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The Impact of Oil Prices on the GDP of V4 Countries

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Abstract
This study is concerned with forecasts of GDP growth for the Visegrad countries (V4-hereafter) and oil prices simultaneously. The series for GDP and Oil prices are quarterly, covering the period from December 1, 2000, to October 1, 2023. Neural network techniques were performed to generate individual forecasts. The forecasts for oil prices maintain higher accuracy than the GDP ones due to autoregressive lags. In other words, current oil prices absorb significant influence from past prices. The GDP forecasts for the V4 group indicate tremendous shock and moving growth to a lower steady state. The lower growth observed by the end of the period under review can be attributed to two subsequent non-economic shocks: the Russia-Ukraine war and the COVID-19 pandemic. The V4 countries faced difficulties after the outbreak of COVID-19, mainly due to the stringency measures. In addition to accelerating inflation, the war also disrupted energy commodities within supply chains. These and other facts justify the low growth that awaits these countries until 2028. Ultimately, the oil price until 2028 is estimated to oscillate between $60 and $90 per barrel.

Keywords
GDP, Oil prices, Neural Network, COVID-19, Russia-Ukraine war, forecasting.

Introduction

Oil prices significantly influence countries' economic growth and are the subject of considerable attention in research and political discussions. This raw material is a necessary consumer product for industrial production and has an irreplaceable role in the economic sector (Ge & Tang, 2020). Since the Pennsylvania oil rush in 1859, oil quickly became the dominant fuel of industrial societies (Delannoy et al., 2021). Oil is an important industrial material, a financial tool, and a vital strategic reserve in the interest of national security (Chai et al., 2018). According to Gbatu et al. (2017), oil price shocks have different economic effects. Rising oil prices can lead to high labour and capital intensity, slowing economic activity (Hasanli & Ismayilova, 2017). Regarding economic growth forecasts, the change in oil prices is a crucial factor (Nonejad, 2021). According to Bergmann (2019), the oil market significantly impacts countries' economic development. Higher oil prices increase production costs, reducing their efficiency. In this context, De et al. (2019) state that higher oil prices accelerate the general price level, reducing households' real income and limiting consumption.

Moreover, it limits the population's purchasing power and hinders private and state investments. Vochozka et al. (2020) indicate that price changes in the oil sector significantly impact the global equity market as well. Commodity prices are generally considered indicators of future growth, where their price swings signal robust economic prospects (Ge & Tang, 2020; Gavurova et al. 2020). Sustainable development, always conditioned by growth dynamics, is one of the most critical indicators of a healthy economy (Skare et al. 2024). To this end, Ranosz & Kowal (2020) argue that international trade, financial development, and trade openness can directly support growth drivers. The level of resource endowment shows that economies with lower resource security face other significant challenges compared to less dependent countries. It highlights the need for policy responses, as no "one-size-fits-all" policy is effective for all countries (Tkacova & Gavurova, 2023; Togonidze & Kočenda, 2022). According to Gomółka & Kasprzak (2022), the V4 countries have similar economic settings, e.g., income per capita, unemployment rate, and GDP growth. The synchronization of the economic cycles of GDP and the volume of oil products is a modern approach to investigating the issue of sustainable development and early warning based on forecasting economic development, as they are primary sources of energy production (Ertung, 2019; Sinicakova & Gavurova, 2017; Bilan et al. 2017).

This research paper aims to analyze the effect of oil prices on economic growth in the Visegrad Group countries. Furthermore, it aims to identify the potential relationship between oil prices and gross domestic product in these countries. The following research questions are set to fulfil the objective:

RQ1: How did the development of oil prices from 2000 to 2023 reflect the economic growth or decline of V4 countries?

RQ2: How will the price of oil develop concurrently with the GDP of the V4 countries until 2028?

The importance of oil prices for the economy will be demonstrated through their potential interrelationship. This question is relevant, at least because the goal of the European Union (EU), represented by the European Commission, is to reduce greenhouse gas emissions to 55% of 1990 levels by 2030. Additionally, it aims to achieve zero emissions from new cars by 2035. To attain these ambitious goals, the focus lies on critical aspects such as reducing energy consumption. The overall economic impact of this change in EU energy policy could be considerable. It is expected to affect the overall demand for oil in the world market. In this context, it is essential to consider factors such as economic growth, which will be investigated in a specific study. We will concentrate on the economic impacts of changing prices of non-renewable energy sources, especially oil.

The rest of the paper is organized as follows. Section 2 presents the literature review. Section 3 outlines the data and methods used. Section 4 presents the analysis results of the relationship and neural network techniques. Section 5 contains the discussion. Finally, Section 6 provides concluding remarks, limitations, and suggestions for future research.

Literature Review

The relationship between oil prices and economic growth has produced varied results. A study by Karaki (2017) investigated the asymmetric response of real GDP to the rise and fall of accurate oil prices, showing that the results could be more stable for different nonlinear transformations of oil prices. Evidence of asymmetry disappeared after calculating critical values that were robust to the sample specification. The estimates of the economic impact of oil price shocks vary widely due to underlying economic factors and methodological differences. A study by Oladosu et al. (2018) provided insights using a quantitative meta-analysis of oil price elasticity to GDP for net oil importers, using the United States as an example. The results showed that the US's elasticity of GDP to oil prices ranges from -0.124 to +0.017. A meta-regression model was used to forecast the average elasticity of GDP to the oil price, with a resulting mean of -0.020% and a 68% confidence interval from -0.035 to -0.006 four quarters after the shock.

