quad (1)$$

To include green innovation (R&D investment), its direct effect on financial performance is modeled as follows:

$$\text{Ln ROA it} = \beta0 + \beta1 \text{ Ln Cash ETRit} + \beta2 \text{ LnGAAP ETR it} + \beta3 \text{ Green Innovation it} + \beta4 \text{ Gender Diversity it} + \beta5 \text{ Board Size it} + \beta6 \text{ Firm Size it} + \varepsilon \text{ it} \quad (2)$$

The moderating role of green innovation is analyzed by introducing an interaction term between tax rate and R&D investment (noted Moderator_RD):

$$\text{Ln ROA it} = \beta0 + \beta1 \text{ Ln Cash ETRit} + \beta2 \text{ Ln GAAP ETR it} + \beta3 \text{ Green Innovation it} + \beta4 (\text{Ln Cash ETR it} \times \text{Green Innovation it}) + \beta5 \text{ Gender Diversity it} + \beta6 \text{ Board Size it} + \beta7 \text{ Firm Size it} + \varepsilon \text{ it} \quad (3)$$

Robustness checks focus on the COVID-19 period (2020-2022 for U.S. firms, extended to 2019 for Chinese firms) to assess consistency under fiscal disruptions. The model for this test follows the baseline structure. This framework provides a rigorous analysis of taxation, green innovation, and financial performance, integrating direct and moderating effects while validating results across diverse contexts. It contributes valuable insights into fiscal policies, innovation, and corporate strategy.

4. EMPIRICAL RESULTS AND DISCUSSIONS

4.1. Descriptive statistics and correlation

Table no. 1 reports the descriptive statistics (mean, standard deviation, minimum and maximum) of each of the variables retained in our empirical study, namely, the dependent, independent and control variables.

Table no. 1 – Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Ln ROA	776	1.189	1.902	-2.725	3.199
Ln Cash ETR	776	2.94	.489	1.747	3.714
Ln GAAP ETR	776	11.533	2.246	7.585	15.245
Board size	776	9.323	2.31	2	15
Gender Equity	776	.321	.467	0	1
Firm size	776	15.806	2.106	10.034	19.936
Invest RD	776	2.403	5.93	0	73.2

The data, drawn from 776 observations of U.S. and Chinese technology firms, highlight variability in financial performance, taxation, green innovation, and structural characteristics, offering a basis for analyzing the relationships among these factors.

Firm performance, measured by the logarithm of return on assets (Ln ROA), has an average of 1.189 with a range from -2.725 to 3.199, reflecting significant differences in firms' ability to generate profits. Taxation, represented by the logarithm of cash ETR (Ln Cash ETR) and income taxes (Ln GAAP ETR), shows averages of 2.94 and 11.533, respectively. These values highlight varying tax burdens, influencing resource allocation for strategic investments.

Green innovation, proxied by R&D investment (mean 2.403, standard deviation 5.93, and a maximum of 73.2), exhibits high dispersion, indicating uneven engagement in innovation. Some firms invest heavily in R&D, potentially leveraging these investments to mitigate taxation's impact on financial performance.

Structural characteristics also provide meaningful insights. Firm size, with an average logarithm of 15.806, indicates diverse resource capacities, while board size (mean 9.323) reflects governance structures that may influence strategic oversight. Gender diversity, with a mean of 0.321, highlights limited but evolving representation of women in leadership roles, potentially affecting decision-making and innovation.

These descriptive statistics underscore the dynamic interplay between taxation, green innovation, and financial performance, influenced by firms' structural and strategic characteristics. To deepen our understanding of the relationships between these variables, we now examine the correlations to identify the direct links between financial performance, taxation, green innovation, and the structural characteristics of our sample.

Table no. 2 presents the correlation matrix, highlighting relationships between financial performance, taxation, green innovation, and structural characteristics. Financial performance (Ln ROA) shows a moderate negative correlation with Cash ETR (-0.274), suggesting that higher taxes reduce profitability by constraining cash flow. Conversely, a positive correlation with GAAP ETR (0.497) indicates that more profitable firms face higher tax liabilities.

Ln ROA also correlates positively with board size (0.316), gender diversity (0.187), and firm size (0.443), suggesting that larger boards, diverse leadership, and economies of scale

enhance profitability. R&D investment (0.218) further supports the role of innovation in driving financial performance.

Table no. 2 – The pairwise correlations between the variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Ln ROA	1.000						
(2) Ln Cash ETR	-0.274	1.000					
(3) ln GAAP ETR	0.497	-0.138	1.000				
(4) Board size	0.316	-0.141	0.437	1.000			
(5) Gender equity	0.187	-0.134	0.185	0.187	1.000		
(6) firm size	0.443	-0.042	0.703	0.425	0.115	1.000	
(7) invest RD	0.218	-0.107	0.458	0.209	0.241	0.362	1.000

Among control variables, firm size strongly correlates with income taxes (0.703), while R&D investment shows positive associations with board size (0.209) and gender diversity (0.241). These findings provide foundational evidence supporting the study's hypotheses.

Our models do not exhibit multicollinearity issues, as the correlation between our independent variables remains below 80% and to further confirm the absence of multicollinearity, we examine the Variance Inflation Factor (VIF) values for our independent variables, as shown in Table no. 3.

Table no. 3 – Variance Inflation Factor test

Dimension	VIF	1/VIF
Ln GAAP ETR	2.129	.47
Firm size	2.067	.484
Board size	1.312	.762
Gender equity	1.063	.941
Ln Cash ETR	1.048	.955
Means VIF	1.524	.

Table no. 3 shows that all variables have VIFs below 3, with a mean VIF of 1.524, indicating that there is no significant multicollinearity in the model. Each variable has a tolerance value close to 1, confirming that they are sufficiently independent of each other based on Ding and Stolowy (2003).

To assess whether the variance of error terms is consistent across observations, we conduct a heteroskedasticity test, with results presented in Table no. 4. Detecting heteroskedasticity is essential, as any inconsistency in variance could lead to biased standard errors and impact the robustness of our model. These results help determine if adjustments, such as robust standard errors, are necessary to ensure reliable regression analysis.

Table no. 4 – The heteroskedasticity test

	Coef
Chi2(61)	317.63
P-value	0.0000

White's test for heteroskedasticity produced a chi-squared statistic of 317.63 with a p-value of 0.000, indicating significant heteroskedasticity in the model. This result rejects the null hypothesis of homoscedasticity, confirming that the variance of residuals is not constant across levels of the independent variables. Such a violation can bias standard error estimates, potentially affecting the validity of coefficient significance tests. To address this issue, adjustments to the model, such as robust standard errors, are necessary to ensure reliable and accurate results. Correlations between the explanatory variables were first examined to identify any potential multicollinearity issues. A heteroscedasticity test was then carried out to check for constant error variance. To determine the most appropriate estimation method for the panel data, we compared clustered OLS, random-effects and fixed-effects models using diagnostic tests. The Breusch-Pagan Lagrange multiplier test was applied to assess the suitability of the random-effects model (Table no. 5). Furthermore, the Hausman (1978) test was used to compare the fixed-effects and random-effects estimators (Table no. 6). In this context, the clustered OLS model was selected for the final estimation, with the corresponding results presented in Table no. 7.

Table no. 5 – The Breusch-Pagan Lagrange Multiplier test

	Coef
Chibar-square test value	0.00
P-value	1.000

The Breusch and Pagan Lagrangian multiplier test (Table no. 5) yields a chi-square statistic of 0.00 with a p-value of 1, indicating no significant variation across entities. This result suggests that a random effects model is unnecessary, and a pooled OLS model is more appropriate for the dataset.

To address potential endogeneity, the Hausman test was employed. The null hypothesis (H0) assumes no systematic difference in coefficients, while the alternative (H1) indicates the presence of endogeneity. This ensures the robustness of the econometric analysis.

Table no. 6 – Hausman (1978) **specification Test**

Durbin (score) chi2(1)	**.83345 (p = 0.3613)**
Wu-Hausman F(1,709)	.826263 (p = 0.3637)

The results shown in Table no. 6 indicate that there is no endogeneity problem. Accordingly, we accept the null hypothesis as our P-value exceeds 5%.

4.2. Empirical results of the impact of taxation on firm performance and discussion

The regression results reveal the interplay between corporate taxation, financial performance, and green innovation. Analyzing American and Chinese technology firms highlights how tax policies and sustainable investments influence financial outcomes, linking findings to existing theories and prior studies.

The regression results, shown in Table no. 7, provide a comprehensive overview of the interactions between taxation, green innovation, and financial performance, for the full sample and the sub-samples representing the US and China.

Table no. 7 – Regression results

Ln ROA	Full Sample	US	China
Ln Cash ETR	-.805***	-.562***	-1.252***
	(.126)	(.158)	(.16)
ln GAAP ETR	.245***	.166***	.354***
	(.028)	(.034)	(.05)
Gender	.288**	.269***	.513**
	(.115)	(.095)	(.207)
Board size	.053**	-.003	.031
	(.024)	(.037)	(.04)
Firm size	.176***	.07	.091*
	(.051)	(.046)	(.053)
Constant	-2.649***	.178	-1.229**
	(.732)	(.835)	(.565)
Mean dependent var	1.189	1.907	0.172
Overall r-squared	0.321	0.137	0.219
Chi-square	2200.312	218.087	252.982
R-squared within	0.319	0.130	0.218
SD dependent var	1.902	1.412	2.040
Number of Obs	776	455	321
Prob > chi2	0.000	0.000	0.000
R-squared between	0.651	0.470	0.309

Note: *** p<.01, ** p<.05, * p<.1

Table no. 7 highlights key relationships between corporate taxation, financial performance, and firm characteristics. The Cash ETR's significant negative coefficient (-0.805, $p < 0.01$) confirms that higher taxes reduce financial performance, supporting Transaction Cost Theory (Coase, 1937; Williamson, 1985), as they constrain cash flow and limit reinvestment, aligning with Djankov *et al.* (2010) and Gadzo *et al.* (2013). Conversely, the positive coefficient for GAAP ETR (0.245, $p < 0.01$) suggests that profitable firms manage higher taxes without compromising performance, aligning with Zimmerman (1983). Firms engaged in CSR may also benefit reputationally, attracting customers and improving profitability despite higher tax obligations.

Gender diversity (0.288, $p < 0.05$) positively influences financial performance, consistent with Stakeholder Theory (Freeman, 2010), as diverse leadership enhances decision-making and innovation (Homayoun *et al.*, 2023). Board size (0.053, $p < 0.05$) shows a positive effect, supporting Legitimacy Theory (Suchman, 1995), with larger boards providing better governance and oversight. Firm size (0.176, $p < 0.01$) positively impacts financial performance, supporting the Natural Resource-Based View (Hart, 1995), as larger firms benefit from resources, economies of scale, and strategic capacity.

These findings establish a baseline for understanding taxation's effects on financial performance and set the stage for country-specific analyses of the United States and China to explore economic and regulatory differences.

Column (2) from Table no. 7 provides significant insights into the relationships between corporate taxation, financial performance, and firm characteristics in the U.S. The negative coefficient for the tax rate (-0.562, $p < 0.01$) confirms that higher tax rates reduce financial performance (Ln ROA), aligning with Transaction Cost Theory. High taxes reduce net profits

and reinvestment capacity while increasing financial constraints. The complexity of state tax environments further amplifies these challenges, as companies operating in high-tax states face greater profitability reductions than those in lower-tax states.

The positive coefficient for income taxes (0.166, $p < 0.01$) indicates that profitable firms manage to sustain strong financial performance despite higher tax obligations, supported by effective tax strategies (Zimmerman, 1983). Such firms may also benefit reputationally from being perceived as socially responsible taxpayers, which can attract customers and enhance profitability. Gender diversity (0.269, $p < 0.01$) significantly improves financial performance, reinforcing Stakeholder Theory (Freeman, 2010). Diverse leadership enhances decision-making, strengthens governance, and aligns with growing investor and regulatory expectations for inclusivity. These attributes build investor confidence, improve transparency, and enable firms to make more balanced strategic decisions, ultimately boosting financial outcomes. Board size (-0.003, $p = 0.934$) and firm size (0.070, $p = 0.129$) show no significant effects, suggesting these factors are not decisive in influencing financial performance in the U.S. context. This could reflect that their advantages are already integrated into other governance or operational mechanisms.

Column (3) of Table no. 7 provides findings for the China sub-sample. The regression results for Chinese firms provide valuable insights into the relationships between taxation, financial performance, and company characteristics within this distinct economic context. The negative and significant coefficient for the tax rate (-1.252, $p < 0.01$) highlights a stronger adverse impact of higher tax rates on financial performance (Ln ROA) compared to the U.S. firms. This suggests that in the Chinese context, tax burdens may pose even greater constraints on firms' cash flow and investment potential, aligning with transaction cost theory (Coase, 1937; Williamson, 1985).

The positive and highly significant coefficient for income taxes (0.354, $p < 0.01$) indicates that profitable firms in China, similar to those in the U.S., manage to maintain strong financial performance despite higher tax obligations. This underscores the importance of effective tax strategies in maintaining profitability under significant tax pressures, in line with Zimmerman (1983).

The coefficient for gender diversity (0.513, $p < 0.05$) shows a significant positive impact on financial performance, reinforcing the notion that diverse leadership contributes to better strategic decision-making and corporate outcomes. This finding supports stakeholder theory (Freeman, 2010), which emphasizes the benefits of meeting stakeholder expectations, including diversity in management. Board size, with a non-significant coefficient (0.031, $p = 0.43$), suggests that, similar to U.S. firms, the size of the board may not play a decisive role in financial performance for Chinese firms. This could point to the quality of governance being more critical than the number of board members. The coefficient for firm size (0.091, $p < 0.1$) is positive and marginally significant, implying that larger firms in China may benefit from economies of scale and resource advantages, although this effect is weaker compared to other factors. The comparison between U.S. and Chinese firms reveals important differences in how taxation and company characteristics influence financial performance. The impact of tax rates is more severe in China, where the negative coefficient (-1.252) is significantly stronger compared to the U.S. (-0.562). The stronger negative impact of tax rates in China may be due to stricter tax policies or fewer opportunities for tax optimization compared to the U.S, making taxes more burdensome for Chinese firms. This suggests that higher tax rates are more restrictive for Chinese firms, possibly due to more stringent tax policies or limited tax planning strategies.

4.3. Empirical results of the moderation of green innovation in the impact of taxation on firm performance and discussion

4.3.1. Results of the impact of green innovation on firm performance

We have now included R&D investment as an independent variable to test its impact on financial performance. Results are given by Table no. 8 below.

