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Contact
Faculty of Economics University of Kragujevac,
Liceja Knezevine Srbije 3, 34000 Kragujevac, Serbia;
Tel. +381 34 303 507
www.horizonti.ekfak.kg.ac.rs horizonti@kg.ac.rs

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EDITORIAL

After conducting the double-blind peer review process, Issue 3 Volume 27 Year 2025 of the scientific journal *Economic Horizons* contains three original scientific papers, three review papers, and the List of the Authors and Titles of all the contributions published in the Journal in 2025.

The coauthors *Andrija Popović, Andreja Todorović* and *Vladan Vučić* analyze the relationship between economic growth, competitiveness and innovations in the circular economy of the 27 European Union countries in the period from 2011 to 2020. By applying descriptive statistics, Principal Component Analysis (PCA), panel data regression and cluster analysis, the paper examines how the key economic indicators such as gross domestic product (GDP), GDP *per capita* and gross fixed capital formation affect the performances of the circular economy. The results obtained are indicative of a positive correlation between overall economic growth and circular competitiveness. The analysis underscores the need for tailored, specific national policies in order to promote the sustainable practice of the circular economy, especially in less developed economies. The research generates empirically relevant insights for policymakers, who tend to reach a balance between economic growth and sustainability.

Starting from the attitude that theoretical-methodological research studies have confirmed the thesis that the accumulation of physical capital only partly explains the dynamics of countries' economic growth rates, and that researchers' and policymakers' focus ever increasingly rests on human capital, the coauthors *Đorđe Kotarac* and *Zoran Popović* did research in the influence of this capital on the *per capita* income growth rate. The results of the research obtained by utilizing the panel regression model point to the statistically significant influence of the improvement of human capital on an increase in *per capita* income on a sample of ten Central and Eastern European (CEE-10) countries. Thus, the paper adds to scientific literature dedicated to the investigation of the relationship between human capital and income growth in these economies. The paper also highlights the significance of investing in human capital as an efficient tool for the improvement of countries' economic development.

Pointing out that the economic literature comprised of a large number of papers deals with the effects of the inflow of foreign direct investment (FDI) and the influence of institutional quality on economic activity, and that there are relatively few studies examining the influence of institutional quality on attracting foreign direct investment (FDI) and/or the joint influence of these two factors on economic growth, the coauthors *Iva Glišić* and *Slavica Manić* research exactly this connection. In the paper, they analyze the panel data of the five countries of the Western Balkans in the period from 2007 to 2022. The research results indicate the unexpected positive effect of the institutional environment of a lesser quality on economic activity through the FDI channel. A potential explanation for the results like this lies in the thesis that the less developed legislation (especially the ecological legislation) in the Western Balkan countries attracts exactly the FDI that, together with economic growth, also produce negative external effects. Additionally, the findings like these point to the need for considering long-term risks to the economic growth that predominantly relies on this type of FDI.

In their paper, the coauthors *Paskal Zhelev* and *Olga Malashenkova* consider the Eurasian Economic Union (EAEU) as a regional economic integration block, simultaneously analyzing its evolution, trade integration, and industrial policy framework amidst changes in global dynamics. The numerous pressures and challenges which the EAEU has been faced with since its very establishment have led to a disruption in trade flows, expanded the economic disparities between the Union member states and tested the

* *Correspondence to*: M. Jakšić, Faculty of Economics of Kragujevac University, Liceja Kneževine Srbije 3, 34000 Kragujevac, Republic of Serbia; e-mail: milenaj@kg.ac.rs

cohesion of that bloc. The paper emphasizes the fact that increasingly strong competitiveness is of critical significance for the resilience of the EAEU, with the industrial policy serving as the cornerstone of that effort. Applying trade indicators, such as interregional trade shares and the Revealed Comparative Advantage (RCA) Index, the paper highlights uneven integration and dependence on resource-based exports. The findings obtained in the study are indicative of the fact that encouraging industrial modernization and achieving a better synergy between domestic policies and regional ambitions could strengthen the bloc's resilience and its global competitiveness.

In line with the attitude that economic rivalry between the BRICS countries and the Group 7 (G-7) member countries has for decades been the central topic of global development, the coauthors *Farial Faizi, Mariam Sawas, Dina Abohassan, Ilija Stojanović* and *Marko Selaković* compare the GDP growth dynamics between these groups of countries. At the same time, the coauthors examine the differential influence of the key macroeconomic indicators on their respective economic trajectories. For that purpose, the paper utilizes the statistical methodology that also includes the tests of between-subjects effects in order to assess the variations in the effects of the regression coefficients for the macroeconomic factors that affect the GDP growth. The research starts from the assumption that the distinctive economic structures of the BRICS countries and the G-7 member countries lead towards varying macroeconomic conditions that give shape to the growth patterns of those countries in different ways. The results obtained in the study provide insights into the strongest and weakest GDP growth determinants within those economic blocs which may also have their practical application and may also contribute to a broader research framework in the domain of global economic competition.

The coauthors *Ventsislav Vasilev* and *Radka Vasileva* consider the selected methods for risk assessment and determining optimal risk retention levels in motor casco insurance, especially focusing on the comparison of the three statistical techniques: Chebyshev's Inequality, the Monte Carlo Simulation, and Normal Distribution. Based on historical data from the Bulgarian insurance market pertaining to claims, which are published by the Financial Supervision Commission of Bulgaria, this study investigates the probability that a claim will exceed risk retention thresholds, simultaneously comparing the accuracy and precision of each of the mentioned methods. While, on the one hand, Chebyhev's Inequality offers a conservative assessment, the Monte Carlo simulation offers a probabilistic approach which models different outcomes, and Normal Distribution assumes a symmetrical loss pattern, on the other. The research results show that the Monte Carlo Simulation offers a high level of the accuracy and reliability of the assessment when risk retention decisions in the domain of motor casco insurance are concerned, thanks to their flexibility in the modeling of different loss scenarios.

On behalf of the Editorial Board of the Journal and on my own behalf, I hereby express my gratitude to the authors of the contributions published in Issue 3 of the Journal. At the same time, our special gratitude goes to the reviewers, whose constructive and critical comments and suggestions to the authors of the submitted papers have contributed to raising the level of the quality of the published papers.

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Milena Jakšić
Editor-in-Chief

Milena Jakšić is a full professor teaching at the Faculty of Economics of the University of Kragujevac. She earned her PhD degree at the Faculty of Economics of the University of Kragujevac in the narrow scientific field of general economics and economic growth. The key areas of her scientific and research interests are the financial system, financial markets, financial instruments and financial institutions.

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ASSESSING THE INFLUENCE OF ECONOMIC GROWTH ON COMPETITIVENESS AND INNOVATION IN THE CIRCULAR ECONOMY

Andrija Popović[1*], Andreja Todorović [1] and Vladan Vučić[2]

[1] *University of Niš, Innovation Center, Niš, Republic of Serbia*
[2] *University „UNION - Nikola Tesla", Faculty of Law, Security and Management, Niš, Republic of Serbia*

This research explores the relationship between economic growth and competitiveness and innovation in the circular economy across the 27 EU countries from 2011 to 2020. Using descriptive statistics, Principal Component Analysis (PCA), panel data regression, and cluster analysis, the research investigates how the key economic indicators, such as GDP, GDP *per capita*, and gross fixed capital formation, affect the performance of the circular economy. The results obtained indicate a positive correlation between overall economic growth and circular competitiveness, though wealthier nations do not consistently lead in circular transitions. The analysis underscores the need for tailored, country-specific policies to promote sustainable practices in the circular economy, especially in less developed economies. These findings provide valuable insights for policymakers aiming to balance economic growth with sustainability.

Keywords: circular economy, economic growth, innovation, sustainability, EU, competitiveness

JEL Classification: Q56, O44, O33

INTRODUCTION

In the modern global economy, competitiveness and innovation have emerged as the main drivers of growth, sustainability, and prosperity. A country's potential for productivity and growth is shaped by its competitiveness, which influences resource allocation, production affordability, and the overall economic output (Vuță, Vuță, Enciu & Cioacă, 2018). Innovation, especially in the context of the circular economy (CE), offers new technologies and practices that improve competitiveness by optimizing resource use and minimizing waste (Mitrović & Veselinov, 2018; Silvério, Ferreira, Fernandes & Dabić, 2023). The European Union (EU) has prioritized these developments through initiatives such as the European Green Deal and the Circular Economy Action Plan, aiming to promote sustainable solutions (OECD, 2019; European Commission, 2020). Yet, a

* *Correspondence to:* A. Popović, University of Niš, Innovation Center, Vardarska 10/6/11, 18000 Niš, Republic of Serbia; e-mail: andrija.m.popovic@gmail.com

recent audit conducted by the European Court of Auditors (European Court of Auditors, 2023) finds "limited evidence" that CEAP actions have so far accelerated upstream circular design, underscoring the gap between policy ambition and tangible progress.

Despite progress, however, gaps in understanding the relationship between economic growth and circular competitiveness across different countries still remain. While much attention has been given to how circular practices impact economic growth, less is known about how economic growth itself influences a country's ability to innovate and compete in the CE (Karman & Pawlowski, 2021). This is particularly important for the EU countries, where sustainable growth is considered crucial to future competitiveness (Popović & Milijić, 2022). Recent studies have revealed that overall GDP is positively associated with circularity (Hondroyiannis, Papapetrou & Tzeremes, 2024), whereas the link with GDP *per capita* is far more ambiguous, being positive in some, neutral or even negative in other contexts, depending on consumption footprints and policy quality (European Court of Auditors, 2023; Lacko, Hajduova & Dula, 2024). These findings echo the earlier evidence that high economic growth alone does not guarantee advanced CE performance without concurrent technological innovation and resource efficiency gains (Ying & Wen-Ping, 2015; Jakopin, 2020).

Globalization has increased concerns that the countries that do not embrace circular innovation may lose competitiveness. Those prioritizing resource efficiency are better positioned so as to attract foreign investments and remain competitive in global markets (Ferrante & Germani, 2020; Silvério *et al*, 2023). Thus, it is crucial to examine whether economic growth is in line with the EU efforts to improve circular competitiveness and innovation. Large cross-country disparities, most visibly persistent North-South and West-East divides into the CE efficiency (Hondroyiannis *et al*, 2024; Lacko *et al*, 2024), suggest that structural, institutional, and investment factors mediate this alignment.

Moreover, research gaps persist in developing standardized tools for measuring the performance of the circular economy across countries (Vuță *et al*, 2018; Busu & Trica, 2019). Although the EU updated its monitoring framework in 2023, scholars still highlight data gaps, particularly on product design and social outcomes, and call for richer indicator sets and harmonized methodologies (Ghormare, Patil & Petrescu, 2024). Previous studies have largely focused on developed economies, leaving questions about how slower-growing countries fare in circular competitiveness (Popović, Ivanović Đukić & Milijić, 2022). This study aims to fill these gaps by exploring the extent to which slower-growing economies can keep pace with more advanced countries in transitioning to the circular economy.

This research analyzes how economic growth influences circular competitiveness and innovation across the 27 EU countries between 2011 and 2020, focusing on the key indicators such as GDP, GDP *per capita*, and gross fixed capital formation (GFCF). The performance of the circular economy is assessed through the Circular Material Use rates (CMUr), circular patents, and employment in circular sectors. The study aims to investigate whether economic growth drives competitiveness and innovation in the circular economy.

The research is structured around the three key hypotheses:

H1: Higher GDP, GDPpc, and their respective growth rates are positively associated with higher competitiveness and innovation in the CE.

H2: Countries with higher resource productivity (ResP, ResPppp) exhibit better CE performance.

H3: Countries with higher investments (GFCF, InvAbs) tend to have more significant innovations and higher levels of competitiveness, measured by the Circular Competitiveness and Innovation Index - CCII (patents, GVA) in the CE.

Beyond testing these hypotheses, the paper contributes to theory by contextualizing the GDP-circularity

paradox through the lenses of the consumption footprint and investment targeting, and to practice by identifying policy levers, design-stage incentives, innovation-focused finance, and digital traceability that can accelerate the EU's lagging transition. The remainder of the paper is structured so as to offer a literature review, explain the data, the variables, and the methods, present the empirical results, discuss the implications and policy recommendations, and finally conclude the whole research study.

LITERATURE REVIEW

The relationship between economic growth and competitiveness in the circular economy (CE) has garnered increasing attention. Yet, the literature remains divided on its mechanisms and outcomes. The CE aims to address sustainability challenges, though the extent to which growth fosters circular practices remains under debate. In this context, J. Korhonen, A. Honkasalo and J. Seppälä (2018) highlight the paradox between growth-driven consumption and the CE model's principles of resource efficiency and waste reduction.

GDP growth has been both an enabler and a barrier to the CE transitions. W. R. Stahel (2016) argues that high-growth economies are better equipped to scale the CE practices through investments in research, development, and infrastructure, while also warning that unchecked growth may fuel unsustainable consumption. Similarly, A. Popović *et al* (2022) suggest that, although a higher GDP can drive circular innovation, it can also entrench linear economic activities unless properly managed. Đ. Mitrović and M. Veselinov (2018) add that, while being more capable of implementing the CE practices, wealthier countries are not immune to challenges, especially if policy incentives are weak. A surge of recent panel studies has confirmed a positive long-term correlation between aggregate GDP and national circularity rates (Hondroyiannis *et al*, 2024), yet revealing an ambiguous, sometimes negative, association with GDPpc once rising consumption footprints are controlled for (Lacko *et al*, 2024; Marjanović, Stanković, Östh, Marković & Stanojević, 2025). The evidence from F. Ying and Z. Wen-Ping (2015) and E. Jakopin (2020) further demonstrates that a rapid economic expansion without synchronous technological upgrading can stall CE progress.

Being a key CE indicator, ResP reflects how efficiently economies use natural resources to generate value. M. Busu (2019) found that the countries with higher ResP tended to be more competitive in the circular sectors, whereas X. Zhou, M. Song and L. Cui (2020) argue that improving ResP is often linked to investments in circular technologies, reinforcing the connection between economic growth and competitiveness in the CE. Similarly, E. Hysa, A. Kruja, N. U. Rehman and R. Laurenti (2020) claim that innovation is essential for circular transitions, with higher innovation levels typically leading to greater circular competitiveness. More granular evidence shows the influence of ResP is context-dependent: investment enables uptake of circular technologies (Karman & Pawłowski, 2022), innovation capabilities increasingly shape performance as systems mature (Hysa *et al*, 2020; Herrero-Luna, Ferrer-Serrano & Latorre-Martinez, 2022), and EU-wide efficiency dispersion is documented using a DEA composite indicator (Marjanović *et al*, 2025).

Investments, particularly those made in physical assets, are critical for promoting innovations in the CE. A. Karman and M. Pawlowski (2021) stress that higher levels of GFCF support the adoption of circular technologies, especially in renewable energy and sustainable manufacturing. However, S. Herrero-Luna *et al* (2022) note that, while investment leads to short-term competitiveness gains, the long-term effects of circular investments, such as those on employment and income distribution, are less understood. The European Court of Auditors (2023) cautions that the EU funds remain disproportionately channeled to end-of-pipe waste management rather than upstream circular design, which is a misalignment blunting the effectiveness of capital flows. Complementary firm-level evidence on the ISO 14001 adoption, such

as in D. Jovanović and V. Janjić (2018) and on green-accounting expenditure, such as in A. P. Egbunike and E. G. Okoro (2018), corroborates that targeted spending on environmental management can raise efficiency and profitability.

Table 1 synthesizes the extant empirical studies most pertinent to the three hypotheses set in this study, grouping them by the primary economic lever examined (growth, resource productivity, or investment/innovation).

The literature identifies both opportunities and challenges in aligning economic growth with circular competitiveness. While higher growth can support CE transitions, it risks undermining sustainability without proper regulation. Gaps remain in understanding the long-term impact of economic growth on competitiveness in the CE, particularly for less developed countries. Future research should adopt longitudinal designs in order to explore how this relationship is evolving over time. Moreover, scholars spotlight unresolved measurement issues (Busu & Trica, 2019; Ghormare *et al*, 2024) and persistent regional divides within Europe (European Court of Auditors, 2023), signaling the need for harmonized indicators and context-sensitive policy interventions.

Table 1 The synthesis of the empirical studies

Group/ Hypothesis	Authors	Sample and period	Key economic variables	CE metrics	Method	Principal finding
H1: Growth	W. R. Stahel (2016)	Conceptual	GDP growth	CE scalability	Theory	Growth enables the CE but can also undermine it.
	F. Ying and Z. Wen-Ping (2015)	Shaanxi, 2000-12	GDP, GDPpc	CE stage via IPAT	IPAT/OLS	High GDP with weak tech keeps the CE at the "intermediate" stage.
	G. Hondroyiannis et al (2024)	EU-28, 1995-2022	Real GDP	Circularity rate	FMOLS	Long-term GDP leads to higher circularity.
	R. Lacko et al (2024)	EU-11 post-2004	GDPpc	CE efficiency	DEA	The GDPpc effect is positive for some, and negative for others.
H2: Resource productivity	M. Busu (2019)	EU-27, 2008-17	ResP	CE index	Panel FE	Higher ResP increases competitiveness in the CE.
	X. Zhou et al (2020)	China, 2000-16	ResP, tech change	GDP growth	Spatial panel	ResP gains drive eco-growth.
	I. Marjanović et al (2025)	EU-27, 2019	Inputs/ outputs from Eurostat CE indicators	DEA efficiency score (CCR; super-efficiency ranking)	DEA efficiency score (CCR; super-efficiency	Large cross-country heterogeneity; many EU members inefficient; CE efficiency moderately correlated with development.
H3: Investment and Innovation	A. Karman and M. Pawlowski (2021)	EU-27, 2010-19	GFCF	CE competitiveness index	Catastrophe prog./PCA	GFCF strongly linked to CE leadership.
	S. Herrero-Luna et al (2022)	38 studies	Investment	Mixed CE outcomes	Systematic review	Long-term socio-economic impacts unclear.
	D. Jovanović and V. Janjić (2018)	Serbia, survey	EMS investment	Efficiency, profit	Descript./logit	ISO 14001 yields efficiency and profit gains.
	A. P. Egbunike and E. G. Okoro (2018)	Nigeria, 2012-16	Green CAPEX	ROE, Tobin's Q	Canonical corr.	Green spend neutral to profits – needs policy support.

Source: Authors

RESEARCH METHODOLOGY AND DATA

This research employs an all-inclusive quantitative methodology to assess the interaction between economic growth, competitiveness, and innovation in the CE across the 27 EU member countries in the period from 2011 to 2020. The design directly addresses the research objectives and tests the hypotheses while safeguarding robustness and reliability.

The selection of the variables was based on a detailed review of the previous literature and the availability of reliable data sources, following approaches similar to those used by M. Vuță *et al* (2018) and Đ. Mitrović and M. Veselinov (2018). The data were collected from the two main sources:

- World Bank: For the macroeconomic indicators such as GDP, GDPpc, and GFCF (World Bank, 2024).
- Eurostat: For the CE-specific indicators such as ResP, CMUr, and Patents related to circular innovation (Eurostat, 2024).

The dataset contains independent variables (economic growth indicators) and dependent variables (circular economy performance indicators). The independent variables GDP, the GDP growth rate (GDPgr), GDPpc, the GDPpc growth rate (GDPpcg), GFCF, the GFCF growth rate (GFCFgr), ResP, and ResP in Purchasing Power Parity (ResPppp) were included in the initial set. The dependent variables included CMUr, the patents related to climate change mitigation technologies, employment in the circular sectors, and investment in the circular sectors. It is worth noting that there was no missing data in the dataset.

Prior to analysis, the authors conducted a thorough examination of the distribution of the variables in order to identify any outliers or anomalies. In line with contemporary discussions on measurement complexities (Ghormare *et al*, 2024), special attention was paid to ensuring that data values were consistent across all countries and years. To ensure comparability across the different scales and units of measurement, the authors applied the following normalization techniques: Log Transformation, Z-score, and Min-Max Normalization.

These normalization techniques are consistent with those used in similar studies (Hysa *et al*, 2020; Karman & Pawlowski, 2021). Such procedures also align with the approach of F. Ying and Z. Wen-Ping (2015), who underscore the importance of addressing skewed economic indicators when examining circular performance stages.

The authors employed Principal Component Analysis (PCA) so as to reduce the dimensionality of the dataset and create two composite indices, following the approach of A. Androniceanu, J. Kinnunen and I. Georgescu (2021):

- the Circular Competitiveness and Innovation Index (CCII), aggregating the indicators related to performance in the CE.
- the Economic Growth Index (EG), compiling traditional economic growth indicators.

Both indices were standardized and scaled from 0 to 100 for ease of interpretation and comparison across the countries and the time periods.

The PCA for the CCII was performed on nine variables, namely CMUr, Patents, PatentsPM, PersEmp, PersEmpPerc, InvAbs, InvPerc, GVA, and GVAperc. For the EG index, PCA was conducted on the reduced set of the five variables: GDP, GDPpc, GFCF, RESP, and RESPppp.

The authors initially conducted a panel data regression analysis using both fixed-effects and random-effects models to examine the relationship between the economic growth indicators and the CE outcomes. The Hausman test was applied in order to determine the most appropriate model specification, following the approach of M. Busu (2019). Following the initial regression analysis, the authors performed several diagnostic tests, Breusch-Pagan, the Wooldridge test, and the Variance Inflation Factor (VIF), in order to ensure the validity and reliability of the results.

Based on the results of these tests, the authors refined the model by adjusting the set of the independent variables. The final set of the independent variables

included GDP, GDPpc, GFCF, ResP, and ResPppp, addressing the issues of multicollinearity and improving the model fit. This approach aligns with the recent findings (Jakopin, 2020; Lacko *et al*, 2024) that highlight how controlling for both the growth level and resource efficiency can better capture the drivers of circular competitiveness.

Using the adjusted set of variables, the authors conducted a revised panel data regression analysis. For further clarity, the general baseline model can be expressed as:

$$CCII_{it} = \alpha + \beta_1 GDP_{it} + \beta_2 GDPpc_{it} + \beta_3 GFCF_{it} + \beta_4 RESP_{it} + \beta_5 RESPppp_{it} + \epsilon_{it} \quad (1)$$

where:

$CCII_{it}$ - CCII stands for the country *i* at the time *t*,

GDP_{it} - GDP stands for the country *i* at the time *t*,

$GDPpc_{it}$ - GDPpc stands for the country *i* at the time *t*,

$GFCF_{it}$ - GFCF stands for the country *i* at the time *t*,

$RESP_{it}$ - ResP stands for the country *i* at the time *t*,

$RESPpps_{it}$ - ResPppp stands for the country *i* at the time *t*,

ϵ_{it} - the error term,

α - the constant,

$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ - the coefficients to be estimated.

which enables the joint testing of the study's three hypotheses.

To identify the patterns and groupings among the countries based on their CE and the economic growth performance, the authors performed a K-means clustering analysis using the standardized CCII and EG indices, which allowed the countries to be categorized into distinct groups based on their performance in both competitiveness in the CE and economic growth, similar to the approach used by R. Bucea-Manea-Tonis, A. Ševic, M. P. Ilić, R. Bucea-Manea-Tonis, N. Popovic Ševic and L. Mihoreanu (2021). Here, the clustering results were interpreted in light of potential North-South and West-East divides in the EU (Hondroyiannis *et al*, 2024).

To ensure the reliability of the findings, the authors conducted several robustness checks: Cronbach's Alpha analysis, sensitivity analysis, and alternative model specifications.

It is essential to acknowledge several limitations in the applied methodology:

- potential endogeneity issues in the relationship between economic growth and CE performance, and
- the challenge of capturing all the aspects of competitiveness and innovation in the CE in quantitative indicators.

Despite these limitations, the applied methodology provides a comprehensive approach to examining the relationship between economic growth and competitiveness and innovation in the CE across the 27 EU member states. A combination of panel data regression, the composite index creation, and cluster analysis offers a complex perspective on this relationship. Moreover, referencing complementary firm-level insights (Jovanović & Janjić, 2018; Egbunike & Okoro, 2018) underscores the importance of the targeted environmental investments for reinforcing the macro-level findings.

RESEARCH RESULTS

In this section, the findings of the study are presented in detail. These results provide insights into the economic trajectories and their implications for the CE development in the EU.

Descriptive statistics

To better understand the relationship between economic growth and the CE, the authors begin with a descriptive analysis of the selected variables across the 27 EU countries.

Table 2 accounts for a synoptic view of the descriptive statistics for the selected variables, encompassing both the economic indicators and the CE metrics for the EU27 member states from 2011 to 2020.

The descriptive analysis highlights significant disparities in both economic and CE performance across the EU27, simultaneously emphasizing the

Table 2 The descriptive statistics of the key variables for the EU27 (2011-2020)

Country	Variable	N	Mean	Std. dev.	Median	Trimmed	Mad	Min	Max	Range	Skew.	Kurt.	SE	p-value
EU27	CMUr	270	8.61	6.22	6.95	7.79	5.63	1.3	29.1	27.7	1.12	0.78	0.38	5.35E-13
EU27	Patents	270	11.94	19.33	4.13	7.44	6.12	0	110.25	110.25	2.71	8.04	1.18	1.79E-23
EU27	PatentsPM	270	0.84	1.31	0.48	0.58	0.71	0	11.9	11.9	4.4	27.11	0.08	5.34E-25
EU27	PersEmp	270	136250.60	189837.14	51803.00	94489.90	51436.58	1700.00	764770.00	763070.00	1.77	1.74	11553.12	5.60E-23
EU27	PersEmpPerc	270	1.79	0.5	1.75	1.79	0.67	0.4	3.5	3.1	0.04	-11.47	0.04	2.05E-03
EU27	InvAbs	270	3240.46	5650.32	741	1806.15	917.73	33	34489.00	34456.00	2.87	9	343.87	9.01E-25
EU27	InvPerc	270	0.67	0.34	0.6	0.63	0.3	0.1	1.7	1.6	0.87	0.55	0.02	1.42E-09
EU27	GVA	270	8453.77	14424.51	2587.00	4651.55	3249.86	144	79177.00	79033.00	2.66	7.12	877.85	9.62E-25
EU27	GVAperc	270	1.74	0.73	1.6	1.66	0.44	0.5	6.2	5.7	3.16	15.33	0.04	6.41E-21
EU27	GDP (USD bn)	270	557.85	882.92	227.73	329.96	269	9.46	3974.44	3964.98	2.36	4.88	53.73	5.03E-24
EU27	GDPgr	270	1.63	3.61	1.95	1.81	2.13	-11.17	24.48	35.64	0.16	6.8	0.22	1.27E-12
EU27	GDPpc	270	33664.95	22852.78	25689.15	30372.64	17580.27	7078.86	123678.70	116599.84	1.7	3.57	1390.78	1.56E-16
EU27	GDPpeg	270	1.4	3.59	1.54	1.61	2.45	-11.6	23.3	34.9	0.02	5.83	0.22	2.71E-11
EU27	GFCF	270	20.95	4.37	20.49	20.81	3.22	10.69	54.27	43.59	2	1..8	0.27	5.48E-15
EU27	GFCFgr	270	3.09	11.5	2.34	2.04	6.09	-25.37	100.69	126.06	3.48	22.93	0.7	1.29E-20
EU27	RESP	270	1.74	1.05	1.39	1.63	0.99	0..3	4.47	4.17	0.76	-0.29	0.06	1.59E-10
EU27	RESPppp	270	1.83	0.8	1.62	1.77	0.66	0.62	4.09	3.48	0.65	-0.28	0.05	6.02E-09

Source: Authors based on the World Bank (2024) and Eurostat (2024)

necessity for tailored approaches to foster circular competitiveness. These differences set the stage for more complex analyses using PCA and panel regression.

The GDP data reveal significant variability across the EU countries, with the SD ($882.92 billion) substantially exceeding the mean ($557.85 billion), pointing to considerable economic dispersion. The high coefficient of variation (158.27%) and skewness (2.36) highlight the presence of the high-performing outliers, contributing to the economic disparities that will shape the circular competitiveness outcomes explored later.

CMUr also shows substantial dispersion (the mean 8.61%, the SD 6.22%, the CV 72.24%)), reflecting the varied adoption of the CE principles (Busu, 2019). The range of typical CMUr values (4.33% to 18.75%) suggests significant differences in the CE implementation across the EU countries (Popović *et al*, 2022).

The patent metric exhibits a high kurtosis (8.04), indicating a distribution with heavy tails (Herrero-Luna *et al*, 2022) and suggesting that a few countries produce a disproportionately large number of the CE-related patents, while most lag behind (Zhou *et al*, 2020).

These insights provide the foundation for advanced modeling techniques in order to capture complex relationships between economic growth and CE performance (Androniceanu *et al*, 2021).

As the EU's largest economy, Germany has an average GDP of $3,716.90 billion and an average GDPpc of $45,427.04. CMUr is 11.67% (slightly above the EU average), and RESP is 2.44 EUR/kg. This illustrates that economic strength alone does not ensure CE leadership (Stahel, 2016).

France has an average GDP of $2,689.12 billion and an average GDPpc of $40,411.76. CMUr is 18.15%, outperforming the EU average, and GFCF is 22.42% of the GDP. There is a positive correlation between economic development and the CE adoption (Hysa *et al*, 2020).

The Netherlands has an average GDP of $863.11 billion, the highest CMUr (26.55%), and patents per million (1.35), which exemplifies how smaller,

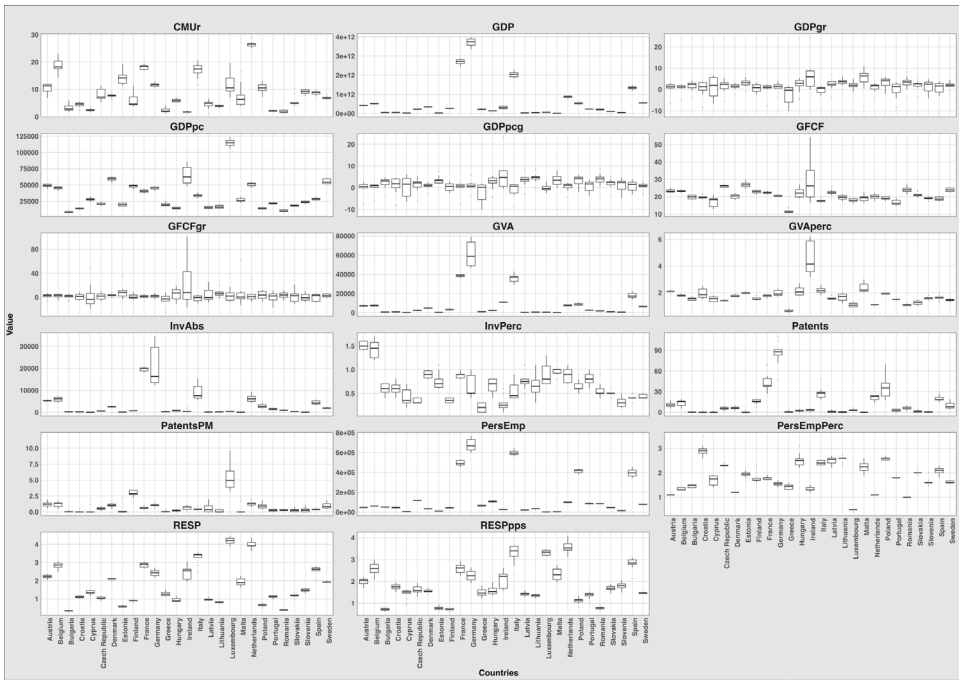

Figure 1 The boxplots of the descriptive statistics of the variables in the individual countries

Source: Authors based on the World Bank (2024) and Eurostat (2024)

developed economies can excel in circular practices through targeted policies (Busu, 2019; European Commission, 2020).

Poland's average GDP is $533.05 billion, and its GDPpc is $14,030.31. CMUr is 10.55%, which is near the EU average. It shows a commitment to the CE despite economic constraints (Popović *et al*, 2022).

Romania has a low GDPpc ($10,562.86), CMUr of 1.94%, and patents of 0.30 per million. This highlights challenges for the Eastern European countries in circular transitions (Zhou *et al*, 2020).

Luxembourg has the highest GDPpc ($114,426.14), CMUr 11.97%, and patents 5.84 per million, which underscores that high GDPpc does not guarantee the success of the CE (Mitrović & Veselinov, 2018).

This analysis reveals that, while developed economies generally show stronger CE metrics, exceptions suggest complex dynamics. It supports A. Andronicean *et al*'s (2021) call for tailored strategies across the EU. Disparities in RESP and CMUr offer opportunities for knowledge transfer (Ferrante & Germani, 2020). Economic strength provides the foundation for the development of the CE but is not the sole determinant.