Alonso & Quintero (2017) also focused on the effect of oil prices on GDP in member countries of the Pacific Alliance. Their analysis showed a long-run relationship between each country's international oil price and GDP. The unexpected increase in oil prices had diverse effects on the economic activity of these countries. In the case of a net oil importer such as Chile, the price increase positively affected GDP. Conversely, unexpected price shock increases for net oil exporters such as Mexico and Colombia also positively impacted GDP. The diverse responses of these countries to price shocks point to the importance of coordinating economic policies. Husaini et al. (2023) performed similar analyses and used the ARDL method to investigate the relationships between oil price, energy consumption, and energy subsidies. Their study indicated a negative effect of oil prices on energy consumption, offset by the positive effects of energy subsidies, which are essential for policy decisions in the energy sector. Using the neural network, Vochozka et al. (2020) find the relationship between the price of Brent crude oil and the EUR/USD exchange rate.

Bergmann (2019) dealt with forecasting the effect of oil price fluctuations on GDP growth, one of the most popular ways of linear and nonlinear VAR models. Research has shown that nonlinear effects caused by the decline in the share of oil in energy have a significant impact on the causal relationship between oil prices and economic growth. The study also revealed that adverse movements in oil prices have a causal effect on more countries than expected, indicating the complexity of the relationship between oil prices and economic growth. Al Jabri et al. (2022) analyzed the effects of price shocks on fiscal policy and real GDP, showing that oil price shocks explain 22% of changes in government revenue and 46% of real GDP. A more detailed analysis showed that price shocks explain 26% of the variability in oil revenues and 90% in oil GDP. The study also highlighted the fact that although GDPs in oil-related and non-oil-related areas respond positively to price shocks, government spending is not directly affected by oil prices but depends on government revenue. A study by Altaee & Al-Jafari (2022) focused on oil abundance and economic growth in the Gulf Cooperation Council (GCC) countries. Their analysis showed the positive contribution of the oil sector to economic growth in these countries, highlighting the importance of "investment" in economic development. The aforementioned studies provide important insights into the complex relationships between oil prices and economic growth, emphasizing the importance of applying political measures, energy policy management, and economic coordination to grow the economies of countries dependent on oil reserves. Seraj et al. (2021) and Suleiman (2019) analyzed the relationship between oil prices and exchange rates in several major countries. Their analyses confirmed the causal relationship between oil prices and exchange rates, aggregate oil consumption, and prices, indicating the importance of monitoring and analyzing the economic effects of the oil market on currency markets.

Gershon et al. (2019) focused on net oil importers such as Cape Verde, Liberia, Sierra Leone, and Gambia. Applied regression analysis showed that an increase in oil prices can temporarily increase GDP per capita in the short run, which can be a significant factor for these economies. The impact of the oil sector on economic growth was also addressed by Javed & Husain (2020). The study aimed to analyze the influence of the oil sector on Oman's economic growth in 1989-2018. The research included oil revenue, price, capital formation, total revenue, and production. ARDL cointegration model and Granger causality test revealed that economic performance was significantly affected by capital formation, oil price, and production. A study by Salisu et al. (2023) analyzed the impact of oil price shocks on GDP in 33 examined economies, where an adverse effect of price uncertainty on GDP was recorded in most countries over the 39 years since 1980 (28). In some countries, the impact of oil price uncertainty was less pronounced, although the need for prudent economic policies in response to oil price fluctuations was highlighted. Perifanis & Dagoumas (2019) also dealt with economic activity related to oil price fluctuations from 2008 to 2017.

The above-mentioned fluctuations in oil prices identified the main factors influencing the price. The methodology used included regression analysis, which showed that oil prices are primarily driven by market fundamentals such as consumption, OPEC production, and OECD stocks. The findings suggest that demand and supply factors have a crucial influence on the price of oil. A study by Lu et al. (2020) summarized the new characteristics and factors that influenced oil prices. The importance of supply, demand, and financial markets in determining oil prices was confirmed using the Dynamic Bayesian Structural Time Series Model (DBSTS) and the Google Trend indicator. The model identified vital turning points in historical data, including the 2008 financial crisis. In addition, DBSTS was found to successfully forecast short-term oil prices, making it a valuable tool for analyzing and forecasting price movements in the short term. Sun et al. (2021) emphasized the need to measure energy, economic and environmental performance. For this purpose, it is necessary to obtain reliable and relevant information from the official websites of the International Energy Agency (IEA) and Our World in Data (OWID). Many attempts have been made to forecast the development of the GDP variable. According to Ge & Tang (2020), common forecasting routes are complex data, including industrial production and financial indicators that reflect the real economy. Soft data in confidence indices or business surveys reflected expected economic trends. Although existing studies show that both data types are relevant for explaining GDP development, there still needs to be a gap in forecasting models that is gradually filled by commodity indicators.

The above studies underline the importance and complexity of the relationship between oil prices and economic growth. Moreover, they emphasize the need for coordinated policy measures and highlight the

importance of price dynamics for macroeconomic efficiency. Official internet sources, namely the websites of Trading Economics, the International Energy Agency (IEA), and Our World in Data (OWID), will be used to collect information on price movements in the oil sector. Data on quarterly GDP in the V4 countries (Czech Republic, Hungary, Poland, and Slovakia) will be drawn from the official websites of the countries' national statistical offices and the OECD (Organization for Economic Cooperation and Development). The cited sources provide the current and reliable data necessary for an analysis in this study.