Table no. 8 – Results of the model estimation integrating the R&D investment variable

Ln ROA	Coef.		St. Err.		t-value		p-value		[95% Conf		Interval]	
	China	US	China	US	China	US	China	US	China	US	China	US
Ln Cash ETR	-1.29***	-.565***	.165	.159	-7.81	-3.55	0	0	-1.613	-.876	-.966	-.253
R&D Investment	-.7 ***	-.004	.224	.003	-3.13	-1.16	.002	.248	-1.139	-.011	-.261	.003
Ln GAAP ETR	.386 ***	.171***	.046	.034	8.41	5.02	0	0	.296	.104	.477	.238
Gender	.555**	.284***	.216	.095	2.57	2.99	.01	.003	.131	.098	.979	.47
Board size	.035	-.004	.04	.038	0.87	-0.11	.383	.916	-.044	-.078	.114	.07
Firm size	.157 **	.073	.065	.046	2.42	1.58	.015	.115	.03	-.018	.285	.163
Constant	-2.197***	.087	.774	.814	-2.84	0.11	.005	.915	-3.714	-1.509	-.679	1.683

	China	US		China	US
Mean dependent var	0.172	1.907	**SD dependent var**	2.040	1.412
Overall r-squared	0.227	0.137	**Number of Obs**	321	455
Chi-square	300.912	223.043	**Prob > chi2**	0.000	0.000
R-squared within	0.227	0.130	**R-squared between**	0.257	0.472

Note: *** p<.01, ** p<.05, * p<.1

Results show that, for US firms, R&D Investment has a negative coefficient (-0.004) and is not statistically significant ($p = 0.248$). This result suggests that, within this sample, R&D spending does not have a clear, immediate impact on financial performance as measured by Ln ROA. This outcome may indicate that the direct financial returns from R&D investments, particularly those focused on green innovation, may not be realized in the short term and could be counterbalanced by substantial initial costs associated with such projects.

The non-significant result aligns with prior findings in the literature that highlight the complex nature of R&D investments. Ghisetti and Rennings (2014) noted that while green innovation can boost long-term competitiveness and profitability, it often incurs significant upfront expenses that may dampen immediate financial performance. Similarly, Cegarra-Navarro *et al.* (2016) observed that high compliance and innovation costs associated with sustainable practices could limit short-term profitability, despite potential long-term benefits.

For Chinese firms, it becomes clear that while R&D, representing green innovation, is essential for long term growth, it has a significant negative impact on short-term financial performance (-0.7, $p < 0.01$). This suggests that the immediate costs of R&D outweigh its short-term financial benefits, reflecting the resource intensive nature of sustainable innovation. Despite this, Ln Cash ETR continues to have a strong negative impact.

4.3.2. The moderating role of green innovation on the relationship between taxation and firm performance

In this stage of the analysis, we examine the moderating effect of R&D investment on the relationship between taxation and financial performance (measured by Ln ROA) across the full sample, US and Chinese firms (Table no. 9). This allows us to determine whether R&D investment influences the way tax rates affect financial performance and to observe how this interaction differs between the US and China, highlighting potential differences between countries in terms of industrial policies and structures.

Table no. 9 – Results of Green Innovation moderation on taxation and firm performance

Variables	Full sample Ln ROA	USA firms Ln ROA	China firms Ln ROA
Ln Cash ETR	-0.807***	-0.543***	-0.746**
	(0.132)	(0.168)	(0.299)
R&D Investment	-0.00803	0.0247	4.415**
	(0.0442)	(0.0364)	(1.773)
Moderator_RD (1)	-0.00296	-0.0106	-1.803***
	(0.0177)	(0.0142)	(0.659)
Ln GAAP ETR	0.261***	0.173***	0.393***
	(0.0266)	(0.0350)	(0.0440)
Gender equity	0.320***	0.282***	0.602***
	(0.123)	(0.0957)	(0.223)
Board size	0.0518**	-0.00443	0.0231
	(0.0242)	(0.0376)	(0.0399)
Firm size	0.181***	0.0743	0.206***
	(0.0524)	(0.0457)	(0.0690)
Constant	-2.862***	-0.0114	-4.436***
	(0.812)	(0.829)	(1.341)
Observations	776	455	321
Number of Year	13	13	13

Note: (1) Moderator_RD is the interaction term between tax rate and R&D investment (as noted in the equation model).

Results are given by Table no. 9. For U.S. firms, the tax rate has a significant negative impact on financial performance (-0.543, $p < 0.01$), supporting Transaction Cost Theory (Coase, 1937; Williamson, 1985). R&D investment is positive but non-significant (0.0247, $p = 0.34$), as is its moderating effect (-0.0106, $p = 0.27$). Supportive fiscal measures like the Research and Experimentation Tax Credit likely buffer the effects of taxation, enabling firms to sustain financial resilience while encouraging innovation (Hall and Van Reenen, 2000).

In China, the tax rate remains significantly negative (-0.746, $p < 0.05$). Unlike in the U.S., R&D investment is significant and positive (4.415, $p < 0.05$), indicating its independent financial benefits. However, its moderating effect is significantly negative (-1.803, $p < 0.01$), suggesting that higher R&D spending exacerbates the financial strain of higher taxes. This aligns with Ghisetti and Rennings (2014), who noted the high initial costs of green innovation. These results may reflect less comprehensive R&D support in China, where incentives such

as the 2008 corporate tax reform are unevenly applied and insufficient to offset the burden of taxation under high R&D investment levels (Xiong *et al.*, 2023).

4.4. Robustness tests

To test robustness, we analyzed the impact of taxation on firm performance during the COVID-19 period. For U.S. firms, the analysis covers 2020-2022, while for Chinese firms, it extends to 2019 to account for the earlier onset of the pandemic. This narrowed timeframe captures the unique challenges and dynamics firms faced during this period, assessing the consistency of our findings. The Table no. 10 below presents the regression results for U.S. firms during the COVID-19 period.

Table no. 10 – Results of the robustness test

Ln ROA	Coef.		St. Err.		t-value		p-value		[95% Conf		Interval]	
	China	US	China	US	China	US	China	US	China	US	China	US
Ln Cash ETR	-.807**	-.671**	.815	.264	-0.99	-2.54	.025	.013	-2.427	-1.194	.812	-.147
Ln GAAP ETR	.289**	.193*	.133	.116	2.18	1.66	.032	.099	.026	-.037	.553	.424
Gender	-.047	-.069	.418	.278	-0.11	-0.25	.912	.805	-.877	-.621	.784	.483
Board size	.07	-.038	.098	.069	0.71	-0.54	.479	.59	-.125	-.175	.265	.1
Firm size	.094	.154	.128	.093	0.73	1.66	.467	.101	-.161	-.03	.348	.337
Constant	-2.079	-.67	3.037	1.542	-0.68	-0.43	.495	.665	-8.109	-3.73	3.951	2.39

	China	US		China	US
Mean dependent var	0.297	2.119	**SD dependent var**	1.973	1.299
R-squared	0.163	0.199	**Number of Obs**	100	105
F-test	3.668	4.913	**Prob > F**	0.004	0.000
Akaike crit. (AIC)	412.836	340.619	**Bayesian crit. (BIC)**	428.467	356.543

Note: *** p<.01, ** p<.05, * p<.1

For the U.S. sample, the robustness checks confirm the consistency of our findings. The Cash ETR maintained a significant negative impact on financial performance (-0.671, p = 0.013), highlighting increased fiscal pressures during the pandemic. The positive association between income taxes and financial performance persisted (0.193, p = 0.099), though slightly reduced, reflecting firms' ability to manage tax strategies effectively. Governance factors, including board size and firm size, remained insignificant, indicating a strategic focus on immediate fiscal challenges. These results validate the robustness of our analysis, reaffirming the critical role of taxation in shaping financial outcomes during global disruptions.

For the Chinese firms, the robustness checks for the COVID-19 period confirm a consistent negative relationship between the Cash ETR and financial performance (Ln ROA), with a reduced magnitude (-0.807 versus -1.252 in the full period). This indicates that fiscal constraints remained significant but were partly mitigated by adaptive strategies or temporary policy measures during the pandemic. The positive link between GAAP ETR and financial performance persists (0.289 versus 0.354 in the full period), highlighting the role of effective tax planning in maintaining stability under uncertainty. These findings reinforce the resilience of firms and validate the core relationships identified in the broader analysis.

5. CONCLUSION

Our study sheds light on the complex relationship between corporate taxation, financial performance, and the moderating role of green innovation through a comparative analysis of technology firms in the US and China. By examining a sample of 35 U.S. and 25 Chinese listed companies over the period 2010 to 2022, our research provides critical insights into how tax policies affect firm financial performance and how green innovation moderates this relationship.

The results demonstrate that high tax rates significantly constrain financial performance by reducing companies' financial flexibility and limiting their ability to invest in strategic initiatives, particularly those focused on sustainability. However, the impact of taxation on performance varies notably between the two economic contexts. In the U.S., tax management strategies, supported by mechanisms such as R&D tax credits, allow companies to partially offset the negative effects of taxation, fostering financial resilience and innovation. Conversely, for Chinese firms, while R&D investment contributes to long-term performance improvements, it often exacerbates financial pressures in the short term, particularly in the absence of robust and consistent tax support for green innovation.

Our results align with those of Pan *et al.* (2021) and Pénard and Poussing (2010). Pan *et al.* (2021) show that tax incentives improve companies' net cash flow, providing them with sufficient funds to invest in R&D and improve the efficiency of their production in terms of innovation. According to Pénard and Poussing (2010), tax incentives have a positive communication effect. As they send a positive signal to financial institutions and private investors, companies can attract more social capital investment.

According to Lei *et al.* (2022), environmental taxes can encourage companies to reduce their emissions, strengthen their capacity to control pollution, and improve the technological level of environmentally friendly products by transforming their production processes and increasing their investments in green innovation, which will increase the market share of their products and eventually improve their performance. This allows to ensure both environmental protection and business development.

This study makes several contributions. Both theoretically and empirically, this study enriches the literature by addressing an angle that has yet to be thoroughly investigated. Previous research has mainly focused on studying the direct effects of environmental taxation on innovation performance or outcomes. However, the relationship between taxation, green innovation and financial performance remains insufficiently documented. Using a comparative approach, this research fills this gap by jointly analysing environmental taxation, green innovation and corporate financial performance. Through a comparative analysis, our study explores this relationship and highlights the moderating role played by green innovation, shedding new light on the dynamics through which environmental taxation can strengthen or weaken, the financial performance of companies. The comparative approach between the U.S. and China represents a major contribution of this study, as it highlights how differing regulatory and economic environments shape the interplay between taxation, green innovation, and financial performance. This comparison offers valuable insights into the diverse challenges and opportunities firms face, underscoring the need for tailored policy solutions. Furthermore, the robustness tests conducted, particularly during the COVID-19 period, add empirical depth to the findings, reinforcing the validity of the results across varied contexts.

The practical implications of this research are significant for both policymakers and corporate leaders. For governments, it is imperative to design targeted tax policies that not

only reduce the financial burden on companies but also incentivize investment in sustainable technologies. Well-structured tax credits and subsidies for green innovation can play a pivotal role in promoting sustainability while enhancing long-term competitiveness. For businesses, the findings highlight the importance of adopting balanced strategies that integrate tax efficiency with strategic investments in innovation. This dual focus enables firms to navigate fiscal constraints, meet growing societal and environmental expectations, and maintain resilience and competitiveness in an increasingly demanding global marketplace.

However, this study is not without limitations. Using R&D investment as a proxy for green innovation does not distinguish projects specifically targeting sustainability from other forms of innovation. A more precise measure, such as expenditures on certified sustainable initiatives, could enhance future analyses. Additionally, the absence of detailed data on tax incentives explicitly linked to green innovation restricts our ability to fully assess their influence on financial outcomes. Expanding the dataset to include such variables would provide a more comprehensive understanding of the mechanisms at play.

Finally, to obtain a broader perspective, future research could explore these dynamics across other sectors and economies with diverse tax structures and regulatory environments. These extensions would further illuminate the interplay between taxation, green innovation, and financial performance in a global context.

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Current Overview of Tourism Governance: A Systematic Literature Review

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Abstract: This article aims to offer a comprehensive theoretical approach to tourism governance and its current state by conducting a systematic literature review and bibliometric analysis. The study seeks to understand how governance aligns the interests of governments, businesses, and local communities in order to promote sustainable and competitive development in a globalized environment. Based on the SALSA framework, the research analyzed a sample of 84 scientific studies extracted from the Web of Science and Scopus databases. Quantitative and qualitative analysis techniques were employed using statistical and content analysis tools to identify trends, regions, stakeholders, and key governance attributes. Findings reveal a significant increase in tourism governance research since 2016, particularly after the pandemic. The most studied area is tourism planning, followed by community-based tourism and smart destinations. Geographically, Asia and Europe dominate scientific production, with the public and private sectors being the main actors. The study identifies three fundamental models or "clusters": community-oriented governance, data-driven smart governance, and network-based governance. Business management approaches tend to focus on efficiency and planning, leaving critical political dimensions such as power, trust, and distributive justice in the background. Although governance has evolved toward more collaborative forms, a technocratic logic appears to be emerging that could replace democratic deliberation. The effectiveness of these models depends on their adaptation to the local context and the balance between economic competitiveness and the empowerment of local actors.

Keywords: governance; tourism; literature review; managerial approach; power relations; stakeholders.

JEL classification: A14; D62; D74; D82.

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1. INTRODUCTION

The transformations resulting from globalization and digitalization have profoundly impacted the structure and dynamics of tourism destinations. These transformations have promoted the decentralization of power and the emergence of non-state actors, such as companies, non-governmental organizations (NGOs), and local communities, in decision-making processes related to tourism planning and management at multiple levels (Timothy, 2019; Bock *et al.*, 2021). While these actors can have positive impacts, they can also create tensions within local economies and with regard to sustainability. According to Codina *et al.* (2022b), tourism reconfigures power relations by turning spaces into disputed resources where objective and subjective aspects, such as identities and economic benefits, are negotiated. Local actors use different forms of capital (economic, social, and cultural) to exert power and exclude others. This translates into different aspects generated by the dispute and integration of tourism in a destination. New technologies, such as social networks used by tourism companies for communication and dissemination, can create asymmetries of power and information between consumers and different stakeholders (Gutiérrez-Barroso *et al.*, 2021). Other authors, such as del Hoyo *et al.* (2019), argue that patrimonializing cultural events and local festivities for their tourism potential – events that are manifestations of local traditions and identity – can generate positive externalities, such as an increase in cultural and real estate value. However, it also entails negative effects, such as visitor saturation and the commodification of heritage. These phenomena have led to the need for alternative management, governance, and mitigation strategies. Governance is the result of a long historical process of social and institutional adaptation in which power administration and social coordination have evolved from centralized, hierarchical models to complex, collaborative dynamics among multiple actors, scales, and sectors (van Assche *et al.*, 2014; Ansell and Torfing, 2022). The authors explain that there is no single theory of governance. Rather, there are multiple, overlapping theoretical discussions that offer a set of conceptual tools to address a wide range of problems in political science, public administration, sociology, economics, law, and so on. In this sense, the current concept of governance encompasses the capacity to direct diverse groups and the existence of formal and informal institutions that interact within a globalized, dynamic system. Thus, contemporary governance is inseparable from historical processes such as social differentiation, market expansion, diversification of actors, and the crisis of the state model. It consolidates itself as an analytical framework for managing complex, transnational societies.

The objective of this work is to show and understand the various forms of research aimed at studying tourism governance, collaboration, coordination, and the participation of local actors in different tourism areas. To achieve this objective, we will conduct a systematic bibliographic review, apply search criteria to specific databases, analyze these documents with statistical tools (both qualitative and quantitative), and synthesize the results. This will help us explore the main approaches, trends, and directions carried out in the field of tourism governance thus far.