These insights inform subsequent analytical techniques to unravel the dynamics driving competitiveness and innovation in the CE across the EU.

The correlation matrix (Figure 2) reveals the key relationships in the development of the CE:

- CMUr correlates positively with RESP (r = 0.66) and Patents (r = 0.43), supporting previous findings on resource efficiency and innovation in circular economies.
- Patents strongly correlate with Investment (r = 0.79) and GVA (r = 0.85), confirming A. Karman & M. Pawlowski's (2021) argument on the role of investments in circular innovation.
- GDPpc strongly correlates with RESP (r = 0.76) but weakly with CMUr (r = 0.33), suggesting that wealth does not directly translate to higher CMUr.
- GFCF shows weak or negative correlations with the CE indicators, challenging the assumptions about the role of capital formation.

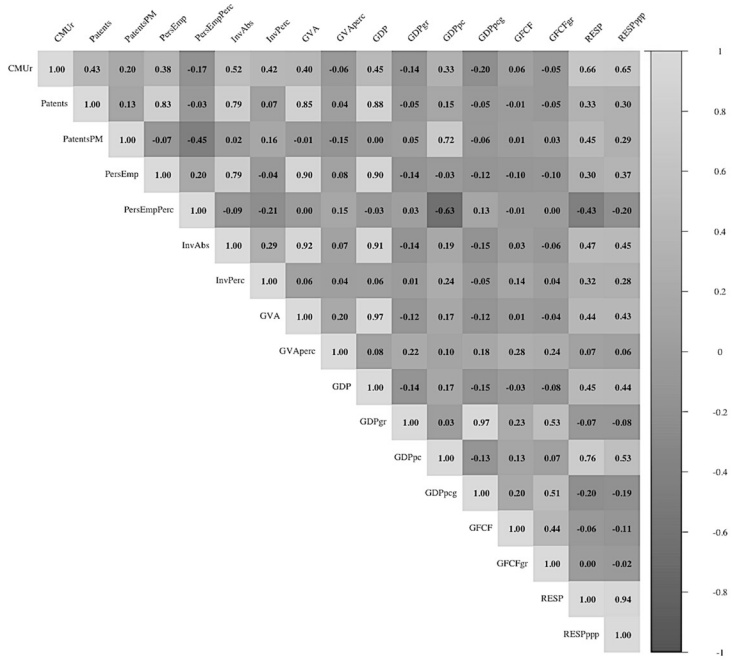

Figure 2 The correlation matrix of the key variables

Source: Authors based on the World Bank (2024) and Eurostat (2024)

- RESP and RESPppp strongly correlate (r = 0.94), indicating consistency across the purchasing power differences.
- PersEmp correlates strongly with GVA (r = 0.90) and InvAbs (r = 0.79), aligning with the European Commission's (2020) emphasis on the job creation potential.

These relationships highlight the complex nature of the development of the CE, suggesting that, while economic prosperity generally facilitates adoption, pathways vary across the indicators. This analysis underscores the need for sophisticated modeling and tailored policies.

Principal Component Analysis (PCA) and indices development

Following the descriptive analysis, PCA was conducted so as to further explore the key drivers of circular competitiveness and economic growth. It revealed the central variables influencing these outcomes. This step allowed the construction of the two indices, the CCII and the EG, in order to evaluate performance across the EU27 during the period from 2011 to 2020.

PCA for the CCII revealed that the first four components explained 87.30% of the total variance in the CE indicators, indicating a high degree of information retention. Table 3 presents the component loadings:

Table 3 The CCII component loadings

Varijable	PC1	PC2	PC3	PC4
CMUr	0.421	-0.183	0.265	0.102
Patents	0.475	0.112	-0.138	-0.092
PatentsPM	0.453	0.165	-0.201	-0.073
PersEmp	0.418	-0.246	0.185	0.124
PersEmpPerc	-0.089	0.587	0.321	0.418
InvAbs	0.399	-0.278	0.194	0.153
InvPerc	-0.065	0.595	0.302	0.385
GVA	0.412	-0.258	0.189	0.138
GVAperc	-0.078	0.592	0.315	0.401

Source: Authors

The first principal component (PC1) shows strong positive loadings for Patents, CMUr, and Employment in the circular sectors, suggesting that it captures the overall CE performance. This aligns with the findings by E. Hysa *et al* (2020) on the importance of these factors in the CE transitions. The second principal component (PC2) appears to emphasize the relative importance of the circular sectors in the economy, with high loadings on the percentage-based variables, reflecting the structural aspects of the CE integration as discussed by M. Busu (2019).

For the EG, the first three components explained 91.21% of the total variance, demonstrating a high level of data compression. Table 4 presents the component loadings:

PC1 shows strong positive loadings for GDP, GDPpc, RESP, and ResPppp, representing overall economic performance, which supports Đ. Mitrović and M. Veselinov's (2018) emphasis on these indicators in assessing economic growth. PC2 and PC3 capture additional details in economic growth, with PC2 emphasizing investment (GFCF) and PC3 showing a contrast between investment and resource productivity, reflecting the complex relationship between GFCF and resource efficiency as noted by A. Karman and M. Pawlowski (2021).

Table 4 The EG component loadings

Variable	PC1	PC2	PC3
GDP	0.512	-0.245	0.168
GDPpc	0.498	0.312	-0.215
GFCF	0.089	0.687	0.718
RESP	0.487	0.325	-0.398
RESPppp	0.495	0.307	-0.242

Source: Authors

Based on these PCA results, the authors constructed the 10-year CCII and EG indices for each country and each year in the dataset. The indices were standardized and scaled from 0 to 100 for ease of interpretation and comparison across the countries and the time periods. Figure 3 presents a scatter plot of the average CCII and EG scores for each EU27 country over the period from 2011 to 2020.

The scatter plot reveals the key patterns in the performance of the CE in the EU:

- Positive Correlation: The CCII and EG scores generally correlate positively, supporting W. R. Stahel's (2016) argument that economic strength facilitates circular transitions.

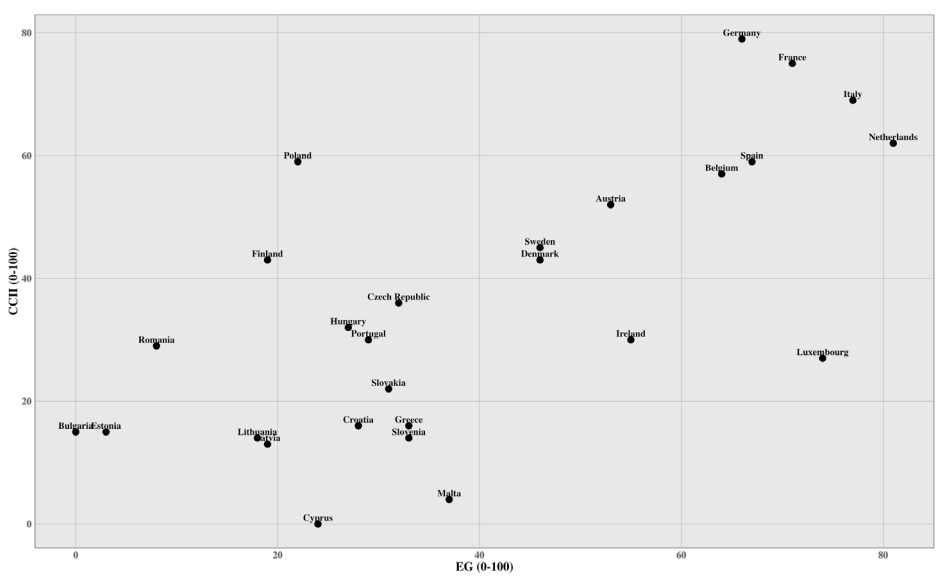

Figure 3 The scatter plot of the average CCII vs. EG scores for the EU27 countries (2011-2020)

Source: Authors based on the World Bank (2024) and Eurostat (2024)

- Leaders Cluster: Germany, France, Italy, and the Netherlands excel in both economic growth and circular practices.
- Divergent Performances: Luxembourg and Ireland show a high EG but a moderate CCII, whereas Poland has a higher CCII relative to the EG, thus supporting Đ. Mitrović and M. Veselinov's (2018) observation that GDPpc does not guarantee CE leadership.
- Catch-up Potential: The Eastern European countries cluster in the lower-left quadrant, aligning with A. Popović *et al*'s (2022) findings on transition challenges.
- Mid-range Performers: Austria, Sweden, Denmark, and Finland show moderate-to-good performance on both indices.
- Outliers: Cyprus has a notably low CCII relative to its EG score.

This analysis provides a comprehensive view of the EU's CE landscape. It forms the basis for subsequent panel data and cluster analyses, enabling a nuanced understanding of the relationship between economic growth and competitiveness in the CE in the EU.

Panel data analysis

After identifying the key drivers of circular competitiveness through PCA, the authors proceeded with panel data regression. The initial model encountered challenges like heteroskedasticity, multicollinearity, and autocorrelation, which were addressed through the model refinement.

The authors conducted both fixed-effects and random-effects panel data regression analyses using the refined set of the independent variables (GDP, GDPpc, GFCF, ResP, and ResPppp) and the CCII as the de-

Table 5 The results of the panel data regression analysis for the CCII

Country	Model Type	Independent Variable	Dependent Variable	Est.	Std.E.	t-value	p-value
EU27	Fixed Effects	GDP	CCII	1.8609	1.0148	1.8338	0.0679
		GDPpc		-2.2070	2.3615	-0.9346	0.3509
		GFCF		1.6993	0.6652	2.5545	0.0113
		RESP		-1.9733	0.9421	-2.0946	0.0373
		RESPppp		1.5892	0.5328	2.9828	0.0032
		(Intercept)		0.4063	0.3362	1.2084	0.2269
	Random Effects	GDP		3.3335	0.2450	13.6055	0.0000
		GDPpc		-2.8025	1.1574	-2.4215	0.0155
		GFCF		1.4024	0.6302	2.2252	0.0261
		RESP		0.4017	0.4984	0.8059	0.4203
		ResPppp		0.2879	0.3260	0.8830	0.3772
	Hausman Test					8.493	0.1332
	Fixed Effects	GDP	CCII standardized	0.4713	0.2570	1.8338	0.0679
		GDPpc		-0.5589	0.5981	-0.9346	0.3509
		GFCF		0.4304	0.1685	2.5545	0.0113
		RESP		-0.4998	0.2386	-2.0946	0.0373
		RESPppp		0.4025	0.1349	2.9828	0.0032
		(Intercept)		0.0676	0.0852	0.7939	0.4273
	Random Effects	GDP		0.8442	0.0621	13.6055	0.0000
		GDPpc		-0.7098	0.2931	-2.4215	0.0155
		GFCF		0.3552	0.1596	2.2252	0.0261
		RESP		0.1017	0.1262	0.8059	0.4203
		ResPppp		0.0729	0.0826	0.8830	0.3772
	Hausman Test					8.4493	0.1332
	Fixed Effects	GDP	CCII (0-100)	9.8311	5.4296	1.8106	0.0715
		GDPpc		-12.1820	12.6354	-0.9641	0.3360
		GFCF		8.7066	3.5593	2.4461	0.0152
		RESP		-10.6121	5.0407	-2.1053	0.0363
		RESPppp		8.5221	2.8508	2.9893	0.0031
		(Intercept)		41.1882	1.7983	22.9034	0.0000
	Random Effects	GDP		17.8408	1.3099	13.6198	0.0000
		GDPpc		-15.4568	6.1943	-2.4953	0.0126
		GFCF		7.1202	3.3750	2.1097	0.0349
		RESP		2.3215	2.6675	0.8703	0.3841
		ResPppp		1.4344	1.7450	0.8220	0.4111
	Hausman Test					9.4332	0.0930

Source: Authors

pendent variable. The Hausman test was employed in order to determine the most appropriate model specification. The results are given in Table 5.

The Hausman test result suggests that the random-effects model is more appropriate for the analysis, which aligns with the findings of A. Karman and M. Pawlowski (2021), who noted that random-effects models often capture both within-country and between-country variations more effectively in studies on the CE.

At the EU27 level, the random-effects model reveals several significant relationships. GDP shows a strong positive association with CCII but, interestingly, GDPpc shows a negative relationship with CCII. GFCF demonstrates a positive relationship with CCII. The results for RESP and RESPppp are not statistically significant in the random-effects model.

The panel data analysis reveals distinct country-level patterns in the relationship between economic growth and competitiveness in the CE. These patterns can be grouped as follows:

- The first group consists of the countries with a significant positive relationship between GDP and CCII, those countries including Belgium, Malta, and the Netherlands. They show a strong positive relationship between GDP and competitiveness and innovation in the CE, suggesting that overall economic growth is closely linked to CE performance in these nations.
- The second group of countries shows a significant negative relationship between GDPpc and CCII. Belgium and the Netherlands show a negative relationship, indicating that higher individual wealth does not necessarily translate to better CE performance.
- The third group of countries shows a significant positive relationship between GFCF and CCII. Ireland and Portugal demonstrate a strong positive relationship between GFCF and competitiveness in the CE, suggesting that investment in fixed assets plays a crucial role in the development of their CE.
- The fourth group consists of the countries with a significant positive relationship between RESP and CCII, where Belgium, Denmark, Hungary, Ireland, and Malta show a positive relationship between RESP and competitiveness in the CE, indicating that the efficient use of resources is a key factor in their CE performance.
- The fifth group comprises the countries with a significant negative relationship between RESP and CCII, with Bulgaria standing out with a negative relationship between RESP and CCII, suggesting a unique dynamic in the development of its CE.
- The sixth group comprises the countries with a significant negative relationship between RESPppp and CCII, with Denmark, Hungary, and Ireland showing a negative relationship between RESPppp and competitiveness in the CE, indicating a complex interaction between resource efficiency and the economic factors.
- The seventh, final and largest group of countries has no significant relationships. Austria, Croatia, Cyprus, the Czech Republic, Estonia, Finland, France, Germany, Greece, Italy, Latvia, Lithuania, Luxembourg, Poland, Romania, Slovakia, Slovenia, Spain, and Sweden show no statistically significant relationships between the variables and CCII. This large group of countries demonstrate the complexity of the development of the CE across the EU.

These findings underscore the heterogeneity of the development of the CE across the EU and the need for tailored, country-specific approaches to promoting competitiveness in the CE. They also align with the observations made in A. P. Egbunike and E. G. Okoro (2018) that capital and green expenditures do not always yield uniform outcomes across diverse contexts.

The sensitivity analyses and alternative model specifications reinforced the robustness of the findings:

- The EU15 countries showed a similar GDP-CCII relationship ($\beta = 3.5621$, $p < 0.001$) to the EU27 ($\beta = 3.3335$, $p < 0.001$).
- The GDPpc-CCII relationship varied from negative in the EU27 ($\beta = -2.8025$, $p < 0.05$) to non-significant in the EU15 ($\beta = -1.9876$, $p = 0.1234$).

- The GDP-CCII relationship strengthened over time (2011-2015: $\beta = 2.9876$, $p < 0.01$; 2016-2020: $\beta = 3.7654$, $p < 0.001$).

Alternative specifications revealed the following:

- the lagged variables improved the model fit, thus supporting X. Zhou *et al*'s (2020) findings on delayed effects,
- the GDP-RESP interaction was significant ($\beta = 0.4567$, $p < 0.05$), thus indicating a stronger GDP impact on CCII in the countries with higher resource productivity, and
- the quadratic GDP term ($\beta = -0.0234$, $p < 0.05$) suggested diminishing returns at high economic output levels.

These analyses highlight the complex, nonlinear, and time-dependent nature of the factors influencing competitiveness in the CE, simultaneously emphasizing the need for the dynamic approaches that consider both the immediate and the long-term effects of economic policies.

Cluster analysis

To further explore the patterns identified through the panel regression, the authors performed a K-means clustering analysis by grouping the EU countries based on their CCII and EG. This clustering provides additional insights into how different economies align or diverge in their CE trajectories. Based on the elbow, silhouette, and gap statistical methods for K-means clustering and the average silhouette width for hierarchical clustering, the optimal number of clusters was determined to be two. The analysis revealed distinct clusters, as illustrated in Figure 4.

The cluster analysis revealed two distinct groups:

- Advanced Circular Economies (Cluster 1): This cluster includes the countries with generally higher scores in both CCII and EG, such as Germany, France, Italy, the Netherlands, Spain, Belgium, Austria, Sweden, Denmark, Finland, Luxembourg, and Ireland, which all demonstrate varying degrees of success in combining their economic growth with CE practices. Within this cluster, multiple sub-groups were distinguished:

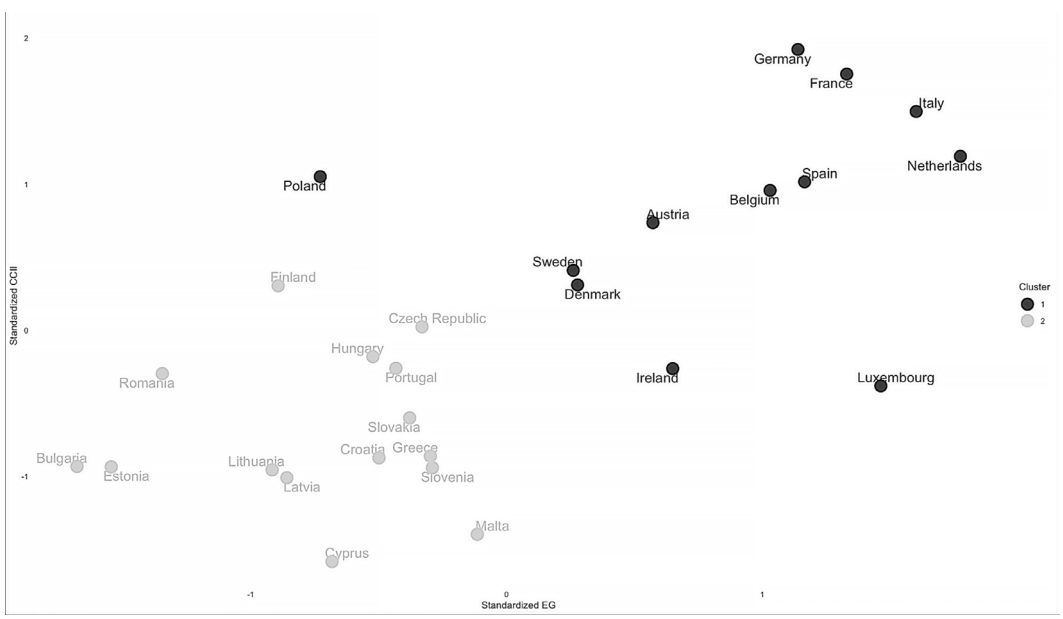

Figure 4 The cluster plot of the standardized CCII vs. EG scores for the EU27 countries

Source: Authors

  - Top Performers: Germany, France, and the Netherlands - the countries showing the highest combined scores, indicating a strong alignment between economic performance and CE practices.
  - Strong Performers: Italy, Spain, and Belgium - the countries demonstrating high scores, albeit slightly lower than the top performers.
  - Nordic Countries: Sweden, Denmark, and Finland - the countries forming a distinct sub-group with an above-average performance in both indices.
  - Economic Powerhouses with Moderate Circularity: Luxembourg and Ireland - the countries showing high EG scores but relatively lower CCII scores, which aligns with Đ. Mitrović and M. Veselinov's (2018) observation that high GDPpc does not automatically translate to CE leadership.

- Developing Circular Economies (Cluster 2): This cluster primarily comprises the Eastern and Southern European countries, including Poland, the Czech Republic, Portugal, Hungary, Romania, Bulgaria, Croatia, Slovakia, Slovenia, Greece, Lithuania, Latvia, Estonia, Cyprus, and Malta, which all generally show lower scores in both EG and CCII but with significant variations:
  - Emerging Leaders: Poland stands out within this cluster, showing a higher CCII score relative to its EG score, suggesting the successful implementation of CE practices despite its lower overall economic output.
  - Transitional Economies: The countries such as the Czech Republic, Portugal, and Hungary show moderate scores, indicating progress in both economic growth and CE adoption.
  - Developing Economies: The countries such as Romania, Bulgaria, and the Baltic states show lower scores in both indices, reflecting the challenges faced by less economically developed EU members in transitioning to CE models, as noted by L. Ferrante and A. R. Germani (2020).

In conclusion, the results obtained from the descriptive statistics, PCA, panel regression, and cluster analysis reveal the complex relationship between economic growth and circular competitiveness in the EU. While economic strength generally supports circular innovation, the variability perceived across the countries emphasizes the need for tailored, country-specific policies, which highlights the fact that each country's unique economic and structural characteristics must be considered for effective circular transitions. Moreover, these findings resonate with the European Court of Auditors (2023) observation that policy ambition must be matched by more differentiated strategies, especially in lower-performing regions.

DISCUSSION

This study examined how economic growth influences CE competitiveness and innovation across 27 EU countries from 2011 to 2020. The findings reveal intricate interactions between economic indicators and circular performance, highlighting that while growth can support circular transitions, these dynamics are not uniform across countries.

Relationship between economic growth and competitiveness and innovation in the circular economy

Hypothesis 1 (*H1*) posited that higher GDP, GDPpc, and their respective growth rates would positively correlate with greater competitiveness and innovation in the CE. The findings partly support this hypothesis, highlighting the nuanced relationship between economic growth and circular performance. While GDP strongly correlates with CE success, as evidenced by the positive association with CCII, the negative coefficient for GDPpc underscores that economic strength alone does not guarantee advanced implementation of the CE, which aligns with the complexities identified by F. Ying and Z. Wen-Ping (2015) in high-growth but lower-tech contexts. This suggests that wealthier nations may face additional challenges in achieving circular competitiveness, potentially due to entrenched linear economic practices or weak policy incentives for sustainability, which is in line with W. R. Stahel's (2016) argument

that economic strength provides necessary resources for circular transitions.

However, the relationship between GDPpc and CCII was found to be negative, thus contradicting part of the first hypothesis. This unexpected result echoes the observations of Đ. Mitrović and M. Veselinov (2018), indicating that higher individual wealth does not necessarily translate to better CE performance. It further echoes the contrasting outcomes observed in some advanced economies with moderate circular metrics (European Court of Auditors, 2023). This finding challenges the assumption that wealthier countries are automatically more adept at implementing CE practices. It suggests that other factors, such as policy frameworks, industrial strategies, and societal attitudes towards sustainability, may be more crucial in driving competitiveness in the CE than *per capita* income alone.

The cluster analysis further illuminates this complex relationship. While the countries classified into Cluster 1 generally show high scores in both EG and CCII, there are notable exceptions. Luxembourg and Ireland demonstrate high EG scores but relatively lower CCII scores, reinforcing the idea that high GDPpc does not automatically lead to CE leadership. Conversely, Poland in Cluster 2 shows a higher CCII score relative to its EG score, suggesting that effective policies and targeted efforts can drive CE performance even in the countries with a lower overall economic output. This aligns with A. P. Egbunike and E. G. Okoro's (2018) emphasis on targeted environmental investments and policy instruments, which may overcome lower baseline income levels.

The role of investment in the development of the circular economy

Hypothesis 3 (*H3*) proposed that countries with higher investments (GFCF, InvAbs) tend to have more significant innovations and higher levels of competitiveness in the CE. The results support this hypothesis, highlighting the importance of capital formation in driving CE transitions.

The random-effects model showed a positive relationship between GFCF and CCII. This finding aligns with S. Herrero-Luna *et al*'s (2022) assertion that investment in tangible assets is crucial for CE transitions, which suggests that the countries allocating more resources to fixed assets, potentially including the infrastructure and technologies supporting CE practices, tend to perform better in terms of competitiveness in the CE.

At the individual-country level, this relationship was particularly pronounced in Ireland ($\beta = 2.0618$, $p < 0.05$) and Portugal ($\beta = 23.3467$, $p < 0.05$). These results indicate that targeted investments can significantly boost CE performance, even in the countries with different overall economic standings. Such targeted approaches further resonate with the findings of E. Jakopin (2020) regarding structural reform and capital allocation, indicating that aligning investment with CE goals can overcome growth constraints.

The importance of investment is further underscored by the alternative model specifications, which showed that including the lagged GFCF variables had improved the model fit and reduced autocorrelation, which is supportive of X. Zhou *et al*'s (2020) findings on the delayed effects of economic factors on CE outcomes, suggesting that the benefits of investments in CE initiatives may not be immediately apparent but may have significant long-term impacts.

Resource productivity and circular economy performance

Hypothesis 2 (*H2*) suggested that countries with higher ResP and ResPppp exhibited better CE performance. The results provide limited and mixed support for this hypothesis, revealing a complex relationship between resource efficiency and competitiveness in the CE.

In the EU27 random-effects model, the RESP and RESPppp results were not statistically significant. This ambiguity echoes M. Busu's (2019) observations on the complex relationship between resource productivity and CE performance. It suggests that, while resource efficiency is theoretically crucial for CE practices, its

impact may be mediated by the other factors such as technological adoption, regulatory frameworks, and industrial composition.

At the individual-country level, mixed results were noticed. Some countries, like Belgium (RESP: β = 33.1388, $p < 0.1$) and Denmark (RESP: β = 22.3519, $p < 0.05$), showed positive relationships between resource productivity and CCII. Some others, however, like Bulgaria (RESP: β = -40.2117, $p < 0.1$), demonstrated negative relationships. This variability suggests that the impact of resource productivity on CE performance is context-dependent and may interact with the other country-specific factors.

The interaction term between GDP and RESP in the alternative model specifications (β = 0.4567, $p < 0.05$) provides an additional insight. It suggests that the positive impact of GDP on CCII is stronger in the countries with higher resource productivity. This finding is consistent with EU-wide efficiency dispersion documented by I. Marjanović *et al* (2025), which shows pronounced cross-country differences in circular economy efficiency, so the scale of gains from economic expansion depends on a country's initial efficiency level. Overall, resource efficiency may act as a moderator, enhancing the effectiveness of economic growth in driving competitiveness in CE.

Implications for policy and practice

The findings have several important implications for policymakers and practitioners:

- While GDP supports circular development, the negative correlation with GDPpc indicates that wealthier nations need targeted policies to convert economic prosperity into circular competitiveness.
- Prioritizing investments in infrastructure, technologies, and systems that support circular practices will be essential for sustained competitiveness.
- Resource efficiency impacts CE performance differently across countries. Policymakers should develop context-specific strategies that integrate resource productivity into broader CE goals.
- Clustering analysis shows the need for tailored CE policies, depending on a country's stage of development and economic characteristics.
- The time-lagged effects of investments and resource productivity require sustained, long-term planning to see meaningful CE outcomes.

Limitations and Future Research Directions

While this research study provides valuable insights, it has several limitations that point to directions for future research:

- The composite indices (CCII and EG) may obscure relationships between specific variables. Future research should explore granular interactions between individual economic and circular indicators.
- The analysis is limited to the data pertaining to the period from 2011 to 2020. Incorporating more recent data would provide insights into the evolving nature of CE practices.
- Focusing on the EU countries limits the generalizability of the findings. Comparative studies involving non-EU countries could broaden the scope of research in the CE.
- Future research could investigate additional factors influencing circular competitiveness, such as policy interventions and sector-specific initiatives. It may also be worthwhile to examine firm-level heterogeneity, aligning with D. Jovanović and V. Janjić (2018) and A. P. Egbunike and E. G. Okoro (2018), in order to explore how corporate spending on environmental measures interacts with macro-level indicators.

Finally, the research reveals the complex relationship between economic growth and competitiveness and innovation in the CE in the EU. While economic strength generally facilitates the development of the CE, the path to CE success is not straightforward and depends on a variety of factors beyond a mere economic output. These findings underscore the need for nuanced, context-specific approaches to promoting

CE practices across the diverse landscape of the EU. Elevating resource efficiency, directing capital effectively, and addressing structural disparities are key to ensuring that economic gains translate into tangible circular outcomes (European Court of Auditors, 2023).

CONCLUSION

This research highlights the complex relationship between economic growth and competitiveness in the CE across the EU from 2011 to 2020. While economic growth measured by GDP generally supports CE performance, this relationship varies across countries, emphasizing the need for tailored, country-specific policies. Notably, the negative link between GDPpc and circular outcomes, which is also observed in high-growth contexts (Ying & Wen-Ping, 2015; European Court of Auditors, 2023), demonstrates that wealth alone does not guarantee circular leadership. Instead, factors like policy frameworks, industrial strategies, and societal attitudes may play a more crucial role.

Investment in fixed assets emerged as a key driver of circular transitions, reinforcing the importance of infrastructure and technology in promoting circular practices. Such targeted capital allocation echoes findings that green expenditure policies can foster efficiency and competitiveness (Egbunike & Okoro, 2018). The relationship between resource productivity and circular performance proved more complex, with country-specific variations indicating that economic structures and resource use influence circular outcomes differently.

Cluster analysis revealed two distinct groups of countries, the first including advanced and the second including developing circular economies. Some lower-output countries, such as Poland, demonstrated strong circular performance, showing that effective policies can drive success even in less wealthy nations. The research also underscores the time-lagged effects of investments, requiring long-term planning and sustained commitment for a lasting impact. Moreover, aligning macro-level growth strategies with structural reforms (Jakopin, 2020) can help ensure these investments generate enduring circular gains.

Overall, the study shows that, while economic strength aids circular development, success depends on various factors beyond the economic output. Tailored, country-specific approaches will be vital as the EU advances towards a more sustainable CE. In practice, as emphasised by European Commission (2020) and European Court of Auditors (2023), and consistent with the EU-wide efficiency dispersion evidenced by I. Marjanović *et al* (2025), growth strategies should be integrated with resource-efficiency and circularity measures so that expansion translates into durable circular competitiveness.

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Andrija Popović is a Research Assistant at the Innovation Center of the University of Niš. He specializes in macroeconomics, economic development, sustainability, circular economy, and Industry 4.0. Popović has authored several scientific papers and book chapters in the field of economic development and circular economy.

Andreja Todorović is a Research Assistant at the Innovation Center of the University of Niš. He specializes in research on bank net interest margins. He works at the University's Innovation Center and has published papers on finance and banking and presented at national and international conferences.

Vladan Vučić is an Associate Professor at the Faculty of Law, Security and Management, "Konstantin Veliki" of "Union - Nikola Tesla" University in Belgrade. He specializes in competition protection, market analysis, public finance, macroeconomics, and economic development. Vučić has authored several textbooks, monographs, and scientific papers.

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THE IMPACT OF HUMAN CAPITAL IMPROVEMENT ON PER CAPITA INCOME DYNAMICS IN THE CENTRAL AND EASTERN EUROPEAN COUNTRIES

Đorđe Kotarac[1]* and Zoran Popović[2]

[1]*University of Belgrade, Faculty of Agriculture, Belgrade, Republic of Serbia*
[2]*University of Belgrade, Faculty of Economics and Business, Belgrade, Republic of Serbia*

Theoretical and empirical findings confirm the thesis that the accumulation of physical capital partly explains the movement of countries' economic growth rates. Researchers in the field of development economics, as well as creators of economic policies, are shifting their focus from physical (PC) to human capital (HC) as a determinant of countries' economic development. The subject matter of this paper is the analysis of the impact of HC on achieving higher *per capita* income growth rates. According to the "Lisbon Strategy" and the "Europe 2020 Strategy", HC is placed on a pedestal of importance, all with the aim of making the EU-27 the most competitive market in the world. The empirical part was conducted using a panel regression model. The research results indicate a significant impact of HC on the *per capita* income of the CEE-10 countries. This research study contributes by reducing a gap in the scientific literature by examining the impact of HC on the *per capita* income of the European countries. The concluding implications point to the importance of HC development as an effective instrument for ensuring countries' greater economic growth.

Keywords: human capital, GDP *per capita*, economic growth, CEE-10, panel data

JEL Classification: E24, C33, O15, O47

INTRODUCTION

Human capital is defined as one of the leading factors of countries' economic growth and economic development, as recognized in a scientific research study from the second half of the 20th century (Mincer, 1958; Schultz, 1961). An analysis of the influence of human capital as an effective instrument for economic development was carried out with the establishment of the first growth theories in the 1950s and 1960s by R. M. Solow (1956) (Nguyen, 2023; Aslam, Mudassir, Ghouse & Farooq, 2024). In this context, the term "human capital" was defined in both a narrow and a broader sense.

