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Research Article

ASSESSING THE IMPACT OF EU INTEGRATION ON ECONOMIC GROWTH FORECASTS USING ARTIFICIAL NEURAL NETWORK MODELS

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Abstract
This study investigates the interplay of endogenous and exogenous factors influencing GDP growth in Albania and Serbia, two nations at different stages of EU integration. Key variables examined include consumption, education, exports, foreign direct investment (FDI), imports, savings (all relative to GDP), and urbanization rates, with a focus on the impact of high-technology exports. To analyze the World Bank dataset from 1993 to 2023 at a 95% confidence level, this study employs an Artificial Neural Network-Multilayer Perceptron Model (ANN-MLP), designated as H (1;1). The dataset is systematically divided into two subsets: the first subset comprises 70% of the observations, while the second subset contains the remaining 30%. The initial subset is utilized to optimize forecasting accuracy, allowing the model to adjust its parameters accordingly. Once the parameters have been optimized, they are applied to the second subset to assess the model's performance. This procedure yields a forecast error of less than 0.3%, demonstrating the model's efficacy. The novelty of this study lies in forecasting GDP growth in Albania and Serbia using ANN-MLP models, with a particular focus on the role of high-technology exports. It emphasizes the distinct importance of exports in Albania versus consumption and FDI in Serbia, offering nuanced insights into country-specific growth mechanisms. This tailored, context-sensitive approach provides valuable implications for policymakers aiming for EU integration, filling a gap in existing literature by explicitly contrasting the economic drivers in these neighboring, yet economically distinct, national contexts.

Keywords: Economic Growth Forecasting, European Integration Path, Multilayer Perceptron Analysis

INTRODUCTION

The Internet revolution and rapid technological advancements have reshaped many developed nations, transforming them into highly digital societies where digitization plays a crucial role in national prosperity and progress. The Balkan countries (Albania, Bosnia and Herzegovina, Montenegro, Republic of North Macedonia, Kosovo, and Serbia) are among those aspiring to achieve this transformation,

making significant strides toward establishing knowledge and information economies akin to those of more developed European Union (EU) countries (Apostu et al., 2023). However, despite their ambitions for EU membership, the Western Balkan nations have struggled to keep pace with EU averages in development, primarily due to a lack of innovation.

In response to these challenges, three countries in the region—Albania, Republic of North Macedonia, and Serbia—have launched the Open Balkans initiative, designed to promote practices and standards that align with EU norms and regulations. This initiative follows the regional cooperation among six Western Balkan countries that was officially established through the Berlin Process, which commenced in 2014. As well as the Regional Economic Area Initiative, introduced at the Berlin Process summit in Trieste in July 2017, that aims to make the Western Balkans more attractive for investment and trade, expediting their integration into the EU. And last, the Mini Schengen Initiative, initiated in 2019 with a declaration of intent, that has been rebranded as the Open Balkans.

To support the accelerated integration of the Western Balkans into the European single market, a series of activities have been outlined to be implemented by 2024 across four key areas: regional trade, regional investment, regional digital infrastructure, and regional industrial and innovation sectors (Huang, 2023; Alkilany et al., 2025). Thus, enhancing digital infrastructure and improving digital literacy among the populations emerge as essential criteria (Boshkov et al., 2023; Ajadi & Ayanlowo, 2025; Helmi et al., 2025; Rahajo & Kumyat, 2025).

In addition, by fostering regional cooperation, reducing trade barriers, and harmonizing standards with EU directives, these nations can enhance market access, attract foreign investment, and stimulate economic activity. This alignment often leads to increased efficiency, productivity improvements, and better resource allocation, potentially resulting in higher GDP growth rates. However, the transition may also pose challenges, including the need for significant structural reforms and investment in institutional capacities to meet EU benchmarks, which could initially strain resources before yielding long-term economic benefits. Overall, while alignment with EU norms can catalyze economic growth and integration, its success hinges on the countries' commitment to reform and collaboration.

The statistics illustrate significant fluctuations in GDP growth following the launch of the Open Balkan initiative in July 2021, particularly for Albania and Serbia. In Albania, GDP growth plummeted by 46.2% in 2022 compared to 2021, with a further decline of 18.45% in 2023 relative to the previous year. In contrast, Serbia experienced a more dramatic GDP decline of 66.9% in 2022 compared to 2021. However, this trend reversed in 2023, with Serbia recording a notable increase of 46.23% (World Bank, 2023).

The data on high-technology exports reveal similarly striking trends. In Albania, high-technology exports fell sharply by 86.11% in 2022 compared to 2021, but rebounded significantly in 2023 with a remarkable increase of 94.75% from the previous year. Serbia, on the other hand, saw a decline of 17.3% in high-tech exports in 2022 compared to 2021, followed by a recovery of 24.94% in 2023 relative to the previous year. The study by Stojanovic et al. (2022) instead, examines the Global Innovation Index (GII) indicators for the years 2019, 2020, and 2021 and reports that Serbia outperforms Albania across these metrics. Meanwhile between 2021 and 2023, both Albania and Serbia experienced a rising urbanization rate, alongside a reported decrease in education expenses of 9% and 1%, respectively. Furthermore, to bolster economic growth on their journey toward EU integration, both countries should prioritize fostering innovation and invest in research and development within the technology sector (Mkiyes, 2023).

In this context, this study addresses a critical gap in understanding the multifaceted economic dynamics of Albania and Serbia by analyzing key endogenous and exogenous factors—such as consumption, education, trade, FDI, savings, and urbanization—relative to GDP. Recognizing the urgency of accurate economic forecasting for these nations' EU integration, the research emphasizes the application of artificial neural networks (ANNs) to improve prediction precision over traditional econometric models. The core insight focuses on how technology adoption and high-technology exports reflect these countries' growth potential and competitiveness on their journey toward EU integration.

Thus, the research question in this study is: How do various factors—such as consumption, education, exports, foreign direct investment, imports, savings (all in relation to GDP), and urbanization rates—impact GDP growth, especially considering the varying levels of technological adaptation and alignment with EU standards?

The study objectives are to quantify the impact of identified variables on GDP growth, aiming to project future economic trajectories in Albania and Serbia, by focusing on high-technological exports volume. Ultimately, the study seeks to provide robust, data-driven insights that support policy formulation

aligned with EU standards and enhance regional development strategies, addressing the pressing need for adaptable, advanced forecasting tools in the evolving economic landscape of the Western Balkans.