2. UNDERSTANDING GOVERNANCE

Multiple governance research articles offer a key insight: the concept of governance has emerged and evolved alongside the dynamics of contemporary capitalism (Eagleton-

Pierce, 2014). Governance is understood as the manner in which institutions and individuals collaborate to achieve specific goals. It has been influenced by the changes in global capitalism. Governance not only refers to the management of institutions but is also influenced by the logics and values of capitalism. The capacity of states to govern in the traditional way is declining, and the importance of non-state actors in policy formulation and implementation is increasing due to the growing influence of international markets and supranational organizations. Due to capitalist dynamics, governance has been approached from different perspectives, which has affected the design of institutions and policies. These institutions and policies are characterized by a focus on efficiency, competitiveness, and self-regulation (Peters and Pierre, 1998; Rhodes, 2007; Ruhanen *et al.*, 2010; Eagleton-Pierce, 2014). Another prevailing idea is that governance provides an opportunity to create self-organizing networks that supplement markets and hierarchies in allocating resources. These networks are characterized by trust, which fosters innovation and reciprocity, especially in initiatives requiring collective action (Rhodes, 1996; Ruhanen *et al.*, 2010; Clegg, 2019). According to Ruhanen *et al.* (2010), from a political science point of view, governance has emerged as a response to public sector reforms in the US and the UK in the 1980s, where privatization and cross-sector collaboration were promoted. Authors as Rose-Ackerman and Palifka (2016), and Bauhr and Grimes (2014) analyze and emphasizes the importance of transparency and accountability as mechanisms for combating corruption and enhancing development. From the point of view of corporate governance, Aguilera and Jackson (2003), or Stoelhorst and Vishwanathan (2024) argue that it is a system of rules, practices and processes through which a company is directed and controlled, seeking to balance the interests of the various stakeholders (shareholders, managers, employees, customers). It has shifted to a more inclusive approach that considers multi-stakeholder relationships. As previously discussed, there is no clear consensus on the definition of governance because the term is used broadly and from different perspectives. Several scholars have defined governance as the sum of the ways in which individuals and institutions, public and private, manage social, economic, and political processes that provide for them and allow for the coordination of individual actions to achieve collective outcomes (Rhodes, 1996; Colebatch, 2014; Scott and Marzano, 2015; Clegg, 2019). It also refers to the processes and structures used to direct and manage organizations and societies. This approach suggests that social actors have become more influential in policy and administration. This challenges the traditional concept of government as a central controlling entity, as well as traditional models of public administration. This is due to the reduced ability of national governments to insulate their economies and societies from global trends. This has overtaken the well-known nation-state (Rhodes, 1996; Peters and Pierre, 1998; Rhodes, 2007). Thus, the rise of networks has become a predominant feature of governance, complementing markets and hierarchies in the allocation and control of resources (Rhodes, 1996; Peters and Pierre, 1998; Tomba, 2004). This concept is paralleled by the idea of the "hollowing out of the state" (Rhodes, 1996; Peters and Pierre, 1998), which refers to the reduction of central government's role and sovereignty. This shift transfers more responsibilities to private actors and networks at multiple territorial levels. Stoker (1998) presents five propositions regarding the meaning and representation of governance. First, governance involves institutions and actors, both governmental and non-governmental, in service provision and decision-making. Second, it acknowledges the absence of clear boundaries in responsibilities for addressing social and economic issues as

the lines between the public and private sectors have become blurred. Third, it identifies the dependence of power among the involved actors, where no single organization has absolute control. Institutions depend on each other to achieve their objectives, which requires the exchange of resources, negotiation, and agreements. These are autonomous networks of interconnected, yet independent, actors. Finally, governance depends not only on government power in the form of orders, but also on new tools and techniques for directing and guiding. In summary, governance is a complex concept that encompasses a variety of approaches and practices. Some trends that reflect a shift towards more decentralized and collaborative forms of administration are networks and stakeholders (Freeman, 1984; Jamal and Getz, 1995; Rhodes, 1997; Dredge, 2006; Klijn and Koppenjan, 2012); multilevel coordination and decision-making (Hooghe and Marks, 2001; Dredge and Jamal, 2015); resilience and adaptability (Dietz *et al.*, 2003); sustainable development (Bramwell and Lane, 1993; Dredge and Jenkins, 2007); joint or collective action (Ostrom, 1990; Hall, 2011); and "governance without government" (Rhodes, 1996; Peters and Pierre, 1998). This shift has weakened states' traditional capacity to control and direct policy, highlighting the importance of non-state actors and the influence of international markets.

In the context of tourism, the pandemic significantly and temporarily disrupted global tourism dynamics. It exposed the sector's structural weaknesses and provided an opportunity to restructure it into a more sustainable, resilient, and secure model (Rivera *et al.*, 2024). Consequently, tourism governance encompasses collective decision-making processes involving multiple public and private stakeholders in the management of tourism resources and the resolution of conflicts of interest arising from the impact of tourism. Action mechanisms, such as the United Nations' Sustainable Development Goals (SDGs) related to tourism, seek to integrate economic prosperity, social inclusion, and environmental protection in order to achieve a sustainable future. These goals promote responsible consumption practices because tourism depends on natural resources. Tourism can serve as an economic engine that helps reduce poverty by generating productive and decent employment in local communities (Carius and Job, 2019; Moyle *et al.*, 2021). These ideas about sustainable tourism from social, environmental, and economic perspectives are reflected in the European context within the transition pathway for tourism (European Commission, 2022). Through a process of joint creation with various stakeholders from European Union member countries, a set of measures is designed to combat the challenges facing the tourism sector. Governance is established as a fundamental axis for achieving these objectives. However, there is criticism about how tourism growth can perpetuate inequalities. Its relationship with sustainable development is also ambiguous due to its dependence on international tourists and foreign investment (Trupp and Dolezal, 2020; Bianchi and De Man, 2021; Moyle *et al.*, 2021). Additionally, Rasoolimanesh *et al.* (2020) demonstrate in their recent studies that residents are the most involved stakeholder group, while tourists are the least engaged compared to governments and businesses. These studies emphasize objective indicators over subjective ones. According to Ruhanen (2013) local governments are responsible for land use planning, development application regulation, and local infrastructure provision. This positions them as key players in sustainable tourism development. Their proximity to issues associated with tourism, ability to implement sustainability plans, and representation of the local community give them a central role. They can address negative impacts on communities and the environment. Hall (2011) presents governance archetypes for tourism based on characteristics and elements to provide

a general understanding through models. These archetypes include hierarchies (centralized and vertical governance structures), markets (governance based on market mechanisms and competition), networks (governance through networks of interdependent actors), and communities (governance based on cooperation and the self-organization of communities). Each archetype defines its own success criteria, implementation formulas, and policy instruments, with protagonists focusing on different actors.

3. METHODOLOGY

Several literature review techniques can be used to develop a theoretical approach, conceptual understanding, or state-of-the-art analysis. These techniques include critical analysis (Arksey and O'Malley, 2005) and mixed approaches that combine quantitative and qualitative methodologies (Creswell and Creswell, 2019). This study applies a systematic literature review accompanied by a bibliometric analysis. Although a systematized literature review does not follow all the principles of a systematic review typically associated with the health sciences, it does adopt an approach.

This type of review is commonly found in scientific articles within the human and social sciences (Codina, 2020). A bibliometric analysis is a systematic, quantitative research method used to analyze scientific production within a specific field of study. The main purposes are to discover and examine research trends, map the intellectual context of an area, and provide an overview of existing literature (Khraiwish and Alsharif, 2024). In this case, the review process is based on the SALSA framework (Search, Appraise, Synthesis, Analysis), which, according to Grant and Booth (2009) and Codina *et al.* (2022a, p. 71), is "a framework that uses four critical phases to guide and evaluate a systematic review."

1. *Search*: Design search commands tailored to the research objectives. Use relevant academic databases such as Web of Science and Scopus.

WOS search commands: ("tourism" and "governance" and "citizen participation" and "policy" and "network") or ("tourism" and "governance" and "participation" and "policy" and "local" and "community" and "network") or ("tourism" and "governance" "participation" and "collaboration" "local" and "community" and "network" or "policy") or ("tourism" and "governance" and "smart tourism").

Scopus search commands: ("tourism" and "governance" and "participation" and "collaboration" or "citizen participation") or ("tourism" and "governance" and "smart tourism") or ("tourism" and "governance" and "collaboration" and "network" or "local") or ("tourism" and "governance" and "participation" or policy and "local" and "community" or "planning" or "network"). The search parameters in Scopus were modified because of the null or scarce results extracted from some search commands used for WOS.

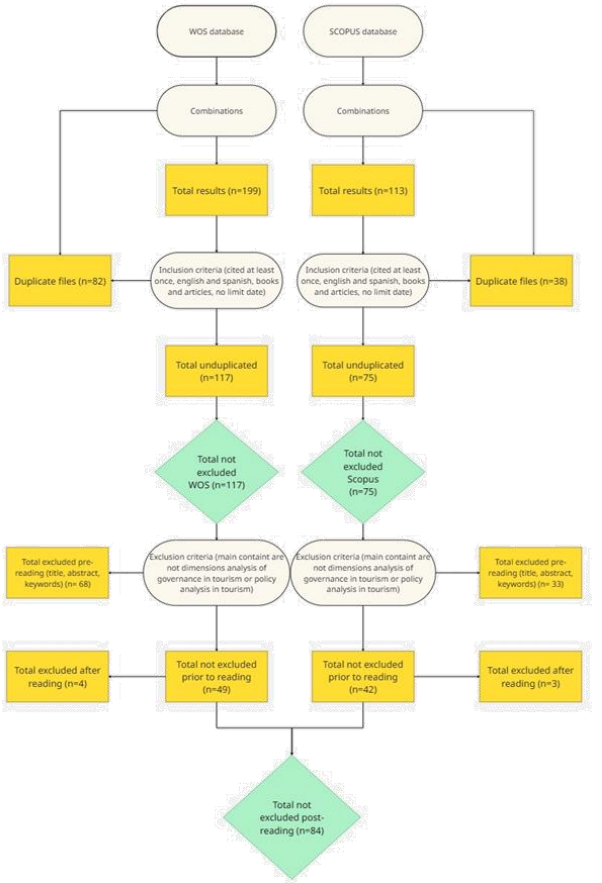
2. *Appraise*: Apply inclusion and exclusion criteria to filter the collected documents. Geographical, theoretical or methodological parameters are taken into consideration according to the objectives of the study.

WOS inclusion criteria: That they have been cited at least once in any database or journal, English and Spanish, books and articles without date or year limit, areas of social science sociology, anthropology, urban studies, history, economy and business, public administration, geography, government law, global geographic scope, and applied theoretical and empirical studies.

SCOPUS inclusion criteria: that have been cited at least once in any database or journal, English and Spanish, books and articles without date or year limit, areas of Social Sciences, Business, Management and Accounting, Environmental Science, Economics, Econometrics and Finance, Decision Sciences, global geographic scope, and applied theoretical and empirical studies.

Exclusion criteria: book, articles, documents not found (unable to access content, 17 content not found excluded) or not related to studies on tourism governance, excluded prior to reading (title, abstract, subject, keywords). Studies were excluded if, both prior to and after reading, their main objectives were not the analysis of governance in tourism (with its main dimensions as stakeholders, participation, partnership, cooperation and so on) or policies implemented in tourism.

These steps are represented through a PRISMA flow chart shown in Figure no. 1, a graphic tool used to clearly and transparently represent the study selection process (Ghesh *et al.*, 2024; Gupta *et al.*, 2024), which took place between December 2024 and February 2025.



Source: own elaboration

Figure no. 1 – Flow chart

3. *Analysis*: A procedure has been implemented to review the selected documents. The inclusion criteria focus on including documents related to tourism governance models or tourism decision-making processes. Then, analysis sheets are created for each document, covering aspects such as methodology, object of study, contributions, and main results.

In this case, we conducted a post-reading analysis of the selected studies in a comparative table. We used specific coding to measure the frequency of the following attributes:

Study authors, tourism field of study (coded as tourism planning, tourism policy, or tourism marketing), smart tourism destinations, agritourism, ecotourism, community tourism, events, sports, nature, rural tourism, urban tourism, cultural tourism, and coastal and marine tourism. Then, the year of publication of the study, the region in which it was carried out, and the stakeholders involved were coded as follows: local/resident community; civil society (NGOs, social groups, students, visitors, religious organizations, trade unions, etc.); public sector (town halls, governments, administrations, authorities, DMOs, etc.); private sector (companies, industry, local businesses, lobbies); academia; and/or experts. The methodology is coded as qualitative, quantitative, or mixed. The measures or analysis techniques are coded as qualitative (DELPHI method, interviews, participatory workshops, observation, focus groups, documentary analysis, literature review, and conceptual framework) or quantitative (network analysis, surveys, secondary data analysis, and case study review). Finally, the type of study is coded as theoretical, practical, or both.

Finally, we created frequency matrices using the R statistical program, version 4.3.2, for the variables Year, Regions, Tourism Areas, and Stakeholders Involved. Are there more stakeholders involved in studies of a specific tourism area? Are there more stakeholders involved in studies in a specific region or continent? Have more studies on a specific tourism area been carried out in a specific year? Have more studies on a specific tourism area been carried out in a specific region or country? We analyzed pre-selected attributes of tourism governance with the content analysis software Atlas.ti and examined their frequencies in English and Spanish articles. The attributes were accountability, alliance, social capital, collaboration, competitiveness, cooperation, coordination, effectiveness, efficacy, efficiency, empowerment, influence, management, participation, partnership, planning, power, resilience, sustainability, transparency, and trust.

4. *Synthesis:* Generate a new product that combines the analyses performed to produce descriptive and critical results. This synthesis can take the form of a narrative supported by tables and diagrams to identify trends, patterns, and research gaps. In some cases, explanations can be generated to support theories or hypotheses for future research.

4. RESULTS

As shown in Table no. 1, studies on tourism governance increased beginning in 2016, especially in the years following the pandemic. Within the field of tourism, the most studied topic is tourism planning, i.e., management, policies, and planning related to the tourism sector itself. Thus, tourism governance is primarily studied in the tourism planning area, followed by community tourism and smart destinations. Most studies on tourism governance have been conducted in Asia, mainly in China, the Philippines, Malaysia, India, and Indonesia, followed by Europe, well ahead of America and Africa. The stakeholders with the greatest presence and participation in these studies are from the public and private sectors. The academic sector has a stronger presence than local communities or civil society in the studies.

Table no. 1 – Frequencies according to year, tourism activity, continent and stakeholders

Year	N	%	Tourism types	N	%	Continent	N	%	Stakeholders involved	N	%
2005	1	1.19	Tourism planning	27	22.50	Asia	36	42,35	Public sector	65	25.79
2007	1	1.19	Smart tourism destination	13	10.83	Europe	26	30,59	Private sector	58	23.02
2008	1	1.19	Agrotourism	1	0.83	North America	3	3,53	Local community	45	17.86
2010	2	2.38	Ecotourism	9	7.50	South America	3	3,53	Civil society	37	14.68
2011	1	1.19	community-based tourism	19	15.83	Africa	4	4,71	Academia and/or experts	47	18.65
2012	3	3.57	event tourism	2	1.67	Oceania	2	2,35			
2013	3	3.57	sports tourism	2	1.67	General	11	12,94			
2014	3	3.57	nature tourism	10	8.33						
2015	3	3.57	rural tourism	9	7.50						
2016	6	7.14	urban tourism	11	9.17						
2017	6	7.14	coastal and/or marine tourism	9	7.50						
2018	8	9.52	cultural tourism	2	1.67						
2019	9	10.71	heritage tourism	6	5.00						
2020	3	3.57									
2021	11	13.10									
2022	4	4,76									
2023	12	14,29									
2024	7	8.33									

Source: own elaboration

In terms of methodology, qualitative studies predominate (see Table no. 2), employing techniques such as interviews, documentary analysis, literature reviews, and focus groups. Regarding the typology of studies, the vast majority focus on case studies, i.e., practical research applied to a specific context.