According to the narrower approach, human capital refers to the education level of an individual or the entire population, as well as the quality of training

* *Correspondence to:* Đ. Kotarac, University of Belgrade, Faculty of Agriculture, Nemanjina 6, 11000 Belgade, Republic of Serbia; e-mail: djordje.kotarac@agrif.bg.ac.rs

for work operations (Petrović, 2010). It is enhanced through various measures, including the allocation of funds to the education sector, subsidizing patents and start-up products, the improvement of workers' skills, the regulation of occupational safety measures, ensuring the social and health care of the workforce, increasing the share of human capital in exported products and services, as well as the other factors that contribute to increased labor productivity (Balogh, 2013).

The assumptions of the neoclassical model of economic growth indicate that improvements in the quality of human capital have only a short-term effect, which results in the absence of further increases once the long-term equilibrium point is reached (Solow, 1999). The neoclassical growth model also implies the exogeneity of the variables representing the total workforce and physical capital, both of which directly affect changes in labor productivity (Pelinescu, 2015). One of the criticisms of the neoclassical growth model is its omission of the effect of educating population on economic growth, as well as subsidizing resident and nonresident patents, and an insufficient budget allocation to the education sector. Investing in R&D activities and human capital ensures the application of new technologies in order to achieve higher labor productivity, which causes the growth of *per capita* income (Borović, Tomaš & Trivić, 2023). According to traditional growth models, the accumulation of physical capital, the initiation of technological progress and the development of human capital lead to higher labor productivity (Solow, 1999). The neoclassical growth model neglects the education of the workforce and the innovation of production processes, i.e. the size of the volume of the workforce is analyzed instead of the efficiency in performing work operations (Hanushek & Woessmann, 2012). Therefore, the quality of human capital causes growth in labor productivity and the profitability of companies across markets (Yahaya, Salman, Abdulsalam & Adegbayibi, 2022).

At the beginning of the 1980s, the endogenous growth model was developed, which observes the effect of human capital on the economic growth rates of countries (Barro, 2015). The proponents of this model point out the fact that the allocation of funds to the education system, the subsidizing of patents, and technological innovations are an indispensable part of the structure of human capital (Aghion & Howitt, 1998). Achieving higher rates of economic growth requires improving the quality of human capital by encouraging entrepreneurial activities and enhancing the education of the working-age population (Molnar, Josipović & Baškot, 2024). The modified model suggests that human capital has a long-term effect on changes in *per capita* income (Ogbeifun & Shobande, 2022). This effect is seen in the development of the education system and the growth of the human capital stock, both of which contribute to greater economic development (Benos & Zotou, 2014).

In the economic policy measure adoption process, the role of human capital is emphasized as a significant determinant for increased labor productivity, which further reflects in the growth of income *per capita* (Lucas, 2015). Therefore, the countries that allocate a larger portion of their budgetary funds to the education system - as an incentive for technological progress - achieve higher rates of convergence, or the "catch-up effect", in *per capita* income levels compared to more developed economies (Wolff, 2013). Motivated by these considerations, the European Union has adopted a series of strategies based on knowledge and investment in research and development activities so as to become the most competitive and the most dynamic market in the world in the foreseeable future (Lucian, 2015). In March 2000, the Lisbon Summit was organized, at which the representatives of the governments of the European Union developed a strategy based on knowledge, innovation, and the optimization of human capital, all directed at achieving higher labor productivity, higher rates of economic growth and greater social cohesion. During 2005, a revised version of the Lisbon Strategy was adopted, which aimed to place human capital on a pedestal in terms of importance, so that knowledge and innovation would be used in support of economic growth (Mićić, 2009).

The recognition of the importance of human capital as an instrument for improving the state of the economies of different countries was achieved

through the implementation of a new development strategy, whose draft was published by the European Commission in 2009, the final version being released in 2010 (Silander, 2019). The priorities of the aforementioned strategy relate to ensuring intelligent growth, i.e. the development of an economy based on knowledge and innovation.

Within the "Europe 2020" Strategy, several initiatives have been established, namely the Innovation Union, Youth on the Move, the Digital Agenda for Europe, and the Agenda for New Skills and Jobs (European Commission, 2010). The strategy aims to drive smart growth by investing in innovation and technical and technological advancement, and by increasing the share of the population with secondary and tertiary education (European Commission, 2010). Numerous studies have confirmed that the influence of human capital on economic growth is significantly greater than the effect of physical capital. Along with the improvements of the education structure of the population, human capital also grows through investment in the development of patents and technological innovations (Habibi & Zabardast, 2020). A country exports products that make intensive use of human capital. Therefore, foreign trade openness is considered when analyzing the relationship between human capital and economic growth (Petrović, 2010).

According to the subject matter and aims of the research, the following hypothesis is set and tested:

H1: The improvement of human capital has a positive effect on an increase in income *per capita* on the sample of ten Central and Eastern European countries.

The empirical tools used in this research include the descriptive, analytical and synthetic methods. The methodological part of the study employs econometric tests involving the application of a balanced panel regression model. In the Introduction, theoretical implications are presented, and the objectives and the subject matter of the research are explained. In the second chapter, other empirical scientific studies that confirm a positive impact of human capital on increases in *per capita* income are reviewed. In the third section, an overview of the data sources used to form the research sample frame is given. Additionally, this chapter also explains the methodological approach, focusing on the use of the balanced panel regression model. In the Conclusion, the results obtained from this research are interpreted.

LITERATURE REVIEW

Since the 1980s, alongside the modification of traditional growth models, a series of scientific studies have been conducted, examining the influence of human capital on changes in income *per capita*. However, a distinction is made between the research investigating the impact of the education level on earnings *per capita* and those examining the effect of human capital on income *per capita*, which include a broader range of variables.

According to M. R. Guisan and I. Neira (2006), the influence of human capital on the economic development of the countries of North America, Europe, Asia, and Africa, was confirmed for the period from 1960 to 2004. The authors carried out panel regression analysis to demonstrate a statistically significant relationship between the average number of the years of schooling, the state investments in the education system and research and development, population growth incentives, and foreign trade openness on population income growth. The results of this research are consistent with the previously obtained results of a number of studies. In a research study conducted by R. J. Barro (1991), a direct effect of the population's primary and secondary levels of education on economic growth was confirmed in the period from 1960 to 1985. In their research, K. Lee and B. Y. Kim (2009) prove that there is a statistically significant impact of population growth with secondary and tertiary education on *per capita* income on a sample of 63 countries in the period from 1965 to 2002. Additionally, the authors T. Suri, M. A. Boozer, G. Ranis and F. Stewart (2011) confirmed a statistically significant effect of secondary education on an increase of *per capita* income on a sample of 79 countries.

In their research, F. Habibi and M. A. Zabardast (2020) point out the importance of investing budgetary funds in education and technological progress in the countries of the Middle East and the OECD countries. The results of the research conducted by Q. Kong, D. Peng, Y. Ni, X. Jiang, and Z. Wang (2021) confirm the impact of a country's foreign trade openness on achieving higher growth rates and population income. This effect is attributed to the incorporation of human capital in the production of export goods and services. The same result was obtained by the authors D. Dekkiche and O. B. Leila (2024), who confirmed a statistically significant correlation between foreign trade openness and economic development within the BRICS countries by applying the ARLD panel method.

According to I. Hasan and C. L. Tucci (2010), countries with high-quality patents achieve higher rates of economic growth, as demonstrated on a sample of 58 countries from 1980 to 2003. The same conclusion was reached by A. M. Pece, O. Simona, and F. Salisteanu (2015), who found that investment in technological innovation led to higher *per capita* income in the CEE-10 countries. According to C. P. Nguyen and N. Doytch (2022), the impact of registered patents on *per capita* income was demonstrated in a study of 43 countries from 1998 to 2016. The above-mentioned references are a motivation to examine the impact of human capital on the income *per capita* of the CEE-10 countries.

METHODOLOGY AND DATA

The methodological part of this research concerns the formation of a research sample consisting of the European Union countries that joined the Union during or after 2004. The study uses data from a group of ten Central and Eastern European countries for the purpose of constructing the sample frame. The analysis includes the new members of the European Union, namely Bulgaria, Hungary, Romania, Poland, the Czech Republic, Latvia, Lithuania, Estonia, Slovakia and Slovenia. The sample does not include data for five members of the European Union that are geographically located in Central and Eastern Europe. Specifically, Malta, Croatia, Luxembourg, Ireland and Cyprus were excluded from the analysis, the reason for their exclusion being primarily economic. These prominent EU member states have significantly smaller economies and notably lower annual *per capita* income growth rates compared to the ten countries of Central and Eastern Europe included in the study. An additional reason for their exclusion lies in the partial unavailability of data on *per capita* income over the entire observed period. Similarly, these countries have incomplete time series data on human capital indicators. Therefore, the time series for the ten countries of Central and Eastern Europe will be used for the sampling frame of this research, which will be marked with the three-digit abbreviation CEE-10, according to the instructions of the International Organization for Standardization (ISO standard).

The research period includes the interval from the first quarter of 2012 to the fourth quarter of 2023. The research refers to the period after the appearance and duration of the negative effects of the world financial crisis (2008), which avoids the negative impact of structural breaks on the movement of the time series of the income *per capita* of the CEE-10 countries. The collected data pertain to the period up to the last quarter of 2023 as the last year with available data at the time of conducting the research. For the purpose of data collection, the publicly available database of the World Bank was used, as well as the publicly available database of Eurostat.

In order to complete the methodological part of the research and obtain relevant research results, the panel data method was applied. This approach involves the analysis of several different units of observation , where , across the previously defined time period , which, in this model, is , providing a sufficient number of observations for conducting panel analysis. The applied panel data are balanced, which means that there is an equal number of observations for each unit . The relation N<T is characteristic of the panel model in this research study - the number of the observation units is smaller than the number of the period, which classifies this dataset as a micro-panel, which falls into the group of linear models.

The primary advantages of using panel data as a methodological tool include control of individual heterogeneity, the absence of multicollinearity among the included variables, increased variability, and the provision of more precise and more robust research results (Hsiao, 2022). By analyzing the impact of several different units of observations of the economics variables for multiple countries or companies within a single period, the method including comparative data is applied. However, time series analysis models are implemented when measuring the effects of a certain variable for a single company or country across different periods.

The empirical analysis of the simultaneous effect of different observation units across multiple time units will require the use of panel data methods (Baltagi, 2008). The research includes ten units of observation in different time periods, which suggests that the use of the methods including comparative data or a multiple model for time series analysis will lead to biased evaluations of the research, as well as unreliable results and conclusions (Wooldridge, 2010). Therefore, the impact of human capital on the change in the growth rate of *per capita* income will be assessed using the panel method. The analysis starts with the use of a pooled effects panel model (the Pooled OLS model). To implement the panel model, the regression equation is estimated as follows:

$$Y_{it} = \alpha + \beta_1 X_{1,it} + \beta_k X_{k,it} + V_t + \varepsilon_i + u_{it},$$
$$i = 1,\ldots,N,\ t = 1,\ldots,T,\ k = 2, 3, 4,\ldots,n \qquad (1)$$

where the symbols represent:

N - the number of the observation units, T - the number of the periods,

α - this symbol implies an intercept and predicts where the regression line will cross the y axis,

Y_{it} - the value of the growth rate of income *per capita*, for the *i*-th unit of observation in the unit of time *t*,

β_k - predicts the change in for each unit change in the *k*-th independent variable for the *i*-th unit of observation in the unit of time *t*,

$X_{k,it}$ - the value of the independent variable X_k, for the *i*-th unit of observation in the unit of time *t*,

V_t - the time effects,

ε_i - the individual effects,

u_{it} - the random error value, which follows a normal distribution with a mean of zero and constant variance.

The pooled effects model (Pooled OLS model) is rejected due to the thesis that the model neglected the assumption of heterogeneity between different units of observation, which leads to the conclusion that the included countries within the panel model react according to the identical principle (Hsiao, 2022). In order to overcome the potential absence of heterogeneity between different observation units, fixed effect panel models or stochastic effects panel models are applied. In the first phase of the methodological part, the analysis of the fixed effect panel model is carried out, followed by data analysis using the random effects model. Within the fixed effects model, individual effects are directly included in the model as the fixed parameters through the free terms or the intercept and predict where the regression line crosses the y axis. To obtain results and evaluate the equation using the fixed effects model, the following equation is formulated:

$$Y_{it} = \alpha + \alpha_i + \beta_1 X_{1,it} + \ldots + \beta_k X_{k,it} + \varepsilon_{it},$$
$$i = 1,\ldots,N,\ t = 1,\ldots,T,\ k = 2,3,4,\ldots,n \qquad (2)$$

The fixed-effects panel model assumes that the random errors and explanatory variables in the model are uncorrelated. However, the fixed effects panel model allows for the correlation of individual effects and independent variables (Baltagi, 2008). For the purposes of overcoming the problem of the correlation of individual effects and random errors and testing which of the models is more representative, i.e. which of the models provides more scientifically robust results, the random effects model is applied. Thus, the regression equation is evaluated, which is set in the following form:

$$Y_{it} = \alpha + \beta_1 X_{1,it} + \ldots + \beta_k X_{k,it} + V_{it},$$
$$V_{it} = \alpha_i + \varepsilon_{it},\ i = 1,\ldots,N,\ t = 1,\ldots,T \qquad (3)$$

In support of the explanatory variables of this research study, whose impact on the dependent variable is assessed using the panel data method, there are the following variables:

$X_{1,it}$ - the explanatory variable that implies the education level of the total population by measuring the number of the residents with a high-school and university degrees. The variable refers to the share of the population with secondary and tertiary education in the total population.

$X_{2,it}$ - the explanatory variable that monitors the total number of the patents registered annually, which is in the domain of intellectual property. The variable represents the patents registered by residents and nonresidents for the observation unit *i* in the time unit *t*.

$X_{3,it}$ - the explanatory variable that refers to the total investment of the state, i.e. investment in the education sector. It is measured by the percentage share in the gross domestic products of the observation units *i* in the period *t*.

$X_{4,it}$ - the explanatory variable that implies the total amount of the products and services exported from one country to the other countries in a certain period (the annual data). The export of products and services is a measure of the trade openness of the observation units *i* in the time unit *t*.

$X_{5,it}$ - the explanatory variable that is an indicator of the population health and is measured by predicting the average life expectancy of newborns, provided that the mortality level of certain years-of-age categories remains constant in the observation unit *i* in the period *t*.

$X_{6,it}$ - the explanatory variable that measures change in the prices of the products and services purchased by households in order for them to satisfy their own needs in the observation unit *i* in the time *t*.

$X_{7,it}$ - the explanatory variable that measures the percentage share of the urban population in the total population, which means the share of the population living in the biggest cities of the observation units *i* in the period *t*.

The dependent variable of this research implies the variable that measures the total annual income *per capita* of the CEE-10, i.e. the GDP *per capita* of these countries. The abbreviation for the dependent variable in the model is Y_{it}. According to E. N. Wolff (2013), *per capita* income is equated with labor productivity, which is an alternative measure of the economic growth rate. Namely, the movement of GDP *per capita* follows GDP per employee, which refers to the definition of labor productivity. The condition for the previously said refers to the stability of the measured unemployment level, i.e. the absence of sudden changes in the movement of the unemployment rate. Therefore, in the sampling frame of the research, the income *per capita* variable is used as the measure of the economic growth of the countries (Wolff, 2013).

The analysis of the influence of the explanatory variables on the dependent variable is initially conducted using the fixed effects model, after which the random effects model is applied. For the purpose of obtaining a more representative panel model, the Hausman test is used. The assessment of the validity of the obtained research results is carried out using the panel regression equation, only to be followed by testing for multicollinearity, the autocorrelation of the variables, and the heteroskedasticity of the random error. The Wooldridge test is performed so as to assess the presence of autocorrelation between the variables in the selected panel model. If the results of the Hausman test point to the application of the model with fixed effects, the Wald test will be used to examine the presence of the heteroskedasticity of the random error.

The Breusch Pagan Lagrange multiplier test was used to examine the heteroskedasticity of the random error, which is characteristic of the random model (the RE model). Fulfilling the assumptions about random error in the panel regression model is stated as a prerequisite for obtaining relevant research results.

In Table 1, the data sources are listed along with the presentation of the research variables. In the following table, the results of the panel test of the explanatory effects on the dependent variable are interpreted. To obtain relevant results, a regression equation is set

and evaluated applying diagnostic tests. Table 2 The descriptive statistics of the variables included in the panel model

The descriptive statistics were calculated based on the included variables in the panel regression model presented in Table 2. The dependent variable represents the annual value of income *per capita*, reaching an average value of 31,502.48 dollars. The first explanatory variable is the fundamental measure of the quality of human capital, where the share of the population with secondary and tertiary education is 86.41% of the total population. Average investment in education amounted to 4.87% of the GDP of the CEE-10 countries.

The average number of the patents registered by the residents and nonresidents of the CEE-10 countries is 17.77. The estimated average trade openness of the CEE-10 countries is 8.45e+10 dollars. The average life expectancy of newborns is 76.44 years of age. The average share of the urban population in the total

Table 1 The definition of the dependent and explanatory variables, the labels and the data sources

The names of the variables	Label	Description of the variables	Data sources
Income *per capita* (GDP *per capita*)	Y_{it}	The annual value of the realized income in one unit of observation in the period measured *per capita*. The variable mentioned is calculated as the ratio of the value of the annual gross domestic product and the total number of the country's inhabitants. Per capita income is measured in constant prices expressed in US dollars.	The World Bank data (2023)
Education level (% of population)	$X_{1,it}$	The education level of the population refers to the total number of the residents with a high school diploma and a college degree ranging in the interval from 18 to 64 years of age. The variable is a measure of the percentage of the citizens with secondary and tertiary education in the total population.	Eurostat database -European Commission
Number of registered patents	$X_{2,it}$	This variable is a measure of the annual number of the patents registered by the residents and nonresidents of the observed country in the observed period. It is expressed in natural numbers for the unit of observation measured at the annual level.	The World Bank data (2023)
State investments in the education sector (% of GDP)	$X_{3,it}$	This variable represents the share of the country's GDP allocated to the development of the education sector and the production of highly educated personnel on the labor market. The variable represents the share of the country's GDP invested in the improvement of the education sector.	Eurostat database - European Commission
Trade openness (% of GDP)	$X_{4,it}$	This variable is measured through the percentage share of the exports of products and services in the formation of the total value of the country's GDP. The variable implies the annual volume of foreign trade exchange with foreign countries' markets in constant prices and expressed in US dollars.	The World Bank data (2023)
Total life expectancy at birth, total (years)	$X_{5,it}$	This variable measures the life expectancy of newborns, provided that the mortality rate, which is specific to a certain population cohort, remains constant. The variable is an indicator of the general health status of the population.	The World Bank data (2023)
Consumer Price Index (CPI)	$X_{6,it}$	This variable measures the weighted average market price for the basket of goods and services bought by consumers. The CPI indicator reflects the change in the cost of living over time.	The World Bank data (2023)
Population in the biggest city (% of Urban Population)	$X_{7,it}$	This variable implies the percentage share of the urban population in the countries' total populations, which refers to the segment of the population living in the biggest cities, i.e. the metropolises of the observed countries.	The World Bank data (2023)

Source: Authors

Table 2 The descriptive statistics of the variables included in the panel model

Variables	Mean	Standard deviation	Minimum	Maximum
id	5.5	2.884324	1	10
Y_{it}	31502.48	8292.13	15747.39	51695.17
$X_{1,it}$	86.41417	4.798534	73.6	93.6
$X_{2,it}$	17.77317	17.79044	0.99	78.48
$X_{3,it}$	4.8725	0.9662335	2.8	6.9
$X_{4,it}$	8.45e+10	7.61e+10	1.36e+10	3.59e+11
$X_{5,it}$	76.44309	2.146859	71.46341	81.52927
$X_{6,it}$	114.7837	10.92856	101.8029	151.9433
$X_{7,it}$	28.29007	15.30413	7.419745	55.751

Source: Authors

Table 3 The results of the causality testing between the variables (Dumitrecsu and Hurlin-Granger test)

Causality Direction	Zbar-Stat.	Prob.	Causality Direction	Zbar-Stat.	Prob.
Y_{it} does Granger-cause $X_{1,it}$	3.6126	0.000	$X_{1,it}$ does Granger-cause Y_{it}	3.6488	0.003
Y_{it} does Granger-cause $X_{2,it}$	7.3710	0.000	$X_{2,it}$ does Granger-cause Y_{it}	2.0158	0.043
Y_{it} does Granger-cause $X_{3,it}$	3.8869	0.001	$X_{3,it}$ does not Granger-cause Y_{it}	-1.1338	0.256
Y_{it} does not Granger-cause $X_{4,it}$	0.9272	0.353	$X_{4,it}$ does not Granger-cause Y_{it}	-0.7324	0.463
Y_{it} does Granger-cause $X_{5,it}$	7.9841	0.000	$X_{5,it}$ does Granger-cause Y_{it}	5.6542	0.000
Y_{it} does not Granger-cause $X_{6,it}$	-0.968	0.333	$X_{6,it}$ does not Granger-cause Y_{it}	0.9522	0.341
Y_{it} does Granger-cause $X_{7,it}$	8.9933	0.000	$X_{7,it}$ does Granger-cause Y_{it}	4.3292	0.000

Note: If the p-value is less than the significance level of 0.05, the null hypothesis is rejected, which leads to the conclusion that there is causality between the variables within the model

Source: Authors

population living in the biggest cities is 28.29%. The relevance of the selection of the research variables is confirmed by testing causality applying the E. I. Dumitrescu and C. Hurlin (2012) Granger test.

The causality test results indicate a causal relationship between the explanatory variables and the dependent variable, such as the education level, life expectancy, the population of the biggest city, and the number of the registered patents. Conversely, the results confirm a causal effect of the dependent variable on the explanatory variables, namely education, the number of the registered patents, life expectancy, public investment, and the population of the biggest city.

RESULTS AND DISCUSSION

The stationarity of the time series included in the panel model is tested using unit root tests, which, commonly used in the panel data analysis, share a similar characteristic with the unit root tests employed in the time series analysis. In this research, both first- and second-generation unit root tests are applied. According to first-generation tests, events and changes in economic conditions in one country do not affect economic conditions in neighboring countries, which makes these tests applicable to independent panels. In contrast, second-generation tests indicate that changes in economic conditions in one country can influence economic conditions in neighboring countries, which makes them suitable

for dependent panels. In various scientific studies, the use of first-generation unit root tests has been found to be prevalent in comparison with that of second-generation tests (Pesaran, 2012). In our research, however, both first- and second-generation tests are equally applied in order to examine the stationarity of the series in the constructed panel model. To obtain robust research results, an examination of the stationarity of the panel is carried out by performing the following tests: the Levin-Lin-Chu test (2002), the Harris-Tzvalis test (1999), the Im-Pesaran-Shin test (2003), Fisher's test (2001), the Breitung test (2000) and so on. The previously mentioned unit root tests have a null hypothesis stating that the observed series has a unit root, whereas an alternative hypothesis indicates the absence of a unit root in the time series. By rejecting the null hypothesis at the significance level (α = 0.05) the stationarity of the panel model is confirmed.

According to the results in Table 4, the stationarity of the panel model is confirmed. The application of the logarithmic data ensures the stationarity of all the time series included in the panel model through the use of the first difference. The calculated probability of the unit root tests is less than *prob.=0.05%*, which confirms the stationarity of the observed time series. To examine the nature of the relationship and the collinearity among the explanatory variables, the Pearson correlation coefficient is calculated. The results of the linear correlation analysis between the dependent variable and the set of the explanatory variables are presented in Table 3.

Based on Table 5, it is concluded that there is a weak correlation among the variables included in the panel regression model, the highest being observed between investment in education (% of GDP) and the number of the registered patents, with the value of 0.5771, and the lowest being found between trade openness (% of GDP) and income *per capita* (% of GDP) at the level of 0.0187. In this sense, the correlation between any of the included variables in the model formed is not higher than 0.58, which points to the conclusion that there is no multicollinearity between the variables included in the set panel regression model.

Table 4 The examination of the stationarity of the time series included in the panel model

Variables	Y_{it}	$X_{1,it}$	$X_{2,it}$	$X_{3,it}$	$X_{4,it}$	$X_{5,it}$	$X_{6,it}$	$X_{7,it}$
Levin-Lin-Chu test	-6.0618 (0.0000)	-6.7577 (0.0000)	-6.9503 (0.0000)	-5.3366 (0.0000)	-2.8981 (0.0019)	-4.0417 (0.0000)	-4.8864 (0.0000)	-1.4922 (0.0678)
LLC trend test	-4.3686 (00000)	-10.9779 (0.0000)	-8.2728 (0.0000)	-7.3692 (0.0000)	-2.7105 (0.0034)	-5.4342 (0.0000)	-3.3946 (0.0003)	-1.4922 (0.0678)
Harris-Tzvalis test	0.0165 (0.0000)	-0.0787 (0.0000)	-0.2343 (0.0000)	-0.0603 (0.0000)	-0.1734 (0.0000)	-0.4484 (0.0000)	0.5274 (0.0000)	-0.8734 (0.0000)
HT trend test	0.0995 (0.0011)	0.0889 (0.0008)	-0.1930 (0.0000)	-0.0412 (0.0000)	-0.1140 (0.0000)	-0.4270 (0.0000)	0.0392 (0.0015)	-0.7668 (0.0000)
Breitung test	-3.7943 (0.0001)	-3.2997 (0.0005)	-4.3196 (0.0000)	-3.8587 (0.0001)	-5.0245 (0.0000)	-6.9674 (0.0000)	-3.6131 (0.0002)	-2.4694 (0.0068)
BT trend test	-2.9848 (0.0014)	-1.7860 (0.0370)	-4.2417 (0.0000)	-2.3293 (0.0099)	-3.6599 (0.0001)	-1.5905 (0.0597)	-1.3885 (0.0825)	-2.0780 (0.0189)
Im-Pesaran-Shin test	-2.9219 (0.0017)	-3.6562 (0.0001)	-4.9999 (0.0000)	-3.0436 (0.0012)	-4.2613 (0.0000)	-4.0766 (0.0000)	-2.2107 (0.0135)	--6.2933 (0.0000)
IPS trend test	-4.2730 (0.0000)	-3.7333 (0.0001)	-4.9800 (0.0000)	-3.8170 (0.0001)	-4.4512 (0.0000)	-3.8551 (0.0001)	-2.2243 (0.0131)	-1.7654 (0.0388)
Fisher dfuller test	7.4440 (0.0000)	9.3479 (0.0000)	29.9766 (0.0000)	6.6583 (0.0000)	10.8235 (0.0000)	9.6253 (0.0000)	29.9766 (0.0000)	6.8505 (0.0000)

Source: Authors

The value of the Hausman test was used for the selection of the methods for evaluating the panel data on a sample of ten CIE-10 countries in the period from 2012 to 2023. According to the calculated statistics of the Hausman test, which are higher than x^2 (the number of the freedom degrees) with the confidence interval the null hypothesis is rejected, and the alternative hypothesis of the test is accepted. The alternative hypothesis suggests that the random effects model is a more relevant methodological approach than the fixed effects model. Namely, to evaluate the regression equation and come to a valid conclusion, the method of random effects is applied, whereby $x^2(6) = 1.95$, while *prob.* > $x^2(5) = 0.9245$. To calculate the statistical significance of the influence of the variables representing the quality of human capital to an increase in the annual growth rate of income *per capita*, as well as the overall economic development of the Central and Eastern European countries, a regression equation is set and evaluated as follows:

$$YCEI(10)_{it} = \alpha + \beta_1 X_{1,it} + \beta_2 X_{2,it} + \beta_3 X_{3,it} + \beta_4 X_{4,it} + V_{it} \quad (4)$$

Immediately before evaluating the regression equation using the random effects model, an analysis of the results of the diagnostic tests is conducted. The original Breusch Pagan Langrange multiplier test is used to test heteroskedasticity in the random effects model. The assumptions of the random effects model include: $E(\alpha)=0$ and $Var(a_i) = \sigma_\alpha^2 > 0$. The value of the Breusch Pagan LM test statistic is $x^2(45)=91.64$, while the probability value implies *prob.=0.0000*. Based on the obtained value of the Breusch and Pagan LM test, the null hypothesis is rejected, and the alternative hypothesis of the test is accepted with the significance level of 0.05. The residual heteroskedasticity in the model is confirmed, i.e. the variance of the residual deviations is not constant. To examine the presence of autocorrelation in the random effects model, the Wooldridge test is used. The value of the Wooldridge test statistic is $x^2(7) = 589.61$, while the calculated probability is *prob.* = 0.0000. By calculating the

Table 5 The examination of multicollinearity in the panel model

	Y_{it}	$X_{1,it}$	$X_{2,it}$	$X_{3,it}$	$X_{4,it}$	$X_{5,it}$	$X_{6,it}$	$X_{7,it}$
Y_{it}	1.0000							
$X_{1,it}$	0.1755	1.0000						
$X_{2,it}$	0.1063	-0.0882	1.0000					
$X_{3,it}$	0.1523	0.0587	-0.2713	1.0000				
$X_{4,it}$	0.5771	0.0187	0.1465	-0.1649	1.0000			
$X_{5,it}$	0.2477	-0.0260	0.1115	-0.1932	0.1855	1.0000		
$X_{6,it}$	0.5326	0.0503	0.0987	0.0395	0.3563	0.4627	1.0000	
$X_{7,it}$	0.0892	-0.0618	0.0523	-0.0938	-0.0472	0.0826	0.1272	1.0000

Source: Authors

Table 6 The diagnostic tests of the panel model

Central and Eastern European countries	Hausman test	Wooldridge test (Random Effects model)	Breusch and Pagan Lagrange multiplier test
The value of the test statistics	$x^2(6) = 1.95$	$x^2(7) = 589.61$	$x^2(45) = 91.646$
Probability test (Prob.)	0.9245	Prob.statist.= 0.0000	Prob. statist.= 0.0000

Source: Authors

probability of the test, with the significance level of α = 0.05, the null hypothesis of this test is rejected, which implies the absence of autocorrelation, i.e. the existence of a mutually correlated relationship between the random errors within the random effects model.

According to D. Hoechle (2007), to overcome the problem of heteroskedasticity and the problem of autocorrelation in the random effects model (*abbreviated the RE model*), robust standard errors are included in the model (*vce robust).* Based on the research conducted by B. H. Baltagi (2008), the random effects model estimation procedure is carried out using robust random errors, which leads to solving the problem of the inconsistency of random errors. The model evaluation method based on the covariance matrix is presented by the scientists H. White (1980), and G. Frahm (2009). By applying the mentioned correction, the consistency of random errors is ensured, regardless of the confirmed heteroskedastic residual. Immediately after overcoming the problems with both heteroskedasticity and autocorrelation in the observed model, a panel regression evaluation is performed, which provides robust results and valid conclusions.

The influence of the level of human capital development on the change in the annual income of the population, i.e. the income *per capita* of the ten Central and Eastern European countries, is examined using the regression equation and the results obtained presented in Table 7. Obtaining a higher income *per capita* of the population represents an alternative measure of economic growth and the development of countries (Wolff, 2013). In analyzing the individual

Table 7 The estimation of the panel regression equation

Model Variables	Panel model (Random-effects GLS regression)	
Income *per capita* (GDP *per capita*)	Estimated regression coefficients	Standard error values
Education level (% of the population)	0.8843876** (0.028)	0.4033031
Number of the registered patents	0.0097988** (0.021)	0.0422565
State investments in education (% of GDP)	0.14818*** (0.002)	0.0477228
Trade openness (% of GDP)	0.3847617*** (0.000)	0.0431631
Consumer price index (CPI)	0.2829279*** (0.003)	0.096777
Total life expectancy at birth, total (years of age)	0.1356885 (0.488)	0.1958549
Population in the biggest cities (% of the urban population)	0.4570091 (0.107)	0.2839146
Constant	0.0273071*** (0.000)	0.0038577
Number of the observations	120	N = 1,2,3, …,8,9, 10 T= 1,2,3, …, 10, 11, 12
Coefficient of determination (R^2)	0.7350	
Probability test	Prob. > (x^2) = 0.0000	

Note: The marks ***, **, * imply a significance level of 0.01, 0.05, and 0.10, respectively, based on which a decision is made

Source: Authors

elements considered under the term human capital, the coefficients of each of those variables are estimated using the regression equation with the measurement of their influence on the dependent variable. In the further course of the research, the results obtained are interpreted. The validity of the set model is ensured by the value of the total statistics of the model 589.61, with the level of significance of 0.01. Based on the coefficient of determination, whose value is 0.7350%, it has been proven that approximately 74% variability in income *per capita*, i.e. in GDP *per capita*, is explained by the independent variables of the model. The regression coefficients were estimated so as to explain the model's variables and ensure the statistical significance of the influence of the independent variables on the dependent variable.