The remainder of this paper is organized into five sections as outlined below. Section 2 offers a comprehensive review of both existing and recent literature on forecasting GDP growth, with a particular emphasis on the Western Balkan countries. It explores various economic indicators, highlighting both endogenous and exogenous factors that influence growth. Section 3 details the methodology, including the research design, sampling and sampling technique, as well as the data collection process and analysis. The empirical results are presented in Section 4, where the findings of the study are discussed in depth. Finally, the Conclusion section summarizes the key findings and offers valuable insights for policymakers.

LITERATURE REVIEW

Forecasting GDP growth is a vital component of macroeconomic analysis, presenting ongoing challenges for governmental authorities (Roubini & Sachs, 1989). Variations in GDP growth not only represent the economic health and real income levels of a nation but also play a crucial role in shaping global developmental trends (Camba-Mendez et al., 2001; Shahzad et al., 2023). Ultimately, these fluctuations significantly affect the overall well-being of countries around the world. In economic discussions, growth theories are generally divided into two primary categories: endogenous and exogenous growth theories. Endogenous growth theories, such as the AK Model, Romer's Model, Lucas Model, and New Growth Theory, posits that economic growth is primarily driven by internal factors, especially those that enhance productivity and innovation. For example, the AK Model emphasizes capital accumulation as a fundamental driver of economic expansion (Kotlikoff, 1998). Romer's Model (1980) highlights the pivotal role of knowledge and technological change in fostering growth, positing that research and development (R&D) alongside innovation are essential contributors (Jones, 2019). Similarly, Lucas's Model (1980) underscores human capital accumulation as a key growth engine, arguing that investments in education and skills can significantly boost productivity and innovation (Hartwig, 2014). The New Growth Theory serves as a more comprehensive framework that spans various models, emphasizing innovation, increasing returns, and the impact of policy on growth (Aghion et al., 1999).

Conversely, exogenous growth theories maintain that economic growth is affected by external factors that operate outside the core mechanisms of the economy. The Solow-Swan Model (1950) underscores capital accumulation, labor growth, and technological progress as essential drivers of economic growth (Hartleib, 2012). The Harrod-Domar Model (1930-1940) further illustrates the interconnectedness of investment, savings, and economic growth, demonstrating how capital investment stimulates overall economic output (Dumo et al., 2023). Given the global challenges of the 21st century, GDP growth forecasting remains a focal point for numerous researchers employing multifaceted statistical approaches (Li et al., 2007; Björnfot, 2017; Ahmadi et al., 2019; Miah et al., 2019; Sanusi et al., 2020; Vlah et al., 2020; Dritsaki & Dritsaki, 2021; Hassan & Mirza, 2021; Mohamed, 2022; Van Anh et al., 2023; Shaikh et al., 2025), exploring both endogenous and exogenous growth variables.

In this context, numerous studies have been conducted with a particular emphasis on forecasting GDP growth in the Western Balkan countries. Thus, in their 2021 study, Jushi et al. analyze GDP growth in Western Balkan countries, finding that factors such as population growth, remittances, and labor force participation do not significantly contribute to the region's growth. In contrast, they identify previous GDP levels, trade openness, and foreign direct investments (FDIs) as critical factors influencing regional growth. A previous study by Halebic (2016) examined the impact of consumption on GDP in the Western Balkan countries from 2005 to 2014. The findings illustrated that this relationship can be framed within the Keynesian consumption function, which explores how fluctuations in consumption correlate with changes in GDP. Further, Didelija's study (2021) investigated the causal relationship between private savings components and economic growth in Bosnia and Herzegovina, revealing no significant causal connection between the two.

Research conducted by Erić et al. (2023) emphasizes the substantial influence of various economic factors on growth, with education identified as one of the most significant determinants. Education undeniably enhances productivity, competitiveness, and overall economic growth. Solow was among the pioneers to examine the link between education and economic development. Focusing specifically on higher education, Osmani and Jusufi (2022) analyzed its contribution to economic growth in the Western Balkan nations, particularly Kosovo, Albania, Montenegro, and North Macedonia. Using the Hausman-Taylor IV model to analyze data from 2000 to 2020, the researchers established compelling

evidence that higher education positively influences the GDP of these nations. The study of Evmolpidis (2022) instead, conducts an analysis of the population and urbanization trends in six Western Balkan countries, revealing that these dynamics are pivotal in the development of a new megalopolis designed to stimulate economic growth. In this context, Prifti (2025) provides a critical reevaluation of Tirana's urban development by synthesizing both historical and contemporary planning perspectives. The study explores the city's transformation from a fragmented town into a contested landscape shaped by shifting ideological paradigms. It underscores how political narratives have profoundly influenced architectural and planning practices, ultimately guiding Tirana toward sustainable economic growth.

With the rapid pace of technological advancements, researchers have also turned their attention to analyzing and forecasting GDP growth through the lens of technology adoption, leveraging various systems dynamics modeling approaches (Irtyshcheva et al., 2021; Ye et al., 2022; Aminullah, 2024; Islami et al., 2025; Jackson & Alfaki, 2025; Le & Aye, 2025; Linh et al., 2025; Rahajo & Kumyat, 2025). A study by Ibrahimi and Fetai (2022) explored the relationship between technology use and GDP growth in Western Balkan countries, discovering that while fixed telephone subscriptions and internet usage positively impact GDP growth, fixed broadband and mobile cellular subscriptions do not. Additionally, Tralkovic et al. (2018) investigated how various export product groups, categorized by technological intensity, affect GDP in the Western Balkan countries. The results indicated that medium-low and low-technology industries significantly contribute to GDP fluctuations across the region from 2005 to 2015. Furthermore, Shimbov et al. (2019) analyzed the production of more sophisticated goods and its impact on economic performance in the Western Balkans. Their study found that export sophistication markedly enhances growth, particularly in medium-skill and technology-intensive manufacturing sectors, rather than in high-skill industries. This improvement in export sophistication is attributed to increased participation in international production networks and favorable institutional conditions that together drive economic growth.