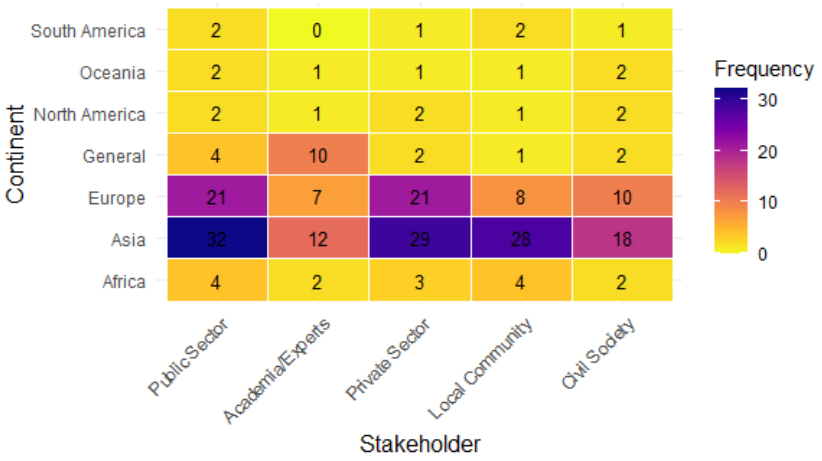
Table no. 2 – Frequencies by methodology applied and type of study

Methodology	N	%	Type of study	N	%
Qualitative	62	73.81	Theoretical	13	15.48
Quantitative	3	3.57	Practical	63	75.00
Mixed	19	22.62	Both	8	9.52

Source: own elaboration

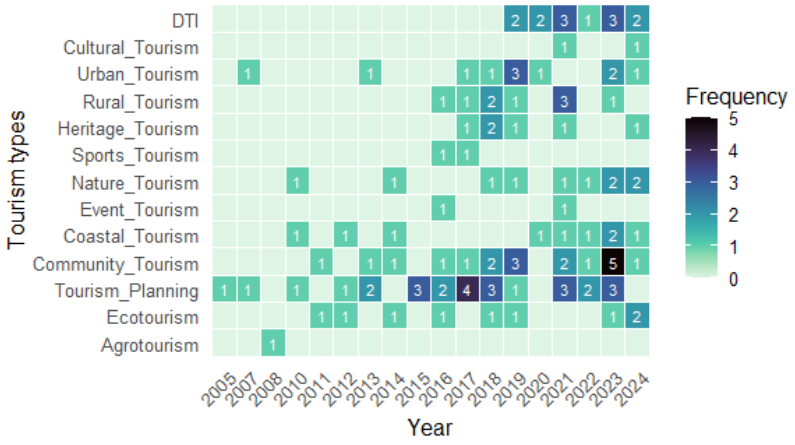
Looking at the frequency matrix of stakeholders involved in studies by region (see Figure no. 2), we see that in Europe, the public and private sectors have the greatest presence, with the local community involved in only 30% of tourism governance studies. In Asia, Africa, and South America, however, the local community shares a comparable presence and level of participation with the public and private sectors, representing 78% of the total number of studies on tourism governance carried out in Asia.

Examining the frequency matrix of publications by year and tourism field (Figure no. 3), we see that, from 2014 to 2018, tourism planning, management, and policies were the most studied area of tourism governance. Of the six publications in 2017, almost 70% were in tourism planning. Starting in 2019, community-based tourism and smart tourism destinations (from now on DTI) gained relevance in tourism governance studies. Studies on governance are also beginning to be applied to rural, urban, and nature tourism. Of the 12 publications on tourism governance in 2023, nearly half focused on community-based tourism.



Source: own elaboration

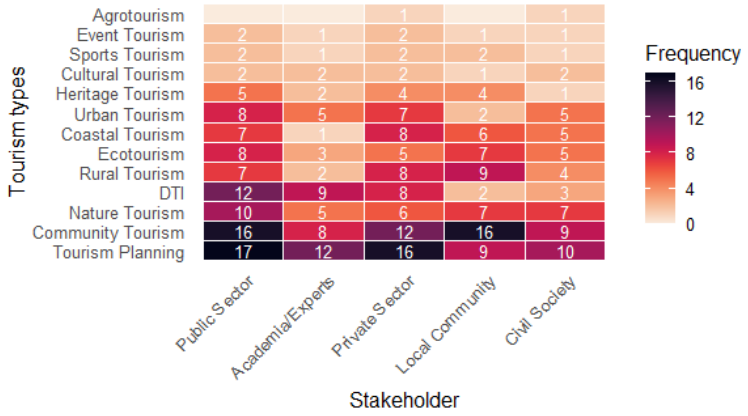
Figure no. 2 – Stakeholder frequency matrix - studies by continent



Source: own elaboration

Figure no. 3 – Matrix of frequencies in the tourism field - year of publication

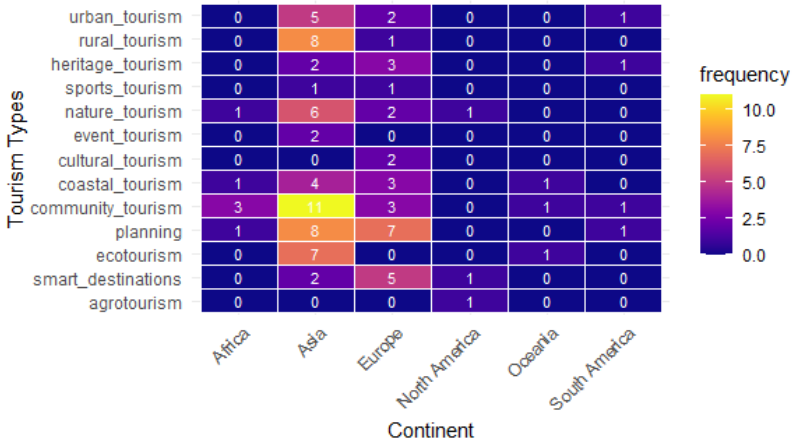
Figure no. 4 shows the frequency matrix of the stakeholders involved in the tourism studies. As can be seen, civil society has the greatest preponderance in the governance of nature and ecotourism. Academics and experts are more prevalent in smart tourism destinations and tourism planning, while local communities have a stronger presence in ecotourism, community-based tourism, nature tourism, and rural tourism. The private sector is more prevalent in coastal and marine tourism, sports tourism, events, heritage tourism, cultural tourism, urban tourism, and tourism planning. Of the total presence and participation of local communities in tourism governance studies, 35% is concentrated in community tourism. Conversely, almost 30% of the total presence and participation of the private sector is in tourism planning.



Source: own elaboration

Figure no. 4 – Matrix of frequencies in the tourism field - Stakeholders involved

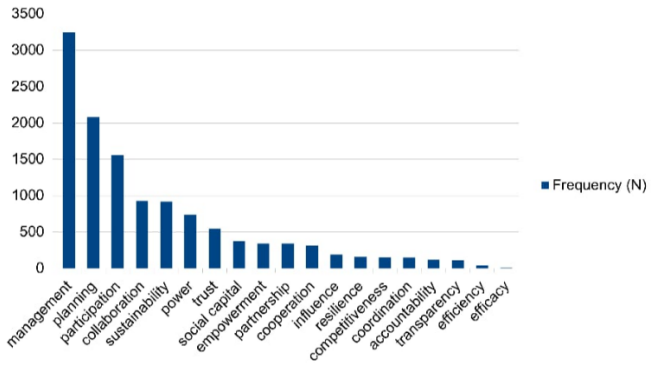
As shown in Figure no. 5, when we calculate the matrix between the field of tourism studies and the continent where they are conducted, we clearly observe that Asia has a tourism governance approach that is more oriented towards community-based tourism, while Europe focuses its studies more on smart destinations and tourism management.



Source: own elaboration

Figure no. 5 – Frequency matrix - tourism field – continent

Figure no. 6 shows the results of analyzing the selected variables through the frequency of words in the total number of scientific studies (84). The figure shows that the most frequently used variables in English and Spanish studies are "management," "planning," and "participation," followed by "collaboration" and "sustainability." However, words such as "power," "trust," "social capital," and "empowerment" are not far behind and are more prominent tourism governance variables than "resilience," "efficiency," "transparency," "competitiveness," and "accountability."



Source: own elaboration

Figure no. 6 – Frequency of governance attribute words

Depending on the field of tourism, the actors involved, the regions studied, and the object of study in each context, we could group the forms of governance into three main clusters, as shown in Table no. 3 below.

Table no. 3 – Main models of tourism governance

Governance Model	Governance oriented to community participation	Data-driven smart governance	Network-based governance
Primary Focus	Participation and empowerment of local stakeholders, equitable distribution of benefits	Digital innovation, use of technologies for management, evaluation and participation.	Collaborative networks, inter-agency coordination and critical policy reflection
Key Actors	Residents and local community	Destination Management Organizations (DMO's)	Multi-actors in collaborative networks
Role of the Public Sector	Facilitator of public participation, communication and dissemination of information	Main support to correct digital divides, centralization of information	Meta-governance in decentralization system, network capacity building support
Role of the Private Sector	Assistance in planning, promotion and implementation of events, product co-creation	Technology companies as relevant actors, development of digital platforms	Participation in multi-stakeholder collaborative networks
Role of the Local Community	Active participation in planning and decision making, local control of resources	Involvement in innovation processes, key quality of life measurement indicator	Integration in collaborative networks
Role of Academics/Experts	Neutral role, support in information analysis and collective action processes	Support to OGD, definition of indicators and provision of theoretical models	Contribution of analytical frameworks and methodologies
Implementation Mechanisms	Bottom-up participatory processes, decentralization policies	Collaborative platforms, Living Lab models, big data and indicators	Indicator systems, consultative processes, dialogue and conflict management

Source: own elaboration

5. DISCUSSION

This leads us to ask a key question about understanding the complexity of measuring and assessing the impact of tourism governance, as well as the sectorization of stakeholders. This study brings us closer to synthesizing tourism governance from a holistic perspective. The three "clusters" shown in Table no. 3 above are the result of Hall (2011)'s four standardized models of tourism governance. However, we understand that these pure models do not exist in reality, but rather are combinations of them. Similarly, there are no models from a purely managerial or political perspective; rather, both are mixed. Management and policy perspectives ("how" and "why") explain governance models ("what"). Tourism governance is an inherently hybrid and complex field involving human actors, such as governments, businesses, communities, and tourists, as well as non-human actors, such as natural resources, infrastructure, technologies, cultural heritage, and animal species. The first step is recognizing that tourism is an inherently hybrid phenomenon. Therefore, it cannot be rigidly separated from society or discourse in the analysis, technique, or science of tourism, as Latour and Goldstein (2012) explained in their premise of the three misunderstandings. Agencies and institutions can "speak" in governance processes. Climate data, endemic species, digital platforms, and infrastructures are not passive resources; they influence decisions and the exercise of power.

However, these governance models have their own intentions and configurations. Their strategy, technique, and methodology cannot be considered "neutral," but rather are conditioned by various factors:

– The technical and political profiles of decision-makers and coordinators. Which dimensions are relevant and prevailing based on their worldview? Professional profiles in law may emphasize accountability, while political science emphasizes trust and transparency. Social science focuses more on participation and equity, and economics focuses more on efficiency and planning. When a few professions dominate public administration, views of reality that are not represented emerge.

– The agenda and power: The geographical concentration of most tourism governance studies and scientific production in Asia and Europe can influence the theoretical and methodological approaches to researching this topic. The presence of certain stakeholders in the studies analyzed does not necessarily imply their effective participation in actual governance processes. This distinction between what is studied and what actually happens raises a key question about understanding the complexity of measuring the impact of tourism governance and the sectorization of stakeholders. Does greater involvement, collaboration, and participation by a particular stakeholder imply greater influence or decision-making power over public issues? In a tourism context, does greater participation and involvement in alliances or decision-making processes offer greater power over implemented policies? Redefining governance as a form of state deregulation to the detriment of self-regulation changes the power dynamics between the government, businesses, and civil society. This shapes the concept of "smart" management, which comes from the organizational and business sphere and refers to tourism or tourist destinations. Inaction is also interpreted as an exercise of power in governance. Power struggles in local contexts hinder the adoption of sustainable policies and are reflected in symbolic public consultations whose decisions are predetermined.

Despite the creation of new forms of participation, such as citizen participation bodies, assemblies, and consultations, governance approaches have moved away from democratic deliberation and toward technocratic and economic management logic. The involvement of certain actors in decision-making processes is often insufficient. This can be seen from the need to incorporate more participatory methodologies, integrating socio-analysis or participatory action research in a complementary manner with quantitative governance indicators. It can also be seen from the perspective that governance (and its methodological study) is also influenced by social power relations, which are often asymmetrical. Failing to consider these asymmetrical power relations between social groups and actors in tourism governance studies can result in conceptualizing governance as purely technoscientific and overlooking the political elements of power, social capital, and the (dis)empowerment of actors. This can lead to a biased interpretation of decision-making in tourism matters, which would undoubtedly cause complications in achieving sustainability goals and objectives for the sector.

6. CONCLUSION

The conceptual framework of governance seems to stem mainly from two perspectives: corporate management and political science. This is reflected in the attributes analyzed most frequently, where "management," "planning," and "collaboration" predominate over attributes such as "power," "trust," "social capital," and "empowerment." The overwhelming focus of studies on tourism planning and management is seen as reflecting the dominance of a managerial approach. This dominance comes at the expense of perspectives that focus on power, legitimacy, trust, and distributive justice.

Since the boom in tourism governance studies between 2015 and 2017, most studies have been developed from a corporate and institutional perspective of management, planning, and public policies. However, these approaches diversified in two stages: the pre-pandemic period, during which tourism governance began to be applied to urban areas, communities, and the concept of smart destinations, and the post-pandemic period, during which rural and natural areas were also included. Tourism governance practices vary significantly across regions and sectors. The level of stakeholder relevance and participation is sectorized according to the tourism field. Europe and the West tend to focus on the role of networks and place greater emphasis on public-private partnerships. Their approach is geared toward planning and managing smart tourist destinations. Civil society and local communities in Asia and Africa, particularly in China, have a level of participation that is comparable to that of the private sector. The private sector appears to play a larger role in rural and urban areas, as well as in coastal and marine areas and smart destination management. Conversely, local communities are also relevant in rural areas but are more prevalent in ecological, nature, and community areas. The least studied areas of tourism in terms of governance are mainly cultural tourism, agritourism, and sports tourism. The predominance of qualitative methodologies in case studies suggests that a greater understanding of tourism governance can be achieved in specific, subjective contexts, making it difficult to standardize quantitative indicators or forms of measurement applicable to all cases. Finally, most of the research focuses on practical case studies, each of which is studied and analyzed based on its particular dimensions and characteristics.

The dominant dimensions of each model are closely linked to its objectives and the leading actors. Community governance emphasizes participation, empowerment, trust, and

equitable distribution of benefits. This model aims to grant the local community more control over resources. In data-driven smart governance, the dominant dimensions are efficiency, competitiveness, and decision-making planning. It focuses on modernizing management through digital platforms and big data. Meanwhile, network-based governance emphasizes collaboration, cooperation, transparency, and resilience. This model emphasizes creating strategic alliances and managing conflicts between multiple actors.

7. IMPLICATIONS OF THE STUDY

The typology proposed in this study provides the necessary structure to organize a field of study that has, until now, been characterized by significant conceptual and methodological fragmentation. By synthesizing the literature into three clear models, the study enables the integration of tourism governance approaches, which are often focused on corporate efficiency, with political science approaches, which emphasize power, legitimacy, and transparency.