Based on the calculated values of the regression coefficients which measure the impact of education on *per capita* income (i.e. GDP *per capita*), the statistical significance of the effects of education on income has been confirmed for the sample of the CEE-10 countries. According to the results shown in Table 7, the education level of the population has a statistically significant and positive influence on the changes in *per capita* income among the CEE-10 countries. A 1% increase in the education level results in a 0.8843% increase in income *per capita*. Namely, the population with a higher level of education achieves an average higher income *per capita* compared to the less educated segment of society. Therefore, an individual's education represents a signal of their ability and work efficiency, which leads to the achievement of potentially higher income levels. Within the Eurozone, the residents with primary education earned an average annual salary of 17,590 euros, the residents with secondary education 23,006 euros, while the residents with tertiary education earned 30,081 euros, according to the measurement data at the end of 2023 (Eurostat, 2024).

According to the results obtained, the variable number of the patents registered by the residents and nonresidents of the CEE-10 countries has a positive and statistically significant effect on the change in the countries' income *per capita* during the observed period. Due to the 1% increase in the number of patents in the country, the income *per capita* increases by 0.009%. Also, the 1% increase in the weighted average value of the market basket of goods and services (CPI) affects the increase in *per capita* income by 0.2829% in the sample of the CEE-10 countries in the observed period. The results of the panel model indicate a positive and statistically significant influence of the countries' trade openness on the change in income *per capita* observed in the sample of the CEE-10 countries. The countries' trade openness is measured by the annual amount of the products and services produced and exported from the CEE-10 countries. The increased level of labor productivity developed through the process of improving working skills and technological progress and the participation of human capital in the production of export outputs has effects on the growth of income *per capita*. With that in mind, the 1% increase in the exports of goods and services of the CEE-10 countries leads to an increase of 0.3847% in *per capita* income.

Investing into the education sector implies an important measure within the education development strategy which implies increasing the literacy of the total population. Above-average investment in the education sector through the improvement of the education system infrastructure and the implementation of educational reforms lead to an increase in the quality of human capital and ensure greater economic growth in the CEE-10 countries. The research has proved a positive and significant relationship between investing in education and higher *per capita* income. The 1% increase in the share of the countries' budgetary funds in the education sector leads to the increase in *per capita* income of 0.1481% in the sample of the CEE-10 countries in the observed period. In conclusion, increasing state investment in the development of the education sector increases *per capita* income. A positive and statistically significant influence of the variables representing the measure of the quality of human capital on the growth of the income *per capita* of the CEE-10 countries is also confirmed.

CONCLUSION

Human capital, or the alternatively used term "human value", refers to the measure of the education of a country's population, their possession of working skills, efficiency in performing tasks, propensity to start patents and develop innovations. From one point of view, human capital implies the starting point for the development of technical-technological innovations, on the one hand, and the functions of human capital refer to the possession of the capacities needed to create a modern technologies acceptance infrastructure, as well as their implementation and further development, on the other.

The results of this research study reveal the positive and statistically significant influence of human capital on the change in income *per capita* on the sample of the ten Central and Eastern European countries (CEE-10). Therefore, the increased participation of the population with secondary and tertiary education, accompanied by the increase in the number of registered patents, a greater allocation of the budgetary funds to research and development activities, the encouragement of start-up ideas and the increase in the amount of export products and services significantly affects the achievement of a higher level of the income *per capita* of the observed countries. Based on the empirical results obtained, the initial research hypothesis is confirmed. Contemporary criticisms of human capital theory are stated as a limitation of this research. Namely, a higher level of the education of the population does not necessarily lead to an increase in the labor productivity of individuals, but rather represents an indicator of their cognitive abilities, talents and working skills, which potentially affect the achievement of higher labor productivity. The recommendation for future research is to expand the regression equation by including the variable measuring the average number of the years of education along with an analysis of its impact on the *per capita* income of the CEE-10 countries. The recommendation involves conducting future research after the prior expansion of the sampling frame by including the other regions of the European Union (27) and making a comparative analysis of another group of countries with the results for the CEE-10 group of countries.

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Đorđe Kotarac is a PhD candidate at the Faculty of Economics and Business, University of Belgrade, where he specializes in the scientific field of general economic theory and development economics. He serves as a teaching assistant at the Department of Economics, Faculty of Agriculture, University of Belgrade. His key research areas include growth and development economics, convergence theories, digital economy, and knowledge economy.

Zoran Popović is an Associate Professor at the Faculty of Economics and Business, University of Belgrade. He obtained his PhD from the same faculty, with a dissertation on the analysis of dynamic general equilibrium models. His main fields of scientific research include general economic equilibrium, game theory, and mathematical programming.

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FOREIGN DIRECT INVESTMENT AND/OR INSTITUTIONS IN THE GROWTH FUNCTION OF THE WESTERN BALKANS: EXPECT THE (UN)EXPECTED

Iva Glišić and Slavica Manić*

University of Belgrade, Faculty of Economics and Business, the Republic of Serbia

The economic literature is rich in papers analyzing the effects of FDI inflows or the impact of institutional quality on economic activity. The same is not true for analyzing the impact of institutional quality on FDI attraction and/or the joint impact of these two factors on economic growth, especially concerning the Western Balkans region. Our analysis covers five countries in this region over the period from 2007 to 2022 and aims to contribute to the relevant literature in that segment. The panel data were modelled using the GLS method. The result of the final model (out of the three evaluated) indicates an (un)expected positive effect of a lower institutional quality on economic activity through the FDI channel. One possible explanation for this finding is the hypothesis that "weaker" legislation (especially in the environmental field) in the Western Balkan countries attracts precisely the FDI that generates negative externalities in addition to economic growth. Nevertheless, it also suggests the necessity for considering the long-term risks associated with economic growth, relying predominantly on this type of FDI.

Keywords: foreign direct investment, institutions, economic growth, the Western Balkans

JEL Classification: E02, F21, O43, C33

INTRODUCTION

The integration of the Western Balkan countries into global capital flows and the development of market conditions in Albania, Bosnia and Herzegovina, North Macedonia, Serbia, and Montenegro have led to an increased inflow of foreign direct investment into this region. In theory, investor interest is based on high returns, and confidence in the security of investments is strengthened by the continuous improvement in the business climate and economic progress of the economies in which they invest (Hanson, 2001). Additionally, economic theory cites numerous advantages for host countries as well in relation to foreign direct investment (Blomström & Kokko, 1998; Forte & Moura, 2013). Empirical research directions in economic growth, institutions and FDI are mostly based on pairwise analysis, rarely considering the interaction of these variables. Moreover, most analyses have been conducted on the

* *Correspondence to:* S. Manić, University of Belgrade, Faculty of Economics and Business, Belgrade, Kamenička 6, Serbia; e-mail: slavica.manic@ekof.bg.ac.rs

example of the EU countries, while studies focusing on the Western Balkan countries are rare (mainly due to problems with data availability and quality). The motivation for this paper stems from an aspiration to provide a valuable input and fill the aforementioned gap in the relevant literature by identifying the mechanisms at work in the interaction of foreign direct investment, institutions, and economic growth for the Western Balkan countries. This paper seeks to provide an insight into the correspondence or divergence of reality from economic theory in relation to the benefits of FDI inflows and the quality of institutions for the Western Balkan countries through the economic interpretation of the results obtained using the quantitative methods applicable to databases with numerous limitations, such as those that exist in the statistics of the region.

The choice of a suitable methodology for the research is determined, among other things, by the characteristics of the region itself. Generally speaking, the Western Balkans experienced significant and growing FDI inflows in the period from 2007 to 2022 (World Bank, 2024a). In terms of total FDI inflows (especially in the last ten years), Serbia dominates (with a share of around 60%), while the average shares for the countries of the region in the mentioned period range from 3.2% of GDP (the FDI share in Bosnia and Herzegovina), to 14.9% of GDP (the FDI share in Montenegro). The structure of FDI varies from country to country, depending on the country of origin and the sector in which the investment is made. A significant share of the manufacturing industry has been recorded in Bosnia and Herzegovina, North Macedonia, and Serbia over the last five years (Eurostat, 2024). Individually, the largest investors in the past few years (2021-2023) for Albania, Bosnia and Herzegovina, North Macedonia, and Serbia have been the Netherlands, the United Kingdom, Turkey and China, respectively, whereas the European Union in its entirety remains the most important investor for the region as a whole (Eurostat, 2024). The quality of institutions varies as well. The indicators measured by the World Bank are quite volatile, with periods of improvement alternating with periods of deterioration. On the other hand, measured in terms of real GDP growth in the same period, economic growth shows less variation, ranging from 2.4% to 3.3% (World Bank, 2024b). Based upon the above (albeit sparse) data, this region clearly demonstrates a certain degree of heterogeneity, as well as a considerable number of common factors (historical, geographical and economic), which are still the subject of interest (Jano, 2022) and therefore lends itself to some form of panel data analysis. The panel structure reduces to some extent the shortcomings of the individual databases for each country (which is discussed in more detail below), simultaneously allowing for more complex analyses thanks to a larger number of observations.

The following hypotheses are tested in this paper:

H1: FDI inflows are statistically significant in explaining GDP growth in the Western Balkan countries.

H2: Institutional quality further enhances the effect of FDI inflows on GDP growth.

H3: The interaction variable between FDI inflows and institutional quality has a positive effect on the GDP growth rate in the Western Balkans.

After the introductory remarks, the paper is structured as follows: the Introduction is followed by a review of the relevant literature, an overview of the indicators used and the available data, an evaluation of the panel model in three iterations (without the effect of the quality of institutions, with the isolated effect of institutions, with the interaction between the FDI inflow and the indicators of institutions), and the concluding remarks.

LITERATURE REVIEW

In recent years, a number of papers have dealt with the impact of FDI on economic activity in general, such as those regarding the growth driven by FDI (e.g. Kisswani, Kein & Shetty, 2015; Lee & Dolfriandra, 2020), i.e. the dependence on this type of investment, which is very widespread in the Western Balkan countries. In addition, there are also papers in the

recent literature that focus on analyzing the impact of FDI on some aspects of economic activity, such as the impact this type of investment has on domestic investment (Sucubasi, Trenovski, Imeri & Merdzan, 2021). On the other hand, although the number of the papers dealing with the impact of institutions on FDI flows using the Western Balkan region as an example is not large, their observations and findings also represent an undisputed contribution to the relevant literature and are an important starting point for this research. For example, T. Stevanović, I. Marković and V. Lepojević (2022) use the panel model approach to identify the importance of institutions in attracting foreign capital in the Western Balkans. The main conclusion they come to is that, for the Western Balkan countries observed, the economic benefits of foreign direct investment are real but cannot be achieved automatically and rather depend on the quality of the business environment.

One of the papers indirectly using the indicator of institutions refers to a study of the impact of the composite innovation index on the competitiveness of the economies of the Western Balkan countries. I. Stojanović, A. Puška and M. Selaković (2022) analyzed the impact of innovation in the Western Balkan countries using the GII (Global Innovation Index) in the period from 2019 to 2021. The GII quantifies a comprehensive innovation effect of countries and consists of the indicators for institutions, human capital, infrastructure, market and business development. The authors ranked the Western Balkan countries according to the value of the aforementioned index, with the best result achieved by Montenegro, which has the best overall average value of the indicators for institutions in the period from 2007 to 2022 as well, according to the World Bank's World Governance Indicators database.

R. Desbordes and V. Vicard (2009) also raise the question of the causality between the quality of institutions and the inflow of foreign direct investment. One of the conclusions they come to is that return on FDI depends to a considerable extent on the quality of political relations between the country of origin and the country in which the investment is made. Similarly, A. Dorakh (2022) presents a thesis on the importance of the link between the EU countries and candidate countries regarding FDI flows. He concludes that the old EU member states are generally net investors, while the new EU member states, the accession candidates and the new EU candidates (including the Western Balkan countries) are generally net recipients of intra-European FDI. With regard to the EU accession process and the impact on FDI, L. Benfratello, A. D'Ambrosio, A. Sangrigoli and G. Scabbia (2022) analyze the impact that the different phases of the EU accession process (the pre-negotiation phase, the negotiation phase, the approval and actual membership phases) can have on the likelihood of a country in the Balkan region to attract FDI. The authors show that all the phases are associated with positive FDI growth and identify the "expectation effect" that occurs in the approval phase and affects both European and non-European investments. This result emphasizes the importance of both actual and potential EU membership in the decision to invest in the Balkans. The only exception is the negative impact of EU membership on attracting foreign direct investment in the manufacturing sector.

A. Hayat (2019) deals with the question of what role the quality of institutions plays in a country's economic growth, also raising the question of the extent to which the influence of institutions is transmitted to economic growth via the FDI channel. The database used in this paper covers 104 countries and is therefore suitable for the application of the generalized method of moments for dynamic modelling of panel data. Based on the data used in the GMM model, it is concluded that foreign direct investment has a positive impact on economic activity in low- and middle-income countries, whereas it makes a negative contribution in high-income ones. The quality of institutions has a positive effect on economic activity regardless of the income level, but the effect of improving the quality of institutions is more pronounced in low- and high-income countries than in middle-income ones. Finally, the higher quality of institutions further strengthens the positive effect of FDI inflows on economic activity in low- and middle-income countries. In a similar fashion, also using the GMM model, S. Arsov and A. Naumoski (2024) find that the institutional environment plays

an important role in attracting foreign investors in the EU countries, as FDI is significantly higher in the countries with less corruption, more effective governance, and greater trust in the legal system.

Of particular interest is a recent paper (Smolo, 2023) that analyzes the impact of foreign direct investment, institutions and their interaction on the economic activity of the Western Balkans. The author's analysis reveals that foreign investment and institutions have a negative impact on economic growth in the region. When foreign investment is combined with the indicator of institutional development, both factors, including their interaction, show a negative (although not statistically significant) impact on economic growth.

This result closely relates to the topic of institutional arbitrage, which, according to M. Perkmann, N. Phillips and R. Greenwood (2022), refers to "how actors profit from bringing together incompatible institutional logics". Although the term originates from finance, it can be applied more broadly, i.e. to any attempt to capitalize on the existence of differences. As such, it is applicable to the situation presented in the above-mentioned paper, considering the fact that the Western Balkan countries benefit from not having improved their institutional frameworks, whether intentionally or not (which is one of the questions).

The models used in the relevant literature are mostly based on the application of panel methods, whether dynamic or not, while the choice of a specific model for our analysis is largely limited by the characteristics of the database, which are presented below.

DATA, VARIABLES AND MODEL SPECIFICATION

The modelling of the impact of FDI and institutions on real GDP growth through individual and joint effects is based on the panel database of five countries, the time dimension covering a period of 16 years, and six potential individual explanatory variables (excluding the joint effect). The initial framework of the potential explanatory variables includes the control variables that are expected to have certain explanatory power in relation to the modelling of the growth of economic activity through the real GDP growth indicator and was selected based on the models evaluated in relevant papers, such as T. Stevanović *et al* (2022) and A. Hayat (2019). In this case, an additional limitation is imposed by a relatively small database, considering the fact that the main objective of the paper is to establish the effect and interaction of the FDI indicators and institutions with respect to the Western Balkan countries. For the aforementioned reasons, the set of potential regressors consists of the indicators of fixed capital formation, government expenditure and the volume of foreign trade through the logarithmic values of the GDP shares as the control variables, then the variables of interest for this particular paper, namely the FDI shares in GDP and a composite measure of institutional quality and their interaction variable (for a detailed description, see Table 1). The group of countries included in the analysis consists of Albania, Bosnia and Herzegovina, North Macedonia, Montenegro, and Serbia.

When preparing the data, the variables were tested for the presence of a unit root using the Im-Pesaran-Shin unit root test (Table 2), which showed that the logarithmized values of the control variables and the untransformed values of the FDI and institution variables were stationary.

The multicollinearity test indicates a potentially statistically significant correlation between fixed capital formation and government spending, which is to be expected to a certain extent given the still significant contribution of government investment to economic growth in the Western Balkan countries. There is also a potentially significant correlation between the trade volume indicators and the other control variables. To examine the overall significance of these correlations in terms of their impact on the model, variance inflation factor (VIF – Table 3) analysis was carried out, based upon the ratio of the variances in the model with multiple regressors versus the model with only one regressor. As with correlation coefficients, there is no consensus on the tolerance threshold for this analysis. Considering the fact that the individual values of this test, as well

Table 1 The overview of the variables

Variable	Description	Source
GDP	The gross domestic product growth rate.	Eurostat
FDI/GDP	The share of foreign direct investment inflows in GDP.	Eurostat
Fixed investments/ GDP	The share of fixed investments (investment in buildings, machinery, equipment, software, literary and artistic originals, etc.) in GDP.	Eurostat
Government consumption/GDP	The total government spending on goods and services expressed as a share of GDP.	World Bank (2024b)
Trade volume/GDP	The total value of the exports and imports of goods and services expressed as a percentage of GDP.	World Bank (2024b)
Institutions	A composite indicator consisting of the following six indicators:	
Rule of Law	A measure of trust in compliance with rules, especially those related to the implementation of contractual obligations, respect for property rights, trust in the police and courts, as well as the likelihood of crime and violence.	World Bank (2024c)
Control of Corruption	The indicator measuring the extent to which public power is used for private gain, including larger and smaller forms of corruption, as well as the "capture" of the state by elites and private interests. It also measures the strength and effectiveness of a country's policy and institutional framework for preventing and fighting corruption.	World Bank (2024c)
Regulatory Quality	The perception of the government's ability to formulate and implement sound policies and regulations that allow and promote the private sector development.	World Bank (2024c)
Government Effectiveness	Perceptions of the quality of public services, the quality of the civil service and its degree of independence from political pressures, the quality of policy formulation and implementation, as well as the credibility of the government's commitment to such policies.	World Bank (2024c)
Political Stability and Absence of Violence	The perception of the likelihood of political instability and/or politically motivated violence, including terrorism.	World Bank (2024c)
Voice and Accountability	The perception of the extent to which the citizens of a country can participate in the election of their representatives, whether the media are free or not, and whether there are freedoms of expression and association or not.	World Bank (2024c)

Source: Eurostat, World Bank

as the overall value, are between 1 and 5, even if more conservative guidelines are followed, it can be concluded that the problem of multicollinearity is not crucial when modelling these variables. All the control variables show a significant degree of correlation with the dependent variable. On the other hand, the *FDI* and *institutions* variables show a significant degree of mutual correlation, yet no correlation with the dependent variable. The reciprocal correlation between the *FDI* and *institutions* variables may represent an endogeneity problem that can best be solved employing the GMM model. Unfortunately, the available data set is not suitable for such an analysis as the number of available observations is relatively small (80 in the T and N dimensions), which is a "long panel" with the T dimension dominating the N dimension. On the other hand, the correlation

Table 2 The stationarity test results

IPS test stacionarnosti	
Explanatory variable	Test statistic
Fixed investment/GDP	-3.901 (0.000)
Government spending/GDP	-3.924 (0.000)
FDI/BDP	-3.406 (0.000)
Trade volume/BDP	-4.762 (0.000)
Institutions	-2.01 (0.018)

Notes: The brackets contain the p-values; Ho: The panels contain the unit roots.

Source: Authors

Table 3 The correlation coefficients and the VIF values

Correlation coefficients	GDP	Fixed investment/ GDP	Gov. spending/ BDP	FDI/GDP	Trade volume/GDP	Institutions	VIF
GDP	1						
Fixed investment/GDP	0.254	1					1.32
Government spending/ GDP	-0.518	0.224	1				1.45
FDI/BDP	0.039	-0.050	0.062	1			1.32
Trade volume/BDP	0.644	0.301	-0.421	-0.157	1		1.55
Institutions	-0.060	-0.041	-0.020	0.470	-0.033	1	1.29
							Mean VIF: 1.38

Source: Authors

coefficient of <0.5 is not necessarily problematic, especially in conjunction with the moderately low VIF value (less than 1.5). Against this background, the benefits of applying an appropriate quantitative framework to such limited data somewhat outweigh the risks of endogeneity bias, at least until more data are available to overcome such challenges.

The test for the presence of autocorrelation in the panel using the Wooldridge test also shows a statistically significant autocorrelation in the database, which must be taken into consideration during the modelling phase (the test statistic value of 6.238 and the p-value of 0.066). Taking into account the long structure of the panel (T>N), the use of the generalized least squares method is appropriate when modelling panel data, which is particularly useful in the case of autocorrelation, according to D. Hoechle (2007). It is also necessary to check whether heteroscedasticity is present in the data. Considering the fact that the use of the GLS as a method to evaluate the parameters of the panel model certainly yields scores by the maximum likelihood method, it is easy to apply the LR test, which indicates the presence of heteroscedasticity (the test statistic value of 13.81 and the p-value of 0.008). It is therefore a database in which both autocorrelation and heteroscedasticity are present. Finally, it is necessary to perform a test for cross-sectional dependence. According to R. E. De Hoyos and V. Sarafidis (2006), the structure of the "long" panel (in which the number of the observation units is less than the number of the periods) indicates the use of Pesaran's CD test for cross-sectional dependence, the results of which are given in Table 4.

Table 4 The cross-sectional dependence test results

Pesaran's cross-sectional dependence test	
Explanatory variable	Test statistic
Fixed investment/GDP	3.537 (0.000)
Governemnt spending/ GDP	6.027 (0.000)
FDI/BDP	1.982 (0.048)
Trade volume/BDP	9.637 (0.000)
Institutions	4.449 (0.000)

Notes: The brackets contain the p-values; Ho: Weak cross-sectional dependence.

Source: Authors

It is certain that, when modelling panel data, autocorrelation, heteroscedasticity and the presence of interdependences between the panel units, as well as the fact that it is a panel with a T>N structure, must be taken into consideration. All the above-mentioned limitations can be taken into account using the *xtgls* commands in the STATA program, with which robust (but optimistic) standard errors are obtained (Hoechle, 2007). The following three models are evaluated:

$$Y_{it} = const + \beta X_{it} + \gamma SDI_{it} + \varepsilon \quad (1)$$

$$Y_{it} = const + \beta X_{it} + \gamma_1 SDI_{it} + \gamma_2 Inst_{it} + \varepsilon \quad (2)$$

$$Y_{it} = const + \beta X_{it} + \gamma_1 SDI_{it} + \gamma_2 Inst_{it} + \gamma_3 (SDI_{it} \times Inst_{it}) + \varepsilon \quad (3)$$

where, in all three equations, X_{it} denotes the matrix of the control variables. In the model (1), the FDI variable is included as an explanatory variable, in addition to the matrix of the control variables; then, the iterations (2) and (3) include the institutional quality variable and their interaction variable, respectively.

RESULTS AND DISCUSSION

The evaluation results of the suggested model are given in Table 5. The original model (1) contains only control variables, which leads to the conclusion that all the indicators, with the exception of the share of fixed capital formation in GDP, are statistically significant when modelling real GDP growth. As far as the signs of the coefficients are concerned, the indicators for foreign direct investment and the volume of foreign trade have the expected positive sign, as they should have a positive impact on economic growth. On the other hand, the indicator for government spending has a negative coefficient. The literature on the expected impact of government spending on economic activity is not uniform. On the one hand, it is assumed that higher government spending stimulates the economy and thus makes a positive contribution, at least through some of its segments, such as investment in education (Hansson & Henrekson, 1994). On the other hand, an excessively large government sector can have a negative impact on economic activity. There

Table 5 The model results

	The GLS method with the panel-specific autocorrelation of AR(1) type and correction for heteroscedasticity and cross-sectional dependence			
Explanatory variable	(1)	(2)	(3)	(4)
Fixed investment/GDP	3.499 (2.237)	3.387 (2.193)	2.078 (2.363)	
Government consumption/ GDP	-20.556*** (3.730)	-20.021*** (3.769)	-21.341*** (3.856)	-21.208*** (3.790)
FDI/GDP	0.063* (0.038)	0.127 *** (0.049)	0.159*** (0.049)	0.138*** (0.043)
Trade volume/GDP	14.342*** (2.493)	15.421*** (2.523)	14.537*** (2.603)	14.872*** (2.403)
Constant	1.656*** (0.559)	0.775 (0.669)	0.739 (0.648)	1.076** (0.552)
Institutions		-2.552** (1.223)	-0.469 (1.547)	
Interaction term			-0.595** (0.261)	-0.569*** (0.184)

Notes: The number of the observations for all the model iterations is 80. The dependent variable in the model is real GDP growth. The Wald test with the null hypothesis of no statistical significance of the included parameters is rejected for all the iterations of the model. *** The statistical significance of the coefficient at the level of 1%. ** The statistical significance of the coefficient at the level of 5%. * The statistical significance of the coefficient at the level of 10%. The value of the standard error is given in parentheses.

Source: Authors

are numerous reasons for this, such as inefficient investment and excessive social benefits (Kutasi & Marton, 2020). In addition, the fact that the period covered by the database (2007-2022) includes several challenging periods for the Western Balkan countries included in the analysis must also be taken into account. In the period mentioned, the effects of the financial crisis, several weather disasters, the pandemic, and heightened geopolitical tensions were recorded, in which higher government spending was expected to partially neutralize the negative effects mentioned. As government spending is not fully (and sometimes not even mostly) efficient in this endeavor, multiple periods will see weak growth in economic activity, combined with a high share of government spending. Nominally, a longer time series would neutralize the effect of these breaks, but due to their size, distribution and intensity, as well as limited data availability, the database is inevitably affected by this problem.

In the model's second iteration, the impact of institutions on economic activity is included and its contribution is statistically significant. The negative sign of the investment coefficient requires additional clarification. For all the countries except Montenegro, a negative mean value of the institutional variable in the range from -0.08 to -0.36 is recorded. Montenegro records a slightly positive arithmetic mean of 0.08. Out of the 80 observations, only 22 recorded non-negative values for the indicators for institutions, and 15 were recorded in Montenegro.

This result implies a greater positive effect of institutions on economic activity when institutions are rated lower, and the question arises as to how such a result should be interpreted. One of the reasons for such a result could be the absence of a variable that accounts for the effect of convergence to more developed economies (the so-called catch-up effect), when countries with lower standards, income, and growth rates experience stronger growth when favorable policies are implemented. In this case, the institutions would be a proxy for the starting position and its development and would thus show the combined effect of several omitted indicators. For future analyses, it would be useful to explore a similar form of the model proposed, taking into consideration not only the level of institutional quality but also its change over time, which would better isolate the effects of an improvement in the institutional environment. For the purposes of this analysis, an attempt was made to interpret this result from the perspective of FDI by further refining the model itself.

Therefore, the interaction effect of FDI and the institutional variable is also included in the third iteration. The interaction variable allows the estimation of a part of the influence of the quality of institutions on economic activity through its impact on FDI. In such a specification of the model, the FDI inflow coefficient shows an effect on economic activity when the quality of institutions is ignored, and it is 0.138. The overall effect of the FDI inflow on economic activity can further be decomposed into this direct effect and the effect stemming from institutional quality. To obtain the total effect for an individual country, the average value of the composite indicator for the quality of institutions needs to be calculated. Using Serbia as an example, it can be seen that the average value of the quality of institutions indicator is -0.12. The effect of FDI can thus be broken down into a direct effect, defined by the FDI variable coefficient, and an indirect effect, which is the product of the interaction coefficient and the average value of the institutional quality indicator, i.e. 0.068. Thus, the overall effect of FDI on the GDP growth rate is not 0.138, but 0.206. Interestingly, when the indirect effect of institutions through the FDI channel is identified, institutions no longer have a statistically significant direct effect on GDP growth. A similar result was presented in A. Hayat (2019), although the statistical significance is not lost, only the value of the coefficient decreases with the investment indicator, which is expected due to the isolation of the effect manifested by the FDI channel.

The result obtained in the third and final iteration of the model can help us to some extent to identify possible reasons for the negative sign of the coefficient of institutions, as the effect of "more favorable bad institutions" is now manifested through the FDI channel, while the direct effect on economic activity is statistically insignificant. Similar to the direct effect,

the explanation could lie in a more favorable climate for foreign investors when developing and emerging countries are concerned. As A. Dorakh (2022) shows, new member states and countries in the process of joining the EU tend to be the net recipients of foreign direct investment, not only because of a potentially higher return on investment, lower competition and lower costs, but also because of the relationships established between the two countries, the investors and the host country.

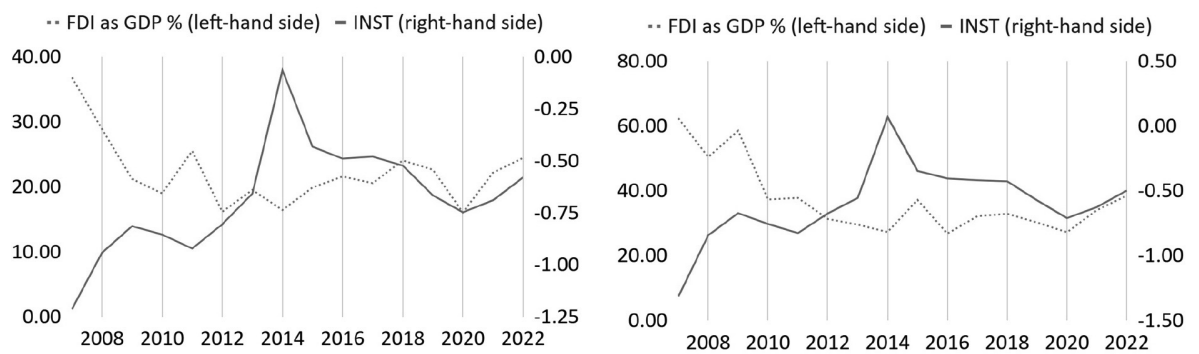
There is another perspective on this result that calls into question investors' motivations and implies a significantly different interpretation of the results. In the analysis made by A. Pavlović M. Njegovan, A. Ivanišević, M. Radišić, A. Takači, A. Losonc and S. Kot (2021), the Balkan countries are characterized as a safe haven for foreign polluters, and they conclude that their "weaker" environmental legislation attracts, among other things, foreign direct investment, which, together with economic growth, brings negative externalities (e.g. pollution) with it. Interestingly, Montenegro stands out from this group of countries (which includes Slovenia, Greece, Bulgaria, Croatia, and Romania, in addition to the Western Balkan countries) as a country with excellent environmental legislation, which has contributed to its characterization as a bearer of the "environmental halo". This is in line with the results of this model and the lower contribution of foreign direct investment to economic activity when the indirect effect of institutions in the Montenegrin economy is taken into account. From this perspective, the lack of regulation and efficiency in law enforcement, a greater tendency towards corruption, and the lack of accountability are the reasons for investing in the Western Balkan countries, which would have a positive effect on economic activity (in the short run). This finding is to a certain extent similar to the finding of E. Smolo (2023), where the author suggests improving infrastructure and making necessary economic adjustments as an appropriate measure to attract more foreign investment, which in turn would support the development of institutions and infrastructure. Our recommendation to overcome the above challenges implies attracting better quality FDI rather than its quantity. A similar finding on the impact of institutions on economic activity can be found in N. Alimi and L. B. Dhiab (2023), in whose study the results of the panel analysis point to the negative relationship between economic growth and the quality of institutions. However, they also emphasize that such a result should not deny the importance of quality institutions for long-term economic progress, but points to the importance of creating an appropriate environment in which it is possible for institutions to improve, and such an improvement is not made at the expense of economic growth. Even if reference is made to the paper by L. Benfratello *et al* (2022), in which the EU accession process is associated with growth in FDI inflows, manufacturing is the only exception. If the EU accession process is treated as identical to the improvement of the institutional environment, this means that such a process is undesirable for investors in the manufacturing industry (as it has the greatest pollution potential) and its share is the largest in the Western Balkan countries. In addition, some previous analyses (Estrin & Uvalić, 2016) point to a lack of spillover effect when FDI in manufacturing in the Western Balkans is concerned, i.e. there is no statistically significant increase in value added, employment or exports in manufacturing, and, among other causes, they cite the institutional environment of the countries mentioned as a possible one. To test whether the results presented in this paper hold across all industries, it would be beneficial to use the disaggregated categories of FDI instead of gross FDI as the variables, which would represent a valid improvement to the model. Qualitatively, it is worth noting that the manufacturing, construction, and mining industries accounted for over 60% of the total FDI inflow in Serbia from 2021 to 2023 (National Bank of Serbia, 2024), which was only over 30% in North Macedonia (National Bank of the Republic of North Macedonia, 2024), and slightly more than 40% in Bosnia and Herzegovina (Central Bank of Bosnia and Herzegovina, 2024). The data are only available for these countries. Manufacturing dominates in all three, although the overall industrial structure varies significantly, making quantitative testing essential for obtaining meaningful results. Unfortunately, as data become even more limited when disaggregated by industry, such testing would be very challenging to perform.