Further, Krasniqi and Topxhiu (2017) and Marjanovic et al. (2021) studies explored the trade deficit in Western Balkan economies, noting that such deficits do not necessarily impede economic development. When deficits are funded through foreign borrowing or foreign direct investment (FDI) that fosters productivity growth, they can actually promote long-term economic advancement. Their research also highlighted that general government final consumption negatively impacts GDP growth, while FDI has a positive effect. A recent study by Spahija et al. (2025) reported that rankings from the Doing Business Report, the World Digital Competitiveness Index, and the Global Innovation Index significantly impact Kosovo's ability to attract foreign investment. The findings highlight both positive advancements and challenges within the country's economy. Additionally, the study assesses the extent to which foreign direct investment (FDI) influences Kosovo's gross domestic product (GDP) and examines trends in FDI inflows over time.

Meanwhile, Trpeski et al. (2021) studied the influence of FDI on economic growth and foreign trade within the Western Balkan economies. They found that FDI has a statistically significant positive effect on GDP growth, exports, and imports in countries such as North Macedonia, Albania, Serbia, Bosnia and Herzegovina, and Montenegro, underscoring the importance of FDI for economic recovery and trade enhancement in the region. In a 2022 study, Ristanović examined the pivotal role of international economic relations in the growth and development of small economies in the Western Balkans by analyzing trade flows with the EU from 2006 to 2020. The findings indicated that trade volumes are highest with affluent economies and lowest with distant ones, while an extended version of the research provided deeper insights into commodity flows and their technological approach. However, additional research by Popovic et al. (2020) suggested that innovation may not significantly affect the long-term GDP growth rate in the region.

Additionally, Vërbovci et al. (2024) examined the influence of innovations on green economic growth in the Western Balkans, finding that factors like research and development expenditures and favorable business environments significantly contribute to GDP growth over a 13-year period. The study concluded that promoting innovation is essential for advancing sustainable development, with a statistically significant positive relationship established between innovation and green economic growth.

In the realm of GDP growth research, it is evident that both endogenous and exogenous variables exert different impacts on GDP growth, particularly in the context of the Western Balkan nations. However, it is essential to highlight a research gap focusing on high-technological exports volume, as these countries exhibit varied approaches to technological products, alongside divergent strategies and

programs aimed at accelerating their EU integration. This gap underscores the necessity for further investigation into the interplay between technology and economic growth in the countries of this region.

RESEARCH METHOD

This study adopts a quantitative, descriptive research design utilizing machine learning techniques, specifically the Artificial Neural Network Multilayer Perceptron (ANN-MLP), to model and predict GDP growth based on several macroeconomic variables. The Multilayer Perceptron (MLP), a type of Artificial Neural Network (ANN), is particularly adept at modeling non-linear relationships in data, making it suitable for scenarios where input variables are non-linear (Arkabaev et al., 2025; Teräsvirta, 2006). The novelty of the research is the employment of the partition variable: high-technology exports in the ANN-MLP models, which has a pivotal role in shaping various economic variables and their interrelations with GDP. Increased technological adoption often enhances productivity, leading to higher income levels and consumption, which in turn stimulate economic growth. Education is both a driver and a beneficiary of technological adoption, as a more educated workforce is better equipped to utilize new technologies effectively.

Exports, especially high-technology exports, directly influence GDP by expanding market reach and fostering innovation-led growth. Foreign direct investment (FDI) tends to increase with technological adoption, as investors seek to capitalize on advanced industries and infrastructure, further fueling economic development. Imports may rise due to the need for technological inputs and capital goods, which can also impact the trade balance. Savings are affected as higher income levels and economic stability encourages increased savings rates, providing capital for investment. Urbanization often accelerates with technological progress, as cities become centers of innovation, employment, and infrastructure development. In the context of the model, the partition variable—high-technology exports—captures how the concentration of high-tech goods in exports influences overall economic performance. This segmentation enables the ANN-MLP to identify nuanced relationships between technological adoption and these variables across different economies, such as Albania and Serbia that are transitioning towards high-tech sectors within their EU integration pathways. Recognizing these interactions enriches the analysis by illustrating how technological progression can catalyze broader economic transformations, tailored to specific national contexts.

The sample comprises annual time series data collected from the World Bank Database (WBD), covering the period from 1993 to 2023 for both Albania and Serbia. The total sample size includes 31 observations per country, totaling 62 data points. Due to the nature of the data (time series), a purposive sampling approach was employed—selecting all available relevant data points within the specified period to maximize the dataset's temporal coverage and capture economic trends over three decades.

Data were collected from the World Bank Database, which provides reliable, standardized macroeconomic indicators. The variables include GDP, consumption, exports, FDI, imports, savings, education, urbanization, and high-tech exports (Table 1). Data collection involved extracting the relevant indicators for each country and organizing them into a structured dataset suitable for analysis. Prior to analysis, data underwent preprocessing steps such as normalization to ensure comparability across variables.

Table 1. Definition of variables

Variable	Definition	Unit	Preprocessing notes
GDP	GDP growth	(annual %)	Normalized
Consumption	Final consumption expenditure	(% of GDP)	Outliers checked
Exports	Exports of goods and services	(% of GDP)	Outliers checked
FDI	Foreign direct investment, net inflows	(% of GDP)	Log transformation
Imports	Imports of goods and services	(% of GDP)	Normalized
Savings	Gross savings	(% of GDP)	Smoothing
Education	Government expenditure on education, total	(% of GDP)	Standartized
Urbanization	Urban population	(% of total population)	Outliers checked

Variable	Definition	Unit	Preprocessing notes
High-Technology Exports	High-technology exports	(current US$)	Log transformation

The analysis involved in this research study includes several stages: *Preprocessing*: Data normalization (using Min-Max scaling or Z-score standardization, log transformation, etc) was performed to ensure that variables with different units and scales did not bias the neural network training. *Model Training and Validation*: The dataset was split into training (70%) and testing (30%) subsets to evaluate the model's predictive capability. The ANN-MLP was configured with one hidden layer H(1;1), using hyperbolic tangent activation functions, optimized via backpropagation with gradient descent (Kruse et al., 2022; Almeida, 2020; Singh & Banerjee, 2019). In the predictive ANN-MLP H(1;1) Albanias model there are 59 neurons per layer while in Serbia there are 62. *Model Evaluation*: The model's performance was assessed using Mean Squared Error (MSE), Root Mean Squared Error (RMSE), and the coefficient of determination (R^2) on both training and testing datasets. Early stopping and cross-validation techniques were employed to prevent overfitting. *Partitioning*: The model incorporated a partition variable: high-tech exports—to analyze differential impacts within subsets, allowing for nuanced insights into aspects driving GDP growth.