The importance of meta-governance is emphasized. According to Meuleman (2010), the state should not abandon its function but rather adopt the role of facilitator and designer of frameworks. This approach warns against the risks of overly technocratic methods, which can transform governance into a purely technical matter. These methods prioritize certain dimensions over others depending on the context and time, overlooking the asymmetries of power and the social capital necessary for effective cooperation, collaboration, and coordination between multiple actors, especially when it comes to achieving sustainable development goals.

Although the community model promotes citizen participation and equity, the shift toward "smart" or managerial approaches to governance requires monitoring to prevent democratic deliberation from being replaced by symbolic consultations with predetermined outcomes. This shift can generate conflicts between sustainability and well-being, on the one hand, and competitiveness, efficiency, and tourism growth, on the other. National political and administrative traditions influence which combinations of the models presented in this study are viable. Good practices cannot be transferred between countries without profound adaptation to the local context. Metagovernance can play a key role as a post-dogmatic tool that prioritizes flexibility over rigid doctrines based on cultural preferences to solve complex social problems. The legitimacy of the system depends on governance being a tool not only for market self-regulation but also for empowering local actors.

8. STUDY LIMITATIONS

The review was limited to the Web of Science and Scopus databases. While these databases are considered benchmarks in the academic field, excluding others may have resulted in the omission of relevant studies in specific local contexts. Additionally, the Scopus search commands had to be modified due to the initial scarcity of results, which suggests that the search terms may be too specific. The inclusion criteria were restricted to documents in English and Spanish. This limits our understanding of governance in regions where scientific output is predominantly published in other languages. Furthermore, the majority of studies are concentrated in Asia and Europe, leaving the dynamics of America and Africa underrepresented. This leads us to conclude that there may be dynamics and

concepts that are less explored outside the anglo-hispanic axis. This could make the idea of governance in tourism even more complex, while also providing a more holistic view.

The creation of a comprehensive analytical framework and the development of standardized dimensions for two cross-cutting, multidimensional concepts such as governance and tourism can be complicated by conceptual ambiguity and the fact that almost 74% of the analyzed studies are qualitative in nature and 75% are specific case studies. This makes it a highly fragmented field of study that could fall into excessive relativism.

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A Pathway towards Sustainable Economic Development: The Role of Stock Market Development from Cross-Country Reference

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Abstract: Stock market is the financial enabler of sustainable economic development as stock market enables the corporations with long-term capital. The aim of this study is to estimate the effect of stock market development on the development of an economy. The article is grounded on the sample of 51 developing and 32 developed countries from the year 1991 to 2022. The study has considered two stock market development indicators i.e., stock market capitalization (MCAP) and listed domestic companies, and applied the panel VAR model. In the short run, both the indicators of stock market development are positively related with the economic advancement of the developed as well as developing countries. Interestingly, investment and government expenditure are adversely associated with the economic progress of developed as well as developing countries. Furthermore, savings and trade are positively connected with the economic development of developing countries whereas this linkage is adverse in the developed countries. Panel causality test reports bidirectional relationship between MCAP and economic performance. This result supports the feedback theory of financial system as MCAP and economic development reinforce each other. Variance decomposition test and IRF are also applied to support the above results. This study is significant for the government and policymakers in formulating effective strategies for developing the stock market and views it as an important avenue for mobilizing the capital towards innovation, sustainable environment and governance practices.

Keywords: stock market development; economic development; Panel VAR; cross-country analysis.

JEL classification: B22; E44; F63; G15.

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1. INTRODUCTION

Stock market is viewed as a significant sub-sector of the financial system and is presumed to exert a significant developmental role on the global finance and economy (Adjasi and Biekpe, 2006)). Sound financial system is prerequisite for financial efficiency, financial inclusion, and financial depth. Put differently, financial development enables the corporations with eco-friendly technology, helps in eliminating inequality and poverty which are closely associated with the sustainable economic development (Ahmed *et al.*, 2022; Dutta and Saha, 2023). Well-developed financial sector efficiently allocates the resources towards real sector of an economy by giving the diversification benefits of portfolio, reducing the liquidity risk of financial instruments to investors (Nowbutsing and Odit, 2009). Therefore, advanced stock market facilitates an economy through numerous networks, among them important are capital allocation and total factor productivity (Ang, 2008). Another way, improved financial system accelerates the economic development via improved financial services, liquidity and investment, (Adjasi and Biekpe, 2006; Ho, 2019) upgrading the problem of information asymmetry, human capital development, (Fanta, 2017; Pradhan, 2018) lessening the cost of corporate governance and information cost (Guru and Yadav, 2019). This view is termed as supply-lending hypothesis in the literature (Calderón and Liu, 2003; Ibrahim and Alagidede, 2018; Pradhan, 2018; Taddese Bekele and Abebaw Degu, 2023).

Another view in this regard figured out that, economic development through an enhanced demand for financial services acts as a chief driving force of financial sector development (Mtar and Belazreg, 2023). As enhanced demand for financial services emerges more financial products, services, intermediaries and financial institutions (Ang, 2008). Additionally, economic growth generates surplus in the economy, which supports in fueling the financial sector (Pan and Mishra, 2018). This view is termed as demand-following hypothesis (Calderón and Liu, 2003; Pradhan, 2018).

The rising status of stock market throughout the globe has recognized the fact that finance is a crucial element of growth. Healthy stock market of a nation assists the corporates and enhances their efficiency and financial strength (Zhang *et al.*, 2011). Development of stock market is defined as in terms of expand of size, liquidity and stability of the market along with greater access to the market which can provide several advantages to the economy (Guru and Yadav, 2019). Otherwise, the role of equity market in the advancement of an economy is measured by the volatility level of share market (Pan and Mishra, 2018). As more fluctuations in the market may be the reason of scams in the market which reduces the credibility of the market in the eyes of investors. Financial development generally affects the economic development directly through the expenditure channel and indirectly through the inflation (Pradhan *et al.*, 2014). Ibrahim and Alagidede (2018) opined that financial sector enlargement hampers the economic progress when there is a disproportionate growth of real and finance sector output.

Well-developed financial system, specifically stock market of a country helps in efficiently mobilizing foreign capital and domestic savings (Pan and Mishra, 2018; Mehmood and Bilal, 2024) toward the productivity of real goods and services. Second, an efficient stock market assists the institutions through the adoption of modern technology and by the provision of financial facilities and other related financial services. Third, stock market creates an avenue for the corporations to meet their financial requirements in an efficient and inexpensive way. Fourth, developed stock market helps in increasing the transparency and

reporting standards; funds innovation and green environment and shifts its funding towards ESG (environment, social and governance) stocks, which are directly aligns with the targets of sustainable development goals (SDGs). Therefore, it is perceived that stock market acts as an engine in the growth of corporations and ultimately sustainable economic development.

Developed and developing country's economy carries varied characteristics in terms of social, political, geographical, environmental, financial and other related factors. Share prices reflect all these factors related to the economy. These above stated factors influence the level of development in the dissimilar manner. Considering these factors, government, stock market regulators, stock market analysts and policymakers regulate the financial sector through various policy decisions and reforms. So, it is also important to empirically analyse the nexus in the framework of developed and developing country's economy separately. This study is framed to cover the gap of the existing literature through various paths. Firstly, this study shows the linkages of stock market development (hereafter, SMD) with the development of an economy. Second, it shows the degree of effect, magnitude and causal direction among the economic development, SMD parameters and various macroeconomic control variables. Third, this study is focusing on the large number of developed countries as a group and developing countries as a group so that generalisation of the results is possible. Fourth, in empirically analysing the results, this study considers four macroeconomic variables (investment, public expenditure, savings and trade) as control variables for the robustness of the result. As, these macroeconomic indicators have an influence on the stock market as well as on the overall economy.

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

In many countries' economy, due to the unavailability or constraints in debt finance, the importance of equity market is rising for raising the funds by the corporates. In the prevailing literature, there is no harmony concerning the association of SMD and real economy as the association varies from one nation to another depending on the institutional factors, macroeconomic factors, firm level factors, structural factors, technological, global and other factors.

Nowadays, the need of stock market is growing around the world as it efficiently allocates the savings toward the productivity of real output, which eventually leads to the sustainable economic development. Stock market provides liquidity of the investment amount, diversification benefit and information to the investors. Many researchers argue that, stock market capitalization does not truly capture the picture of the real economic situation as it is largely driven by the share prices of the big multinational companies (Pan and Mishra, 2018).

In the research executed in the scope of 12 MENA region countries, Ben Naceur *et al.* (2007) have found that, savings rate, stock market liquidity and financial intermediaries are a significant positive element of the SMD. According to Yartey (2010), good quality of institutions, economic growth, domestic investment and stock market liquidity are substantial elements for developing the stock market. Taking quarterly data over the period from 2001Q4 to 2016Q4, Ho and Odhiambo (2018) have identified the various macroeconomic determinants of SMD in the Philippines. Through ARDL approach, the study highlighted that, trade openness adversely affects the SMD in the long period of time. In another study, Pradhan *et al.* (2020) have investigated that, development of equity segment and bond market are cointegrated with the economic progress, interest rate and inflation rate of G-20 countries. Share market liquidity

and size are positive contributors in the mobilization of savings and mitigation of risk with the easiness of share trading in the developing economy of Nepal (Bhattarai *et al.*, 2024).

Kassimatis and Spyrou (2001) have found in the economies of India and Taiwan that, stock market adversely affects the economic expansion rate but in South Korea, equity market is effective in promoting the economic development. Osinubi and Amaghionyeodiwe (2003) have assessed the nexus between Nigerian SMD and economic progress and exposed that indicators of SMD does not pose significant impact on the economic expansion. By applying quarterly data from the period 1979Q1 to 1998Q4, Caporale *et al.* (2005) have exposed that, in the long term, SMD accelerates the economic progress rate through the channel of investment productivity in the less developed countries. Positive correlation of economic growth with the Ivorian SMD index, FDI, public investment, development aid and expenditure has been showed by the N'Zué (2006). On the one hand, Deidda (2006) has exposed that, the connection between finance and growth is strongly positive in the relatively developed economies. On the other side, this connection is much weaker in the comparatively less developed countries. In the same year, Nieuwerburgh *et al.* (2006) have confirmed that advancement of stock market caused the economic progress specifically between the perioud 1873 and 1935. In the region of MENA, Naceur and Ghazouani (2007) have considered the nexus between bank, equity market and economic growth and infer no significant association between bank and SMD and economic progress. In Egypt and South Africa, Enisan and Olufisayo (2009) have studied the favorable long-run impact of SMD on economic progress. Though, weak sign of growth induced finance is evidenced in Nigeria, when market size is taken as a parameter to gauge the SMD. Interaction between financial development and economic progress through the dynamic panel GMM model was tested by Fung (2009) and reported the convergence to growth path in both financial development and per capita GDP of high and middle-income countries. Besides, in high-income economies, economic freedom positively affects the growth path of financial development and per capita GDP.

Choong *et al.* (2010) have investigated that, in emerging countries, market capitalization (MCAP) is adversely associated with the economic progress but another measure of stock market i.e., total stock value traded is positively associated. In developed countries both, value of traded stocks and MCAP are positively linked with the economic growth. Over the period 1995-2010, based on Granger causality test, Carp (2012) attempts to evaluate the bondage of SMD with the economic progress. Experiential results indicated that, MCAP and value traded does not influence the economic progress rate of Romania. In the same year, Yu *et al.* (2012) have noticed a slower rate of economic progress despite the development of financial and stock market in the short term in underdeveloped countries. In the context of ASEAN nations, Pradhan *et al.* (2014) have conducted the study and observed that, a sophisticated stock market is indispensable for the smooth operating of overall financial system and to elevate the productivity and investment level in the economy, which will further enhance the growth level and attracts the FDI in the economy. Later on, Ngare *et al.* (2014) have found that countries having relatively developed stock market, tend to grow slower than the stock market of less developed countries. Interestingly, Palcau and Pop Silaghi (2025) have experienced that, nations with stock market oriented financial sector, exhibits strong causal nexus towards economic growth from the stock market. By taking three pointers of development of equity market into consideration i.e., MCAP, turnover ratio and value of traded shares, Naik and Padhi (2015) have checked the impact of these on the growth rate of GDP. In the context of 27 emerging economies the research reported that, all three equity market development parameters significantly contributed towards the growth of an economy.

In the framework of 34 OECD countries, Pradhan *et al.* (2015) have found that in the long-term, SMD does not spur the further economic growth. From CCE and AMG estimation, Durusu-Ciftci *et al.* (2017) have reported that, SMD positively impacts the economic growth of financially developed stock market-based economies and this impact is found insignificant for some other countries. In a quite similar study, Nyasha and Odhiambo (2017) have stated that, stock market based financial development has a favorable impact on the economy of Kenya. However, Fanta (2017) has revealed that, in developed economies, bond markets are more paying towards the economic growth as compare to stock market and banks. But the same is not true for developing economies. In line with the other studies, Pan and Mishra (2018) have figured out the several channels by which financial markets drive the economic advancement of Chinese economy. Within the framework of ARDL bound test, Qamruzzaman and Wei (2018) have confirmed that, three undertaken indicators of equity market development are enhancing the economic growth. Among macroeconomic control indicators, investment and government expenditure shows positive relationship however, inflation shows an adverse relationship with the economic growth.

Krinichansky and Sergi (2019) have presented that, financial development upsurges the economic progression of Russian's region through productivity growth. In the same manner, Guru and Yadav (2019) through generalized method of moment estimation have stated that, when value of shares traded regressed as a gauge of financial development, then it is rising the economic progress. But when turnover ratio is regressed then the result does not remain same. Along these lines, Yang (2019) has categorized the countries as high-income group, middle to high graduates and middle-income group to check the consequence of financial development on the economic progress. The study observed that, SMD has a strong positive impact on the growth of all three categories of economies. Linkages among monetary stability, financial stability and growth have empirically searched by the Apostolakis and Papadopoulos (2019). Bidirectional causality is marked between financial stress and GDP and between inflation and economic growth. Moreover, positive shock in financial stress has an adverse impact on all the macroeconomic indicators. Cave *et al.* (2020) have revisited the issue and terminated that, positive relationship is observed between SMD indicators and economic growth up to a fixed level but beyond that this relationship becomes negative. In both advanced and developing economies, financial development promotes environmental sustainability (Kirikkaleli and Adebayo, 2021).

Dabwor *et al.* (2020) have evaluated the impact of share market volatility on the economy of Nigeria and resulted the insignificant bearing of share market returns on the economic progress. Throughout the period 1996-2018, Fakudze *et al.* (2022) have revealed through the ARDL test, the presence of association (long-run) between financial expansion and economic advancement. Employing FMOLS and DOLS models, Ahmed *et al.* (2022) have asserted that, both financial development and institutional quality are positively and in a significant manner related with the green growth of South Asian Countries. More recently, Ibrahim *et al.* (2022) have documented the threshold point of inflation, below which financial development accelerates the economic progress rate. But, beyond that threshold point, inflation weakens the power of financial development in effecting the level of economic progress. Based on the above drawn literature, the following hypotheses are stated:

H*$_1$: Stock market capitalization does affect the economic development.*

H*$_2$: The numbers of listed domestic companies do affect the economic development.*

3. DATA AND METHODOLOGY

3.1. Data

This study is undertaken with the aim to find out the effect of SMD on the economic development of 83 countries worldwide in the presence of some control variables. These 83 countries are separated into 51 developing and 32 developed countries for the empirical results. List of all the developed and developing countries are reported in Annex. In the study developed and developing countries are taken as per the accessibility of data. The classification of developed and developing countries are as per the report of "World Economic and Prospects (2022)", United Nations (Sidek and Asutay, 2021; Agarwalla and Sahu, 2025). Annual data of all the variables are considered over the time period of 1991 to 2022. The time period is considered following the era of post-liberalisation. As liberalisation relaxes the restrictions, trade barriers, laws and regulation, allows the involvement of private sectors (i.e., privatisation), FDIs and overall, integration of domestic economy with the global landscape (i.e., globalisation) has taken place which infuses dynamic competency and expands the activities of financial and real sector. The annual data of all the variables were gathered from "World Development Indicators" of the "World Bank".