A linear regression method will be used to answer the first research question. Oil price volatility will be set as the independent variable, and GDP fluctuation will be the dependent variable. Furthermore, the regression will be supplemented with an autoregressive distribution model with cointegrated variables (ARDL) to solve the first research question. A moving average and local regression will smooth the time series to address the second research question. The time series ARIMA model will serve as a tool for analysis and forecasting in connection with the established research objective. The mentioned combination of analytical tools will identify the potential relationship between the price of Brent oil and the GDP of the V4 countries and their future development.

Material and Methods

Data will be sourced from the Trading Economics website to monitor price movements in the oil sector. Specifically, information on the price of crude oil per barrel will be available at monthly intervals within the Crude Oil WTI section. To analyze the economic development of the Visegrád Group countries, data provided by the European Union's statistical office, Eurostat, will be utilized. These data about the GDP of V4 countries are accessible in the National Accounts section and processed and recorded quarterly. The obtained data will be a crucial element for analyzing the relationship between oil prices and the economic development of the studied regions. Data collection will span from 2000 to September 2023, providing a sufficiently broad timeframe for thorough analysis and evaluation of the relationship between these variables.

Within the opening segment of the research, the potential relationship between Brent oil prices and the GDP of the V4 countries will be examined from the year 2000 to September 2023. Initially, monthly records of oil prices will be gathered from the Trading Economics website, specifically from the Crude Oil WTI section. These monthly records will then be converted to quarterly frequency to align with the quarterly GDP data of the V4 countries. Subsequently, a causal model will be constructed to identify the direction and strength of the relationship between the variables under review. A correlation coefficient value of one will indicate a perfect positive correlation, signifying simultaneous growth or decline in both variables. Conversely, a value of -1 will indicate a perfect negative correlation, where an increase in one variable corresponds to a decrease in the other. A value of 0 implies no linear correlation between the variables. Significant correlations with coefficients above 0.3 will be considered significant mutual connections.

After determining the optimal number of lags, the model will undergo optimization of statistical criteria. This will enable us to apply causality tests and interpret results based on the initial p-value. Given the dynamic nature of oil prices and fluctuations in economic growth, the initial coefficient will serve as a benchmark to assess the baseline level of correlation. Subsequently, the previously mentioned statistical tests will be conducted to confirm or refute the statistical significance of the correlation relationships. Overall, this analysis is a crucial step towards understanding the relationships between oil prices and GDP in the V4 countries, providing insights for further modelling and forecasts of economic development in the region.

In the second part of the research, the focus will be on forecasting oil sector prices and the GDP of the V4 countries until 2028, utilizing Wolfram Mathematica as the chosen software. To achieve this goal, several key steps will be taken. Firstly, historical data on oil prices and the GDP of the V4 countries will be loaded and prepared. Monthly oil price records will be aggregated to quarterly frequency by selecting every third monthly value to align with quarterly data. Subsequently, the forecasting model will be developed, incorporating prepared quarterly inputs and their time series. The implemented model will be based on a neural network. The output will provide an insight into the expected development of oil prices from October 31, 2023, to December 31, 2028. Model parameters, including lags, trends, and seasonal influences, will be carefully adjusted for maximum accuracy. The 'Forecast' command will generate future forecasts of oil prices and GDP based on the created model and prepared input variables. The forecasts will be thoroughly evaluated using relevant metrics such as the coefficient of determination (R-squared) and correlation coefficient. Subsequently, the model will be optimized and visualized through graphs and numerical values. This approach will enable the forecasting of oil prices about the GDP of the V4 countries until 2028. Interpreting results will be crucial for understanding the extent to which changes in oil prices may be associated with economic development in these countries.

Results

The initial results focus on the quarterly Gross Domestic Product (GDP) development in the Visegrád Group (V4) countries. A time series covering the period from 2000 to 2023 is selected to provide a better overview and facilitate assessment. Figure 1 interprets the quarterly GDP development in the V4 countries.

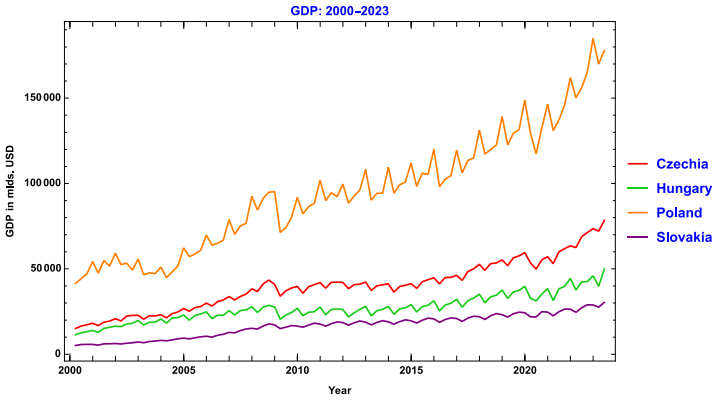

Figure 1. GDP: 2000–2023

Note: The data show the GDP development of the V4 countries from 2000 to 2023 with a three-month frequency. The colour scheme enables tracking specific trends in their economic development. Poland is represented in orange, the Czech Republic in red, Hungary in green, and Slovakia in purple. – source: authors' elaboration based on Eurostat [prepared in sw Mathematica].