The plotting of the variables in the graph reveals that the counterintuitive relationship between FDI and institutional quality appears to have been weaking over the past few years. However, this observation should be interpreted with caution, as the period was largely influenced by the effects of the COVID-19 pandemic. Nevertheless, there may be a shift emerging in the Western Balkan countries – the one supportive of both increased FDI attraction and institutional advancement.

The findings of this paper suggest that a partial adjustment needs to be made towards attaining a more sustainable future, with a regulatory framework positioning the Western Balkan countries better so as to attract "greener" investors. Steps towards such a solution may have already been made. According to J. Jung (2020), any policy change in one country may have considerable repercussions for the sustainability of all surrounding countries. Given the fact that Montenegro has been diligent in repositioning itself as a sustainable beacon in the Western Balkans, spillover effects on the rest of the region can be expected to materialize. Bearing in mind the fact that all the aforementioned countries are on the path to European Union membership, it can reasonably be expected that bringing regulations in line with the EU may speed up the necessary adjustments regarding FDI as well. Another potential policy regulation which could be adapted from X. Wang and Y. Luo (2020) implies that the government should strengthen its efforts to raise public awareness of environmental protection objectives, emphasize the importance of environmental oversight, and uphold strict pollution controls for businesses through a combination of economic, administrative, and legal measures. Any policy recommendation must include the enhancement of environmental regulatory frameworks and the improvement of the ecological evaluation of foreign investments through effective and adaptive monitoring mechanisms.

CONCLUSION

Economic theory suggests that, considered individually, foreign direct investment inflow and the quality of institutions have a positive effect on a country's economic growth. Further consideration would lead us to argue that their interaction must undoubtedly have a positive effect on economic activity. However, as the debate on the potential and/or actual impact of FDI on the real and long-term growth and development of countries is still ongoing, this study has analyzed the issue of the relationship between FDI and economic growth which is still controversial by examining the impact of the different quality of institutions on this relationship. The models analyzed aim to better understand the impact of these



Graph 1. FDI as GDP % and institutional quality, the Western Balkan countries, excluding Montenegro (on the left-hand side), and including Montenegro (on the right-hand side)

Izvor: Obračun autora na osnovu World Bank (2024a) i World Bank (2024c)

variables in the Western Balkans, a region that is difficult to model due to its challenges and complexity. To evaluate the panel model, the generalized least squares method was used in the STATA program, with correction for autocorrelation, heteroscedasticity, and cross-sectional dependence. All the iterations of the model (with the effect of FDI only, with the effect of FDI and the quality of institutions, and with the effect of the variables mentioned and their interaction) are statistically significant. The results of the panel model confirm the statistical significance and the positive effect of the inflow of FDI on the GDP growth rate of the Western Balkan countries. This positive effect is reinforced when the institutional environment is taken into account, which confirms all the three hypotheses put forward in this paper's introduction. However, the direction, i.e. the interpretation of the correlations mentioned, does not correspond to the original expectations, bearing in mind that the result implies a positive effect of a qualitatively poorer institutional environment on economic activity through the foreign direct investment channel. One of the explanations for this (somewhat unexpected) result is the thesis that "weaker" legislation (especially in the environmental field) in the Western Balkan countries attracts foreign direct investment, which, apart from helping economic growth, leads to pollution and makes the countries of the region a safe haven for foreign polluters. The fact is that the growth based on such foundations is short-lived and further analyses are needed to deepen or refute the thesis presented. There are numerous ways to improve the analysis conducted in this paper primarily based on the inclusion of dynamic categories through the indicator change variables, the identification of the influence of the individual indicators of institutions (not only the overall mean indicator), and the identification of the variables that can effectively isolate the environmental effect of the current inflow of foreign direct investment on the Western Balkan region. The challenges of adapting some of them have been discussed more deeply in the paper (such as the GMM estimation and FDI disaggregation). Certainly, more complex analyses require more extensive databases, and the topic discussed in this paper will be another in a series that will benefit from longer, consistent and harmonized time series of both macroeconomic and alternative indicators of economic activity and its drivers in the future. As numerous studies have consistently shown, the benefits of sound institutions are substantial, while the short-term gains arising from weak institutional frameworks rarely outweigh long-term advantages. The potential shift suggested by recent trends is promising but has yet to fully materialize, which it is unlikely to do without a sustained commitment to institutional improvement, especially in the long run.

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Iva Glišić is a PhD student at the Faculty of Economics, University of Belgrade, where she graduated in 2020 (Economic Analysis and Policy Module) as the most outstanding student of her generation and earned the title of a Master of Economics in 2023 (Econometrics Module). The key areas of her scientific research interest include applied macroeconomics, institutional economics, and economic development.

Slavica Manić is a full professor at the Faculty of Economics, University of Belgrade, where she received her bachelor's, master's and PhD degrees. She teaches the following subjects: Methods of Economic Analysis, Introduction to Institutional Economics, Economics of Transition (the undergraduate studies), Methodology of Scientific Research, Competitiveness Policy (the master's studies), Methods of Economic Analysis, Competitiveness Strategy (the PhD studies). The main areas of her scientific research interest include economic methodology, institutional economics, and economic development.

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THE EURASIAN ECONOMIC UNION AT CROSSROADS: NAVIGATING TRADE INTEGRATION AND COMPETITIVENESS

Paskal Zhelev[1]* and Olga Malashenkova[2]

[1]*University of National and World Economy, Department of International Economic Relations and Business, Sofia, Bulgaria*
[2]*Minsk Branch of Plekhanov University of Economics, Minsk, Belarus*

This study investigates the Eurasian Economic Union (EAEU) as a regional economic integration bloc, analyzing its evolution, trade integration, and industrial policy framework amid shifting global dynamics. Established in 2015, the EAEU has encountered structural challenges, geopolitical upheavals, and intensifying sanctions, especially following the war in Ukraine. These pressures have disrupted trade flows, widened economic disparities among member states, and tested the bloc's cohesion. The paper emphasizes the fact that enhancing competitiveness is critical for the resilience of the EAEU, with the industrial policy serving as the cornerstone of this effort. Employing trade indicators, such as intra-regional trade shares and the Revealed Comparative Advantage (RCA) index, the study highlights uneven integration and dependence on resource-based exports. It evaluates the institutional framework of the EAEU's industrial policy, focusing on subsidy harmonization, value-added industry development, and coordination between national and regional priorities. Despite persistent institutional weaknesses and external pressures, the findings suggest that fostering industrial modernization and achieving better synergy between domestic policies and regional ambitions could strengthen the bloc's resilience and global competitiveness.

Keywords: Eurasian Economic Union, industrial policy, international competitiveness, regional economic integration, sanctions

JEL Classification: F15, L52, O24

INTRODUCTION

Amid complex global challenges, economic alliances have become vital strategies for fostering resilience and mutual benefit. Established in 2015 and comprising Armenia, Belarus, Kazakhstan, Kyrgyzstan, and Russia, the Eurasian Economic Union (EAEU) exemplifies this trend. By consolidating economic policies and reducing trade barriers, the EAEU seeks to build an integrated market that leverages collective strengths to drive growth and enhance competitiveness. The Union's tenth anniversary

* *Correspondence to:* P. Zhelev, University of National and World Economy, Department of International Economic Relations and Business, Sofia, Bulgaria
e-mail: pzhelev@unwe.bg

in 2025 provides a timely opportunity to assess integration outcomes and remaining challenges.

The EAEU offers a compelling case study due to its unique context - once part of the Soviet Union, its member states share deep historical, economic, and political ties; however, they are now faced with the complex challenge of balancing national sovereignty with regional integration. Russia's dominant role within the bloc creates a significant asymmetry, influencing the EAEU's internal cohesion and global economic positioning. Moreover, the EAEU aspires to establish itself as a competitive economic power bloc amid shifting global dynamics, making it a valuable lens through which to examine how emerging regional unions address challenges to competitiveness. This is particularly critical for the EAEU, as its long-term viability depends on its ability to deliver tangible economic benefits to its member states, ensuring their continued commitment to the integration project.

Recent global events, including the COVID-19 pandemic and Russia's war in Ukraine, have tested the bloc's resilience. These crises disrupted supply chains, strained economies, and exacerbated geopolitical tensions. Sanctions on Russia and shifts in global alliances further destabilized the EAEU, exposing disparities in its member states' positions and questioning the bloc's capacity to remain cohesive. Additionally, competition for foreign investments and trade opportunities undermines regional collaboration, hindering deeper integration (Krapohl, 2019).

Studying the EAEU is particularly important as countries such as Georgia and Moldova continue to weigh strategic dilemmas akin to the one Ukraine confronted, deciding between deeper ties with the EAEU or alignment with the European Union (EU). This issue is also relevant for Serbia, whose prospective EU accession would require the termination of its free trade agreement with the EAEU. These scenarios underscore the intricate geopolitical and economic trade-offs countries face when balancing competing integration blocs - the choices that profoundly shape their strategic alignments and future development trajectories.

The paper examines the EAEU's trade integration and external competitiveness in the first decade of its operation. The goal is to assess the extent and evolution of intra-regional exchange and the Union's position in world markets under heightened geopolitical and economic stress. Specifically, the study poses the following research questions: (RQ1) Has intra-EAEU trade deepened since the Union's formation in 2015, and how uneven is this integration across the member states? (RQ2) Has the EAEU's global competitiveness improved, as indicated by world-export shares, external-market concentration, and the trade balance? (RQ3) Is structural upgrading underway - namely a shift in comparative advantages from resource-dependent sectors towards more diversified, higher-value-added, and more technology-intensive exports, as proxied by changes in sectoral specialization? (RQ4) What observable advances and persistent gaps characterize the EAEU's industrial-policy coordination to date? To address these questions, the paper adopts a mixed-method design combining quantitative trade indicators - specifically intra-regional export shares, the Union's and member states' shares in world exports, export/import (X/M) ratios, and the revealed comparative advantage (RCA) index - with a qualitative appraisal of industrial-policy coordination across the EAEU member states, guided by an institutional and political-economy perspective on regional integration and competitiveness. The findings aim to deepen the understanding of regional integration under asymmetric power conditions and to inform policy efforts to strengthen competitiveness within the EAEU.

The remainder of the paper comprises a review of the evolution and institutional architecture of the EAEU, an outline of the data and the indicators, a presentation of the results on intra-EAEU trade integration in a comparative perspective, market shares, trade balances, and sectoral specialization, a review of industrial-policy coordination, and the conclusion, including implications and limitations.

THE HISTORY AND EVOLUTION OF THE EURASIAN ECONOMIC UNION

The Eurasian Economic Union (EAEU) traces its origins to the dissolution of the Soviet Union in 1991, which left newly independent states grappling with economic instability and transitioning to market economies. The establishment of the Commonwealth of Independent States (CIS) in 1991 marked an early attempt at regional economic cooperation. However, the CIS struggled due to political conflicts, ideological divides, and economic devastation, leading to its limited success as an integration mechanism (Verdiyeva, 2018; Zhelev & Garashchuk, 2019).

A pivotal moment in post-Soviet regionalism came in 1994, when Kazakhstan's President, Nursultan Nazarbayev, proposed the creation of the Eurasian Union so as to strengthen economic ties. Progress was slow, with the initiatives like the Free Trade Area hindered by a lack of consensus, particularly from Russia. However, renewed efforts led to the establishment of the Eurasian Economic Community (EurAsEC) in 2000, comprising Belarus, Kazakhstan, Kyrgyzstan, Russia, and Tajikistan. EurAsEC aimed to create the Customs Union and Single Economic Space, advancing economic cohesion through qualified majority voting, rather than by consensus (Vinokurov, 2018).

The ambition for a stronger union took a significant step forward in 2006, with Russia, Kazakhstan, and Belarus proposing a new customs union (CU), which laid the groundwork for a unified legal framework to replace individual national laws, marking a crucial progression towards an integrated region. The launch of the Common Customs Tariff among the three principal promoters of integration commenced in 2010, marking the beginning of the CU. Therefore, it can be viewed that the CU served as an important antecedent to pave way for the establishment of the EAEU.

The efforts to integrate more deeply culminated in the formation of the EAEU in January 2015, following the signing of an agreement in January 2012 intended to establish the Single Economic Space (SES), harmonizing the economic and trade policies of the member states. Before the Treaty on the Union, signed in Astana in May 2014, took effect, Armenia and Kyrgyzstan submitted applications for admission. They were subsequently accepted as members in January 2015 and August 2015, respectively.

Article 1 of the Founding Treaty states that, within the EAEU, "the free movement of goods, services, capital, and labor is guaranteed, along with the implementation of coordinated, harmonized, or unified policies in certain economic sectors," outlining the establishment of an international organization for regional economic integration that constitutes an economic union.

The institutional framework of the EAEU facilitates supranational governance through several key bodies. The Supreme Eurasian Economic Council (SEEC), comprising the heads of state, sets strategic directions and rotates meetings annually to share leadership. The Eurasian Intergovernmental Council (EIC), made up of the heads of government, oversees the implementation of the EAEU Treaty, meeting at least twice a year. The Eurasian Economic Commission (EEC), based in Moscow, acts as the regulatory body, handling integration proposals, compliance, and areas like customs and competition policy. It includes the Council (deputy prime ministers) and the Board (ministers from each state), with authority to issue binding decisions. The Court of the EAEU, located in Minsk, ensures legal consistency by interpreting the Treaty and resolving disputes. The Financial Regulatory Authority is planned for Kazakhstan to oversee financial markets but remains unestablished. The geographical distribution of these bodies, alongside the rotational meetings of the SEEC and EIC, reflects the Union's commitment to equitable partnership, balancing the influence among the member states, reducing potential sovereignty conflicts, and enhancing the integration infrastructure.

The EAEU Treaty defines three policy types: unified, coordinated, and harmonized. Unified policies apply uniformly across all the member states, coordinated policies align national strategies without full

unification, and harmonized policies standardize regulations while allowing for national adaptations. Although this flexible approach accommodates differing levels of integration, critics argue it can create legal ambiguities, hinder deeper integration and reduce overall effectiveness.

However, at present, the EAEU cannot even be characterized as a common market due to the existing barriers to the free intra-regional exchange of products and production factors, as well as varying national standards concerning products and resources from third countries. Although the Union's Founding Treaty proclaims the goal of creating a common market, which ultimately should include services and production factors, it lacks provisions for specific measures covering areas beyond goods trade. The expansion of economic integration into realms beyond the trade of goods is seen as a task for "secondary legislation" stemming from the decisions of the EAEU's bodies, which have been scarce or ineffectively implemented so far (Mukhametdinov 2020).

In the area of the free movement of goods, integration within the EAEU is at its most advanced stage, yet progress has not been achieved easily. For example, the EAEU Customs Code (CC) was supposed to come into effect at the beginning of 2016, but its adoption was delayed, forcing economic agents to adhere to various national rules and international agreements, thus presenting a significant administrative barrier to mutual trade. The original Customs Code that had been in place before the creation of the EAEU was plagued by administrative barriers and inconsistencies in regulations. Following the resolution of discussion points at an intergovernmental council attended by the prime ministers of the five member states, a treaty for the EAEU CC was signed on 11th April 2017, which codified all the previously concluded international treaties governing customs relations and all the current customs procedures and technologies. A new EAEU CC was adopted, entering into force on 1st January 2018. The primary goal of this new code was to simplify the customs processes and speed up the customs clearance while removing administrative obstacles among the member nations. The Code introduced several key innovations aimed at optimizing external trade regulations and maintaining a balance of interests between the state authorities and the business community, namely electronic customs declarations, automated operations, shorter timeframes for the release of goods, authorized economic operators, and a "single window" system for services (EDB Centre for Integration Studies, 2019). However, the empirical evidence suggests that, despite such trade-facilitating measures, the EAEU's impact has mainly been confined to boosting mutual trade flows so far, without significant effects on the GDP growth, consumption, or capital formation, and with an even negative influence on employment (Pomerlyan & Belitski, 2024).

Within the EAEU's internal markets, the member states encounter various obstacles that hinder the free movement of goods, services, capital, and labor (see Table 1). These obstacles are classified into three categories (Eurasian Economic Commission, 2023):

Table 1 Obstacles in the EAEU internal market (2015-2024)

	2015	2016	2017	2018	2019	2020	2021	2024
Obstacles	259	60	62	65	71	66	59	50
Barriers	19	9	8	11	16	15	11	1
Restrictions	45	34	37	37	38	37	35	35
Exceptions	195	17	17	17	17	14	13	14

Source: Eurasian Economic Union (2024)

- barriers - obstacles to the free movement of goods, services, capital, and the labor force, arising due to the inconsistencies in the existing or adopted legislative norms not yet entered into force,
- restrictions - obstacles to the free movement of goods, services, capital, and labor, resulting from the absence of legal regulation, and
- exemptions - derogations provided for by the Union law in terms of the non-application by a Member State of the Union of the general rules of the functioning of the internal market.

To effectively address and eliminate these obstacles, the EAEU has established a comprehensive online resource, accessible at *https://barriers.eaeunion.org*. This platform enables businesses, individuals, and other stakeholders to submit appeals and report the identified barriers, restrictions, or exemptions that negatively impact trade or economic activities within the EAEU. The resource provides detailed information on the existing obstacles, procedures for their elimination, and updates on the status of submitted appeals. The platform facilitates communication between stakeholders and the EAEU regulatory bodies, promoting transparency and collaborative problem-solving.

The established procedures for considering and eliminating obstacles involve submitting detailed information about the obstacle identified through the online platform by stakeholders. Then, the EEC reviews it in order to determine its validity and assesses the obstacle as either a barrier, or a restriction, or an exemption. Consultations with the relevant member state are performed, and appropriate steps are taken so as to eliminate the obstacle. Throughout this process, the EEC monitors the implementation of the elimination measures and provides updates to the stakeholder.

Despite the availability of this online resource and the established procedures, challenges persist in effectively removing obstacles within the EAEU internal market, such as bureaucracy, differing national interests over collective EAEU goals, resulting in resistance to removing certain barriers, and variation in the legal frameworks or limited awareness of the platform and procedures.

METHODOLOGY

This study employs a mixed-method approach to evaluate the integration and competitiveness of the EAEU, combining quantitative trade indicators with a qualitative analysis of the policy frameworks and institutional developments. While econometric methods are often used in similar assessments, they are not appropriate here due to the limited available time series data since the EAEU was founded in 2015. Additionally, the structural heterogeneity among the member states, along with significant geopolitical and institutional influences, makes it difficult for standard econometric models to capture the full complexity of the integration process. Instead, the approach employed in this study integrates key trade indicators with insights from the literature review and political economy analysis, offering a more comprehensive understanding of the EAEU's dynamics.

The share of intra-regional trade in the total trade of the region is the indicator most commonly used for measuring the degree of trade integration within a regional economic union (Arupov, Abaidullaeva, Kalieva & Arupova, 2015). To this end, various modifications of the market share indicator (XS) are calculated, following the formula:

$$XS = \frac{\sum_{sd} X_{sd}}{\sum_{sw} X_{sw}} * 100 \quad (1)$$

where s represents the set of the source countries, d is the set of the destination countries, w are the countries worldwide, and X denotes the value of exports.

Thus, the numerator represents the exports from the countries within the studied region (the source countries) to the destination countries (in this case, the partner countries from the same region), while the denominator represents the region's total exports to the world. XS ranges between 0 and 100 percent, with higher values indicating a greater significance of

a given regional trade bloc. An increase in HS over time can be interpreted as indicating the fact that the economies in question are becoming more integrated (Mikic & Gilbert, 2007). For a more comprehensive analysis of the degree of trade integration, a comparative approach will be employed, calculating the market share indicator for intra-regional trade not only within the EAEU but also in other regional economic unions from various parts of the world.

To investigate the international competitiveness of the EAEU and its dynamics, the market share indicator will be used again, this time for the member states on the world market. High and increasing values of this indicator signify improved competitive positions in the global economy. This approach allows for gauging the effectiveness of the EAEU in realizing its integrative objectives and makes it possible to understand the extent to which it has been able to leverage its collective resources in order to enhance the economic standing of its member states on the world stage.

The analysis of the Export/Import ratio data for the EAEU and its member states from 2015 to 2024 provides valuable insights into the trade balance dynamics and economic resilience of the Union and the individual countries within it. This ratio is a crucial indicator, with the values above 1.0 signifying that a country exports more than it imports, indicating a positive trade balance, whereas the values below 1.0 suggest a trade deficit.

Finally, to evaluate the international competitiveness of the EAEU, the RCA index, which measures the relative export performance of a country or regional bloc in a specific product or sector, will be applied. An RCA value greater than one indicates a comparative advantage, suggesting that the country is competitive in that sector on the global market. The analysis of the RCA data for the EAEU member states enables the identification of the areas of strength and specialization, providing insights into how effectively the Union leverages its collective resources to enhance its global trade position.

The RCA index is calculated using the following formula:

$$\mathrm{RCA} = \frac{\left(\frac{X_{ij}}{X_{it}}\right)}{\left(\frac{X_{wj}}{X_{wt}}\right)} \quad (2)$$

where Xij represents the export value of the product j from the country i, Xit is the total export value of the country i, Xwj is the world export value of the product j, and Xwt is the total world export value. An RCA index greater than 1 indicates that the bloc has a comparative advantage in the given product or sector, suggesting the specialisation that could be leveraged in the context of the EAEU's integration objectives.

RESULTS AND DISCUSSION

The trade integration of the EAEU in a comparative perspective

Table 2 demonstrates a significant variation in the intra-regional export shares across the major economic blocs, reflecting differences in their integration levels, economic structures, and geopolitical contexts. The European Union (EU-27) leads with an average intra-regional export share of 58.6% over 2015-2024, peaking at 60.8% in 2022, and remaining close to that level thereafter (60.2% in 2023; 59.7% in 2024). This exceptional performance highlights the EU's advanced integration, supported by the robust legal and institutional frameworks that facilitate the free movement of goods, services, capital, and labor. As the model of regional economic cohesion, the EU often serves as an inspiration for the EAEU's integration ambitions (Klofat, 2017).

In comparison, the EAEU's intra-regional export share averages just 10.4%, aligning more closely with developing regional blocs, such as MERCOSUR (11.7%), COMESA (9.1%), and the GCC (10.0%). This modest figure underscores the bloc's limited economic interdependence and progress in creating a unified internal market.

MERCOSUR and ASEAN illustrate varied integration outcomes among developing regions. MERCOSUR's

Table 2 The intra-regional export shares within the EAEU and the selected integration blocs (2015-2024, %)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2015-24
Gulf Cooperation Council	8.8	8.6	10.1	10.6	11.0	11.9	10.7	9.6	10.6	7.9	10.0
EU-27	56.6	57.4	57.6	58.2	57.7	58.3	59.7	60.8	60.2	59.7	58.6
MERCOSUR	13.6	13.1	12.7	12.0	10.5	11.0	10.8	10.7	11.6	10.9	11.7
ASEAN	24.3	23.8	23.8	24.2	23.3	21.4	21.6	22.9	22.1	21.2	22.9
NAFTA	50.4	50.3	50.1	49.4	49.6	49.2	49.8	49.8	50.7	50.6	50.0
COMESA	9.8	10.5	8.6	8.2	8.5	9.8	9.5	9.1	9.8	7.2	9.1
EAEU	10.9	11.9	12.1	10.7	11.6	12.9	11.7	5.5	7.5	9.2	10.4
Armenia	16.0	21.7	25.8	27.9	28.4	27.4	28.2	46.4	42.7	25.3	29.0
Belarus	40.9	48.2	46.4	41.0	43.9	47.5	37.3	9.4	11.8	13.3	34.0
Kazakhstan	11.1	10.7	10.6	9.7	10.9	11.8	13.0	12.7	14.0	13.4	11.8
Kyrgyzstan	31.0	27.0	31.7	32.2	31.6	27.8	48.4	66.8	38.5	36.9	37.2
Russia	8.3	8.9	9.3	8.4	8.9	9.8	9.3	3.9	5.3	7.5	8.0

Source: Authors based on the ITC data

share trends downward relative to the mid-2010s (from 13.6% in 2015 to 10.9% in 2024, with a trough of 10.5% in 2019), while ASEAN's fluctuating average (22.9%) represents moderate success in fostering economic cooperation despite some easing in the early 2020s. Meanwhile, NAFTA (now the USMCA) maintains stability, with a decade-long average of 50.0%, showcasing strong and durable interdependence among its member states.

The EAEU's modest internal trade intensity reflects pronounced structural asymmetries. Smaller economies - Armenia (29.0%) and Kyrgyzstan (37.2%) - are markedly more reliant on intra-bloc markets, whereas Russia (8.0%) and Kazakhstan (11.8%) remain outward-oriented. Belarus is an outlier: despite a high decade average (34.0%), its shares a plunge to 9.4% (2022), 11.8% (2023) and 13.3% (2024). The timing and magnitude suggest statistical breaks (confidentiality, flow reclassification, mirror-flow lags) layered onto sanctions-related reorientation; these observations should be treated with caution.

War-era shocks accentuated these differences. Russia's intra-EAEU share fell to 3.9% in 2022 and recovered only to 7.5% by 2024 as exports pivoted towards extra-regional partners. Kazakhstan edged up (14.0% in 2023; 13.4% in 2024) but remains with limited regional value-chain links. Armenia and Kyrgyzstan acted as intermediary hubs: Armenia surged to 46.4% in 2022 (42.7% in 2023) before normalizing to 25.3% in 2024; Kyrgyzstan spiked to 66.8% in 2022 and eased to 38.5% and 36.9% in 2023-2024 - still above the mid-2010s levels. Overall, the 2015-2024 evidence points to the internal market that is thin and shock-sensitive: wartime re-exports and intermediation produced only a partial rebound and did not restore pre-war intensity, while revealing divergent member responses to shared shocks.

The geopolitical shifts following the war in Ukraine have forced the EAEU to re-orient its trade focus toward Asia. Figure 1 shows China as the largest destination in 2024 (29.0% of the total exports), followed by India (12.9%) and Türkiye (9.5%). This pivot partly offsets losses in Western markets due to sanctions but increases partner concentration: the top three now absorb just over one-half of the total exports. With negligible sales to the Americas and the limited reach beyond Asia, the export base remains narrow, leaving the bloc exposed to partner- and corridor-specific shocks.

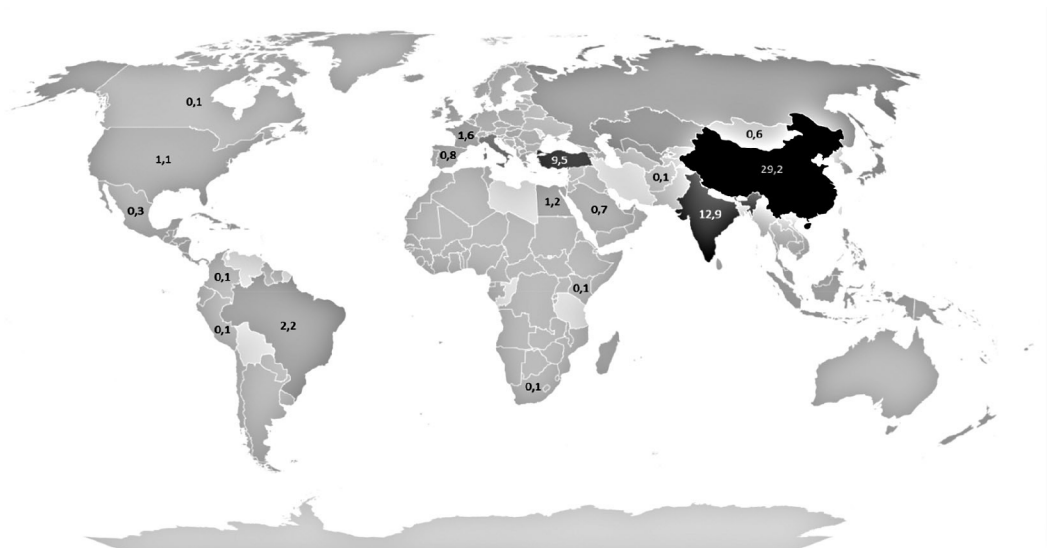

Figure 1 The top export markets of the EAEU in 2024 (in %)

Source: Authors based on the ITC data

The international competitiveness of the EAEU

Regional integration blocs offer countries opportunities to enhance their productivity and international competitiveness through increased market access, economies of scale, foreign investment attraction, technological transfer, and production specialization. Established with these goals in mind, the EAEU seeks to foster stable economic development, improve living standards, and enhance the competitiveness of its member states. Article 4 of the Founding Treaty articulates these objectives, including the creation of a single market for goods, services, capital, and labor, and a comprehensive modernization of national economies for global competitiveness.

Table 3 illustrates the EAEU's fluctuating share in global exports from 2015 to 2024. After the 2016 trough, the share rose to local highs in 2018-2019 (~2.8%), dipped with the 2020 pandemic shock, briefly rebounded in 2021-2022, and then fell to a decade low in 2024 (2.11%). The profile - episodic gains interrupted by sanctions and other external shocks, compounded by internal structural constraints - underscores the bloc's difficulty in achieving sustained improvements in global competitiveness.

Russia, the bloc's dominant economy, largely shapes the aggregate trajectory: after local highs in 2018 (2.32%) and 2022 (2.35%), its share fell to 1.79% in 2023 and 1.67% in 2024. Belarus also contracted sharply - from ~0.17-0.18% pre-2021 to 0.03% in 2023-2024 - but, as indicated earlier, this may reflect a statistical break in the series. By contrast, Kazakhstan edged up from 0.28% (2015) to 0.34% (2024), suggesting relative resilience in commodity exports. The smallest economies, Armenia and Kyrgyzstan, remain marginal in global terms but registered war-era upticks (Armenia from 0.01% to 0.05% by 2024; Kyrgyzstan from 0.01% to 0.02%), consistent with increased re-exports and intermediation.Top of Form

The Export/Import (X/M) ratio, shown in Table 4, reveals the trade-balance dynamics of the EAEU and its member states. While the Union as a whole maintained a positive trade balance, peaking at 2.58 in 2022, the decline to 1.62 in 2023 - and the persistence of 1.62 in 2024 - indicates that the 2022 spike was temporary, driven by the extraordinary price and volume effects that subsequently unwound.

Table 3 The market share of the EAEU and its member states in world exports (2015-2024, in %)

Years	EAEU	Armenia	Belarus	Kazakhstan	Kyrgyzstan	Russia
2015	2.49	0.01	0.16	0.28	0.01	2.03
2016	2.19	0.01	0.15	0.23	0.01	1.79
2017	2.50	0.01	0.17	0.28	0.01	2.03
2018	2.84	0.01	0.17	0.32	0.01	2.32
2019	2.76	0.01	0.18	0.31	0.01	2.25
2020	2.39	0.01	0.17	0.27	0.01	1.93
2021	2.70	0.01	0.18	0.27	0.01	2.22
2022	2.73	0.02	0.05	0.31	0.01	2.35
2023	2.21	0.04	0.03	0.33	0.01	1.79
2024	2.11	0.05	0.03	0.34	0.02	1.67

Source: Authors based on the ITC data

Table 4 The Export/Import ratio of the EAEU and its member states (2015-2024)

Years	EAEU	Armenia	Belarus	Kazakhstan	Kyrgyzstan	Russia
2015	1.67	0.46	0.88	1.50	0.42	1.88
2016	1.44	0.56	0.85	1.46	0.39	1.57
2017	1.47	0.55	0.85	1.65	0.40	1.57
2018	1.72	0.50	0.88	1.87	0.36	1.89
2019	1.56	0.52	0.83	1.50	0.40	1.73
2020	1.34	0.55	0.89	1.23	0.53	1.46
2021	1.54	0.56	0.95	1.46	0.30	1.68
2022	2.58	0.61	0.89	2.46	0.23	2.91
2023	1.62	0.70	0.44	1.29	0.27	1.93
2024	1.62	0.78	0.40	1.37	0.31	1.93

Source: Authors based on the ITC data

Russia, which largely determines the aggregate, sustained a positive X/M throughout, having surged to 2.91 in 2022 before normalizing to 1.93 in 2023-2024. Kazakhstan also remained in surplus, with the wartime peak of 2.46 in 2022, followed by a retreat to 1.29 in 2023 and 1.37 in 2024, consistent with commodity-cycle swings. Belarus continued to register a deficit, deteriorating from near-balance in the late 2010s to 0.44 in 2023 and 0.40 in 2024. Armenia and Kyrgyzstan likewise posted deficits, though their trajectories diverged: Armenia improved steadily from 0.46 (2015) to 0.78 (2024), whereas Kyrgyzstan fell to 0.23 (2022), with only a partial recovery to 0.31 (2024).