For measuring the development of stock market, the present study undertook two measures i.e., 'stock market capitalization' (MCAP) and the 'number of listed domestic companies' (LDC). Besides these explanatory variables, various other control variables are also treated in the model. 'Gross capital formation' is taken here as a measure of investment (GCF), 'general government final consumption expenditure' as a reflector of government expenditure (GE), 'gross savings' and 'trade volume as a percentage of GDP' are taken here as a control variable. The dependent variable of this study is economic development (GDP) proxied by 'per capita gross domestic product'. The dependent variable of this study, that is GDP per capita, is transformed into the log value.

3.2. Methodology

Following the work by Agarwalla and Sahu (2024); Taddese Bekele and Abebaw Degu (2023); Ibrahim *et al.* (2022) and Naik and Padhi (2015), the econometric model to detect the relationship between SMD and economic development in the existence of four control variables (investment, government expenditure, savings and trade) is developed as follows:

$$LnGDP_{it} = \alpha_{0it} + ß_{0it}MCAP_{it} + ß_{1it}LDC_{it} + ß_{2it}GCF_{it} + ß_{3it}GE_{it} + ß_{4it}Savings_{it} + ß_{5it}Trade_{it} + \mu_{it}$$

where i = 1,2,3,4…, N signifies the country of a sample; t = 1,2,3,4…., T indicates the year for each country; α indicates the intercept term, $ß_j$ (here j = 0,1,2,3) denotes the elasticities of economic development concerning market capitalization, listed domestic companies, investment, government expenditure, savings and trade respectively and μ represents random error or disturbance term.

Different statistical and econometric techniques related to the panel data approach are labelled in detail in the following:

3.2.1. Panel Unit Root Test

As we know regression analysis with the non-stationary series leads to false result. Therefore, before any analysis it is required to test the stationarity condition of all the variables to avoid the false result. Following the panel data structure, this study applies three different panel unit root tests viz.: "Levin, Lin and Chu test" (LLC) by Levin *et al.* (2002); "Fisher ADF test" and "Fisher PP test" by Maddala and Wu (1999). Out of these three-unit root tests, LLC considers homogeneity but other two tests by Maddala and Wu (ADF and PP) consider heterogeneity.

3.2.2. Panel cointegration

Following the results of the stationarity test of the variables, if all the variables are stationarity in the same order, then one can apply the cointegration test. In this study we applied the residual-based 'panel cointegration test' of Pedroni (1999) to detect the existence of long-run relationships. The cointegration test of Pedroni is well known, as it presumes independence and heterogeneity into account. The cointegration test of Pedroni is based on the seven test statistics, out of them four are panel based also recognized as within-dimension tests, which considers the common autoregressive coefficients. Another three are group-based test statistics also recognized as between-dimension tests.

3.2.3. Panel Vector Autoregression

In case of non-existence of cointegration between the undertaken variables, one can move towards the PVAR ("Panel Vector Autoregression") model for detecting the short-term relationship. In the VAR model selection of lag length is an important criterion. This model is a multivariate equation model that treats in the system all the variables as endogenous and also considers unobserved individual heterogeneity. Following the Love and Zicchino (2006); Abrigo and Love (2016) this model takes into account the individual sample differences and their impact on the model parameters to appropriately show the interaction among the variables. Unlike the traditional VAR, the PVAR method is more robust as it enhances the estimation sample which allows the result to be more consistent.

3.2.4. Panel Causality Test

The presence of cointegration among the variables implies the existence of causality between at least two variables of interest, although the direction of causality is unknown. For getting the route of the causal relationship between MCAP, LDC, GCF, GE, Savings, Trade and GDP per capita this study has applied the panel VAR causality test.

3.2.5. Robustness Tests

To check the robustness of the causal relationships, the study utilizes Impulse Response Function (IRF), which shows within the system, the response of a variable to the variation in other explanatory variables, while all other shocks are considered as equal to zero.

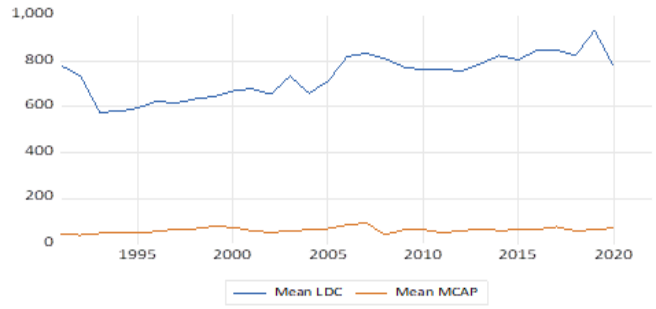
Robustness can also be verified utilizing the variance decomposition analysis (VDA), which accounts for the breakdown of the value of the variable arising from changes in the value of itself along with other explanatory variables in the previous periods. These robustness tests give added support on the existence of causal relationship between the variables.

4. ANALYSIS AND FINDINGS

This section represents the trends and findings of different applied statistical econometric tools namely panel unit root, panel cointegration, panel vector autoregressive, panel causality test, and robustness check (IRF and VDA).

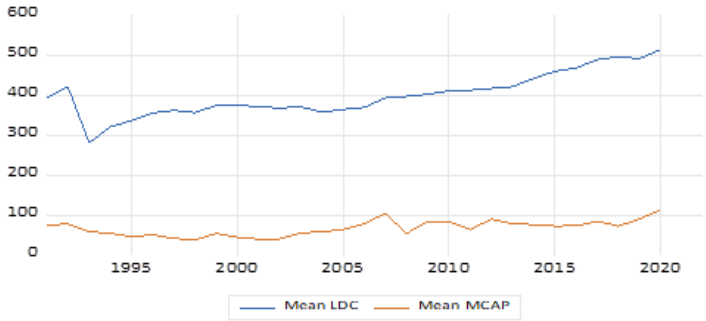
4.1. Trends of MCAP and LDC

In Figure no. 1, the authors display the trend of the means of SMD variables (MCAP and LDC) in the economy of developed nations. From the below figure it is apparent that, in developed economies, the trend of the mean of LDC is increasing with the exception of few years. The volatility of the mean of LDC is high over the years. But the mean value of MCAP is more or less stable throughout the study period and fluctuation in it is less.



Source: prepared by authors

Figure no. 1 – Trend of MCAP and LDC (Developed Countries)



Source: prepared by authors

Figure no. 2 – Trend of MCAP and LDC (Developing Countries)

On the other hand, Figure no. 2 pictured out the same thing as above (Figure no. 1) in developing countries economy. The curve of both mean LDC and mean MCAP are towards the upward direction. In absolute figure, the value of increase in mean LDC is more as compare to the mean of MCAP value. From Figures no. 1 and no. 2 it is clear that, in developing nations, the rate of growth in MCAP and LDC are more as compared to the developed nations. Interestingly, during the timespan of this research work, the difference in the mean value of LDC is too wide in developed and developing economies.

4.2. Descriptive Statistics

In Table no. 1, results of the summary statistics are presented which defines the nature of the variables considered in this study. Mean value of the variable GDP per capita is 10.227 and 8.674 with the standard deviation value of 0.718 and 1.175 in developed and developing countries respectively. It indicates that, in both set of countries inconsistency is not high in the series. In advanced and emerging countries, the average value of market capitalization is 61.169 and 70.182 with a variability of 50.913 and 140.94 respectively. This implies, variability of the variable MCAP is high in emerging countries. In developing countries, the maximum and minimum value of MCAP remains between 1777.2 and 0.009 within the studied timeframe which also supports the above-mentioned result. On the other side, fluctuation of listed domestic companies shows the unstable values of 1299.329 and 855.11 around the mean in advanced and emerging nations respectively. In developed countries, GCF or investment on an average stand at 23.1 with the highest and lowest values of 1.157 and 54.954 respectively. Mean value of government expenditure stands at 19.402 and 14.707 with a steady fluctuation rate of 3.34 and 5.674. The SD value of other control variables i.e., savings and trade are also stable in both types of country sets. Moreover, out of the studied variables, only two variables i.e., GDP per capita and government expenditure are negatively skewed in the result of developed country set but in the developing country set, the only variable savings is negatively skewed.

Table no. 1 – Descriptive Statistics

	Developed Countries						
	LnGDP	**MCAP**	**LDC**	**GCF**	**GE**	**Savings**	**Trade**
Mean	10.227	61.169	728.475	23.100	19.402	22.753	97.584
Median	10.398	46.418	174.500	22.910	19.332	22.421	79.170
Maximum	11.629	321.935	8090.0	54.954	30.323	50.921	388.120
Minimum	8.171	0.023	0.000	1.157	10.424	4.661	15.810
Std. Dev.	0.718	50.913	1299.329	4.088	3.340	6.062	62.479
Skewness	-0.654	1.472	2.740	0.633	-0.098	0.332	1.865
Kurtosis	3.020	5.625	11.263	8.177	3.127	3.704	7.185
	Developing Countries						
Mean	8.674	70.182	402.094	24.613	14.707	24.216	86.099
Median	8.556	34.97	163	23.327	13.957	23.383	72.375
Maximum	11.765	1777.22	5999	48.869	76.222	66.884	442.62
Minimum	6.215	0.009	2.00	5.359	0.911	-236.24	13.753
Std. Dev.	1.175	140.94	855.11	7.381	5.674	13.231	64.478
Skewness	0.379	6.75	4.578	0.647	1.551	-5.321	2.868
Kurtosis	2.552	57.781	25.789	3.146	13.869	109.115	13.046

Source: prepared by authors.

4.3. Panel Unit Root

The results related with the integration order of the variables are stated in Table no. 2. Out of the applied three test statistics, the variable MCAP is stationary at level as per the results of only one test statistic i.e., LLC in developing country set. Another variable, LDC is stationary at level in developed sample set according to the result of only one test statistic out of three, at 5% level of significance. Whereas, in both developed and developing sample sets, all the seven variables become stationarity after the first difference or otherwise, it is said that they are integrated of I(1). In the nutshell, we can say that all the studied seven variables are found to be non-stationary at level and they become stationary after their first difference in both types of sample set.

Table no. 2 – Panel Unit Root Test Result

Variables	Levin, Lin & Chu		Fisher - ADF		Fisher - PP		Order of Integration
	Level	1st Difference	Level	1st Difference	Level	1st Difference	
Developed Countries							
LnGDP	12.86	-11.42***	0.94	253.67***	0.62	460.69***	I(1)
MCAP	-1.31	-24.47***	63.02	574.89***	66.15	848.44***	I(1)
LDC	-2.06**	-15.92***	74.14	364.06***	71.90	551.24***	I(1)
GCF	-0.18	-24.30***	35.51	625.58***	43.26	862.12***	I(1)
GE	0.29	-23.14***	37.66	577.83***	32.19	687.99***	I(1)
Savings	0.76	-20.89***	33.77	503.86***	37.92	810.23***	I(1)
Trade	7.28	-21.30***	5.85	509.86***	3.16	705.45***	I(1)
Developing Countries							
LnGDP	12.43	-11.80***	10.27	460.82***	8.10	717.05***	I(1)
MCAP	-3.73***	-23.96***	106.01	724.26***	122.44	1283.6***	I(1)
LDC	0.85	-20.00***	75.49	547.65***	83.65	691.63***	I(1)
GCF	-1.34	-29.16***	80.97	907.60***	88.09	1607.9***	I(1)
GE	0.51	-27.94***	68.70	836.93***	94.17	1258.3***	I(1)
Savings	-0.68	-27.68***	81.09	841.24***	107.10	1459.0***	I(1)
Trade	0.79	-28.43***	55.48	861.19***	55.06	1698.3***	I(1)

Note: ***Signify statistical significance at 1% level and ** at 5% level.

Source: prepared by authors

4.4. Correlation Matrix

Correlation shows the relationship between the variables considered in the study. From the Table no. 3 it seems that, in the developed countries data set, all the response variables are positively related with the GDP per capita, except the GCF and GE, which are negatively related but this relationship with GCF is not significant. In developing country's data set, all the explanatory variables are positively correlated with the response variable i.e., GDP per capita except the LDC. Moreover, the table shows, explanatory variables are not highly correlated among themselves in the case of both set of countries.

Table no. 3 – Correlation Matrix

Variable	LnGDP	MCAP	LDC	GCF	GE	Savings	Trade
Developed Countries							
LnGDP	1						
MCAP	0.64***	1					
LDC	0.242***	0.416***	1				
GCF	-0.040	0.036	-0.053	1			
GE	-0.09***	-0.33***	-0.19***	-0.16***	1		
Savings	0.433***	0.279***	-0.13***	0.475***	-0.13***	1	
Trade	0.099***	0.004	-0.41***	-0.054	-0.12***	0.116***	1
Developing Countries							
LnGDP	1						
MCAP	0.335***	1					
LDC	-0.09***	0.237***	1				
GCF	0.002	-0.0105	0.339***	1			
GE	0.281***	-0.08***	-0.13***	-0.18***	1		
Savings	0.247***	0.147***	0.293***	0.523***	-0.24***	1	
Trade	0.428***	0.636***	0.029	0.106***	-0.09***	0.315***	1

Note: ***Signify statistical significance at 1% level.

Source: prepared by authors

4.5. Panel cointegration

Undertaken all the variables of this study are integrated of the same order i.e. I(1), which advocates the implementation of a panel cointegration test. Based on the results gained from the cointegration test of Pedroni in Table no. 4, in developed countries set, out of eleven (comprised of weighted and unweighted) statistics, the p-values of only two statistics are less than 0.01 when we consider both of intercept and trend. Moreover, when we consider only intercept or none of the intercept and trend, then the probability value of none of the statistics is statistically significant.

In developing country's data set, when both intercept and trend is taken into consideration, then only three statistic values (out of eleven) are significant. Not even a single statistic value is significant when we take into consideration none of the intercept and trend. Further, in the existence of only intercept, only one statistic (group PP-statistic) is significant at 1% level. Overall, Pedroni's panel cointegration test assures the absence of cointegration among the variables in both developed and developing country's data sets.