When expanding the results further, the development of oil prices per barrel in dollars is included with a monthly frequency. This step is taken to gain a more comprehensive insight into the historical dynamics of oil prices over time. The chosen monthly frequency allows for monitoring short-term fluctuations in the market. Figure 2 elucidates the historical trends in oil prices, which will be referenced in the forecast modelling.

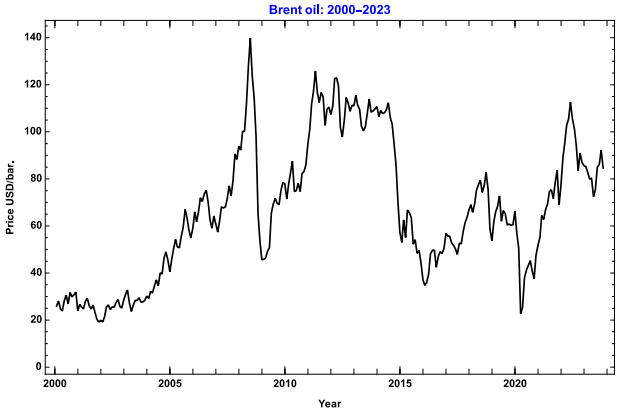

Figure 2. Brent oil: 2000-2023

Note: The data show the price of oil per barrel in dollars for the period from 2000 to 2023 with monthly frequencies. – source: authors' elaboration based on TradingEconomics.com [prepared in Mathematica].

Within subsequent results analysis, statistical tests and modelling are conducted to confirm or refute the existence of causal relationships between the variables under review. If relationships are confirmed with a correlation coefficient above 0.3, these findings will be utilized for future forecasts of the GDP development in the V4 countries considering oil prices. The planned forecast horizon extends until 2028.

To address the first research question, the focus is on calculating the correlation between two key datasets: oil prices and the GDP of individual V4 countries. This analysis quantifies the degree of linear relationship between the variables and provides numerical correlation coefficient values. Based on the initial results, observed correlation coefficient values range from a moderate 0.38 to a moderately strong 0.50 relationship. For the Czech Republic, the correlation coefficient between oil prices and GDP is 0.45. This value indicates a moderate positive linear relationship between oil prices and economic development in the Czech Republic. Hungary exhibits a moderately positive linear relationship with a correlation coefficient of 0.38. Poland shows a moderate positive correlation with a correlation coefficient value of 0.41. Slovakia demonstrates a moderately strong positive correlation with a correlation coefficient value of 0.50.

The first step in fulfilling the second research question is forecasting the expected oil price changes from 31.10.2023 to 31.12.2028. Subsequently, utilizing past and future trends, a forecasting model is proposed to forecast the GDP development in the V4 countries concerning the forecasted values of oil prices. Figure 3 interprets changes in oil prices during the aforementioned period. Related values, highlighted within the chosen timeframe, are also available to better visualize the contrast between actual data and forecasts.

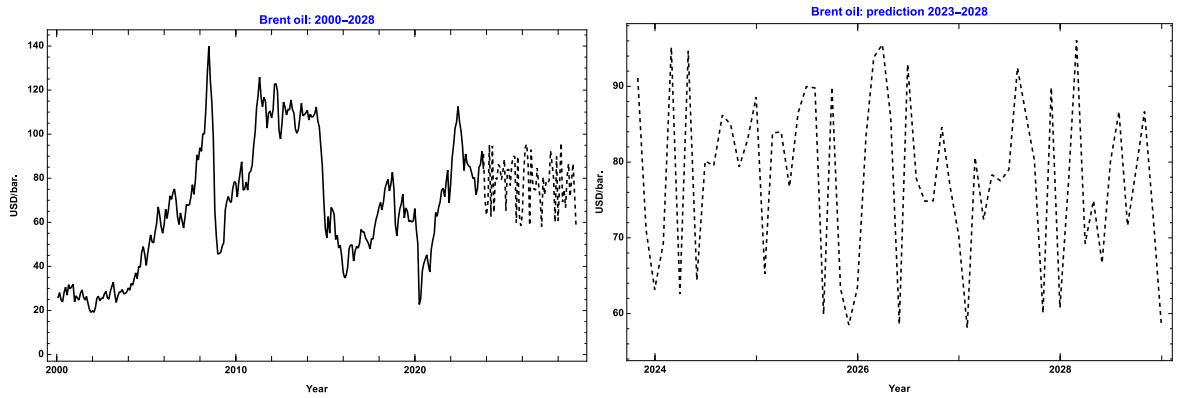

Figure 3. Brent oil: forecast for 2023-2028

Note: The data show the forecasted price of oil per barrel in dollars from October 31, 2023, to December 31, 2028, with monthly frequencies. The split line estimates the oil price from October 31, 2023. The R-square indicates that 97.5 % of the actual values can explain the forecasted one. – source: authors' elaboration based on TradingEconomics.com [prepared in Mathematica].

The Figure 3 output model's precision is indicated by the initial coefficient of 0.97, suggesting a high positive linear correlation between actual and forecasted oil prices. This high correlation implies a strong tendency for the forecasted oil prices to follow the trend of accurate oil prices. Given the high correlation, the chosen model has strong predictive capabilities, and the provided output can be considered relevant. After generating the oil price forecasts, a foundation is prepared to create a model that illustrates how the actual GDP values of the V4 countries differ from forecasts over time. In the Appendix section of this study, Figure A.1 represents a graph of the residuals of the Brent Oil dataset from 2000 to 2023. The residuals graph is utilized to visualize the differences between actual data and model forecasts derived from trends in previous years.