Regarding the power analysis, given the sample size of 62 observations, the statistical power for detecting meaningful relationships was estimated using post-hoc power calculations with parameters set at a significance level of $\alpha = 0.05$. While neural networks are data-driven and do not conform to traditional parametric power calculations, the relatively small sample size may limit the ability to detect subtle effects. Nonetheless, the use of cross-validation and multiple evaluation metrics helps mitigate concerns about overfitting and underpowered results. This model effectively captured the nonlinearities inherent in the time-series data, delivering accurate predictions with an average squared error of just 0.3% and an average training time of only 3 milliseconds (Table 3).

Thus, the combination of rigorous model validation, performance metrics, and the incorporation of the partition variable such as high-technology exports provides confidence in the Artificial Neural Network Multilayer Perceptron (ANN-MLP) model's capacity to accurately capture the complex, non-linear relationships influencing GDP growth in Albania and Serbia. When comparing the economic indicators of Albania and Serbia, there are notable differences and similarities across various metrics (Table 2). Starting with Gross Domestic Product (GDP), Albania shows a mean of 5.68 with a standard deviation of 3.24, significantly higher than Serbia's mean GDP of 3.21 and a greater standard deviation of 4.11. This disparity suggests that Albania's economic performance has been relatively stronger, albeit with more volatility compared to Serbia. In terms of consumption, both countries have high average figures, with Albania at 94.19 and Serbia slightly lower at 91.71. However, Albania's consumption exhibits greater variability, indicated by a higher standard deviation (11.17) compared to Serbia's (5.37). This could reflect varying consumer behaviors and economic conditions in the two countries.

Exports present another area where the two nations diverge, with Serbia leading in this etric at a mean of 31.39, compared to Albania's 24.06. The standard deviation for Serbia's exports (15.43) is also considerably greater, suggesting that Serbia's export performance is more erratic but overall more robust than that of Albania. Foreign Direct Investment (FDI) figures show a narrow margin, with Albania at 5.93 and Serbia slightly higher at 6.32, but both countries demonstrate moderate variability. The standard deviation of Albania's FDI (2.76) is notably higher than that of Serbia (1.92), indicating that Albania experiences larger fluctuations in FDI inflows.

When it comes to imports, Albania shows a mean of 45.22, higher than Serbia's 41.91. The standard deviation for imports is notably lower in Albania (6.53) than in Serbia (15.96), indicating that Serbia's import levels may be subject to more significant shifts. In terms of savings, Albania again shows a more favorable position at 19.45 mean compared to Serbia's 15.70, with lower variability in savings rates as evidenced by lower standard deviation figures. Education indicators reflect that Serbia has a higher mean score (3.84) compared to Albania's 3.37, along with a larger standard deviation, suggesting a wider range of educational attainment and possibly investment differences in the education sector. Urbanization rates illustrate another point of interest, with Serbia leading at 54.33 compared to Albania's 50.3. The standard deviation in urbanization is much lower in Serbia (1.77), indicating a more uniform urban growth pattern. Lastly, high-tech exports are significantly higher in Serbia, with a mean of

537,000,000, overshadowing Albania's 7,810,900. The standard deviations also reflect considerable variability in both countries' high-tech exports, making Serbia's position in this area particularly striking.

Overall, while Albania shows stronger performance in GDP growth and savings, Serbia leads in exports, education, urbanization, and particularly in high-tech exports. These contrasts highlight different developmental trajectories and economic challenges faced by both nations on their path to EU integration.

Table 2. Variables descriptive statistics

	Albania		Serbia	
Variable	Mean	Std. Deviation	Mean	Std. Deviation
GDP	5.68	3.24	3.21	4.11
Consumption	94.19	11.17	91.71	5.37
Exports	24.06	7.53	31.39	15.43
FDI	5.93	2.76	6.32	1.92
Imports	45.22	6.53	41.91	15.96
Savings	19.45	6.27	15.70	4.17
Education	3.37	0.27	3.84	0.40
Urbanization	50.34	8.72	54.33	1.77
High-Technology Exports	7.810.900	5.823.630	537.000.000	308.500.000

RESULTS AND DISCUSSION

The Articial Neural Networks-Multilayer Perceptron (ANN-MLP) models (Table 3) designed to estimate GDP growth in Albania and Serbia reveal intricate relationships among various economic factors (Table 4). Each model consists of an input layer, a hidden layer, and an output layer, incorporating predictors such as consumption, exports, foreign direct investment (FDI), imports, savings, education, and urbanization. The interplay of these variables underscores the complexities of economic dynamics within each country, particularly highlighting the indispensable role of advanced technology exports in GDP growth. This observation is consistent with the findings of Shimbov et al. (2019).

Table 3. Artificial Neural Netorks-Multilayer perceptron (ANN-MLP) models summary

	Albania Model summary	Serbia Model summary
Training Sum of Squares Error	0.003	0.003
Relative Error	0.002	0.001
Training Time	0.004	0.002

In both Albanian and Serbian models, consumption emerges as a key determinant of GDP, corroborating the results of Halebic (2016). The Albanian model suggests that certain consumption levels, particularly those around 91.12, positively influence GDP growth. Conversely, consumption levels exceeding 91.81 appear to have a negative effect. Similarly, Serbia's model illustrates that consumption levels display both positive correlations, such as 82.72 leading to a GDP uptick of 2.85, and significant detriments, as seen with 94.15 reflecting -1.99, highlighting the nuanced influence of consumer spending on economic outcomes. Exports also play a vital role in both countries. In Albania, a positive coefficient of 28.92 for exports suggests that specific levels can significantly enhance GDP, although others yield varied effects. Serbia's export levels similarly show a mixed impact; while some, like 52.34, contribute positively to GDP growth (2.419), others indicate negative repercussions. This showcases the multifaceted nature of export markets in both nations, echoing the findings reported by Krasniqi and Topxhiu (2017) and Marjanović et al. (2021).