Taken together, these patterns underscore the Union's heterogeneity. Russia and Kazakhstan underpin the EAEU's overall surplus position. At the same time, Belarus, Armenia, and Kyrgyzstan continue to face persistent external imbalances, highlighting ongoing challenges in achieving sustained improvements in trade performance across the Union.

In Figure 2, the RCA index provides an analytical view of the EAEU's export specialization across the three post-treaty intervals: 2015-2017, 2018-2020, and 2022-2024. The data confirm a persistent and pronounced comparative advantage in Mineral Products (HS 25-27) and Chemicals (HS 28-38). Mineral Products

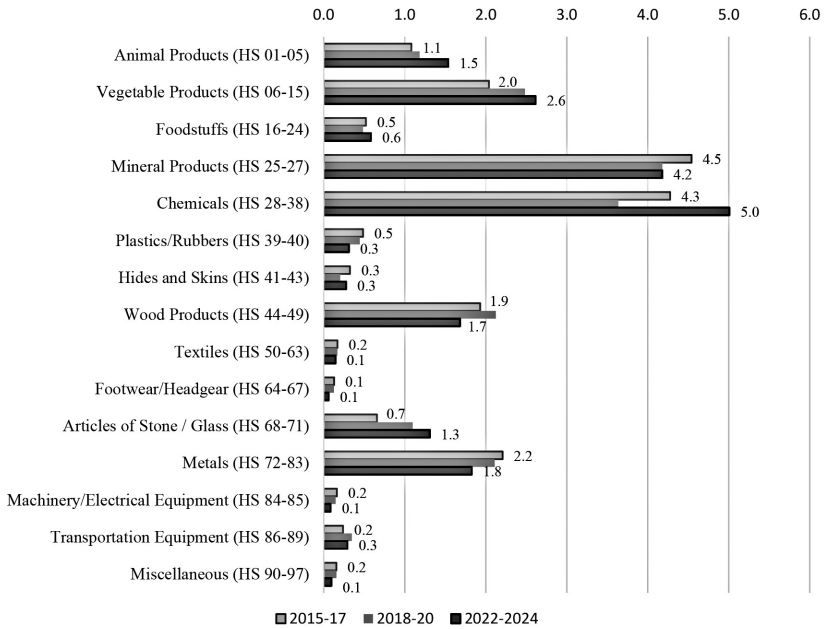

Figure 2 The RCA index (weighted average) of the EAEU in world trade for the period from 2015 to 2017, 2018 to 2020, and 2022 to 2024.

Source: Authors based on the ITC data

remain high and broadly stable (RCA 4.5 in 2015-2017; 4.2 in 2018-2020 and 2022-2024). Chemicals declined during the pandemic (from 4.3 to 3.6) and then rose to 5.0 in 2022-2024, chiefly reflecting the performance of fertilizers. Agriculture strengthens in that RCAs for Animal Products increase from 1.1 to 1.5 and for Vegetable Products from 2.0 to 2.6, while Foodstuffs edge up but remain below unity (0.6 in 2022-2024). This pattern is consistent with the EAEU's emphasis on import substitution and the expansion of domestic agricultural production under sanctions and is primarily driven by developments in Russia.

By contrast, intermediate and higher-technology manufactures weaken: Metals fall from 2.2 to 1.8; Plastics/Rubbers from 0.5 to 0.3; and Machinery/Electrical Equipment remains persistently low at about 0.1. Transportation Equipment improves slightly from 0.2 to 0.3 but remains far below unity. A notable exception is Articles of Stone/Glass, which move above unity (from 0.7 to 1.3), while Wood Products soften (from 2.1 to 1.7).

Overall, the data point to the critical constraints: resilience in the resource-based sectors and gains in agriculture coexist with continued reliance on commodities and weak performance in technology-intensive industries - a configuration also observed in Serbia's post-transition industrial trajectory, where the limited upgrading of the technological base curtailed competitiveness and export diversification (Mićić, 2015). Against this backdrop, it is essential the EAEU's industrial-policy framework, and the mechanisms of intra-regional coordination should be examined more closely, which is the focus of the next section.

The industrial policy of the EAEU - achievements and challenges

The industrial policy of the EAEU is a central pillar of its integration strategy, designed to enhance its economic competitiveness and foster structural transformation across the member states. Rooted in the Treaty on the EAEU, signed in May 2014, the policy

framework emphasizes a balanced development while safeguarding national sovereignty. Article 92 of the Treaty outlines the guiding principles, such as equal rights, respect for national interests, and the protection of economic independence (Eurasian Economic Commission, 2014). Despite these aspirations, the practical implementation of the industrial policy reveals a stark contrast between the stated objectives and the realities on the ground, often hindered by divergent national priorities.

The institutional framework of the EAEU's industrial policy is based on a collaborative model involving both the EEC and national authorities. The EEC is responsible for coordinating policy measures, harmonizing regulations, and overseeing the implementation of industrial initiatives. However, the existing approach has been criticized as disjointed and more theoretical than practical due to the ineffective coordination mechanisms (Gusakov, Andronova, Ganeeva & Dyuzheva, 2019). In practice, the EEC often lacks the necessary authority and resources to enforce its recommendations, especially in politically sensitive areas like subsidies and industrial partnerships. National governments frequently prioritise domestic interests, leading to delays in joint projects such as the development of industrial clusters and technological platforms. This fragmented approach, coupled with conflicting strategies among the member states, undermines collective action and hinders deeper integration (Alzhanova, Dnishev & Alzhanova, 2023).

The "Main Directions of Industrial Cooperation until 2025", a key policy document approved by the Intergovernmental Council in 2015, outlines strategic priorities for industrial development. This plan emphasizes innovation and technological advancement through initiatives such as the creation of technological platforms in sectors like space, medicine, and information technologies (Eurasian Economic Commission, 2015). Additionally, guidelines for financing interstate projects aim to enhance industrial collaboration among the member states. However, progress has been uneven, often hindered by bureaucratic inefficiencies and varying levels of political commitment.

These challenges are compounded by the lack of coordination between national industrial policies, including import substitution programs, which undermines the overall effectiveness of the EAEU's industrial policy. The absence of a structured framework for selecting priority industries and forming integrated value chains further restricts the bloc's ability to achieve cohesive industrial development (Kusainov & Zhumabekova, 2022). Strengthening coordination and aligning national strategies with the Union's goals remain critical for realizing the objectives outlined in the EAEU's industrial agenda.

A persistent challenge in the EAEU's industrial policy lies in the regulation of state subsidies. Article 93 and Annex 28 of the EAEU Treaty classify subsidies into permissible, specific, and prohibited categories to maintain fair competition. However, discrepancies in how subsidies are allocated across the member states create significant barriers to effective policy harmonization. For example, Kazakhstan's broad, untargeted subsidies dilute the impact of industrial support, whereas the low levels of export-credit subsidies hinder competitiveness in key markets (Kamalyan, Tsybulnik & Pak, 2022). The lack of a unified approach to subsidies exacerbates tensions among the member states, complicating the efforts to develop a cohesive industrial strategy and fostering the perceptions of favoritism.

These tensions are evident in the Kazakh dairy sector, where extensive state support to Russian and Belarusian producers, combined with the post-sanctions redirection of their supplies to EAEU markets, has generated an influx of the low-priced imports that Kazakh farms struggle to match. Despite sustained public investment in farm modernization, local producers face weak demand from processing plants and continued persistent price undercutting, broadly perceived as *de facto* dumping, producing acute financial stress (Yesbolova, Abdikerimova, Kuashbay, Sadykbekova & Bigeldieva, 2025). In response, the government has considered additional support to domestic farms; however, absent tighter Union-wide discipline on subsidies and enforceable anti-dumping remedies, unilateral measures risk a subsidy race and deeper intra-Union frictions.

In spite of these challenges, the EAEU has made progress in certain aspects of the industrial policy. The creation of the EAEU Industrial Policy Council and the Agro-Industrial Policy Council has facilitated dialogue among the member states, leading to initiatives such as the integration of the space and geo-information systems and the development of industrialization maps. Consisting of 158 major investment projects worth over $239 billion across 34 industries, the Industrialization Map focuses on promoting import substitution and enhancing cross-border cooperation, particularly in machinery, forestry, and construction materials. Furthermore, the annual review of over 800 subsidy-related legal acts has contributed to improved regulatory coherence, reducing disparities in industrial support measures across the Union (EEC, 2023).

Structural challenges remain a significant barrier to the EAEU's industrial development. Most member states remain focused on traditional, capital-intensive industries, limiting diversification and the development of new growth sectors. The economies of Russia and Kazakhstan are heavily reliant on the export of raw materials, making them vulnerable to fluctuations in global commodity prices. This dependence limits the Union's ability to diversify its industrial base and reduces its resilience against external economic shocks. Moreover, economic disparities among the member states pose a challenge to integration; while Russia and Belarus have established industrial bases, Armenia and Kyrgyzstan lag in terms of industrial development and infrastructure, constrained by structural economic limitations, logistical bottlenecks, and small-scale agricultural production systems (Bekbolotova, Djanibekov & Herzfeld, 2025). The imposition of international sanctions on Russia and Belarus has further complicated the situation, disrupting supply chains and slowing down the efforts to modernize industries across the region (Kamalyan *et al*, 2022).

A significant weakness in the EAEU's industrial policy lies in the insufficient technological integration among the member states, exacerbated by the weak legal frameworks and the inadequate infrastructure for technology transfer, which hinder the development of a cohesive and innovative industrial base (Alzhanova *et al*, 2023). The bloc's heavy reliance on external markets for intermediate goods, alongside limited intra-EAEU trade, reveals critical vulnerabilities in establishing resilient and integrated value chains. Studies indicate that reliance on foreign markets for industrial supplies exceeds intra-EAEU trade volumes by more than five times, highlighting the urgent need for enhanced internal cooperation and robust supply chain development (Krivoguz & Fesenko, 2022).

Looking ahead, the EAEU aims to extend its industrial cooperation strategy to 2030, focusing on smart technologies, expanding cooperation in nonfinancial industrial support mechanisms, and enhancing export promotion to third-country markets such as China, Türkiye, and African nations. These priorities reflect emerging opportunities and strategic directions for the Union's industrial development (Borisenko, 2022).

The financial support mechanism for industrial cooperation in the EAEU, signed in May 2023 and ratified in June 2024, aims to foster technological development, create value chains, and boost mutual investments among the member states. The mechanism provides financial subsidies, primarily through reduced interest rates on loans, to the cooperative projects that involve participants from at least three member countries. While the mechanism seeks to strengthen industrial ties and create sustainable value chains, it faces challenges, including the complexity of coordination between multiple stakeholders and potential disparities in financial and industrial capacities across the member states. The effectiveness of the mechanism will largely depend on its ability to ensure equal participation and benefits for all the member states, as well as its responsiveness to evolving economic conditions.

CONCLUSION

Drawing the evidence together, the EAEU's thin integration and narrow, resource-based specialization are explained through asymmetric endowments and limited supranational authority,

and a transparent indicator framework linking intra-union trade intensity, the world-market share, export concentration, and revealed comparative advantage is proposed.

In direct response to the research questions, only the modest and uneven deepening of intra-EAEU trade across the member states is found (RQ1); there is no sustained improvement in global competitiveness, as indicated by the Union's share of world exports and the diversification of external markets (RQ2); no durable structural upgrading away from resource dependence, with persistent disadvantages in higher-technology, and value-added manufactures is found (RQ3); finally, there is an industrial-policy trajectory marked by demonstrable advances alongside persistent gaps in implementation and enforcement (RQ4).

The EAEU's industrial policy holds a significant potential to enhance global competitiveness but demonstrates a dual reality - notable achievements alongside persistent challenges. Progress has been made in harmonizing regulations, aligning subsidy frameworks, and initiating collaborative projects. Initiatives such as the Industrialization Map and the promotion of green technologies reflect the Union's ambition to foster innovation and reduce import dependency in the key sectors. However, these efforts are often undermined by the inconsistencies between national and regional priorities, uneven industrial development, and a lack of a coordinated implementation. The member states frequently prioritize domestic interests over collective goals, while less industrialized economies struggle to compete with more advanced ones.

To address these challenges, the EAEU must adopt a cohesive and strategic approach to the industrial policy. Strengthening the Eurasian Economic Commission's supranational authority is critical for improving coordination and resolving conflicts between national and regional objectives. Prioritizing technological modernization, with investment in high-tech industries and value-added production, is essential to reducing dependence on raw materials. The comparative evidence from Serbia shows that such shifts require not only investment but also coherent reform strategies and sustained policy consistency to enable transition from low- to high-value-added industries (Mićić, 2015; Jakopin, 2020). Through integrated value chains and reduced trade barriers, enhanced intra-regional trade will also bolster economic resilience. Additionally, diversifying export markets by forging stronger ties with emerging economies will mitigate the risks of over-reliance on limited external markets.

A coordinated, forward-looking strategy that aligns national and regional priorities is vital for the EAEU to overcome internal disparities, advance technological innovation, and foster intra-regional trade. By addressing these challenges, the Union can strengthen its global competitiveness and achieve sustainable economic growth for its member states.

These conclusions should be read with due regard to several limitations: the study is observational and relies on the aggregate goods-trade indicators over a relatively short post-formation horizon punctuated by large exogenous shocks, services and firm-level dynamics are not fully captured, and re-exports and parallel-trade channels may bias intra-union diagnostics. Future research should examine the causal effects of subsidy harmonization and the cooperation-finance mechanism on intermediate-goods trade and upgrading, undertake firm- and product-level studies of technology adoption and export sophistication, improve the accounting of re-exports, extend coverage to services and digital trade, and conduct project-level evaluations of the Industrialization Map and related initiatives, including counterfactual benchmarking against peer regional blocs.

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Paskal Zhelev is an Associate Professor at the University of National and World Economy, Sofia, Bulgaria, and a Researcher (R3) at the Bratislava University of Economics and Business, Slovakia. His research focuses on economic integration, industrial policy, international trade, and foreign direct investment. He was a Fulbright Visiting Scholar at the University of Illinois at Urbana-Champaign (2015) and a Visiting Scholar at Shanghai Jiao Tong University (2019).

Olga Malashenkova is an Associate Professor at the Minsk Branch of Plekhanov Russian University of Economics, Minsk, Belarus, and a Consultant to the United Nations. Her research focuses on economic integration, sanctions and human rights, digital transformation in education, and academic entrepreneurship. She was a Fulbright Fellow and Lecturer at the University of North Carolina at Chapel Hill (2021-2022).

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ANALYZING THE IMPACT OF MACROECONOMIC CONDITIONS ON GDP GROWTH: BRICS VS. G7 COUNTRIES

Farial Faizi[1], Mariam Sawas[1], Dina Abohassan[1], Ilija Stojanović[1] and Marko Selaković[2*]

[1]*American University in the Emirates, Dubai International Academic City, Dubai, UAE*
[2] *S P Jain School of Global Management, Dubai International Academic City, Dubai, UAE*

The economic rivalry between the BRICS countries and the G7 nations has been a central theme in global development for decades. This study seeks to compare the GDP growth dynamics between the BRICS and G7 countries, while examining the differential impact of the key macroeconomic indicators on their economic trajectories. To achieve this, statistical methodologies, including independent t-tests and ANOVA, were utilized so as to compare the group-level differences, while the tests of between-subjects effects were applied to assess the variations in the effects of the regression coefficients for the macroeconomic factors influencing GDP growth. The study posits that the distinct economic structures of the BRICS countries and the G7 nations lead to varying macroeconomic conditions which shape their growth patterns in distinct ways. The findings of this research offer actionable insights into the strongest and weakest determinants of the GDP growth within these economic blocs. It contributes to a broader discourse on global economic competition, offering evidence-based recommendations for balanced growth strategies.

Keywords: macroeconomic conditions, GDP growth, BRICS, G7

JEL Classification: E01, E60, O47, C33, F43

INTRODUCTION

The global economic landscape has significantly been shaped by the interplay between developed and emerging economies, with the G7 and the BRICS nations representing two pivotal blocs in this dynamic. Composed of advanced industrialized countries, the G7 has historically dominated global economic leadership through its technological innovations, robust institutions, and established markets. Formed in 1975, the G7 includes the world's most advanced economies, namely France, Germany, Italy, Japan, the U.S., the U.K., and Canada, which joined in 1976 (Rustamov, 2023). Conversely, BRICS - a coalition of emerging economies - has rapidly risen in prominence, challenging the traditional

* *Correspondence to:* M. Selaković, S P Jain School of Global Management, Dubai International Academic City, Dubai, UAE; e-mail: marko.selakovic@spjain.org

dominance of the G7 with its resource-rich markets, demographic advantages, and increasing integration into global trade. The BRICS nations - Brazil, Russia, India, China, and South Africa - are broadly recognized as a significant economic bloc characterized by their remarkable recent economic growth (Siljković, Dedović & Kalač, 2024). Over the past two to three decades, these nations have undergone unprecedented economic expansion, solidifying their status as pivotal players in the global economy (Budhwar, Tung, Varma & Do, 2017). The 15th BRICS Summit held at the Sandton Convention Centre in Johannesburg, South Africa, from August 22 to 24, 2023, marked a significant milestone for the BRICS Diplomatic Progress Initiative by broadening its membership diversity. Starting January 1, 2024, six new countries were invited to the five existing members, i.e. Argentina, Egypt, Ethiopia, Iran, Saudi Arabia, and the United Arab Emirates (Antony, 2023).

This study is specifically focused on several research objectives, particularly intending:

1. to analyze and compare the GDP growth rates of the BRICS and the G7 countries, identifying the key variations in their economic performances,
2. to investigate the influence of specific macroeconomic factors - such as the inflation rate, the unemployment rate, the real interest rate, the exchange rate stability, the export of goods and services, the government debt-to-GDP ratio, FDI net inflows and outflows, and agriculture, forestry, and fishing value-added - on the GDP growth within each group,
3. to evaluate and contrast the macroeconomic impacts on the GDP growth between the BRICS and the G7 countries, highlighting similarities and differences in how these factors shape economic growth in emerging versus developed economies, and
4. to assess the relative contribution of these macroeconomic factors to the overall GDP growth trends in the BRICS and the G7 countries, providing insights into their economic resilience and adaptability to global economic changes.

In order to identify the key differences in the GDP growth rates between the BRICS and the G7 countries over the past decade, the study's initial hypotheses are as follows:

$H1_0$: There is no significant difference in the average GDP growth rate between the BRICS countries and the G7 countries ($\mu_{BRICS}=\mu_{G7}$).

$H1_a$: There is a significant difference in the average GDP growth rate between the BRICS countries and the G7 countries ($\mu_{BRICS}\neq\mu_{G7}$).

This study also aims to bridge this gap by systematically examining the GDP growth trends in the BRICS and the G7 nations over the past decade and is focused on understanding the key macroeconomic factors driving the GDP growth disparities between the BRICS and the G7 countries and how these factors influence economic performance in emerging and developed economies differently. In this regard, the study's second and third hypotheses are established:

For the BRICS countries:

$H2_0$: The independent variables (Inflation Rate, Unemployment Rate, Real Interest Rate, Exchange Rate Stability, Export of Goods and Services, Government Debt-to-GDP Ratio, FDI Net Inflows, FDI Net Outflows, and Agriculture, Forestry, and Fishing Value-Added) have no significant effect on the GDP growth in the BRICS countries ($\beta1 = \beta2 = \beta3 = ... = \beta_k = 0$).

$H2_a$: At least one independent variable has a significant effect on the GDP growth in the BRICS countries ($\beta_k \neq 0$ for at least one$_k$),

where β_k represents the regression coefficients of the independent variables for the BRICS countries.

For the G7 Countries:

$H3_0$: The independent variables (Inflation Rate, Unemployment Rate, Real Interest Rate, Exchange Rate Stability, Export of Goods and Services, Government Debt-to-GDP Ratio, FDI

Net Inflows, FDI Net Outflows, and Agriculture, Forestry, and Fishing Value-Added) have no significant effect on the GDP growth in the G7 countries. ($\beta1 = \beta2 = \beta3 = ... = \beta_k = 0$).

$H3_a$: At least one independent variable has a significant effect on the GDP growth in the G7 countries ($\beta_k \neq 0$ for at least one$_k$),

where β_k represents the regression coefficients of the independent variables for the G7 countries.

As these blocs navigate their distinct economic trajectories, a comparative analysis of their GDP growth and the underlying macroeconomic factors is crucial for understanding the drivers of economic success and stability in developed versus emerging economies. Given the additional interest in uncovering the impact of FDI net inflows, FDI net outflows, and the government debt-to-GDP ratio on the economic performance in emerging (BRICS) versus developed (G7) countries, and identifying the key similarities and differences in the effect of these factors, the fourth hypothesis was developed as follows:

$H4_0$: There is no significant difference in the effects of the independent variables on the GDP growth between the BRICS and the G7 countries ($\beta_{BRICS}=\beta_{G7}$).

$H4_k$: There is a significant difference in the effects of the independent variables on the GDP growth between the BRICS and the G7 countries. In other words, the regression models differ between the two groups ($\beta_{BRICS}\neq\beta_{G7}$).

LITERATURE REVIEW

Gross Domestic Product (GDP) represents the value of the goods and services produced within a country's economy, overlooking production costs. GDP is also the total of personal consumption expenditures, gross private domestic investment, the net export of goods and services, and the government consumption expenditures and gross investment (Dynan & Sheiner, 2018). GDP is an essential measure of an economy's wellbeing and allows for direct comparisons between countries (Fraumeni, 2022). GDP is measured by assessing the total value of all goods and services produced, using the value-added method to highlight the economy's main drivers. There are two key attitudes for measuring the GDP, which theoretically produce the same outcome. Firstly, the expenditure approach computes GDP by adding personal spending, capital investment, the government expenditure, and net exports. Secondly, the income approach measures GDP by adding firm profits and household income earned from providing resources (Trinh, 2017).

Moreover, GDP measures a country's domestic income and productivity over a definite period. It signifies the total market value of all final products and services generated within the country during that time. Additionally, GDP originates from the total real demand for national products, both local and foreign. Local demand involves spending through governments, households, and organizations, while foreign demand is driven from exports. However, imports, which satisfy part of local demand, may reduce the overall GDP (Khan & Khan, 2021).

The key macroeconomic factors affecting GDP growth

The performance of an economy depends on the stability of the main macroeconomic indicators, such as the supply of money, inflation and the exchange rate, as well as other fundamental factors (Kankpeyeng, Maham & Abubakar, 2021). Macroeconomics focuses on the performance of the overall economy, taking a comprehensive perspective on economic trends. It observes significant economic indicators and interactions among diverse segments to better understand how the entire economy functions. As one of the key macroeconomic factors, inflation considerably affects economic development. It signifies the general rise in the prices of products and services over time within an economy. Moreover, labor force participation, shaped by Foreign Direct Investment (FDI), plays a fundamental role. FDI can improve access to the funds (Selaković, 2022) and

employment opportunities in hosting nations and facilitate the relocation of advanced technological proficiencies (Shah, Asghar & Riaz, 2020). Furthermore, GDP *per capita* and the gross savings rate are positively correlated, indicating that a higher savings rate is associated with a higher GDP *per capita* (Ahsan, 2024).

The economic profiles of the BRICS and G7 countries

Over the last 20 years, economic dominance worldwide has significantly shifted. This transformation has occurred mostly due to the emergence of China (Janković, 2018), but in a broader perspective owing to the BRICS countries, consisting of Brazil, Russia, India, and China. The confidence of BRICS in accomplishing their goals can be seen through their economic efficiency. The economic growth of BRICS has been observed by many countries, except in 2021, when the global economy was impacted by COVID-19. The BRICS economies account for 25.61% of the world's GDP (Paudel, 2023).

The Group of Seven (G7), consisting of the United States, Japan, Germany, the United Kingdom, France, Italy, and Canada, is a political forum containing some of the world's leading economies. These countries are characterized by their significant levels of industrialization, economic strength, and commitment to international economic stability. Advocating for the GDP of over $29 trillion, the United States has the leading economy and is a frontrunner in technology, finance, and healthcare. The third largest economy is Japan, with the GDP of about $4.07 trillion. It is recognized for its advanced technology, export-oriented fields, and automative industries. Germany, on the other hand, with its GDP of $4.71 trillion, is the leading economy in Europe. The country specializes in engineering and the export of machinery and vehicles. With the GDP exceeding $3.59 trillion, the United Kingdom is an international financial center, with London acting as the primary base for banking and financial facilities. With the GDP of $3.17 trillion, France tracks closely because of its varied economy that contains robust sectors for luxury goods, agriculture, and aerospace. With its GDP of $2.38 trillion, Italy is known for its flourishing manufacturing segment, and is particularly strong in the fashion, automative, and design industries. Finally, Canada, with the GDP of $2.21 trillion, is heavily reliant on natural capitals, such as minerals, oil, and gas, and also has an advanced financial sector and close economic bonds with the United States (Statista, 2024).

The GDP growth rate and inflation

The GDP growth of the US has been steady and strong, whereas Japan, the UK, Italy, France, and Canada have faced some fluctuations over the recent years. Inflation is a result of money supply exceeding the production of goods and services in an economy, mainly driven by extreme aggregate demand. Temperate inflation can affect the output, while extreme inflation lessens labor demand, leading to lower production and eventually slowing down economic development (Kankpeyeng *et al*, 2021). The Keynesian School implies a positive connection between inflation and GDP growth, while the neoclassical view claims that rising inflation diminishes the output and wellbeing. Additionally, higher inflation lowers purchasing power, discouraging spending on goods and capital, eventually reducing the stable output (Tien, 2021). Inflation can significantly influence economic progress, making price constancy essential for emerging economies. Defined as the sustained rise in overall price levels over time, inflation poses a significant obstacle to economic balance. By increasing manufacturing costs for businesses, traditional economists reason that inflation obstructs economic growth (Haider, Ullah, Khan, Raza & Ali, 2024). Furthermore, inflation brings out currency devaluation. Excessive inflation lowers product demand, which consequently decreases national production. As production deteriorates, demand for labor declines, thus significantly increasing unemployment (Alam, Nur Alam & Hoque, 2020).

In the long run, GDP growth leads to inflation. If not controlled, inflation can accelerate into hyperinflation, creating a self- perpetuating cycle. In an environment

of rising inflation, people are likely to spend more, expecting that their money will lose value eventually. This increased spending for the time being boosts GDP, further escalating prices (Ali, Yusop, Kaliappan, Chin & Meo, 2022).

An alternative interpretation is that rising inflation is not the cause of gradual economic development, but rather an indication of core concerns, similar to supply disruptions or fiscal imbalances. Certain theories, like New-Keynesian models, imply that inflation may even boost GDP in the short run in specific circumstances. Nevertheless, these theories struggle to account for situations like stagflation, where a high level of inflation and slow growth take place at the same time (Agarwal & Baron, 2024).

National economic competitiveness in global trade relies on inflation, because higher inflation increases export prices while cutting import prices, resulting in trade inconsistencies and the current account gaps. Huge inflation rates trigger capital outflows across countries because investors hunt for low-inflation areas, which eventually stress foreign exchange rates and reduce foreign currency stocks. Certain economists argue that inflation needs to exist at a low rate in order to stimulate economic development through elevated spending, while improving debt viability over time. Sustaining inflation at an average level continues to function as a top policy aim, supporting the stability of the economy and development sustainability (Xavier, Fernandes & de Oliveira, 2021).

The impact of unemployment on GDP growth

Unemployment describes a condition where people who are willing and able to work cannot find appropriate paid employment. As unemployment rates increase in an economy, so do the levels of poverty and related welfare matters. Creating employment opportunities is crucial for economic development and poverty reduction. Moreover, labor plays a vital role in development. Employment concerns are deeply linked to the environment and can generate new challenges in both economic and noneconomic areas. High unemployment results in lower income, thus leading to poverty (Dahliah & Nur, 2021). Besides, excessive unemployment causes a reduced industrial output and the inefficient application of both industrial and social capital. It aggravates inefficiency by deteriorating workers' skills and weakening their motivation (Janoski, 1990). Economic growth leads to employment opportunities, which in turn reduces unemployment, which builds a nonlinear relationship between unemployment and economic growth, causing a zigzag pattern (Hashmi, Khushik, Gilal & Yongliang, 2021). Unemployment rates in France, Italy, and the United Kingdom show long-term persistence (the unit root), while those in Germany and Italy are stationary. In Canada, unemployment rates additionally have a unit root, whereas in Japan and the United States, they are stationary only in the first regime. This suggests that unemployment hysteresis affects France, Italy, the United Kingdom, and the second regime of Japan and the United States (Yilanci, Ozkan & Altinsoy, 2020).

The key differences between the BRICS and the G7 countries

In 2010, the BRICS countries (with 2.8 billion people) had a significantly larger population compared to the G7 countries (740 million). The BRICS united in trade negotiations against the G7, which had controlled global trade for decades. While the G7 lost momentum, the BRICS economies flourished. By 2019, BRICS' GDP reached $21 trillion, whereas the G7's was $39 trillion, reflecting accelerated economic growth, as well as a progressively influential role in the global economy. BRICS' GDP grew 1.8 times, whereas the G7's grew 1.2 times. In terms of science and technology, the G7 countries have a more uniformed structure dominated by biosciences. In contrast, the BRICS countries mainly focus on core sciences, excluding Brazil, where biosciences dominate. Turning to another aspect, BRICS' GDP ratio to the global GDP grew from 0.12 to 0.236 between 2009 and 2019, emphasizing its growing economic effect. In contrast to the G7, BRICS' broadening influence in financial markets has attracted attention as a potential

source of international threats. This shift could reform market integration, affecting investment, speculation, and risk variation strategies (Agyei, Owusu Junior, Bossman, Asafo-Adjei, Asiamah & Adam, 2022).

RESEARCH METHODOLOGY

In terms of the research methodology, the collected secondary data summarize the GDP growth rates through the historical figures of the two groups of countries, namely the BRICS nations (Brazil, Russia, India, China, South Africa, Egypt, Ethiopia, Iran, Saudi Arabia, and the UAE) and the G7 nations (the United States, Japan, Germany, the United Kingdom, France, Italy, and Canada). The dataset was extracted from credible sources, including the Federal Reserve Economic Data (FRED), the International Monetary Fund (IMF), and the World Bank (WB), encompassing a 12-year period from the year 2011 to 2022.

Prior to conducting the analysis, cleaning and organizing the data was performed so as to ensure accurate and reliable results. This process consisted of the elimination of the missing values and the positioning of each observation to its corresponding year in order to maintain consistency and comparability.

To test the first hypothesis, focusing on testing the difference in the average GDP growth rate between the BRICS countries and the G7 countries, an independent two-sample t-test was applied under the assumption that BRICS and the G7 are two independent groups. The data pertaining to the GDP growth rates for BRICS (Brazil, Russia, India, China, South Africa, Egypt, Iran, Ethiopia, the UAE) and the G7 (Canada, France, Germany, Italy, Japan, United Kingdom, the United States) were being collected over the period of 12 years from 2011 to 2022, sourced from the World Bank Open data website. A t-test was conducted in order to compare the means of the BRICS and the G7 groups, determining whether significant differences in the GDP growth do exist between the two groups. Additionally, how the two blocks are concise in terms of their growth was analyzed measuring the growth disparity from the mean within each bloc by evaluating the level of the standard deviation for each group.

In the second step, the research objective on how macroeconomic factors such as the inflation rate, the unemployment rate, and the real interest rate influenced the GDP growth within the BRICS and the G7 countries was distinctively addressed. To test the second and third hypotheses, a multiple regression model was developed:

GDP Growth $(\gamma)_t$: $\gamma = \beta_0 + \beta_1$(Inflation Rate) + β_2(Unemployment Rate) + β_3(Real Interest Rate) + β_4(Exchange Rate Stability) + β_5(Export of Goods and Services) + β_6(Government Debt-to-GDP Ratio) + β_7(FDI Net Inflows) + β_8(FDI Net Outflows) + β_9(Agriculture, Forestry, and Fishing Value-Added) + ε

where:

- β_0 is the intercept.
- β_1 to β_9 are the coefficients for the respective independent variables.
- ε represents the error term.