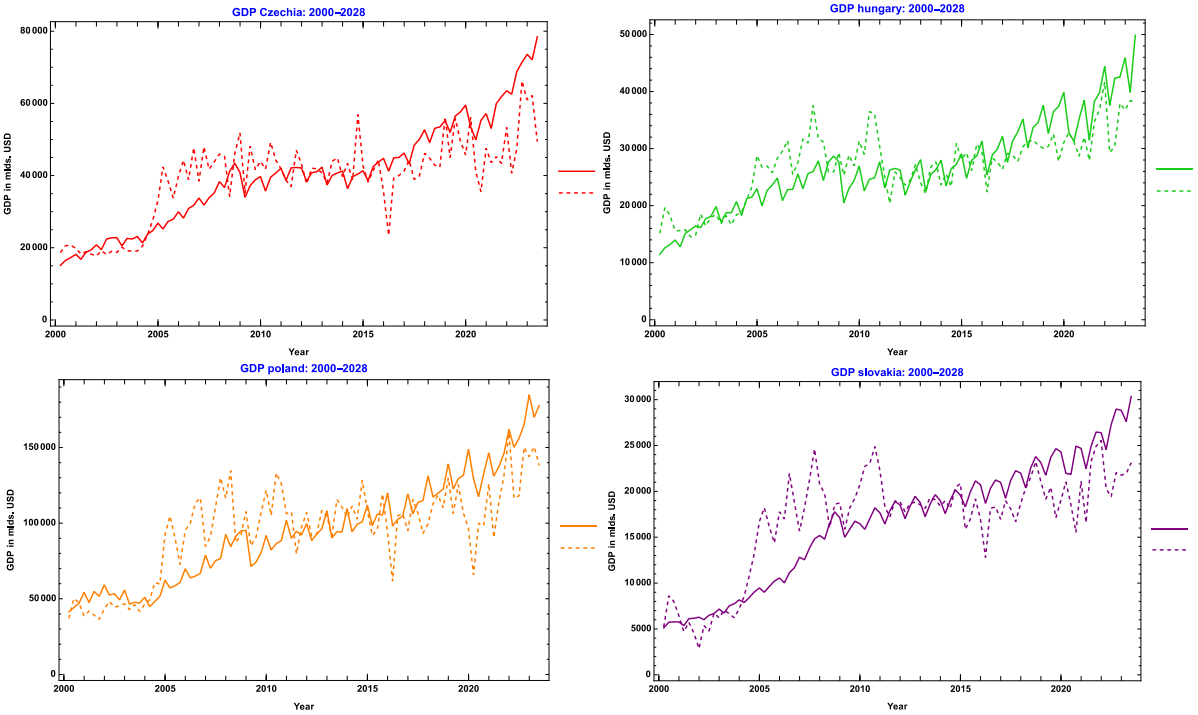

Figure 4. GDP for Czech Republic, Hungary, Poland, Slovakia: 2000–2028

Note: The data show the forecasted and actual values of GDP development for the Visegrad Group from 2000 to 2023, with a three-month frequency. The split line indicates the forecast of the GDP to start from December 31, 2000. - source: authors' elaboration based on TradingEconomics.com [prepared in Mathematica].

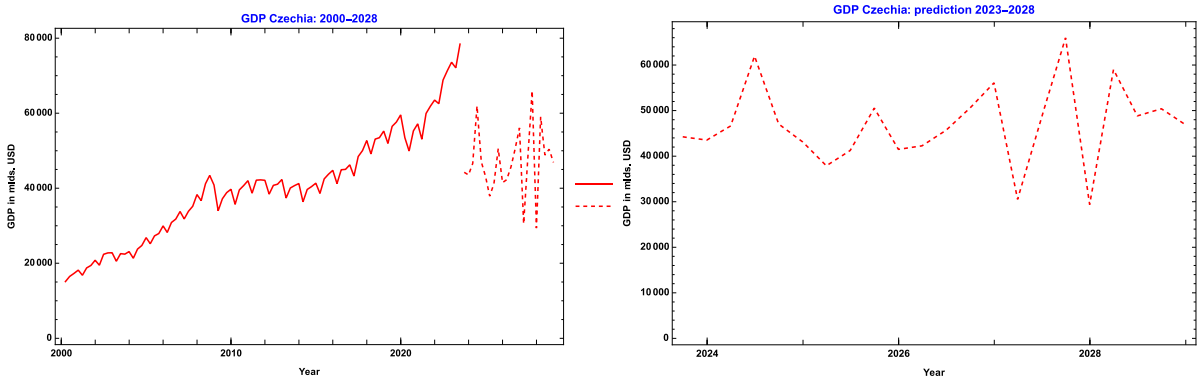

Figure 5. GDP Czech Republic: forecast for 2023–2028

Note: The data show the forecasted GDP development of the Czech Republic from October 31, 2023, to December 31, 2028, with a three-month frequency. The split line estimates the forecast to start from October 31, 2023. The R-square indicates that 79 % of the actual values can explain the forecasted one. - source: authors' elaboration based on TradingEconomics.com [prepared in Mathematica

In Figure 5, the outcome of the GDP forecast for the Czech Republic is displayed within the timeframe from October 31, 2023, to December 31, 2028. The red dashed line on the graph represents the forecast, where the x-axis denotes the years, whereas the y-axis expresses GDP in billions of USD. Regarding the output, it is evident that the forecasted values range from 30,000 to 70,000 billion USD, with the lower value appearing in the early years of 2027 and 2028, while the highest value is forecasted for the same period but with an inter-year distribution. The precision of the output model is indicated by the initial coefficient of .79. In Figure 6, the GDP forecast results for Hungary are available. Related values are also presented to enhance visualization between historical trends and forecasts and highlighted within a specified timeframe.