Table no. 4 – Pedroni's Panel Cointegration Test Result

Estimates	Developed Countries			Developing Countries		
	IT	**I**	**None**	**IT**	**I**	**None**
Common AR coefficients						
Panel v-Statistic (unweighted)	13.252*** (0.0000)	-2.285 (0.9889)	-7.562 (1.0000)	19.386*** (0.0000)	-3.851 (0.9999)	-8.969 (1.0000)
Panel v-Statistic (weighted)	9.976*** (0.0000)	-2.074 (0.9810)	-7.647 (1.0000)	4.566*** (0.0000)	-5.135 (1.0000)	-9.078 (1.0000)
Panel rho-Statistic (unweighted)	7.118 (1.0000)	5.134 (1.0000)	3.743 (0.9999)	7.963 (1.0000)	4.933 (1.0000)	5.287 (1.0000)
Panel rho-Statistic	7.109	5.362	2.656	7.504	6.073	5.380

Estimates	Developed Countries			Developing Countries		
	IT	I	None	IT	I	None
Common AR coefficients						
(weighted)	(1.0000)	(1.0000)	(0.9961)	(1.0000)	(1.0000)	(1.0000)
Panel PP-Statistic	2.541	0.924	1.503	2.707	-0.889	2.198
(unweighted)	(0.9945)	(0.8225)	(0.9337)	(0.9966)	(0.1868)	(0.9860)
Panel PP-Statistic	3.342	2.064	-0.928	0.648	0.335	2.702
(weighted)	(0.9996)	(0.9805)	(0.1766)	(0.7418)	(0.6313)	(0.9966)
Panel ADF-Statistic	3.550	2.422	4.196	1.777	3.563	5.747
(unweighted)	(0.9998)	(0.9923)	(1.0000)	(0.9623)	(0.9998)	(1.0000)
Panel ADF-Statistic	3.984	3.563	1.022	2.276	2.070	5.856
(weighted)	(1.0000)	(0.9998)	(0.8467)	(0.9886)	(0.9808)	(1.0000)
Individual AR coefficients						
Group rho-Statistic	8.802	7.550	6.017	9.569	8.704	7.238
	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)
Group PP-Statistic	0.488	0.510	-0.886	-3.776***	-2.506***	-1.792
	(0.6875)	(0.6950)	(0.1875)	(0.0001)	(0.0061)	(0.0365)
Group ADF-Statistic	3.840	3.153	2.990	1.251	2.254	4.934
	(0.9999)	(0.9992)	(0.9986)	(0.8947)	(0.9879)	(1.0000)

Note: ***Signify statistical significance at 1% level. Values in parentheses signify the prob. values of coefficients. IT= Intercept and Trend, I= Intercept, None= No Intercept or Trend.

Source: prepared by authors

4.6. Panel Vector Autoregression

The outcomes associated with the Panel Vector Autoregression (PVAR) are described in Table no. 5. In developed countries, both the measures of SMD i.e., MCAP and LDC are positively related with the economic development and this result is significant at 1% level. In details, in the short-term, if market capitalization goes up (down) by one-unit, economic development will grow (fall) by 0.035 percent. Besides this, investment, government expenditure, savings and trade all are negatively associated with the economic development of developed countries.

In developing countries, in the short-term, both the SMD indicators i.e., MCAP and LDC are also positively interrelated with the economic advancement and this result is significant at 1% level. If market capitalization goes up (down) by one-unit, economic development will grow (fall) by 0.012 percent. Additionally, investment and government expenditure are adversely linked with the economic development. Savings and trade exert positive impact on the economic development. This signifies that when savings rise in the economy by one unit, then economic development goes up by 0.0368 percent.

Table no. 5 – Panel VAR Result

Dependent variable: LnGDP		
Variables	**Developed Countries**	**Developing Countries**
LnGDP (-1)	1.34488*	1.43745**
	(0.05321)	(0.03863)
LnGDP (-2)	-0.35833*	-0.44111**
	(0.05247)	(0.03853)
MCAP (-1)	0.00035***	0.00012***
	(4.8E-05)	(2.7E-05)

Dependent variable: LnGDP		
Variables	**Developed Countries**	**Developing Countries**
MCAP (-2)	-0.00035***	-0.000155***
	(5.0E-05)	(2.8E-05)
LDC (-1)	3.90E-06***	5.77E-06***
	(7.0E-06)	(2.2E-05)
LDC (-2)	-3.70E-06***	-2.52E-06***
	(7.0E-06)	(2.1E-05)
GCF (-1)	-0.00022***	-0.000993***
	(0.00068)	(0.00047)
GCF (-2)	-0.00107***	0.000757***
	(0.00065)	(0.00046)
GE (-1)	-0.00194***	-0.000732***
	(0.00178)	(0.00120)
GE (-2)	0.00156***	0.000456***
	(0.00176)	(0.00117)
Savings (-1)	-0.00076***	0.000368***
	(0.00055)	(0.00038)
Savings (-2)	0.00157***	2.46E-05***
	(0.00056)	(0.00038)
Trade (-1)	-0.00011***	5.91E-06***
	(0.00017)	(0.00014)
Trade (-2)	0.00012***	-7.02E-06***
	(0.00017)	(0.00014)

Note: ***Signify statistical significance at 1% level, ** at 5% level and * at 10% level. Values in parentheses denote the prob. values of coefficients. Lag length selection: Schwarz Information Criteria.

Source: prepared by authors

4.7. Panel Causality Test

Panel VAR causality test is employed in this study to know the direction of causal relationship between the variables. The result associated with the panel causality test is shown in Table no. 6. As per the result of developed countries data set: bi-directional causal relationship is found between (i) economic development and market capitalization (this observation is dissimilar with the N'Zué (2006); Enisan and Olufisayo (2009) where they found one-way causality from SMD to growth) (ii) economic development and gross capital formation (Carp (2012) observes the one-way causality from investment to economic growth in Romania) (iii) MCAP and LDC (iv) market capitalization and savings. A unidirectional causal relationship is observed from (i) savings to economic development (ii) savings to GCF (iii) MCAP to GCF (iv) trade to gross capital formation (v) government expenditure to savings and (vi) market capitalization to trade. Moreover, the joint influence of all the seven variables on the GDP per capita, market capitalization, GCF, GE, savings and trade are also statistically significant at 1% level.

In developing countries data set: The incidence of bi-directional causality is seen between (i) economic development and MCAP (ii) economic development and savings (iii) economic development and trade. Besides it, one-way causal relationship is noticed from (i) GCF to economic development (ii) MCAP to LDC (iii) GCF to LDC (iv) market capitalization to GCF (v) savings to GCF (vi) market capitalization to trade (vii) GCF to trade and (viii) government expenditure to trade. The joint influence of all the seven variables on the GDP per capita, listed domestic companies, GCF and trade are statistically significant.

Table no. 6 – Panel Causality Test

Developed Countries							
Independent Variables	**Dependent Variables**						
	LnGDP	**MCAP**	**LDC**	**GCF**	**GE**	**Savings**	**Trade**
LnGDP	-	5.62*	0.29	59.3***	15.3***	4.10	3.50
MCAP	58.3***	-	10.3***	55.1***	50.9***	34.0***	47.7***
LDC	0.33	5.0*	-	0.84	1.25	2.30	0.39
GCF	15.5***	4.06	0.84	-	4.73*	4.64	1.03
GE	1.84	2.69	0.32	0.04	-	7.82**	0.53
Savings	14.3***	11.0***	1.11	33.1***	0.87	-	1.63
Trade	0.54	1.89	2.07	7.21**	1.60	1.51	-
Overall	82.6***	34.4***	15.18	164***	81.1***	62.0***	65.4***
Developing Countries							
Independent Variables	**Dependent Variables**						
	LnGDP	**MCAP**	**LDC**	**GCF**	**GE**	**Savings**	**Trade**
LnGDP	-	4.92*	3.47	3.31	1.53	8.0***	8.01**
MCAP	31.0***	-	17.6***	16.8***	1.66	4.12	78.9***
LDC	3.84	3.77	-	1.06	1.28	3.68	0.36
GCF	4.65*	2.81	14.3***	-	3.56	4.40	9.89***
GE	1.17	1.07	0.22	2.29	-	0.41	6.78**
Savings	6.51**	0.30	4.31	23.8***	0.81	-	0.15
Trade	4.65*	1.54	3.74	1.44	3.80	1.34	-
Overall	57.9***	14.77	52.7***	55.3***	11.35	18.49	106.3***

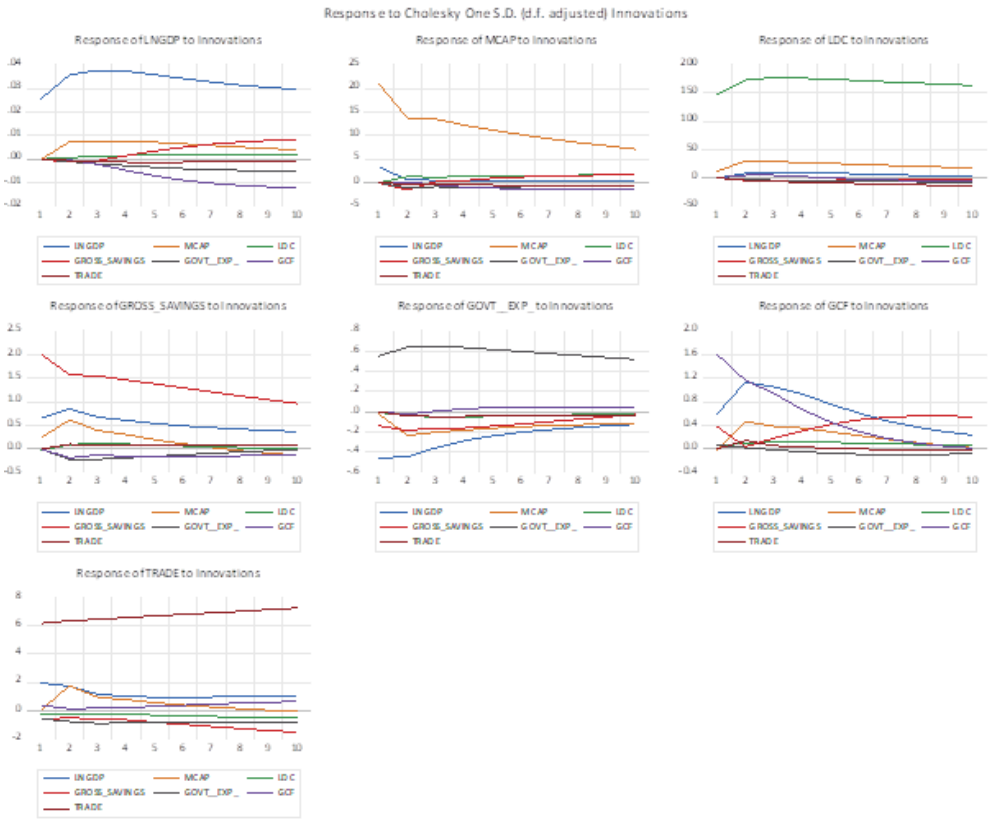
Note: ***Signify statistical significance at 1% level, ** at 5% level and * at 10% level.

Source: prepared by authors

4.8. Impulse Response Function

GIRF ("Generalized Impulse Response Function") focuses further insight into how shocks to each variable can impact and be impacted by the shocks in other variables considered in the study. The outcome of the PVAR model GIRF in the context of developed countries data set is plotted in Figure no. 3. The below drawn Figure no. 3 is the combination of seven individual figures. These seven individual figures depict the response of each variable for the shocks in all the variables considered in the study. From the figure, it is observable that, shocks are becoming disappeared after the period of 5 years (except the variable GCF). It is also clear that, own shock of the variable matters great among other variables in fluctuating the variable except the instance of GCF. In case of GCF, in the initial periods, own shocks affect highly but with the time being along with own shocks, shocks of other variables affect greatly.

Figure no. 4 is the GIRF for the developing sample set. The figure depicts that, in the instance of majority of the variables, the shocks are minimized in the long time frame (i.e., after the period of 5 years). Furthermore, in the case of all the seven variables, maximum variation in the variable is caused by the shock in the said variable. This analysis serves added support for the calculated above results of the test statistics.



Source: prepared by authors

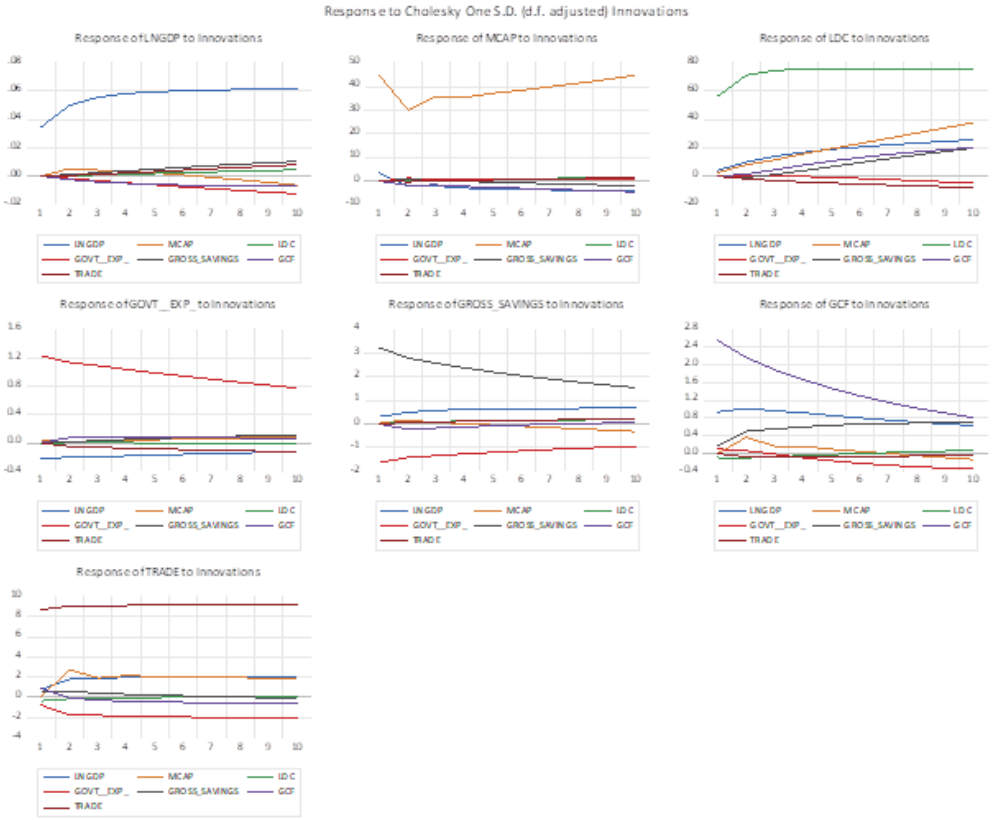
Figure no. 3 – Impulse Response Function: Developed Countries

4.9. Variance Decomposition Test

This study employs the 'variance decomposition test' (VD) to know the exact percentage variation in the value of a variable due to the shock in own and other variables over time. Tables no. 7 and no. 8 provides the variance decomposition result of the variables (GDP, MCAP and LDC) in the developed and developing economies respectively over 10-year of period.

In developed countries data set (as shown in Table no. 7), own shocks of economic development account for 94.47 and 88.291 percent of the variations over the period of 5 and 10 years respectively. In the instance of LnGDP, the influence of own variable is gradually diminishing from the year 1 to year 10. However, in the case of MCAP and LDC, overall the own impact is reducing, but not in each single year. Moreover, for LDC, the percentage of reduction is very less as compare to LnGDP and MCAP. Economic development accounts for 0.795 and 0.152 percent of the variation in MCAP and LDC respectively in the 10 years of time horizon. In both short and long time period (5 year and 10 year), the highest variation in MCAP and LDC are caused by the LDC and market capitalization respectively. This ensures that, market capitalization and listed domestic companies are interdependent on each other.

In the short run, MCAP has the highest degree of influencing power (3.342 percent) to the economic development. While in the long run, GCF caused the 5.509 percent variations in economic development followed by the MCAP (2.746 percentage point). That confirms that, the effect of MCAP is significant in influencing the development of an economy.