This model was applied individually for the BRICS and the G7 groups so as to identify the most impactful macroeconomic factors for the GDP growth in each group for the period t = 2011 to 2022. The initial analytical approach was through ANOVA in order to understand if the set of the independent variables in the regression model collectively explained a significant amount of variance in the GDP growth separately for the BRICS and the G7 countries. Through Multiple Linear Regression (MLR), the relationship between the dependent variable, the GDP growth, and various independent variables was analyzed so as to identify the key macroeconomic factors influencing economic performance. The variables were taken from the WorldBank Open Database. The values were not transformed but rather used in their original percentages or local currency units, as reported by the source. The variables included in the model are as follows:

- Y: GDP Growth,
- X1: Inflation Rate,

- X2: Unemployment Rate,
- X3: Real Interest Rate,
- X4: Exchange Rate Stability,
- X5: Export of Goods and Services,
- X6: Government Debt-to-GDP Ratio,
- X7: FDI Net Inflows,
- X8: FDI Net Outflows,
- X9: Export of goods and services,
- X10: Agriculture, Forestry, and Fishing Value-Added, Agriculture and Rural Development.

The regression models were developed separately for the BRICS and the G7 countries, where each group was treated as an aggregated cross-sectional dataset. The focus was mainly on group-level modelling with the primary objective to evaluate the macro-level differences between the two economic blocs, not within individual countries, over time.

Given the additional interest in uncovering the differences of the effects of the independent variables on the dependent variable in the two different regression models, namely for BRICS and the G7, the fourth hypothesis was tested. To test the aforementioned hypothesis, a Tests of Between-Subjects Effects test was used to determine whether there were significant differences between the coefficients of the two linear regression models, which results from the fact that the relationship between the dependent and the independent variables was suspected to differ across these two groups, namely the BRICS and the G7 countries.

RESEARCH FINDINGS

The group statistics in Table 1 displays the summary of the descriptive statistics comparing the GDP growth rates between the two groups:

- Group 1 (V1 = 1) represents the BRICS countries.
- Group 2 (V1 = 2) represents the G7 countries.

According to the results of the descriptive statistics for the GDP growth rate across the BRICS and the G7 countries, the average GDP growth rate is significantly higher in BRICS, with 3.7%, in comparison with that of the 1.3% rate in the G7 countries. Therefore, the BRICS economies - often categorized as evolving markets - demonstrate stronger growth than the more advanced G7 countries.

Moreover, the standard deviation outcomes underline a greater inconsistency - therefore lesser reliability - in the GDP growth among the BRICS countries (3.79), as opposed to the lower variability and comparatively higher consistency shown in the G7 countries (2.92).

Notwithstanding the results of the descriptive statistics, a t-test was conducted in order to test the H_1 hypothesis for the significance of the difference in the means. The products of Levene's Test for Equality of Variances are shown in Table 2.

The results of the Independent Samples t-test comparing the GDP growth rates (%) between the BRICS and the G7 countries indicated the F-value: 14.355 and the p-value of 0.000. Since the significance level is below 0.05, this shows that the variances are not equal. Therefore, it can be concluded that there is a difference in the variability of the GDP growth among the two groups. Hence, the values based on nonequal

Table 1 The descriptive statistics for the GDP growth

Group Statistics					
	V1	N	Mean	Std. deviation	Std. error mean
GDP Growth Rate %	1	108	3.702214280233629	3.799638393509069	.365620374885950
	2	84	1.335643623688180	2.926090481867369	.319262645796358

Source: Authors

Table 2 The independent samples t-test

		Levene's test for equality of variances		t-test for equality of means					
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference
									Lower	Upper
GDP Growth Rate %	Equal variances assumed	14.355	.000	4.722	190	.000	2.366570656545449	.501230167308057	1.377880025861309	3.355261287229588
	Equal variances not assumed			4.876	189.986	.000	2.366570656545449	.485393547065299	1.409117761254293	3.324023551836605

Source: Authors

variances were applied, rather than assumed, to interpret the outcomes. The results of the independent samples t-test based on the assumption of unequal variances show a statistically significant difference in the GDP growth rates between the BRICS and the G7 countries. The t-value is 4.876 with 189.99 degrees of freedom and the p-value is 0.000, which leads to the conclusion that $H1_0$ should be rejected, meaning that there is a statistically significant difference in the average GDP growth rates among the BRICS and the G7 nations. The mean difference is 2.366%, denoting that the BRICS countries have a higher GDP growth rate on average in comparison to the G7 countries. Thus, a fact can be established that the BRICS countries exceed the G7 countries with respect to the GDP growth rate, as the mean difference shows a positive sign. Since there is a statistically significant difference in the GDP growth rates among the two groups, the null hypothesis $H1_0$ is rejected and the alternative $H1_a$ is accepted, signifying that the average GDP growth rates of the two groups are significantly different.

To evaluate the hypotheses H_2 and H_3, two separate regression analyses were carried out. The findings are showcased in the following sections.

Regression analysis assumptions

To check the model assumptions, the Shapiro-Wilk test was conducted so as to assess whether the residuals from the regression model were normally distributed. According to the findings, the W statistic = 0.968 with the p-value = 0.080. These results indicated that residuals did not significantly deviate from normality. Thus, the assumption was met. Furthermore, the linearity check showed that all the variables demonstrated either linear or approximately linear relationships with the GDP Growth Rate. Thus, the linearity assumption was reasonably met for the regression analysis. The Variance Inflation Factor (VIF) was also checked so as to detect multicollinearity in the multiple regression model. According to the findings, there was no significant multicollinearity among the predictors as all the predictor VIF values were well below 5, which means that the assumption was also met in this case. The Breusch-Pagan test revealed that the test statistic = 13.75, with the p-value = 0.056. Therefore, the assumption of the constant variance of the residuals (homoscedasticity) was reasonably met, although being borderline.

Regression analysis for the BRICS countries

Table 3 demonstrates the results of the regression analysis model for the BRICS countries. Based on R^2=0.725, it was determined that the model had displayed a relatively strong descriptive fit for explaining the variations of the GDP growth in the BRICS countries, drawing from changes in the

independent variables. Here, 72.5% of the variation in the dependent variable is explained by the model. Overall, the model is reasonably well-fitted, as is implied by the standard error of 2.056, which is low to moderate, suggesting that the predictors, which include the key economic indicators such as foreign direct investment (inflows and outflows), exports, and inflation significantly contribute to the explanation of the differences in the GDP growth between the BRICS and the G7 countries.

The ANOVA (Analysis of Variance) outcomes for the regression model forecasting the GDP growth rate for the BRICS countries are portrayed in Table 4. The Regression Sum of Squares (SST): 312.722 represents the variation in the GDP growth rates explained by the predictors (the independent variables), while the Residual Sum of Squares (SSR): 118.370 represents the unexplained ones. To summarize, the independent variables in the model significantly describe the variation in the GDP Growth Rate %. Overall, the ANOVA results signify that the regression model is statistically significant (F = 7.397, p = 0.000), suggesting that the predictors explain a substantial portion of the variation in the GDP growth rates for the BRICS countries. With the SST (312.722) being much greater than the remaining sum of squares (118.37), the model appears to show a strong explanatory power for this dataset, which is consistent with the earlier findings, accounting for the fact that the economic variables, such as foreign direct investment, exports, and inflation are the critical elements of the GDP growth for BRICS.

Table 5 identifies the key elements influencing the GDP growth in the BRICS countries:

Table 3 The regression model summary for the BRICS countries

Model summary[a]				
Model	R	R square	Adjusted R square	Std. error of the estimate
1	.852[b]	.725	.627	2.056090069103176

a. V1 = 1

b. Predictors: (Constant), Agriculture, Forestry, and Fishing, Value-Added (% of the GDP), Government Debt, total (% of the GDP), Inflation Rate %, Foreign Direct Investment, Net Inflows (% of the GDP), Export of Goods and Services (% of the GDP), Foreign Direct Investment, Net Outflows (% of the GDP), Export of Goods and Services $, Exchange Rate Stability (LCU per US$, the period average), Real Interest Rate %, Unemployment Rate %

Source: Authors

Table 4 ANOVA model for BRICS countries

ANOVA[a,b]						
Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	312.722	10	31.272	7.397	.000[c]
	Residual	118.370	28	4.228		
	Total	431.092	38			

a. V1 = 1

b. Dependent Variable: GDP Growth Rate %

c. Predictors: (Constant), Agriculture, Forestry, and Fishing, Value-Added (% of the GDP), Government Debt, total (% of the GDP), Inflation Rate %, Foreign Direct Investment, Net Inflows (% of the GDP), Export of Goods and Services (% of the GDP), Foreign Direct Investment, Net Outflows (% of the GDP), Export of Goods and Services $, Exchange Rate Stability (LCU per US$, the period average), Real Interest Rate % , Unemployment Rate %.

Source: Authors

- FDI Inflows: A 1 percentage point increase boosts the GDP growth by 0.672 percentage points, keeping the other variables constant (Sig. = 0.013).
- FDI Outflows: A 1 percentage point increase raises the GDP growth by 1.38 percentage points, keeping the other variables constant (Sig. = 0.03).
- Agriculture, Forestry, and Fishing Value-Added: A 1 percentage point increase in the GDP share adds 0.58 percentage points to the GDP growth, keeping the other variables constant (Sig. = 0.004).

Apart from the significant factors, the non-significant factors for the GDP growth in the BRICS bloc include the Inflation Rate, the Unemployment Rate, the Real Interest Rate, the Exchange Rate Stability, the Export of Goods and Services ($), the Government Debt and the Export of Goods and Services (% of the GDP).

Based on the significant predictors, the null hypothesis ($H2_0$) is rejected, and the alternative hypothesis ($H2_a$) is accepted. Hence, to drive growth, BRICS must concentrate on drawing FDI, managing FDI outflows, and elevating the agricultural sector's role. The model found to be significant is as follows:

$$Y = -1.911 + 0.672(X7) + 1.380(X8) + 0.580(X10)$$

Regression analysis for the G7 countries

Table 6 outlines the regression model for the GDP growth in the G7 nations. $R^2 = 0.673$ shows that 67.3% of the variation in the GDP growth is defined by the model's predictors, which is lower compared to the model applied for the BRICS countries. Still, the model demonstrates a moderate overall connection between the variables included and the GDP growth. However, with a lower adjusted R^2, policymakers should focus on identifying and stressing the most significant predictors (e.g. FDI, exports, or agriculture) for impactful strategies.

Table 5 The regression coefficients for BRICS

Coefficients$_{a,b}$						
Model	B	Unstandardized coefficients		Standardized coefficients	t	Sig.
		Std. error	Beta			
1	(Constant)	-1.911	4.268		-.448	.658
	Inflation Rate%	-.213	.184	-.164	-1.154	.258
	Unemployment Rate %	.130	.219	.293	.594	.557
	Real Interest Rate %	-.060	.068	-.240	-.881	.386
	Exchange Rate Stability (LCU per US$, the period average)	-.014	.042	-.108	-.320	.752
	Export of Goods and Services $	.000000000003539	.000	.167	.420	.677
	Government Debt, Total (% of the GDP)	-.019	.037	-.146	-.505	.617
	Foreign Direct Investment, Net Inflows (% of the GDP)	.672	.253	.329	2.653	.013
	Foreign Direct Investment, Net Outflows (% of the GDP)	1.380	.602	.423	2.293	.030
	Export of Goods and Services (% of the GDP)	-.088	.210	-.174	-.419	.678
	Agriculture, Forestry, and Fishing, Value-Added (% of the GDP)	.580	.185	.925	3.127	.004

a. V1 = 1

b. Dependent Variable: GDP Growth Rate %

Source: Authors

Moreover, Table 7 shows the ANOVA (Analysis of Variance) results for the regression model predicting the GDP growth rates for the G7 countries. The Regression Sum of Squares is 35.17, while the Residual Sum of Squares is 17.07, which indicates the portion of the variation in the GDP growth rates that is not explained by the model. To summarize, the independent variables are collectively significant in predicting the GDP Growth Rate. Overall, the ANOVA results indicate that the regression model is statistically significant ($F = 3.708$, $p = 0.008$), which means that the predictors account for a considerable portion of the variation in the GDP growth rates for the G7 countries. Thus, the regression model significantly explains the variation in the GDP Growth Rate.

Table 8 highlights the relationship between the GDP growth and several economic elements, offering insights related to the G7 economies. Among the predictors, there are two statistically significant variables:

- Unemployment Rate: A 1 percentage point increase in unemployment reduces the GDP growth by approximately 0.56 percentage points, keeping the other variables constant ($p = 0.02$).
- Real Interest Rate: A 1 percentage point increase in the real interest rates corresponds to a 0.63 percentage points decrease in the GDP growth, keeping the other variables constant ($p = 0.018$).

The other variables, however, show no statistically significant influence, including the Inflation Rate, the Exchange Rate Stability, the Government Debt (% of the GDP), Foreign Direct Investment - Net Inflows,

Table 6 The regression model summary for the G7 countries

Model Summary[a]				
Model	R	R square	Adjusted R square	Std. error of the estimate
1	.821[b]	.673	.492	.973845611784450

a. V1 = 2

b. Predictors: (Constant), Agriculture, Forestry, and Fishing, Value-Added (% of the GDP), Exchange Rate Stability (LCU per US$, the period average), Real Interest Rate % , Foreign Direct Investment, Net Outflows (% of the GDP), Export of Goods and Services (% of the GDP), Inflation Rate %, Unemployment Rate %, Foreign Direct Investment, Net Inflows (% of the GDP), Government Debt, Total (% of the GDP), Export of Goods and Services $

Source: Authors

Table 7 ANOVA model for the G7 countries

ANOVA[a,b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	35.170	10	3.517	3.708	.008[c]
	Residual	17.071	18	.948		
	Total	52.240	28			

a. V1 = 2

b. Dependent Variable: GDP Growth Rate %

c. Predictors: (Constant), Agriculture, Forestry, and Fishing, Value-Added (% of the GDP), Exchange Rate Stability (LCU per US$, the period average), Real Interest Rate % , Foreign Direct Investment, Net Outflows (% of the GDP), Export of Goods and Services (% of the GDP), Inflation Rate %, Unemployment Rate %, Foreign Direct Investment, Net Inflows (% of the GDP), Government Debt, Total (% of the GDP), Export of Goods and Services $

Source: Authors

Table 8 The regression coefficients for the G7 countries

Coefficients[a,b]						
Model	B	Unstandardized coefficients		Standardized coefficients	t	Sig.
		Std. Error	Beta			
1	(Constant)	.924	8.902		.104	.918
	Inflation Rate%	.072	.284	.062	.254	.803
	Unemployment Rate %	-.558	.220	-.743	-2.541	.020
	Real Interest Rate %	-.625	.240	-.704	-2.601	.018
	Exchange Rate Stability (LCU per US$, the period average)	-.010	.027	-.318	-.363	.721
	Export of Goods and Services $	1.075E-12	.000	.637	.642	.529
	Government Debt, Total (% of the GDP)	.002	.025	.064	.068	.946
	Foreign Direct Investment, Net Inflows (% of the GDP)	.328	.335	.257	.978	.341
	Foreign Direct Investment, Net Outflows (% of the GDP)	-.208	.184	-.263	-1.131	.273
	Export of Goods and Services (% of the GDP)	.029	.147	.184	.200	.844
	Agriculture, Forestry, and Fishing, Value-Added (% of the GDP)	2.355	1.960	.688	1.202	.245

a. V1 = 2

b. Dependent Variable: GDP Growth Rate %

Source: Authors

Foreign Direct Investment - Net Outflows, the Export of Goods and Services (% of the GDP), Agriculture, Forestry, and Fishing Value-Added. Overall, the results suggest that, for the G7 economies, the unemployment and real interest rates are the most critical factors impacting the GDP growth, with significant negative effects.

Based on the significant predictors, the null hypothesis ($H3_0$) is rejected, and the alternative hypothesis ($H3_a$) is accepted. Hence, to drive growth, the G7 should focus on reducing the unemployment and real interest rates. The model found to be significant is as follows:

$$Y = 0.924 - 0.558(X2) - 0.625(X3)$$

Comparison of the two regression models

Table 9 lists the two groups with the sample sizes:

- V1 = 1 (N = 39): This group relates to the BRICS economies.
- V1 = 2 (N = 29): This group relates to the G7 economies.

Table 9 The Between-Subjects Factors test

Between-Subjects factors		
		N
V1	1	39
	2	29

Source: Authors

The results of the Tests of Between-Subjects Effects for the GDP Growth Rate (%) in Table 10 enables the comparison of the factors potentially affecting the BRICS and the G7 economies and the determination of the difference in the effects of these factors within the two models. The Real Interest Rate (F = 5.651, p = 0.021), Foreign Direct Investment (FDI) - Net Inflows (% of the GDP) (F = 10.319, p = 0.002) and

Table 10 The Tests of Between-Subjects Effects

Dependent Variable: GDP Growth Rate %					
Source	Type III sum of squares	df	Mean square	F	Sig.
Corrected Model	289.179[a]	11	26.289	7.474	.000
Intercept	.529	1	.529	.150	.700
Inflation Rate	4.039	1	4.039	1.148	.288
Unemployment Rate	8.691	1	8.691	2.471	.122
Real Interest Rate	19.876	1	19.876	5.651	.021
Exchange Rate Stability LCU per US$ period average	4.541	1	4.541	1.291	.261
Export of Goods and Services ($)	3.334	1	3.334	.948	.334
Government debt total (% of GDP)	6.349	1	6.349	1.805	.184
Foreign Direct Investment net inflows (% of GDP)	36.295	1	36.295	10.319	.002
Foreign Direct Investment net outflows (% of GDP)	5.191	1	5.191	1.476	.230
Export of goods and services (% of GDP)	.275	1	.275	.078	.781
Agriculture forestry and fishing value added (% of GDP)	140.848	1	140.848	40.045	.000
V1	6.073	1	6.073	1.727	.194
Error	196.964	56	3.517		
Total	794.212	68			
Corrected Total	486.144	67			

a. R Squared = .595 (Adjusted R Squared = .515)

Source: Authors

Agriculture, Forestry, and Fishing Value-Added (% of the GDP) ($F = 40.045$, $p < 0.001$) are the statistically significant predictors in the model, suggesting they have significantly different influences on the GDP growth in the BRICS and the G7 economies. In contrast, through the individual regression models, the Real Interest Rate has negative effects on the GDP growth in both groups, although it remains an insignificant factor for the GDP growth in the BRICS countries. For FDI Net Inflows, it has a positive impact in both groups, although it is considered to be an insignificant factor for the GDP growth in the G7 countries. Particularly, the significant effect of FDI Inflows emphasizes the significance of external capital in driving growth, especially within evolving markets such as BRICS. Agriculture, Forestry, and Fishing Value-Added has a positive effect on the GDP growth and is not considered as a significant factor for the GDP growth in the G7 countries.

In contrast, the variables such as the Inflation Rate, the Unemployment Rate, the Exchange Rate Stability LCU ($), the Export of Goods and Services $, the Foreign Direct Investment Net Outflows of the GDP, the Export of Goods and Services % of the GDP, and the Government Debt are not statistically significant, indicating similar effects across the two groups.

Since the two groups have significantly different regression models and the p-value being less than 0.05, the null hypothesis ($H4_0$) is rejected, and the alternative hypothesis ($H4_a$) is accepted.

The findings for V1 show p-value = 0.194, which indicates that there is no significant difference in the GDP growth between the BRICS and the G7 countries, which means that the null hypothesis $H4_0$ can be accepted. This means there is no statistically significant difference in the effects of the predictors on

the overall GDP growth between the BRICS and the G7 countries. If going into detail, some variables have different effects between the two models, including the Real Interest Rates ($p = 0.021$), FDI Inflows ($p = 0.002$), and Agriculture, Forestry, and Fishing ($p = 0.000$). These may be considered as the factors of the different economic patterns affecting the different rates of economic growth in these two blocs.

DISCUSSION AND CONCLUSION

The comparative analysis of the GDP growth and the macroeconomic determinants between the BRICS and the G7 nations provides a nuanced understanding of the divergent economic trajectories of these two influential blocs. The BRICS nations, characterized by their emerging market status, demographic advantages, and resource wealth, have demonstrated dynamic economic expansion in recent decades. Conversely, the G7 nations, as a coalition of advanced economies, continue to leverage their technological superiority, institutional stability, and well-established markets to maintain their global economic leadership. In Table 11, the overall conclusion on the research hypotheses is given.

The results show that the BRICS countries are growing faster compared to the G7 countries. However, at the same time, they are less coherent in their GDP growth compared to the G7. This has been proven by testing the difference and variance using t-tests. The economic rivalry between these two blocs underscores the complex interplay of the macroeconomic factors, such as inflation, unemployment, trade variables, and foreign direct investment in shaping their respective growth patterns.

Table 11 The conclusion on the hypotheses

Null hypotheses	Conclusion	Interpretation
$H1_0$: There is no significant difference in the average GDP growth rate between the BRICS countries and the G7 countries.	Rejected	There is a difference in the GDP growth between the BRICS and the G7 nations, with a higher GDP growth in the BRICS countries with a higher variance around the mean.
$H2_0$: The independent variables (Inflation Rate, Unemployment Rate, Real Interest Rate, Exchange Rate Stability, Export of Goods and Services, Government Debt-to-GDP Ratio, FDI Net Inflows, FDI Net Outflows, and Agriculture, Forestry, and Fishing Value-Added) have no significant effect on the GDP growth in the BRICS countries.	Accepted	The model is statistically significant in the prediction of the GDP growth in the BRICS countries with the FDI Inflows (positive), FDI Outflows (positive), Agriculture, Forestry, and Fishing Value-Added (positive) as the significant variables.
$H3_0$: The independent variables (Inflation Rate, Unemployment Rate, Real Interest Rate, Exchange Rate Stability, Export of Goods and Services, Government Debt-to-GDP Ratio, FDI Net Inflows, FDI Net Outflows, and Agriculture, Forestry, and Fishing Value-Added) have no significant effect on the GDP growth in the G7 countries.	Accepted	The model is statistically significant in the prediction of the GDP growth in the G7 countries with the Unemployment Rate (negative), Real Interest Rate (negative) as the significant variables.
$H4_0$: There is no significant difference in the effects of the independent variables on the GDP growth between the BRICS and the G7 countries.	Rejected (partially)	Although the overall model does not show significant differences in the effects of the predictors on the GDP growth between the BRICS and the G7 nations, several predictors still have different effects when observed individually, and they are the Real Interest Rate, FDI Net Inflows, Agriculture, Forestry, and Fishing Value-Added (% of the GDP).

Source: Authors

The findings of this research reveal that the BRICS countries' growth is heavily influenced by their ability to capitalize on demographic advantages and integrate into global trade networks. The factors such as the exchange rate stability, export performance, and the government debt management play a significant role in sustaining their economic momentum (Jakopin, 2012; Čupić & Vržina, 2024). To achieve this, the BRICS countries, especially following the conclusions of the Summit held in October 2024, intend to overcome the regulatory and systemic gaps and foster de-dollarization and cooperative initiatives (Shaarawy, 2024). Meanwhile, the G7's economic resilience is rooted in its capacity to manage inflation, maintain low unemployment rates, and foster innovation-driven growth. These macroeconomic conditions reflect the distinct economic structures and developmental stages of the two blocs, simultaneously highlighting their unique strengths and vulnerabilities. Despite progress and significant achievements in terms of innovations (Huang, 2024), the BRICS countries still partly struggle with income inequality. Coupled with an over-reliance on specific sectors and political instabilities, this poses challenges to their sustained growth path (Milanović, 2016). Confronting these issues through regulatory changes alongside directed developmental funding remains necessary for obtaining enduring development outcomes. Through improved regional partnerships, economic expansion, and the implementation of the measures oriented towards establishing their own cross-border payment system and funding, the BRICS nations intend to obtain increased resistance to market disruptions and improve their economic durability.

By analyzing a comprehensive dataset and applying statistical techniques such as regression, t-tests, and ANOVA, the research reveals significant differences in the growth patterns and the impact of the key economic variables. Characterized by higher but more variable growth rates, the BRICS nations benefit from the factors such as foreign direct investment and exports, whereas the G7 economies demonstrate slower, yet more stable growth. These findings underscore the unique challenges and opportunities each group faces in fostering economic development, offering valuable insights for policymakers and economists alike.

Particularly, some individual predictors of GDP growth demonstrate clear differences in their impact on the GDP growth between the BRICS and the G7 countries. Especially, FDI net inflows, the real interest rate, and agriculture's value-added play differential roles in driving the GDP depending on the group. These results support the notion that economic structures and growth drivers are not uniform across BRICS and the G7 and policies should be tailored accordingly.

The results demonstrate the need for the BRICS nations to expand their economic sectors beyond commodity exports while seeking alternative sources of stability that extend beyond the current period. The plans announced during the BRICS summit in October 2024 indicate a clear intention to establish the long-term stability of BRICS as a solid and well-integrated economic bloc. The propulsive development of innovation, coupled with significant investments in education, research and development, technological infrastructure investments, and the systemic policy and regulatory changes, intends to create economic resilience (Aleksić, Nestić, Huber & Ljepava, 2022; Selaković, Ljepava, Tarabasz & Stojanović, 2023) while steering the BRICS economies towards equilibrium growth paths.

Overall, policymakers' understanding of the differential impact of macroeconomic factors on GDP growth enables them to formulate the strategies that not only enhance domestic economic stability but also contribute to a more balanced and cooperative global economic order. The implementation of collaboration between blocs through exchanges of technology and green energy projects alongside financial integration practices will build stronger economic resistance and creative capacity. In the future, research needs to focus on the way regional economic agreements influence worldwide economic stability. Deeper insights regarding the future growth potential of BRICS emerge when the developing economic policies are studied in detail. The development of thorough economic approaches demands research in both social and political variables affecting economic expansion, along with the impact of digital transformation on predicted economic patterns.

While this study offers an essential analysis of the GDP growth patterns of the BRICS and the G7 countries, various limitations have been noted as well. Variations in data accessibility and reporting requirements, especially among the BRICS nations, may influence the accuracy and uniformity of macroeconomic elements. Moreover, while the study discusses the links between the economic variables and GDP growth, it does not construct direct causation, such as external forces, for instance financial crises, global conflicts, and market fluctuations which may also affect economic flows (Selaković, Ljepava, Tarabasz & Stojanović, 2020). Additionally, although helpful, the chosen decade timeline may not completely reflect the long-term economic trends or structural transformations. Regardless of these limitations, the study provides a strong foundation for future research in advancing economic competition among the BRICS and the G7 nations.

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Farial Faizi is a business management student at the College of Business Administration, American University in the Emirates. Her research interests are connected to the fields of business, management, and entrepreneurship.

Mariam Sawas is a student of hospital and healthcare management at the College of Business Administration, American University in the Emirates. She is passionate about advancing healthcare systems, developing leadership skills, and contributing to innovative solutions that improve the quality and accessibility of healthcare.

Dina Abohassan is a lab instructor at the College of Business Administration, American University in the Emirates. She supports students in developing practical skills in business and management. Her academic dedication and innovative approach highlight her potential for impactful contributions to teaching and research.

Ilija Stojanović is an associate professor at the American University in the Emirates with 5 years of international teaching experience and 12+ years in project and business management training and industry practice. Certified PMP, ECQA EU Project Manager, UNDP SDG Trainer, and Six Sigma holder, with research in operations, supply chains, project management, and quantitative methods.

Marko Selaković is deputy director and assistant professor at S P Jain School of Global Management. With more than 20 years of professional practice and 5 years in academia, he is specialized in strategic reputation management, crisis communication, and stakeholder relations. He is member of IPRA and Global Strategic Communication Consortium and occupies number of Board and decision-making positions in Dubai.

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COMPARATIVE ANALYSIS OF METHODS FOR ASSESSING RETENTION EXCEEDANCE PROBABILITY IN MOTOR CASCO INSURANCE: THE CASE OF BULGARIA

Ventsislav Vasilev* and Radka Vasileva

Tsenov Academy of Economics, Svishtov, Bulgaria

The study explores some methods used to assess risk and determine optimal retention levels in motor casco insurance, specifically focusing on comparing the three statistical techniques: Chebyshev's Inequality, the Monte Carlo Simulation, and Normal Distribution. By utilizing historical claims data from the Bulgarian insurance market published by the Financial Supervision Commission, the study investigates the probability of the claim exceeding retention thresholds and compares the accuracy and precision of each method. While Chebyshev's inequality provides a conservative estimate, the Monte Carlo simulation offers a probabilistic approach that models various outcomes, whereas normal distribution assumes a symmetrical loss pattern. The research aims to identify which method offers the most reliable estimation for setting retention levels in motor casco insurance. By evaluating the accuracy of each technique against real claims data, the study aims to inform insurers about the approach which optimizes their risk management decisions best. The research shows that the Monte Carlo simulation offers the most accurate and reliable estimates for motor casco retention decisions due to its flexibility in modelling various loss scenarios.

Keywords: motor casco insurance, direct insurer's retention, Chebyshev's Inequality, Monte Carlo Simulation, Normal Distribution method

JEL Classification: G22

INTRODUCTION

Motor casco insurance is an essential component of the insurance sector, not only for the insurers but also for society at large. It covers vehicles against damage caused by accidents, theft, or natural disasters, providing a safety net for vehicle owners. For individual policyholders, having a motor casco policy means peace of mind, knowing that they are financially protected in the event of unexpected damages. This coverage is particularly valuable in a society with a growing number of vehicles, where accidents or loss can result in high financial costs.

The insurance policy considered is a voluntary, comprehensive vehicle insurance that covers damages

* *Correspondence to:* V. Vasilev, Tsenov Academy of Economics, 2 Em. Chakarov str, Svishtov, Bulgaria; e-mail: v.vasilev@uni-svishtov.bg

to the policyholder's own vehicle, unlike third-party liability insurance, which only covers damages caused to others. It typically protects against risks such as accidental damage, theft, natural disasters (e.g. storms, floods), fire, and glass breakage. Insurers assess risk based on factors like the vehicle type and age, the driver's profile, and the location. These elements help determine premiums by estimating the likelihood and potential cost of claims. Claims frequency is generally moderate, with frequent minor claims (e.g. scratches) and less frequent but severe events (e.g. theft, total loss). Frequency is influenced by the driver's behavior and road conditions, while severity depends on the nature of the incident itself.

The importance of motor casco insurance extends beyond individual benefits. Broader social benefits include reducing the financial burden on the state and on other individuals in case of accidents or damages. It helps maintain the stability of the automotive sector and ensures that owners and operators can repair or replace vehicles quickly, thus contributing to the overall economic efficiency, which is especially important in a rapidly evolving economy such as Bulgarian, where a significant proportion of the population relies on personal vehicles for transportation.

Motor casco insurance plays a significant role on Bulgaria's non-life insurance market. As of 2023, motor casco represents 29% of the gross premium income, placing it in the second position after the obligatory motor third-party liability insurance, which accounts for 40% of the entire market. Simultaneously, the gross claims incurred related to motor casco insurance amounted to BGN 410,536,263, accounting for 26% of all non-life insurance claims. These figures demonstrate both the market share and the critical importance of motor casco insurance in the country's broader insurance landscape.

One of the key tasks for insurance companies, particularly in motor casco insurance, is determining how much risk they are willing to retain and how much should be transferred to a reinsurer. This decision is far from simple and requires a careful evaluation of various factors. For example, the specifics of motor casco insurance - which includes coverage for theft, damage from natural events, and accidents - present particular challenges. The frequency and severity of claims can vary greatly depending on the type of vehicle, geographic location, and other risk factors.

Insurance companies must also consider their risk appetite, which refers to the level of risk they are prepared to take on in pursuit of profit. This is influenced by the factors such as financial stability, historical loss experience, and claims management capabilities. Historical loss experience plays a crucial role in assessing potential future claims. If an insurer has faced frequent large claims in the past, they might opt for a lower retention threshold to limit their exposure. On the other hand, insurers with a track record of low loss frequency may feel comfortable retaining a higher share of risk.

One of the most effective ways for insurance companies to determine appropriate retention levels is by analyzing past claims data. By examining paid losses related to motor casco insurance, insurers can gain valuable insights into their historical loss experience, which may enable them to make informed decisions on future retention strategies. This data allows insurers to identify trends and patterns in claims frequency and severity, which can help predict the potential for future claims. Armed with this information, insurers can determine the level of risk they are comfortable retaining and make informed decisions on how much risk to transfer to reinsurers.