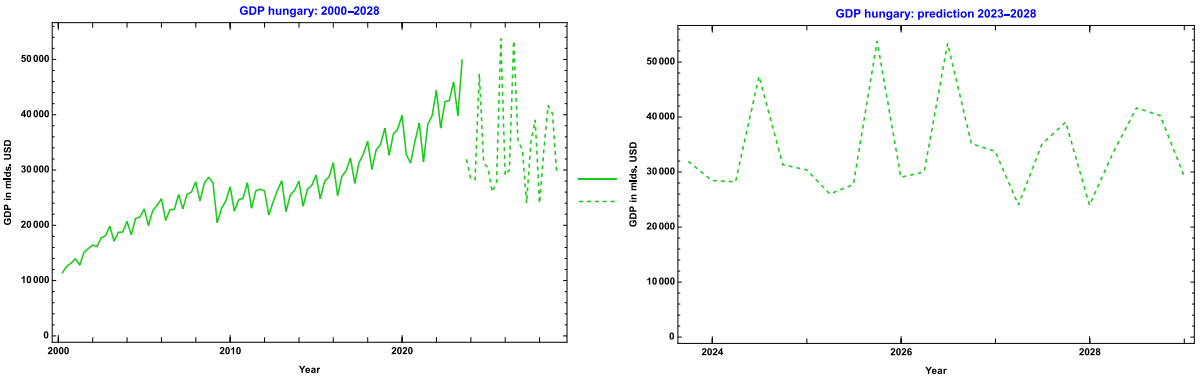

Figure 6. GDP Hungary: forecast for 2023-2028

Note: The data show Hungary's forecasted GDP development from October 31, 2023, to December 31, 2028, with a three-month frequency. The split line estimates the forecast to start from October 31, 2023. The R-square indicates that 78 % of the actual values can explain the predicted one. - source: authors' elaboration based on TradingEconomics.com [prepared in Mathematica].

It can be observed from Figure 6 that related values fluctuate in the range of 25,000 to 55,000 billion USD. Lower values can be seen at the beginning of the period in the years 2027 and 2028, while the highest forecasted value is identified at the end of 2025 and the beginning of 2026. The precision of the output model is indicated by the initial coefficient: 0.78. Figure 7 represents the GDP forecast for Poland. Related values are also presented to enhance visualization between historical trends and forecasts, highlighted within a specified timeframe.

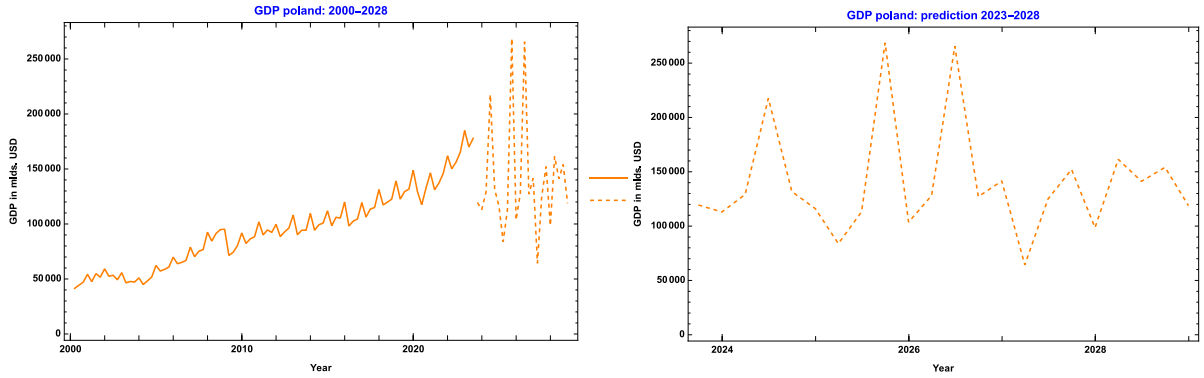

Figure 7. GDP Poland: forecast for 2023-2028

Note: The data show Poland's forecasted GDP development from October 31, 2023, to December 31, 2028, with a three-month frequency. The split line estimates the forecast to start from October 31, 2023. The R-square indicates that 74 % of the actual values can explain the forecasted one. - source: authors' elaboration based on TradingEconomics.com [prepared in Mathematica].

Figure 7 illustrates values that seemingly fluctuate in a wide range from 52,000 to 260,000 billion USD. Lower forecasts appear at the beginning of 2027, while the highest forecasted value occurs several times – firstly at the end of 2025, then decreasing and rising again to the same value. Furthermore, the GDP variable shows a declining trend towards the end of the observed period. The precision of the output model is indicated by the initial coefficient: 0.74. In Figure 8, the GDP forecast results for Slovakia are available. Related values are also presented to enhance visualization between historical trends and forecasts, highlighted within a specified timeframe.