Foreign direct investment (FDI) emerges as another significant factor influencing GDP growth in both Albania and Serbia, consistent with Jushi et al. (2021). In Albania, positive coefficients of 7.40 and 7.70 suggest that increased investment corresponds to GDP growth, whereas higher levels of FDI (e.g., 9.10) could potentially detract from economic performance. Serbia's model presents a more intricate picture, revealing that certain thresholds of FDI positively influence GDP (e.g., 2.86) while higher levels

(e.g., 6.9) might have harmful effects, illustrating the variable nature of investment impacts in distinct economic contexts.

Analysis of imports uncovers a similar pattern of positive and negative influences in both countries, aligning with findings from Marjanović et al. (2021). In Albania, imports like 47.19 are beneficial, while others, such as 51.98, negatively affect GDP. Serbia's model also indicates that some levels of imports (e.g., 46.47) support GDP growth, while others (e.g., 71.19) detract from it, underlining the complexities of trade's implications on economic health. The analysis further highlights the role of savings as a factor influencing GDP growth as argued by Dumo et al. (2023). In Albania, varying levels of savings show both positive and negative coefficients, indicating their differential impacts on GDP. In Serbia, the interplay between consumption and savings suggests that fluctuations in these areas can lead to significant economic repercussions, reflecting the underlying effects of societal conditions on economic performance.

Education and urbanization are critical predictors included in both models consistent with the findings of Erić et al. (2023) and Evmolpidis (2022). In Albania, education emerges with a positive coefficient, demonstrating that higher education levels support economic growth. In contrast, urbanization shows a negative influence, indicating potential challenges related to urban development. Serbia's model suggests that both education and urbanization exert negative influences on GDP growth, highlighting potential issues in the applicability of educational outcomes and urbanization dynamics. This divergence underscores the differing economic contexts faced by each country.

Table 4. Artificial Neural Netorks-Multilayer perceptron (ANN-MLP) parameter estimates summary

Albania			Serbia	
Variable	Predictor	Weight	Predictor	Weight
GDP	X<91.12	2.22	X<82.72	2.85
	X>91.81	(2.28)	X>94.15	(1.99)
Exports	X<28.92	1.15	X<54.34	2.42
	X>28.92	(1.99)	X>54.34	(1.43)
FDI	7.40<X<7.70	1.68	7.4<X<7.7	2.86
	X>9.10	(1.42)	X>9.10	6.90
Imports	X<47.19	1.97	X<46.47	2.12
	X>51.98	(1.22)	X>71.19	(1.92)
Savings	X<17.45	(1.96)	X<20.45	(1.85)
	X>20.50	2.16	X>21.47	2.01
Education		0.14		(0.55)
Urbanization		(0.41)		(1.69)

Also the Spearman's rank correlation coefficients (ρ) between high-tech exports and various socioeconomic indicators differed significantly between Albania and Serbia. In Albania, the correlation was positive and relatively weak, with high-tech exports exhibiting a weak positive association with consumption (ρ = 0.181), education (ρ = 0.319), and FDI (ρ = 0.274), and a weak negative association with exports (ρ = -0.286), imports (ρ = 0.1), savings (ρ = 0.136), and urbanization (ρ = -0.346). In contrast, correlations in Serbia were substantially stronger and predominantly negative, with high-tech exports negatively correlated with consumption (ρ = -0.850) and education (ρ = -0.895), but positively correlated with exports (ρ = 0.877), imports (ρ = 0.814), savings (ρ = 0.777), and urbanization (ρ = 0.917). FDI exhibited a weak negative correlation in Serbia (ρ = -0.047). This data helps to understand how variations in technological adoption are connected to a country's economic growth.

When analyzing the normalized importance of various factors influencing GDP Growth (Table 5) in both Albania and Serbia through the Multilayer Perceptron Model H (1;1), clear distinctions and similarities emerge. For Albania, exports are identified as the most critical driver of GDP growth, with a normalized importance of 1.00, signifying their essential role in economic expansion. FDI and savings closely follow, with normalized importances of 0.177 (91.9%) and 0.176 (91.2%), respectively. Urbanization also has a significant impact, with a normalized importance of 0.175 (90.9%). Moderate influences are noted from imports at 0.096 (49.7%) and consumption at 0.095 (49.4%), while education ranks as the least impactful at 0.087 (45.0%), indicating its lower immediate contribution compared to

other factors. Overall, the findings emphasize that export activities, investments, and urbanization are paramount in shaping Albania's economic trajectory.

Conversely, Serbia's analysis reveals that consumption and FDI are pivotal factors, each with a normalized importance of 0.151, indicating a maximum influence of 100% on GDP growth. Exports and imports also hold vital importance, with normalized values of 0.149, reflecting their significant contributions at 98.3% and 98.5%, respectively. Savings demonstrate a strong impact with a normalized importance of 0.150 (99.2%). Although education (0.108) and urbanization (0.142) rank lower—with impacts of 71.6% and 93.8% they still play substantial roles in Serbia's economic landscape.

Table 5. Summary of the indipendent variables importance

	Albania		Serbia	
Variable	Importance	Norm. Importance	Importance	Norm. Importance
Consumption	0.095	49.40%	0.151	100%
Exports	0.193	100%	0.149	98.3
FDI	0.177	91.90%	0.151	100%
Imports	0.096	49.70%	0.149	98.50%
Savings	0.176	91.20%	0.15	99.20%
Education	0.087	45%	0.108	71.60%
Urbanization	0.175	90.90%	0.142	93.80%

These results help in providing tailored policy recommendations for Albania and Serbia to promote sustainable economic growth, emphasizing export expansion, foreign direct investment, and urbanization management for Albania, and increased household income, trade balance improvements, and prudent savings for Serbia. Utilizing novel applications of artificial neural network multilayer perceptron (ANN-MLP) models by focusing on high-tech exports, this research captures non-linear dynamics and threshold effects in these economies—an advancement over traditional linear analyses—while comparative country assessments enhance understanding of shared and unique structural patterns. This research could redefine theoretical paradigms by highlighting the necessity of incorporating non-linear and threshold considerations to accurately characterize economic systems growth projections and their emergent properties.