Source: prepared by authors

Figure no. 4 – Impulse Response Function: Developing Countries

Table no. 7 – Variance Decomposition Test: Developed Countries

VD of LnGDP per capita							
Period	**LnGDP**	**MCAP**	**LDC**	**GCF**	**GE**	**Savings**	**Trade**
1	100.000	0.000	0.000	0.000	0.000	0.000	0.000
2	97.108	2.653	0.069	0.008	0.057	0.089	0.012
3	96.362	3.085	0.140	0.152	0.155	0.067	0.036
4	95.523	3.302	0.185	0.582	0.254	0.082	0.068
5	94.470	3.342	0.217	1.269	0.370	0.225	0.103
6	93.236	3.286	0.239	2.110	0.492	0.495	0.138
7	91.923	3.177	0.254	3.014	0.615	0.847	0.168
8	90.623	3.040	0.263	3.907	0.733	1.238	0.192
9	89.401	2.893	0.268	4.746	0.845	1.633	0.210
10	88.291	2.746	0.270	5.509	0.948	2.011	0.222

VD of Market Capitalization							
1	2.413	97.001	0.584	0.000	0.000	0.000	0.000
2	1.745	96.372	1.269	0.001	0.209	0.401	0.000
3	1.384	96.422	1.579	0.030	0.254	0.316	0.012
4	1.178	96.193	1.854	0.126	0.335	0.283	0.027
5	1.044	95.833	2.093	0.239	0.415	0.321	0.052
6	0.952	95.388	2.314	0.366	0.498	0.398	0.081
7	0.888	94.894	2.526	0.491	0.580	0.504	0.115
8	0.843	94.374	2.729	0.612	0.660	0.626	0.153
9	0.813	93.842	2.928	0.724	0.738	0.756	0.195
10	0.795	93.307	3.122	0.828	0.813	0.890	0.241
VD of Listed Domestic Companies							
1	1.83E-05	0.000	99.999	0.000	0.000	0.000	0.000
2	0.115	0.535	99.226	0.045	0.015	0.041	0.019
3	0.175	0.575	99.033	0.055	0.035	0.088	0.036
4	0.206	0.581	98.962	0.046	0.049	0.094	0.059
5	0.212	0.559	98.949	0.036	0.063	0.091	0.086
6	0.205	0.526	98.955	0.032	0.078	0.084	0.117
7	0.192	0.489	98.962	0.032	0.092	0.077	0.153
8	0.178	0.454	98.962	0.035	0.106	0.071	0.191
9	0.164	0.420	98.954	0.041	0.119	0.066	0.232
10	0.152	0.390	98.938	0.047	0.133	0.062	0.276

Source: prepared by authors

In developing countries (Table no. 8), economic development defines 0.760 percent of the total variance in the value of market capitalization whereas it labels 5.592 percent of the variation in the value of LDC in the ahead of 10-year period. Own variation in MCAP accounts for the 98.412 percent of the variation, which is too high. While, only 81.657 percent of the variation is explained by the LDC in the long-time frame. In both long and short run, the contribution of economic development is highest among all other explanatory variables in influencing the market capitalization. Even though, in the short run i.e., over 5 years period, the contribution of economic development is highest (3.496 percent) in fluctuating the listed domestic companies but in the horizon of long year, the contribution of market capitalization is more (8.525 percent) as compared to economic development (5.592). This infers that, development of equity market is very sensitive to the shock in GDP per capita.

Table no. 8 – Variance Decomposition Test – Developing Countries

VD of LnGDP per capita							
Period	**LnGDP**	**MCAP**	**LDC**	**GCF**	**GE**	**Savings**	**Trade**
1	100.000	0.000	0.000	0.000	0.000	0.000	0.000
2	98.958	0.765	0.002	0.173	0.018	0.074	0.006
3	98.659	0.683	0.009	0.360	0.040	0.218	0.028
4	98.316	0.587	0.019	0.511	0.074	0.424	0.066
5	97.930	0.471	0.035	0.640	0.114	0.685	0.122
6	97.475	0.374	0.054	0.751	0.159	0.990	0.194
7	96.948	0.310	0.077	0.843	0.210	1.327	0.281
8	96.349	0.288	0.104	0.919	0.266	1.687	0.384
9	95.681	0.314	0.134	0.978	0.325	2.064	0.500
10	94.949	0.392	0.167	1.023	0.387	2.450	0.628

VD of Market Capitalization							
1	0.531	99.468	0.000	0.000	0.000	0.000	0.000
2	0.547	99.272	0.0004	0.105	0.069	0.0004	0.004
3	0.495	99.302	0.0007	0.136	0.059	0.002	0.002
4	0.554	99.176	0.002	0.200	0.056	0.006	0.002
5	0.601	99.059	0.005	0.265	0.049	0.014	0.004
6	0.646	98.928	0.009	0.336	0.043	0.026	0.007
7	0.684	98.798	0.015	0.409	0.038	0.040	0.012
8	0.715	98.668	0.022	0.481	0.033	0.058	0.019
9	0.740	98.539	0.031	0.553	0.028	0.079	0.027
10	0.760	98.412	0.041	0.622	0.025	0.102	0.037
VD of Listed Domestic Companies							
1	0.523	0.183	99.165	0.126	0.000	0.001	0.000
2	1.369	0.833	97.679	0.065	0.0001	0.007	0.045
3	2.155	1.407	96.260	0.064	0.0014	0.013	0.097
4	2.872	2.165	94.553	0.173	0.006	0.080	0.148
5	3.496	3.023	92.669	0.370	0.013	0.225	0.200
6	4.040	3.981	90.628	0.625	0.023	0.447	0.252
7	4.514	5.020	88.473	0.912	0.033	0.740	0.304
8	4.926	6.131	86.240	1.211	0.043	1.092	0.354
9	5.284	7.302	83.959	1.506	0.053	1.492	0.402
10	5.592	8.525	81.657	1.787	0.061	1.927	0.447

Source: prepared by authors

5. RESULTS AND DISCUSSION

Every country's economy desires a well-developed and sophisticated financial system as sound financial system is essential to flourish the economy (Ang, 2008; Tripathy and Pradhan, 2014; Kirikkaleli *et al.*, 2022). The equity market is the chief driver of financial system in developed countries while the banking sector is the chief driver in emerging countries (Zeqiraj *et al.*, 2020). Trend displays that, growth in MCAP and LDC are higher in developing nations as compare to the developed nations. It indicates that in developing nations, the development of stock market is in upward direction. In this article, both the indicators of SMD (market capitalization and listed domestic companies) exert a positive impact on the economic advancement of advanced as well as emerging nations. This signifies that, a smooth drive towards the development of an economy requires a sound and efficient stock market. The stock market optimizes the mobilization of financial resources into productive sectors, funds innovation which eventually leads to the long-term development of the corporations. This finding is similar with the research of Qamruzzaman and Wei (2018), in Bangladesh; Pradhan *et al.* (2014), in ASEAN countries; Kassimatis and Spyrou (2001), in Taiwan. However, this finding does not match with the study of Yu *et al.* (2012), Pradhan *et al.* (2015), Osinubi and Amaghionyeodiwe (2003). The reason of this contradictory outcome underlines the differences in study period, countries studied, underutilisation of capital market in those economies or already developed stock market. On the other side, Arestis *et al.* (2001) have opined that, volatility in stock market has an adverse effect in the economy of Japan and France and insignificant effect in Germany.

In developed economy, investment and government expenditure exerts adverse impact on the smooth functioning of the economies. When investment and government expenditure

are not used effectively, it suffers the growth by elevating the costs. Moreover, in some circumstances, after touching a certain point, excess investment without technological advancement slows the rate of growth, which is also described in the Solow growth model (Solow, 1956). Therefore, quality of expenditure matters more than the amount. Moreover, after the globalization, especially in developed countries, the role of government has contracted due to the budding private sectors. Additionally, savings also acts as a hindrance in the development of advanced economies. Excess saving of advanced economies is associated with the lower domestic demand. That in real term disrupts the economic equilibrium level. Besides, higher trading declines the economic progression of the advanced countries. This may be due to the saturation level of trading in advanced nations. Otherwise, increasing exposure to import-driven trade growth exposes the economy to vulnerability and global recession and hampers the overall economic performance.

On the other hand, in developing economies, growing savings and trade volume supports the progress of an economy. In emerging nations, development is in the process of upward direction so, more savings and trading volume encourage the functions of corporates in the economy. Moreover, developing countries generally suffers from the acute shortage of capital and modern production techniques. In this circumstance, increased savings helps in fulfilling that gap. Growing savings too helps in deepen the financial segment. On the other side, greater trade volume helps the firms in increasing the production efficiency, exploit economies of scale and ultimately expand its market beyond the boundary. Furthermore, investment and government expenditure dampens the performance of an economy. Actually, immediate return from the investment is not expected in general, specifically in developing economies. As their existing level of technology, institutional quality, infrastructure level and governance system is weak. In real terms, these constraints, stretches the actual return period form the investment. Besides, it is important to control the misuse of public funds. At the same time, it is also true that, composition of expenditure matters a lot. If maximum public expenditure directed towards recurring part, then it creates burden on the government without enhancing the productive capacity. The unfavorable effect of public expenditure on the growth is also supported by Smaoui and Nechi (2017); Ngare *et al.* (2014); Fetai (2018). However, the study of Naik and Padhi (2015); Adjasi and Biekpe (2006) found that investment is a significant variable in impacting the growth of an economy. Overall, it is apparent that, both of the undertaken hypotheses of this study are accepted in the context of both developed and developing countries.

Panel causality test reports bidirectional causality between market capitalization and economic development in both developed as well as in developing countries. This infers that, market capitalization causes the development through the circulation of funds to the corporates and development also causes the market capitalization as developed economy encourages more the participants in the stock market. Additionally, in developing countries, market capitalization causes the LDC but in developed countries, MCAP and LDC cause each other. This outcome is also supported by the variance decomposition test. In developed countries, in the short-run, market capitalization has the highest influencing power in effecting the value of economic development and listed domestic companies have the more power in influencing the value of MCAP. In developing countries, economic development is more influenced by the savings and listed domestic companies are more impacted by the market capitalization. In both kinds of sample set, maximum variation in the variable is caused by the own shocks of the variable. This result is also confirmed by the impulse response function. Additionally, IRF discloses that, the shocks are becoming normalized with the time being.

6. CONCLUSION

Sustainable economic development requires a balance between environmental sustainability and socio-economic progress, all of which are dependent on financial development (Dutta and Saha, 2023). Development happens in the market with the increased number of instruments, institutions and investments. Well organized financial market incorporates dynamic efficiency in the entire system through the structural changes and the technological innovation, which are indispensable for the sustainable economic development. This study is viewing the development of stock market for the advancement of an economy. This study has taken data from the period 1991 to 2022 and estimates the result by taking 51 developing and 32 developed countries.

Panel cointegration test shows that, cointegration relationship does not exist among the undertaken variables in the study. Afterward, panel VAR model shows that, in developed economies, both the indicators of SMD i.e., MCAP and LDC are significant in affecting the economic development positively in the short-run. This outcome implies that, greater the size of equity market, better the economic performance will be. Besides it, all the four control variables (investment, government expenditure, trade and savings) are acts as an obstacle in the development of an economy. On the other side, in developing economies too, both of the size parameters of SMD accelerate the economic activities as greater the size of stock market, boosts the confidence of the investors and diversify the risk. But the difference is that, the impact of MCAP is less influential in developing economies. This indicates that, development is still in progress in developing economies. The study by Abid (2025) in the scope of United States, strongly supported the favorable impact of MCAP on GDP, underscoring the importance of well-developed stock market for economic progress. On contrary to the general agreement, the study found that, investment and government expenditure dampens the rate of economic expansion. Another side, saving and trade volume augments the economic progress rate. In this backdrop, it seems that, both of the undertaken hypotheses (H_1 and H_2) of the study are accepted in the framework of both set of countries.

Panel causality test implies a bidirectional causality between MCAP and economic development means they are related in a cyclical pattern. No causal relationship exists between LDC and economic development in the case of both set of countries. Therefore, when MCAP is taken as a parameter of SMD then feedback theory works. In this regard, the study by Shahbaz *et al.* (2018) has asserted that, in the short term between financial development and economic advancement, there remains a feedback effect. Cao *et al.* (2022) also specifies the feedback causality between economic progress and financial advancement in South Asian Nations. Another way, when LDC is used as an indicator of SMD then neutrality theory works. Unidirectional causality is noticed from market capitalization to trade volume in both type of countries data set. Additionally, in developed countries, both-way causal relationship is also observed between economic development and investment and between market capitalization and listed domestic companies. For supporting the above results, IRF and VDT are also employed. Variance decomposition test confirms that in developing countries, economic development has the highest influencing power in affecting the market capitalization in both long and short run. While, in developed countries, in the short-run, the maximum variation in economic development is caused by the MCAP. In the same manner, in the short-run, the maximum variation in economic development is caused by the MCAP. Hence, this confirms that MCAP and economic development are closely associated.

6.1. Policy Implications

Therefore, based on the above result, policymakers, financial researchers and market analysts are requested to implement the appropriate regulations, undertake the reforms, and liberalize the rules and regulation so that participants will be encouraged in entering the stock segment and instinctively consider the platform of stock market as an avenue for facilitating the circulation of funds in the economy. Second, emphasis should be placed on expanding the size of stock market so that, stock market enables the corporations with the easy access of long-term funds and helps them in attaining the targets of SDGs. Third, the results suggest that reducing inefficient government expenditure and diversion of more public funds toward capital expenditure may support smoother economic functioning. Fourth, less involvement of government in economic operations is desirable especially for the developed nations as degree of adversity is more in developed nations. Fifth, developed nations are requested to shift savings toward strategic industries and develop supply chain resilience for derive the positive outcome from it. Sixth, increase of trade volume mainly through the export activities and encourage of private savings through different initiatives like, increasing interest rate etc. is needed for achieving the progress of developing economies.

6.2. Limitations

The reliance on only two SMD indicators (MCAP and LDC) in this research work omit the aspects like liquidity (turnover ratio) or volatility. The study acknowledges this but should treat it as a limitation. Moreover, segregation of government expenditure (like capital expenditure and current expenditure) helps in more accurately targeting the issues. More the number of control variables in the study, enhances the robustness of the study. Overall, individual country-specific study will provide the better result and helps in framing the tailored policies accordingly.

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ANNEX

List of Developed and Developing Countries undertaken in study

Developed Countries	Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Cyprus, Czechia, Denmark, Finland, France, Greece, Germany, Hungary, Ireland, Italy, Japan, Luxembourg, Malta, New Zealand, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United States, United Kingdom.
Developing Countries	Argentina, Bangladesh, Bahrain, Barbados, Bermuda, Brazil, Chile, China, Colombia, Costa Rica, Cote d' Ivoire, Eswatini, Ghana, Hong Kong, India, Indonesia, Iran, Israel, Jamaica, Jordan, Kazakhstan, Kenya, Korea Republic, Kuwait, Lebanon, Malaysia, Mauritius, Mexico, Morocco, Namibia, Nigeria, Oman, Pakistan, Panama, Papua New Guinea, Peru, Philippines, Qatar, Russian Federation, Singapore, Saudi Arabia, South Africa, Sri Lanka, State of Palestine, Thailand, Tunisia, Turkey, United Arab Emirates, Ukraine, Vietnam, Zambia.

Note: Developed and developing countries are according to the report of World Economic and Prospects (2022), United Nations.