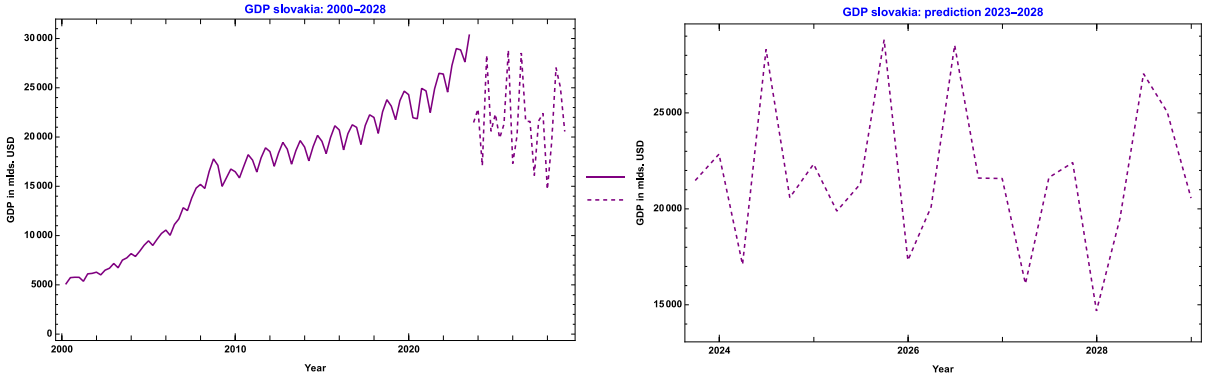

Figure 8. GDP Slovakia: forecast for 2023–2028

Note: The data show the forecasted GDP development of Slovakia from October 31, 2023, to December 31, 2028, with a three-month frequency. The split line estimates the forecast to start from October 31, 2023. The R-square indicates that 78 % of the actual values can explain the forecasted one. - source: authors' elaboration based on TradingEconomics.com [prepared in Mathematica].

Figure 8 shows related values' fluctuation from 15,000 to 23,000 billion USD. Lower forecasts are identified in the year 2028, while the highest forecasted value occurs at several points – firstly during 2024, then at the end of 2025, at the beginning of 2026, and again at the end of the examined period with nearly the same high value around 22,000 billion USD. The potentially variable nature of the studied variable can be observed. The precision of the output model is indicated by the initial coefficient: 0.78.

In the Appendix section of this study, Figure A.2 represents a graph of the residuals in the GDP development of the Visegrád Group countries from 2000 to 2023. The residuals graph is utilized to visualize the differences between actual data and model forecasts derived from trends in previous years.

Discussion

Based on the obtained results, we can address the defined research questions.

RQ1*:* How did the development of oil prices from 2000 to 2023 reflect the economic growth or decline of V4 countries?

Estimates of the economic impacts of oil price shocks exhibited diversity and significant influence due to varying economic factors and methodological approaches. Oladosu et al. (2018) examined the relationship between oil prices and GDP in the United States, finding that the estimated average elasticity of GDP to oil prices

was -0.020%. This implied that if there were a change in oil prices by a certain percentage point, it would be expected that GDP would respond with a decline of 0.020%. The study by Alonso & Quintero (2017), investigating the impact of oil prices on GDP in the Pacific Alliance member countries, confirmed a long-term relationship between international oil prices and GDP in these countries. Their analysis similarly showed that the increase in oil prices had diverse effects on economic activity. For instance, in the case of net oil importers such as Chile, the price increase positively impacted GDP. Furthermore, net oil exporters such as Mexico and Colombia experienced a positive effect of unexpected price shocks on GDP.

Husaini et al. (2023) and Bergmann (2019) utilized the ARDL method to investigate the relationships between oil prices, energy consumption, and energy subsidies. Their findings suggested a negative impact of oil prices on energy consumption, offset by the positive effects of energy subsidies, which are crucial for policy decisions in the energy sector. Bergmann (2019) focused on estimating the influence of oil price fluctuations on GDP growth using linear and nonlinear VAR models. The research showed that nonlinear effects resulting from a decrease in the share of oil in energy have a significant impact on the relationship between oil prices and economic growth. Additionally, based on forecasts and analyses from OPEC (Organization of the Petroleum Exporting Countries), adverse movements in oil prices have a causal relationship across multiple countries, indicating the complexity of the relationships between oil prices and economic growth. This was confirmed in the first phase of the results of the first research question, where statistical tests quantified the degree of the linear relationship, demonstrating the existence of causal relationships between two key datasets: oil prices and the GDP of individual V4 countries. Four correlation coefficients were obtained, each corresponding to one V4 country.

The correlation coefficient values ranged from moderate (0.38) to moderately strong (0.5) relationships between oil prices and GDP in the V4 countries. For the Czech Republic, a correlation coefficient of 0.45 was found between oil prices and GDP, indicating a moderate positive linear relationship between oil prices and economic development in the past period. Hungary similarly exhibited a moderate positive linear relationship with a correlation coefficient of 0.38. Poland showed a moderate positive correlation with a correlation coefficient value of 0.41. Slovakia observed a moderately strong positive correlation with a correlation coefficient value of 0.5. Given the initial correlation coefficients above 0.3, the projection of oil price developments from 2000 to 2023 significantly impacted the economic growth or decline of the V4 countries. Overall, all examined countries have a positive correlation between oil prices and GDP. This positive correlation suggests that an increase in oil prices is usually associated with increased economic activity in these countries and vice versa. However, it is crucial to consider surrounding conditions and external factors that may influence these changes and can be considered as expected.

RQ2: How will the price of oil develop concurrently with the GDP of the V4 countries until 2028?