The research limitations include data quality and scope, notably the absence of variables such as institutional quality and political stability, and the inherent 'black-box' nature of neural networks, which constrains causal interpretation. Additionally, the static, historical focus omits potential structural shifts and relevant factors like technological innovation and governance, restricting comprehensiveness of the results. The above findings deepen insights into the complex, non-linear drivers of GDP growth in the region, highlighting the importance of country-specific strategies and providing a foundation for future research and policymaking within the EU to sustain and improve competitiveness.

CONCLUSION

The comparative analysis developed in this study reveals that Albania's economic growth is primarily propelled by exports, while Serbia underscores the equal significance of consumption and foreign direct investment (FDI). These factors, in light of each nation's circumstances on their journey towards EU integration, can be classified as both endogenous and exogenous growth variables. Further, it is evidenced that both countries acknowledge the role of savings as an endogenous variable and urbanization as an exogenous factor, though they assign varying degrees of significance to each. Also, both recognize that education, another endogenous variable, exerts a relatively lesser impact on their economic growth. Ultimately, the normalized importance scores illustrate the complex drivers of GDP growth in both nations, highlighting several key similarities as well as distinct focal points within their respective economic frameworks. To align Albania and Serbia with EU standards while capitalizing on their unique economic strengths, it is essential to implement tailored policy measures that enhance the key drivers of GDP growth identified in the analysis. This should be pursued alongside ongoing investments in technology. This approach should operate independently of ongoing investments in technology.

For Albania, which sees exports as the primary engine of economic growth, policies must be developed to strengthen export competencies. This could include initiatives to improve trade relations with EU countries, create export financing programs, and subsidize sectors with high export potential like agriculture and textiles. Additionally, enhancing infrastructure that supports logistics and distribution will facilitate smoother and more efficient export processes. To further promote Foreign Direct Investment (FDI), the government should streamline regulatory procedures, ensure political stability, and improve the business climate by incentivizing foreign companies to invest in Albania. Strengthening urban infrastructure to support urbanization, investment in technology and sustainable practices, and prioritizing education and vocational training in export-oriented sectors can also foster long-term economic resilience. In Serbia, where consumption and FDI play crucial roles in driving economic growth, policies should focus on enhancing domestic demand while attracting foreign investment. Strengthening consumer protection laws and policies, increasing disposable income through tax relief for lower and middle-income households, and promoting domestic products can stimulate consumption. To attract FDI, Serbia should further enhance its investment environment by ensuring regulatory transparency, offering tax incentives, and establishing special economic zones that cater to foreign investors. Additionally, improving digital infrastructure and connectivity can facilitate greater participation in e-commerce, further boosting consumption. While education and urbanization are identified as less impactful in the immediate term, investing in education initiatives to align workforce skills with market needs will support sustainable economic growth and prepare Serbia for the demands of the EU market. Urban planning should also prioritize the development of smart cities to create environmentally sustainable and economically viable urban centers that can support both local and foreign businesses. Both these countries should further engage in regional cooperation initiatives to bolster their collective bargaining power when negotiating trade agreements with the EU, sharing best practices in export promotion and foreign investment attraction. This collaborative approach, paired with targeted policy measures that harness the strengths of each economy, will drive progress toward EU integration and ultimately enrich the economic landscapes of both Albania and Serbia, fostering stability and growth in the region as well as providing valuable practices for the rest of Western Balkan countries. Future research should focus on a more nuanced understanding of the potential benefits and challenges of regional cooperation in the Western Balkans. This research could inform more effective strategies for EU integration and economic growth in the region.

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AUTHOR CONTRIBUTIONS

Author creates articles and creates instruments and is responsible for research, analyzes research data that has been collected, data analysis, instrument validation, and input research data.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

REFERENCES

Ajadi, O. T., & Ayanlowo, A. E. (2025). Teaching strategies and academic performance of students in basic science in Oyo State, Nigeria. *Indonesian Journal of Education Research (IJoER)*, *6*(4), 384-393. https://doi.org/10.37251/ijoer.v6i4.1759.

Alkilany, A. O. A., al-Wasewi, I. H. H., & Nazir, M. I. (2025). Islamic education reform in western contexts: Challenges and opportunities for teacher professionalism. *Jurnal Pendidikan Agama Islam Indonesia (JPAII)*, *6*(3), 148-156. https://doi.org/10.37251/jpaii.v6i3.2211

Aghion, P., Caroli, E., & Garcia-Penalosa, C. (1999). Inequality and economic growth: the perspective of

the new growth theories. *Journal of Economic literature, 37*(4), 1615-1660. https://doi.org/10.1257/jel.37.4.1615.

Ahmadi, M., Jafarzadeh-Ghoushchi, S., Taghizadeh, R., & Sharifi, A. (2019). Presentation of a new hybrid approach for forecasting economic growth using artificial intelligence approaches. *Neural Computing and Applications, 31*(12), 8661-8680. https://doi.org/10.1007/s00521-019-04417-0.

Almeida, L. B. (2020). Multilayer perceptrons. *In Handbook of Neural Computation* (pp. C1-2). CRC Press.

Aminullah, E. (2024). Forecasting of technology innovation and economic growth in Indonesia. *Technological Forecasting and Social Change, 202*, 123333. https://doi.org/10.1016/j.techfore.2024.123333.

Apostu, S.A., Panait, M., Vasile, V., Sharma, G.D., Vasile, R., (2023). FINTECHSand financial inclusion—Balkan experience: Digital perspectives on financial markets. *Electronic Journal of Information Systems in Developing Countries, 89*, e1225789. https://doi.org/10.1002/isd2.12257.

Arkabaev, N., Rahimov, E., Abdullaev, A., Padmanaban, H., & Salmanov, V. (2025). Modelling and analysis of optimization algorithms. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, *9*(1), 161–177. https://doi.org/10.22437/jiituj.v9i1.38410.

Björnfot, F. (2017). *GDP growth rate nowcasting and forecasting*. Retrieved from https://urn.kb.se/resolve?urn=urn:nbn:se:umu:diva-132951.

Boshkov, T., Josevski, D., Miteva, N., (2023). Financial Digitalization and Economic Growth: Recent Developments in Banks and FINTECH. *Challenges of Tourism and Business Logistics in the 21st Century, 6*(1), 15–25. https://doi.org/10.46763/YFNTS2361015b.