Given the complexities involved in determining the optimal retention level, insurers frequently rely on various mathematical and statistical methods to assess risk, manage exposure, and optimize retention strategies. These methods help insurers estimate the retention threshold exceedance probability and understand the likelihood of large claims that could impact their financial stability. Among the methods most commonly used for such assessments are Chebyshev's inequality, the Monte Carlo simulation, and normal distribution.

While distinct in their approaches, these methods all aim to help insurers quantify the risks they face and

establish the retention levels that balance profitability with financial stability. Given the complexities involved in setting retention levels, insurers are continually refining these models and exploring new techniques to improve their risk management strategies.

The primary objective of this research is to compare the accuracy and precision of different methods for estimating the probability of a claim exceeding the retention threshold in motor casco. Specifically, Chebyshev's inequality, the Monte Carlo simulation, and normal distribution will be applied to a common dataset so as to assess how closely each method estimates the likelihood of a loss surpassing the insurer's retention level. By evaluating the performance of these methods, the research goal is to identify which approach provides the most reliable and precise estimation for setting appropriate retention levels in the context of motor casco risks. Valuating the "accuracy and precision" of each method will be done using the historical loss data related to motor casco insurance published by the Financial Supervision Commission (https://www.fsc.bg/en/) in Bulgaria.

Based on this, the research hypothesis here is that the Monte Carlo simulation provides a more accurate and precise estimate of the retention threshold exceedance probability in motor casco insurance compared to the traditional methods such as Chebyshev's inequality and normal distribution, which is due to the ability of the Monte Carlo simulation to model numerous possible outcomes based on historical loss data, offering a more detailed and flexible approach to risk assessment. The hypothesis will be tested by comparing the results obtained from each method and analyzing their alignment with the observed claims data, thereby assessing which method most closely predicts the actual risk of exceeding retention. With the intention to support the statement that the Monte Carlo simulation will provide a more accurate and precise estimate, sensitivity analysis will be performed in order to validate the robustness of the results and assess how changes in the key assumptions, such as the mean loss, impact the retention threshold exceedance probability. The theoretical and methodological instruments applied include probability theory, risk modelling, and statistical simulation, with a sensitivity analysis performed on the official motor casco claims data.

The paper is structured into a few sections. Following Section 1, Section 2 is a review of the relevant literature on risk assessment and retention modelling. Section 3 presents the data used in the analysis and outlines the methodological framework, focusing on Chebyshev's inequality, the Monte Carlo simulation, and normal distribution. Section 4 discusses the results obtained by applying the selected methods and interprets their implications. Finally, in Section 5, conclusions are given by summarizing the key findings and suggesting directions for future research.

LITERATURE REVIEW

Research on the optimal motor casco insurance retention, reinsurance, and related distributions is limited, and few studies address this complex problem directly.

An in-depth examination of self-retention in property insurance, including motor casco, has been presented in several studies. In V. K. Kaishev's study (2004), the reinsurance contract is modelled under an excess of loss (XL) treaty (Kaishev, 2004). The goal is to maximize the joint survival probability of both the cedent (direct insurer) and the reinsurer. V. K. Kaishev (2004) calculates survival probabilities for both parties and determines the optimal retention that minimizes the difference between their survival probabilities. The study compares this approach with quota share reinsurance, suggesting that a balance between retention and reinsurance is crucial for optimal outcomes.

F. Glineur and J. Walhin (2006) apply convex optimization techniques to confirm de Finetti's results on proportional reinsurance. They extend these findings to variable quota share and surplus reinsurance, challenging the optimality of these approaches and providing deeper insights into how retention affects reinsurance decisions. A. Tsanakas

and P. Millossovich (2015) focus on the sensitivity and robustness of optimal retention calculations under various distributional assumptions, including normal and non-normal scenarios.

S. Li, Z. Zhu and J. Peng (2022) explore an optimal stop-loss reinsurance model in uncertain claim environments. The results of their study reveals how retention should be determined based on risk measures such as value-at-risk (VaR), which can guide insurers in volatile conditions. J. Cai and K. Tan (2007) develop two optimization criteria based on value-at-risk (VaR) and conditional tail expectation (CTE) so as to determine optimal retention levels in stop-loss reinsurance. They demonstrate that, when optimal solutions exist, both criteria yield the same retention value, although the CTE-based method is generally more applicable due to less restrictive conditions.

L. Noviyanti, A. Z. Soleh, A. Chadidjah and H. A. Rusyda (2018) explore different retention models in quota-share reinsurance and also examine possible retention optimization in Indonesia. Using bivariate lognormal and exponential distributions alongside risk measures like VaR, expected shortfall (ES), and the minimum variance (MV), the authors aim to minimize risks, while simultaneously ensuring financial stability and regulatory compliance. A. Z. Soleh, L. Noviyanti and I. Nurrahmawati (2015) discuss how stop-loss reinsurance can reduce risk exposure by optimizing retention in automobile insurance. Their study models risk using compound Poisson and lognormal distributions, showing that retention can be optimized so as to minimize VaR.

In scenarios with incomplete data, X. Hu, H. Yang and L. Zhang (2015) propose a distribution-free approach to optimize retention in stop-loss reinsurance contracts. This method helps insurers minimize risk, even with incomplete information.

The study by Y. Kroll and D. Nue (1991) introduces a portfolio management approach to retention. This framework analyzes alternative management goals and offers testable implications for setting optimal proportional reinsurance retention levels, helping insurers balance risk and profitability.

More recent studies have introduced advanced analytical tools and empirical investigations into the assessment of retention in motor casco insurance. L. Fu and H. Wang (2021) investigate attrition using survival analysis to distinguish mid-term cancellations from nonrenewal. By incorporating time-dependent macroeconomic variables into retention modelling, they introduce a more responsive approach for insurers to anticipate and manage risk exposure over time. The paper by R. Erusalimov and N. Iliev (2022) offers an empirical contribution by analyzing how the COVID-19 pandemic affected motor casco insurance in Bulgaria. Their study reveals how external shocks alter premium income, claims frequency, and indemnity payouts, thus influencing retention behavior and risk levels during crisis periods. Finally, M. Leiria, E. Rebelo and N. deMatos (2021) explore the role of intermediary loyalty programs and customer behavior in motor insurance cancellations. Their findings, based on logistic regression, show that intermediary involvement and payment methods significantly affect retention probability, adding a behavioral dimension to otherwise quantitatively modelled risk frameworks.

In this context, additional theoretical grounding is provided by research addressing capital allocation and collective risk modeling in non-life insurance. J. Kočović, M. Mitrašević, M. Kočović and M. Jovović (2011) examine the challenges of capital allocation in insurance companies, emphasizing the fact that the adequacy of allocation depends on acknowledging the inverse relationship between risk and capital, as well as the diversification effects that shape solvency and performance outcomes. Their findings highlight the necessity of selecting allocation and risk assessment techniques consistent with insurers' overarching objective of value maximization - the principle that also underpins the determination of optimal retention levels. Building on this theoretical perspective, Z. Djuric (2013) develops a collective risk model for non-life insurance, conceptualizing claim frequency and severity as stochastic processes. This framework provides a rigorous mathematical basis for simulating claim variability and estimating the probability of exceeding predefined retention thresholds, thereby complementing the methodological approach adopted in the present study.

Moreover, recent studies have expanded the application of the Monte Carlo simulation in the analysis of motor casco retention. L. Xiong and D. Hong (2020) demonstrate the fact that the Monte Carlo methods effectively predict solvency and model risk scenarios in captive insurance by simulating historical loss data, closely aligning with probabilistic retention evaluation. T. Heinrich, J. Sabuco and J. Farmer (2021) apply industry-wide simulation models addressing the risk correlation issues pertinent for estimating the probabilities of retention exceedance, thus contributing valuable perspectives on portfolio-level risk in motor casco insurance. B. Bulut Karageyik and Ş. Şahin (2017) propose the excess-of-loss criterion approach for the optimal retention calculation, emphasizing the varying premium and ruin considerations that offer a complementary empirical lens for motor casco retention frameworks. E. Roos, R. Brekelmans, W. van Eekelen, D. den Hertog and J. S. H. van Leeuwaarden (2022) advance theoretical underpinnings by developing tight tail probability bounds extending Chebyshev's Inequality, furnishing a more refined basis for conservative risk estimation in insurance retention modelling. M. Covrig and D. Badea (2017) employ generalized linear models for claim frequency analysis in motor insurance, thereby corroborating the use of normal distribution and other statistical techniques in retention risk assessment. B. Shahriar and S. M. M. Ahmadi (2008) introduce a novel methodology for determining optimal reinsurance retention by minimizing value-at-risk (VaR) via the Monte Carlo simulation, with a focus on capital adequacy and potential loss mitigation. Their empirical application to Mellat Insurance Company's portfolio demonstrates that the optimal retention levels are approximately 58%, BGN 35,845 million and BGN 18,937 million under quota share, excess of loss, and surplus reinsurance contracts, respectively. Using Nigerian motor insurance data, O. Chukwudum (2019) applies the Monte Carlo simulation combined with Extreme Value Theory to model large claims frequency and severity, enabling optimized reinsurance retention decisions using the improved estimation of capital requirements and excess-of-loss pricing.

Together, these recent contributions extend traditional retention theory into contemporary, data-driven practice. Simultaneously, they provide a deeper understanding of the multifactorial nature of retention probability assessment in motor casco insurance - spanning statistical modelling, empirical analysis, and regulatory framing.

DATA AND METHODOLOGY

Data

The analysis of a number of claims and insurance companies' paid losses on motor casco insurance in the Bulgarian insurance market covers the period from 2018 to 2022 and is carried out based on the official statistics published by the Financial Supervision Commission and available on its website (https://www.fsc.bg/en/). The reason for the five-year period chosen is a lack of the officially published market data for a longer period. The data are shown in Bulgaria's official currency - the Bulgarian Lev (BGN). Bulgaria has been on the currency board since 1997, and the exchange rate of the Bulgarian Lev (BGN) is fixed against the exchange rate of the Euro. BGN 1 is exchanged for EUR 0.511292.

The data used in this study are aggregated across the non-life insurance companies operating in Bulgaria that offer motor casco insurance. As of the end of the analyzed five-year period (2018-2022), 17 out of the 22 licensed non-life insurers in the country provided motor casco coverage, according to the official statistics published by the Financial Supervision Commission. The use of aggregated data ensures a comprehensive market-level view, which is appropriate for analyzing trends and assessing the retention threshold exceedance probability in a generalized context.

Methodology

This study employs three distinct methods to estimate the probability of exceeding a given retention

threshold in the context of motor casco insurance: Chebyshev's inequality, the Monte Carlo simulation, and normal distribution. These methods were selected based on their compatibility with the available official data, which consist exclusively of the aggregated and anonymized historical loss records published by the Financial Supervision Commission. While modern actuarial and data-driven techniques such as Generalized Linear Models (GLMs), Usage-Based Insurance (UBI), Dynamic Pricing, Machine Learning, Bayesian Methods, and Catastrophe Modelling are increasingly used in the insurance industry for pricing and risk assessment, their direct applicability to estimating optimal retention levels, particularly in the context of this research, is limited. Most of these methods are primarily designed to assess individual policyholder risk and set premiums, requiring detailed, real-time, or proprietary internal data such as telematics, detailed claims histories, and dynamic behavioral metrics. For instance, GLMs and machine learning models are commonly employed to predict claims frequency and severity at the individual level, while UBI and dynamic pricing rely on the continuous monitoring of driving behavior, and catastrophe models necessitate high-resolution exposure data. In contrast, the current study is exclusively based on the officially published aggregate data, which constrains the use of such advanced methodologies.

While certain elements of these approaches may indirectly inform strategic decisions around reinsurance and retention (e.g. through portfolio-level risk modelling), their effective application demands the data inputs that are not publicly available. Consequently, the research employs alternative methods - Chebyshev's inequality, the Monte Carlo simulation, and the normal distribution approach - which are robust to data limitations and more appropriate for estimating the probability of retention exceedance using the available data.

Each method applied in the study provides a unique approach, based on different assumptions about the distribution of losses. Below is an explanation of how each method is applied in order to estimate the upper bound probability of retention exceedance.

Chebyshev's Inequality is a non-parametric method that provides an upper bound on the probability of an event occurring beyond a certain threshold. This method is particularly useful in situations where the distribution of losses is unknown or not well-behaved, i.e. it may be skewed or have heavy tails. Skewness refers to the asymmetry of a distribution, where data is not evenly spread around the mean; if a distribution has a longer tail on the right, it is positively skewed, and if it has a longer tail on the left, it is negatively skewed. Heavy tails describe a distribution where extreme values (outliers) occur more frequently than they would in a normal distribution, meaning the probability of large deviations from the mean is higher, leading to a slower decay in the tail of the distribution. The method guarantees an upper bound on the probability of exceeding the threshold, regardless of the distribution itself.

$$P(|X - \mu| \geq k\sigma) \leq \frac{1}{k\hat{}2} \quad (1)$$

where:

X is the individual loss,

μ is the mean loss,

σ is the standard deviation of the losses, and

k is the number of the standard deviations from the mean.

In this research, Chebyshev's Inequality will be used to calculate the upper bound probability that the individual loss X will exceed the chosen retention threshold T. The threshold T is defined as:

$$T = \mu + k\sigma \quad (2)$$

where k is the multiple of the standard deviation. To calculate the probability of exceeding the threshold using Chebyshev's inequality:

1. Determine the number of the standard deviations *k:* Calculate how far the retention threshold T is away from the mean μ using the formula:

$$k = \frac{T-\mu}{\sigma} \tag{3}$$

2. Apply Chebyshev's inequality so as to find the upper bound probability of exceeding the threshold:

$$P(\mathrm{X} \geq \mathrm{T}) \leq \frac{1}{k\text{^}2} \tag{4}$$

This approach provides a conservative estimate of the probability that the individual loss will exceed the retention threshold.

The inequality gives the upper bound for the probability that the loss exceeds the retention level *T*. By adjusting *T* (the retention threshold), insurers can balance their risk exposure. Higher retention levels result in a smaller probability of exceeding the threshold, but they also expose the insurer to a greater risk. In reinsurance, this method allows the insurer to quantify the likelihood of extreme losses, which helps in setting an appropriate retention level that aligns with their risk tolerance.

The Monte Carlo Simulation is a numerical approach that estimates the probability of exceeding retention by simulating random losses based on the observed distribution. This method generates a lot of random samples and calculates the proportion of the simulated losses that exceed the retention threshold, which gives the estimated probability *P (X≥T)* or the probability that the insurer's loss exceeds the retention level. The process for applying the Monte Carlo simulation is as follows:

1. The data input. Use historical data for individual losses (e.g. the losses from 2018 to 2022). Future losses are assumed to follow the same distribution as the historical data.

2. Generate random samples. Create a lot of random samples from the observed historical data. Each sample represents a simulated individual loss.

3. Determine exceedances. For each simulation, check whether the simulated loss exceeds the retention threshold *T*. The threshold T is typically calculated utilizing the following formula:

$$T = \mu + k\sigma \tag{5}$$

4. Probability estimation. Estimate the probability *P (X≥T)* by calculating the ratio of the number of the simulations where *X≥T* to the total number of the simulations run. In other words, the probability that the loss exceeds the retention threshold is estimated as the ratio of the number of the samples that exceed the threshold to the total number of the simulations run:

$$P(\mathrm{X} \geq \mathrm{T}) = \frac{Number\ of\ simulations\ where\ X \geq T}{Total\ number\ of\ simulations} \tag{6}$$

By repeating this process for a lot of simulations (e.g. 10,000 or more), the Monte Carlo simulation provides a more accurate estimate of the retention threshold exceedance probability, thus reflecting the inherent uncertainty and variability in the loss data.

Normal Distribution assumes that individual losses follow normal distribution, characterized by the mean *(μ)* and the standard deviation *(σ)*. While this is a simplifying assumption, it is commonly used in insurance modelling when data are expected to follow the bell-shaped curve.

To calculate the retention threshold exceedance probability in a normal distribution, these steps are to be followed:

1. Calculate the *Z*-score. The *Z*-score measures how many standard deviations the retention threshold *T* is away from the mean μ. The Z-score is given by:

$$Z = \frac{T-\mu}{\sigma} \tag{7}$$

where:

μ is the mean individual loss,

σ is the standard deviation of the individual losses, and

T is the retention threshold.

2. Determine the probability. Once the Z-score is calculated, the standard normal distribution table (or the computational tool) can be used to find the cumulative probability *P(Z),* which represents the probability that a loss is less than the threshold. The probability of exceeding the threshold is the complement of this cumulative probability:

$$P(X \geq T) = 1 - P(Z) \quad (8)$$

where *P(Z)* is the cumulative probability corresponding to the Z-score.

Although this method assumes that the losses are symmetrically distributed around the mean, real-world data, particularly in the case of motor casco insurance, may not perfectly follow a normal distribution. Loss distributions in insurance often exhibit skewness or heavy tails, which means that extreme losses are more frequent than predicted by a normal distribution. Despite this limitation, the normal distribution approach provides a convenient and broadly used method for estimating the probability of exceedances under the assumption of normality.

Each of the three methods offers a different way to estimate the retention threshold exceedance probability. Chebyshev's inequality provides a conservative estimate that does not rely on the assumptions about the distribution of losses, making it useful when the distribution is unknown. The Monte Carlo simulation uses historical data to simulate potential future losses, offering a flexible and data-driven approach. Finally, normal distribution assumes a bell-shaped distribution of losses, which simplifies the calculation but may not always reflect the true distribution of losses in real-world insurance data.

By applying these methods, it is possible to estimate the retention threshold exceedance probability under different assumptions, which helps insurers make more informed decisions on their risk retention levels.

RESULTS AND DISCUSSION

The data presented in Table 1 reflect the trends in the number of claims, the paid losses, and the mean losses in casco insurance over a five-year period from 2018 to 2022.

Several key trends and fluctuations can be observed over the five-year period. The number of claims has shown a gradual decrease from 407 760 in 2018 to 352 396 in 2022. This decline may reflect a decrease in the total number of insured vehicles or an improvement in risk management and underwriting.

The paid losses, however, did not follow the same downward trend. While the losses remained relatively stable between 2018 and 2021, they increased significantly in 2022, reaching BGN 380 201 243, which is substantially higher than in previous years.

The mean loss per claim steadily increased from BGN 817 in 2018 to BGN 1,079 in 2022, which indicates that, while the total number of claims decreased, the cost

Table 1 The number of claims and the paid losses in motor casco insurance (in BGN) by year

Year	Number of claims	Paid losses (BGN)	Mean loss (BGN)
2018	407 760	333 303 426	817
2019	403 189	345 203 045	856
2020	369 373	341 883 686	926
2021	351 763	339 662 479	966
2022	352 396	380 201 243	1079
Total mean			929
Standard deviation			102

Source: Authors, based on Financial Supervision Commission (https://www.fsc.bg/en/)

per claim had been rising over the years. In particular, the sharp rise in 2022 (from BGN 966 in 2021 to BGN 1,079) may suggest a change in the nature of the claims, such as higher costs associated with repairs, medical expenses, or legal settlements.

As for the fluctuations and variability, the standard deviation of BGN 102 calculated from the mean loss indicates a moderate variability in the annual loss amounts. The fluctuations in the paid losses between 2018 and 2022, especially the marked increase in 2022, demonstrate that, while there is a general trend of rising costs, the year-to-year differences can be significant. These fluctuations could be driven by various factors, such as changes in the frequency of catastrophic claims, inflation, or shifts in claim handling processes.

Overall, the data suggest that, while the number of claims has been decreasing, the cost per claim is on the rise, which could pose a greater financial burden on insurers. The significant rise in the paid losses in 2022 warrants further investigation into the underlying causes, such as more expensive claims or unforeseen events that led to higher payouts. Overall, while the number of claims shows some stability, the large variations in the loss amounts and the mean losses emphasize the unpredictable nature of the risk involved, underlining the importance of effective risk assessment and retention strategies.

Based on the given data, this study suggests that the direct insurer's retention threshold should be set at BGN 1 115 per individual claim, which is derived from the mean loss of BGN 929 plus 20% of the mean (i.e. BGN 186).

This threshold represents a strategic point where the insurer retains a significant but not excessive amount of risk, transferring the remaining risk to reinsurance. In assessing how accurate risk assessment is for determining this threshold, the following three methods can be utilized, namely Chebyshev's inequality, the Monte Carlo simulation, and the normal distribution approach.

Chebyshev's inequality is a non-parametric method that provides a bound on the probability of extreme outcomes, regardless of the distribution of the data. This method would estimate the probability that a claim will exceed the retention threshold (BGN 1 115) based on the mean and standard deviation of the data. Given the fact that Chebyshev's inequality applies to any distribution, it is more conservative and would likely provide an upper bound on the likelihood of exceeding the threshold. However, it may not offer the level of precision needed for more informed retention decisions because it tends to overestimate the probability in comparison to methods that take the actual data distribution into account.

By contrast, the Monte Carlo simulation is much more flexible and powerful. It simulates many possible future loss scenarios based on historical data and random sampling, generating a probability distribution for losses. Given the data, Monte Carlo simulations would estimate the retention threshold exceedance probability by running thousands of simulations with varying assumptions for claim severity and frequency. This method would offer a more precise estimate of risk and help the insurer better understand the likelihood of extreme events. It is particularly valuable in assessing complex, uncertain risk profiles and would provide a more tailored and accurate estimate than Chebyshev's inequality.

Assuming that a loss distribution follows a normal distribution, the insurer could calculate the retention threshold exceedance probability by considering the mean and the standard deviation. Based on the data, the normal distribution approach could estimate the percentage of the claims that would likely exceed the BGN 1 115 threshold. However, normal distribution is limited by the assumption that losses follow a bell-shaped curve. If the actual distribution of losses is skewed or has fat tails (as is often the case in motor casco insurance), this method may underestimate the probability of extreme losses. Despite its simplicity, the normal distribution approach could still provide a useful baseline estimate, particularly in the absence of more complex data modelling.

Table 2 presents the probabilities of exceeding the retention threshold of BGN 1115 calculated using the three different methods: Chebyshev's Inequality, the

Monte Carlo Simulation, and Normal Distribution. The calculations were performed using Microsoft Excel.

According to Chebyshev's Inequality: the 24.52% retention threshold exceedance probability represents a very conservative estimate. Chebyshev's inequality guarantees that no more than this percentage of claims will exceed the threshold, but because it does not make assumptions about the data distribution, it tends to overestimate the risk. While useful in the absence of detailed information about the loss distribution or when data is limited, it is likely to overstate the risk of large claims exceeding the threshold in this case.

Table 2 The retention threshold exceedance probabilities calculated using the three methods

Method	Retention threshold (BGN)	Retention exceedance probability
Chebyshev's Inequality	1 115	24.52 %
Monte Carlo Simulation	1 115	1.99 %
Normal Distribution	1 115	2.16 %

Source: Authors

The result of the 1.99% probability calculated from the Monte Carlo simulation is a more realistic estimate. By simulating 10000 random outcomes based on the observed loss data, this method captures the underlying variability of the losses. It can model the non-normal features of the loss distribution (such as skewness or heavy tails, providing a more precise risk estimate, which takes into account the full range of potential outcomes and reflects a more accurate risk assessment for the insurer).

The 2.16% probability calculated from the normal distribution approach is very close to the Monte Carlo result, which suggests that, for this particular dataset, normal distribution is a reasonable approximation of the actual loss distribution. Despite the moderate skewness perceived in the data, the normal distribution approach provides a useful and efficient tool for estimating retention thresholds when data are roughly symmetric or near normal by their nature. The close alignment between this method and the Monte Carlo simulation indicates that, in this particular case, the assumption of normality is valid enough to provide a similar estimate.

The results from the above calculations of the retention threshold exceedance probabilities allow for the following summary:

1. The conservatism of Chebyshev's Inequality. The method offers a safe, conservative approach but lacks precision, especially for extreme loss probabilities. The high retention threshold exceedance probability (24.52%) calculated utilizing Chebyshev's inequality emphasizes the method's conservative nature, not taking into consideration the actual characteristics of the loss data, thus leading to an overestimation of risk and to potentially higher reinsurance costs.

2. More accurate assessment by applying the Monte Carlo Simulation and the Normal Distribution Approach. The Monte Carlo simulation and normal distribution approaches provide very similar results, with the probabilities of 1.99% and 2.16%, respectively. These methods provide a more precise and realistic estimate of the retention threshold exceedance risk. The small difference between these two methods suggests that the assumption of normality is reasonably accurate in this case. Therefore, an insurance company can be more confident in using these methods for risk assessment.

3. The reliability of the Monte Carlo Simulation. The Monte Carlo simulation is generally considered the most flexible and accurate method for complex risk assessment. The relatively low probability it provides (1.99%) gives a more realistic view of the risk of loss and can be used for better-informed decision-making when setting retention thresholds. However, this approach is computationally intensive and requires a substantial amount of data and simulation runs.

4. Given the large discrepancy between Chebyshev's Inequality and the other two methods, the Monte Carlo simulation would be the most reliable approach for setting the retention threshold, especially when

dealing with complex, non-normal distributions. The normal distribution approach could also be used as a simpler alternative, but its assumptions about the data distribution should be carefully considered.

5. An insurance company can be confident in using the retention threshold of BGN 1115 based on the lower probabilities obtained through the Monte Carlo and normal distribution methods. This threshold effectively balances risk retention with risk transfer, based on the relatively low (around 2%) probability of exceeding it.

A sensitivity analysis was performed to validate the robustness of the results and assess how changes in key assumptions, such as the mean loss, impact the retention threshold exceedance probability. The purpose of this analysis was to understand how changes in the mean loss (μ) affect the retention threshold exceedance probability (BGN 1,115). The examination of this relationship can allow for the assessment of the impact of varying loss scenarios on the risk profile and provide a further context for the calculated probabilities. The sensitivity analysis helps illustrate the potential variations in the risk that may arise from changes in the loss levels, thereby supporting the results obtained using the Monte Carlo and normal distribution based on the assumptions about the underlying distribution of the losses.

The results presented in Figure 1 after the calculations have been made clearly demonstrate the fact that, as the mean loss increases, so does the retention threshold exceedance probability. When the mean loss is BGN 900, the threshold exceedance probability is 0.0175 (1.75%), which suggests that, with lower mean losses, there is a very small chance of exceeding the threshold, and thus the need for reinsurance remains minimal. As the mean loss reaches BGN 1,100, the probability increases to 0.4415 (44.15%), indicating a significantly higher risk of exceeding the retention threshold, which highlights the increasing likelihood that the insurer will need to transfer risk to reinsurance if the average loss per claim becomes substantial.

These findings underscore the importance of closely monitoring mean loss levels. As the mean loss approaches or exceeds the retention threshold (BGN 1,115), the likelihood of exceeding it rises sharply, suggesting the need for increased reinsurance coverage.

The Monte Carlo simulation generated a probability of 1.99% based on realistic, random variations in claim amounts and frequencies. When comparing this to the results obtained from the sensitivity analysis, the following can be perceived: at the mean loss of BGN

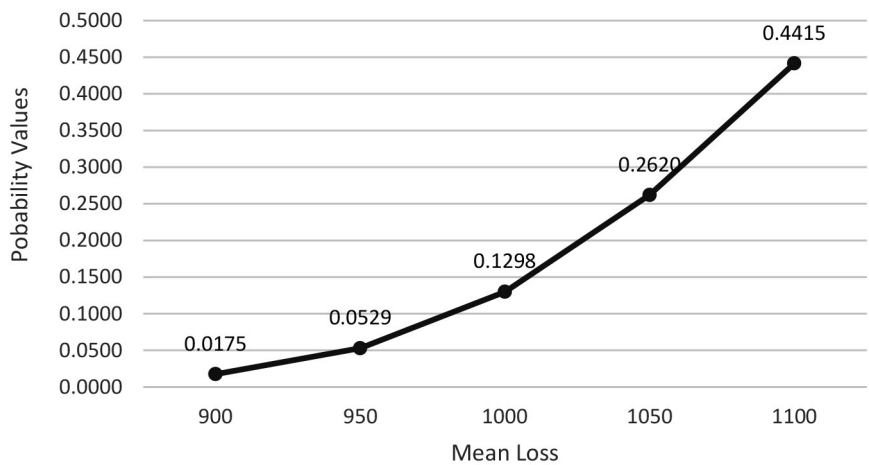

Figure 1 The changes in the retention threshold exceedance probability with the increased mean loss

Source: Authors

950, the threshold exceedance probability is 0.0529 (5.29%). For the mean loss values around BGN 1,100, the probability increases significantly, ranging from 0.2620 (26.20 %) to 0.4415 (44.15%).

Given this, the 1.99% probability derived from the Monte Carlo simulation lies in the lower end of the sensitivity analysis curve, corresponding to a mean loss between BGN 900 and 950, which suggests that the Monte Carlo result represents a scenario where the average claim loss is relatively low, and the threshold exceedance probability remains small. Thus, the Monte Carlo simulation provides a more precise estimate of risk for lower loss scenarios, and the sensitivity analysis supports this finding by showing how small variations in the mean loss directly affect the likelihood of exceeding the threshold.

CONCLUSION

The comparative analysis of the three statistical methods - Chebyshev's Inequality, the Monte Carlo Simulation, and the Normal Distribution - estimates the retention threshold exceedance probability in motor casco insurance. The analysis is exclusively based on the official, aggregated data published by the Bulgarian Financial Supervision Commission for the period from 2018 to 2022. The results indicate that the Monte Carlo simulation offers the most accurate and reliable estimates of retention-level exceedance probabilities, primarily due to its flexibility in modelling complex and non-normal loss distributions. The normal distribution method produced the results that closely align with those of the Monte Carlo Simulation, suggesting a reasonable approximation for the dataset under consideration. In contrast, Chebyshev's Inequality yielded significantly higher and more conservative estimates, reflecting its generalized, non-parametric nature.

The practical significance of these findings lies in their direct applicability to real-world insurance operations. The ability to more accurately estimate the retention threshold exceedance probability is critical for optimizing risk transfer strategies, determining reinsurance structures, and ensuring capital adequacy. Given the substantial role of motor casco insurance within the Bulgarian non-life insurance market, the implementation of more precise risk assessment methods based on available official data can contribute to more efficient financial planning and enhanced sector stability.

Despite the methodological robustness, this research is subject to several limitations. First, the study is constrained by the aggregated market-level data used, since detailed insurer-level information is not publicly available. As a result, the analysis cannot account for the heterogeneity in underwriting practices, risk profiles, or claim management strategies across individual insurers. Second, the examined timeframe is limited to a five-year period due to the absence of longer historical datasets in the public domain, which restricts the ability to assess long-term trends and may limit the generalizability of the findings. Third, all the calculations were made using Microsoft Excel, which, while suitable for the scope of this research, does not offer the computational depth of specialized statistical or actuarial pieces of software. Finally, although other advanced risk modelling techniques such as machine learning or multivariate simulation could enhance the predictive performance, their application is not feasible in this context due to the restricted availability of detailed input data.

Building on the current findings, future research could be conducted to access the insurer-level data that would allow for a better understanding of risk variability and retention behavior across companies. Furthermore, incorporating longer time series or event-based stress testing could enhance the evaluation of tail risk and extreme loss scenarios. More available data could allow for the application of advanced analytical methods, including machine learning algorithms, stochastic modelling, or copula-based approaches, and provide deeper insights into loss dependencies and risk concentration. Additionally, expanding the scope to include multi-line insurance portfolios would offer a broader view of retention optimization at the portfolio level. Finally, future studies may consider the impact of macroeconomic or regulatory changes on frequency

and severity of losses, further informing the dynamic adjustment of retention strategies.

In conclusion, this research supports the use of the Monte Carlo simulation as one of the most suitable methods among the considered ones for determining optimal retention levels in motor casco insurance based on officially available data. It offers a practical framework for insurers operating under data constraints.

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Ventsislav Vasilev is an Associate Professor in the Department of Insurance and Social Security at Tsenov Academy of Economics, Svishtov, Bulgaria. His research focuses on non-life insurance, reinsurance, and insurance company solvency. He completed his undergraduate and doctoral studies at the same institution.

Radka Vasileva earned her doctorate in the Department of Insurance and Social Security at Tsenov Academy of Economics, Svishtov. She is currently a Senior Lecturer in the Department of Foreign Language Teaching at the same institution. Her research interests include reinsurance, especially insurance company retention policy.

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