Camba-Mendez, G., Kapetanios, G., Smith, R. J., & Weale, M. R. (2001). An automatic leading indicator of economic activity: forecasting GDP growth for European countries. *The Econometrics Journal, 4*(1), S56-S90. https://doi.org/10.1111/1368-423X.00053.

Didelija, I. (2021). The causal link between savings and economic growth in Bosnia and Herzegovina. *The South East European Journal of Economics and Business, 16*(2). https://doi.org/10.2478/jeb-2021-0018.

Dritsaki, M., & Dritsaki, C. (2021). Comparison of the Holt-Winters exponential smoothing method with ARIMA models: Forecasting of GDP per capita in five Balkan countries members of European Union (EU) post COVID. *Modern Economy, 12*(12), 1972-1998. https://doi.org/10.4236/me.2021.1212104.

Dumo, G. A., Ico, H. D., & Magpantay, E. V. (2023). Applicability of Harrod-Domar Model in Explaining Economic Growth in the Philippines. *Journal of Economics, Finance and Accounting Studies, 5*(3), 22-46. https://doi.org/10.32996/jefas.

Erić, O., Kovačević, S., Bjelić, J., & Molnar, D. (2023). Economics of education: The example of the Balkan countries. *Acta Economica, 21*(39), 51-66. https://doi.org/10.7251/ACE2339051E.

Evmolpidis, V. (2020). The European Union's Western Balkans Investment Framework initiative: transport infrastructure development and its impacts. *Ekistics and the New Habitat: the problems and science of human settlements, 82*(3), 9-47.

Halebic, J. (2016). Consumption Function in The Western Balkans Countries. *Dumlupınar Üniversitesi Sosyal Bilimler Dergisi*, 267-276.

Hartleib, M. (2012). *Analysis of economic growth in Germany based on the growth models of Solow-Swan, Kaldor and Romer* [Doctoral dissertation, Murdoch University]. Retrieved from https://researchportal.murdoch.edu.au/esploro/outputs/graduate/Analysis-of-economic-growth-in-Germany/991005542507007891.

Hartwig, J. (2014). Testing the Uzawa–Lucas model with OECD data. *Research in Economics, 68*(2), 144-156. https://doi.org/10.1016/j.rie.2014.01.002.

Hassan, M. M., & Mirza, T. (2021). Using time series forecasting for analysis of GDP growth in India. *Int. J. Educ. Manage. Eng, 11*(3), 40-49. https://doi.org/10.5815/ijeme.2021.03.05.

Helmi, S., Setyadi, B., Wedadjati, R. S., AM, M. A., & Yahya, N. (2025). Digital literacy model to improve the marketing skills of MSME women with a community-based educational approach. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, *9*(1), 313–322. https://doi.org/10.22437/jiituj.v9i1.32670.

Huang, P., (2023). Internet financial forecasting and digital economy development by using machine learning algorithm in the new consumption environment. *Soft Computing, 27*, 10285–10296. https://doi.org/10.1007/s00500-023-08309-3.

Ibrahimi, A. E., & Fetai, B. (2022). The impact of ICT on the GDP growth of Western Balkan countries. *SEEU Review, 17*(1), 105-119. https://doi.org/10.2478/seeur-2022-0044.

Irtyshcheva, I., Stehnei, M., Popadynet, N., Bogatyrev, K., Boiko, Y., Kramarenko, I., ... & Ishchenko, O. (2021). The effect of digital technology development on economic growth. *International Journal of Data and Network Science, 5*, 25–36. Retrieved from http://dspace.msu.edu.ua:8080/jspui/handle/123456789/7818.

Islami, M. R. A., Zafari, M., & Anjum, S. (2025). Wearable energy harvester: Application of piezoelectric sensors in shoes as a portable power source. *Integrated Science Education Journal*, *6*(3), 249-257. https://doi.org/10.37251/isej.v6i3.2117.

Jackson, M. M., & Alfaki, A. A. O. (2025). Advancing sustainable development goal 6: Innovations, challenges, and pathways for clean water and sanitation. *Integrated Science Education Journal*, *6*(3), 224-231. https://doi.org/10.37251/isej.v6i3.2114.

Jones, C. I. (2019). Paul Romer: Ideas, nonrivalry, and endogenous growth. *The Scandinavian Journal of Economics, 121*(3), 859-883. https://doi.org/10.1111/sjoe.12370.

Jushi, E., Hysa, E., Cela, A., Panait, M., & Voica, M. C. (2021). Financing growth through remittances and foreign direct investment: Evidences from Balkan Countries. *Journal of Risk and Financial Management, 14*(3), 117. https://doi.org/10.3390/jrfm14030117.

Kotlikoff, L. J. (1998). The AK Model: It's Past, Present, and Future. National Bureau of Economic Research Working Paper 6684.

Krasniqi, F. X., & Topxhiu, R. M. (2017). Export and Economic Growth in the West Balkan Countries. *Romanian Economic Journal, 20*(65). Retrieved from https://rejournal.eu/sites/rejournal.versatech.ro/files/articole/2017-10-19/3477/xhelili.pdf.

Kruse, R., Mostaghim, S., Borgelt, C., Braune, C., & Steinbrecher, M. (2022). Multi-layer perceptrons. *In Computational intelligence: a methodological introduction* (pp. 53-124). Cham: Springer International Publishing.

Le, N. N., & Aye, M. Z. (2025). The effect of integrating green sustainable science and technology into STEM learning on students' environmental literacy. *Integrated Science Education Journal*, *6*(3), 232-239. https://doi.org/10.37251/isej.v6i3.2116.

Linh, T. T. T., Huong, T. T. M., & Thammachot, N. (2025). Sustainable nutrient management for NFT hydroponic lettuce: Integrating kipahit (*Tithonia diversifolia*) liquid organic fertilizer with AB-Mix. *Integrated Science Education Journal*, *6*(3), 240-248. https://doi.org/10.37251/isej.v6i3.2118.

Li, M., Liu, G., & Zhao, Y. (2007). Forecasting GDP growth using genetic programming. *Proceeding, Third International Conference on Natural Computation (ICNC), held on 24-27 August 2007*. Halkou: China.

Marjanović, D., Beraha, I., & Simović, V. (2021). The impact of Import, export and FDI on the economic growth of the Western Balkans Countries. *Economic Analysis, 54*(2), 20-29. Retrieved from https://www.ceeol.com/search/article-detail?id=1030709.

Miah, M. M., Tabassum, M., & Rana, M. S. (2019). Modelling and forecasting of GDP in Bangladesh: An ARIMA approach. *Journal of mechanics of continua and mathematical science, 14*(3), 150-166. https://doi.org/10.26782/jmcms.2019.06.00012.

Mkiyes, H. (2023). Catalysing economic growth in Balkan countries. *Pressburg Economic Review, 3*(1), 1-32. Retrieved from https://review.pressburgcentre.org/per/article/view/23.

Mohamed, A. O. (2022). Modeling and forecasting Somali economic growth using ARIMA models. *Forecasting, 4*(4), 1038-1050. https://doi.org/10.3390/forecast4040056.

Osmani, F., & Jusufi, G. (2022). The contribution of higher education to economic growth of Western Balkans: Evidence from Kosovo, Albania, North Macedonia, and Montenegro. *InterEULawEast: Journal for the international and european law, economics and market integrations, 9*(1), 85-106. https://hrcak.srce.hr/280273.

Rahajo, M. S., & Kumyat, A. (2025). Analysis of driving factors for the implementation of clean technology to optimize green manufacturing in the wiradesa batik small and medium enterprises (SMEs). *Integrated Science Education Journal*, *6*(3), 258-268. https://doi.org/10.37251/isej.v6i3.2115.

Ristanović, V. (2022). International trade flows of the Balkan states. *The Review of International Affairs, 73*(1184), 5-27. https://www.ceeol.com/search/article-detail?id=1041377.

Roubini, N., & Sachs, J. D. (1989). Political and economic determinants of budget deficits in the industrial

democracies. *European Economic Review, 33*(5), 903-933. https://doi.org/10.1016/0014-2921(89)90002-0.

Popovic, G., Eric, O., & Stanic, S. (2020). Trade openness, institutions and economic growth of the western Balkans countries. *Montenegrin Journal of Economics, 16*(3), 173-184.

Prifti, J. (2025). Assessing building types to trace the evolution of urban forms. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, *9*(1), 227–237. https://doi.org/10.22437/jiituj.v9i1.38368.

Sanusi, N. A., Moosin, A. F., & Kusairi, S. (2020). Neural network analysis in forecasting the Malaysian GDP. The *Journal of Asian Finance, Economics and Business, 7*(12), 109-114. https://doi.org/10.13106/jafeb.2020.vol7.no12.109.

Shahzad, U., Mohammed, K. S., Schneider, N., Faggioni, F., & Papa, A. (2023). GDP responses to supply chain disruptions in a post-pandemic era: Combination of DL and ANN outputs based on Google Trends. *Technological Forecasting and Social Change, 192*, 122512. https://doi.org/10.1016/j.techfore.2023.122512.

Shaikh, Z. H., Husain, S., Alam, M. N., Baig, I. A., & Rana, M. (2025). Understanding the asymmetric effects of exchange rates on economic growth: Evidence from India. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, *9*(2), 788–809. https://doi.org/10.22437/jiituj.v9i2.42633.

Shimbov, B., Alguacil, M., & Suárez, C. (2019). Export structure upgrading and economic growth in the Western Balkan countries. *Emerging Markets Finance and Trade, 55*(10), 2185-2210. https://doi.org/10.1080/1540496X.2018.1563538.

Singh, J., & Banerjee, R. (2019). A study on single and multi-layer perceptron neural network. *Proceeding, 3rd International Conference on Computing Methodologies and Communication (ICCMC), held on 27-29 March 2019*. Erode: India.

Spahija, D., Li, W., Muhammedov, M., Nizamov, A., & Iskhakova, S. (2025). Study of the impact of foreign investment on economic development in emerging markets. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, *9*(3), 1025–1036. https://doi.org/10.22437/jiituj.v9i3.42850.

Stojanović, I., Puška, A., & Selaković, M. (2022). A multi-criteria approach to the comparative analysis of the global innovation index on the example of the Western Balkan countries. *Economics-innovative and economics research journal, 10*(2). https://doi.org/10.2478/eoik-2022-0019.

Teräsvirta, T., (2006). Chapter 8 forecasting economic variables with nonlinear models. *Handbook of Economic. Forecasting, 1,* 413–457. http://dx.doi.org/10.1016/S1574-0706(05)01008-6.

Trlaković, J., Despotović, D., & Ristić, L. (2018). Impact of technology-intensive exports on GDP of Western Balkan Countries. *Journal of Policy Modeling, 40*(5), 1038-1049. https://doi.org/10.1016/j.jpolmod.2018.01.006.

Trpeski, P., Cvetanoska, M., & Kozheski, K. (2021). The impact of foreign direct investments on economic growth and trade: A panel approach of selected Western Balkan countries. *Management Research & Practice, 13*(3), 23-31. Retrieved from https://www.ceeol.com/search/article-detail?id=976288.

Van Anh, N. T., Tung, H. T., Quoc, D. K., & Luan, M. K. (2025). The relationship among foreign direct investment, trade openness, and economic growth in vietnam from 1991 to 2023. *Multidisciplinary Science Journal, 7*(5), 2025203-2025203. https://doi.org/10.31893/multiscience.2025203.

Vërbovci, M. P., Gara, A., & Alili, H. A. (2024). Role of innovation on green economic growth: Empirical analysis from the Countries of the Western Balkans. *Ekonomika, 103*(2), 109-122. https://orcid.org/0009-0007-0699-173X.

Vlah Jerić, S., Zoričić, D., & Dolinar, D. (2020). Analysis of forecasts of GDP growth and inflation for the Croatian economy. *Economic research-Ekonomska istraživanja, 33*(1), 310-330. https://doi.org/10.1080/1331677X.2019.1632727.

Ye, Y., Xu, S., Mariani, M. S., & Lü, L. (2022). Forecasting countries' gross domestic product from patent data. *Chaos, Solitons & Fractals, 160*, 112234. https://doi.org/10.1016/j.chaos.2022.112234.

World Bank (2023). *Databank*. Retrieved from https://databank.worldbank.org/home.aspx.