The significance of the second research question was confirmed from the study by Sun et al. (2021), emphasizing the need for a comprehensive measurement of energy, economic, and environmental performance. This research area requires credible information. The official websites of the International Energy Agency (IEA) and Our World in Data (OWID) were evaluated as sources providing relevant information for these purposes. Forecasting GDP development often utilizes complex data revealing the real economy and soft data reflecting expected economic trends, as stated by Ge & Tang (2020). Although both data types are relevant for explaining GDP development, research studies indicated gaps in forecasting models. These gaps could be partially filled by commodity indicators, which were the focus of the second research question.

This topic highlighted and still supports the significant role of combining commodity and economic indicators in forecasting the development of the energy sector. Their inclusion in the analysis contributed to a better understanding of the relationship dynamics between oil prices and the economic growth of the examined V4 countries. The question of forecasting oil prices remains relevant, as it is regularly affected by changes in the global context. Research conducted by Tian et al. (2023) focused on evaluating methods for forecasting oil prices, especially the use of spot prices, in various situations leading to economic uncertainty. The results showed that changes in the global context can significantly impact the predictive ability of different models. One of the main findings was that current events can alter the relationships between external factors and oil prices, resulting in a loss of information necessary for accurate energy price forecasts.

More comprehensive models that consider commodity indicators could provide a more holistic view of the impacts of oil prices on different economies. The output of the first research question confirmed causal relationships between oil prices and the GDP development of the V4 countries with a correlation coefficient above 0.3. Subsequently, this information was used to forecast expected changes in oil prices from October 31, 2023, to December 31, 2028. The selected model realized the possibility of forecasting GDP development considering expected changes in oil prices and demonstrated high accuracy with a default coefficient of 0.97, indicating a strong positive linear relationship between actual and forecasted oil prices. The identified correlation confirmed the model's ability to predict the development of oil prices with an accuracy of 97.05%. A thorough comparison of actual and forecasted GDP values from 2000 to 2023 showed a significant approximation of forecasts to actual trends. This alignment provided relevance to the predictive ability of the model.

Interesting results can be observed in the next phase of the research, forecasting specific values related to individual V4 countries. In the case of the GDP of the Czech Republic, the forecasted values ranged from 30,000 to 70,000 billion USD. The model's accuracy in estimating target variables reached 79%. Hungary's GDP values ranged from 25,000 to 55,000 billion USD. Lower forecasts were apparent at the beginning of 2027 and 2028, while the highest value was identified at the end of 2025 and the beginning of 2026. The default coefficient for the model's accuracy indicated precision at 78%. For Poland, predictions ranged widely from 52,000 to 260,000 billion USD. Lower prediction values were evident at the beginning of 2027, while the highest value was identified at the end of 2025 and reappeared several times during the observed period. The model's accuracy in estimating target variables was lower than that of other examined countries, and it reached 79% accuracy. Forecasted GDP values for Slovakia fluctuated between 15,000 to 23,000 billion USD. Lower values were identified in 2028, while the highest occurred at several points. Firstly, during 2024, then at the end of 2025. Furthermore, at the beginning of 2026 and again at the end of the studied period, with almost the same high value, around 22,000 billion USD. The studied variable has a potentially variable nature. Nevertheless, the model used for forecasting achieves accuracy at 78% in estimating target variables. The combination of analytical tools was crucial in identifying potential relationships and the future development of Brent oil prices and the GDP of the V4 countries. The provided basis for the dynamics of variable development will serve as a foundation for further studies in long-term economic forecasts.

Conclusions

The study aimed to analyze the impact of oil prices on the economic growth of the Visegrád countries. Furthermore, we tend to identify potential relationships between oil prices and V4 GDP growth. The series covers the period from December 2000 to October 2023 based on a three-month frequency. The results showed that correlation coefficients exhibited moderate associations between oil prices and V4 group GDP dynamics. Furthermore, it can be stated that oil prices have a lasting impact on the economic activity of the Visegrád Group (V4) countries. The findings are of interest not only to national governments but also to active businesses. The Government of V4 continuously focuses on GDP forecasts as it determines the budgetary capacities and public debt servicing. Businesses adjust their business plans in harmony with GDP dynamics and the instability of oil prices. In particular, oil prices have a chain effect on the economy, increasing transport costs while reducing purchasing power. However, this work primarily lies in the limited frequency of GDP data, available only with a three-month periodicity. Economic growth for the V4 countries is expected to shift to a lower level. The Russia-Ukraine war and the COVID-19 pandemic produced an unprecedented shock to the growth prospects of these countries—the first due to inflationary issues while the second primarily linked to stringency measures.

The neural networks were performed to forecast oil prices based on three months of observations. Subsequently, GDP forecasts and oil prices were estimated for the next five years until 2028. The results noted the high predictive ability of the model to forecast oil prices, with R-square reaching 97%. This accuracy surpassed the GDP forecasts of R-square, ranging between 74% and 79%. The oil price estimations are supported by autoregressive lags, where previous values strongly influence one. The sensitivity of oil prices and immediate reactivity indicate a significant impact of past price events on current market conditions. In contrast, economic growth exhibits different dynamics, primarily influenced by internal growth factors but not entirely isolated from external shocks. Forecasting oil prices showed higher accuracy, which can be attributed to autoregressive lags. This immediate response to historical trends allows a more accurate estimation of oil than GDP. To this end, oil price swings are more susceptible to their lags and variability in internal factors.

As mentioned in the introduction, the EU's effort to reduce energy consumption and transition to alternative sources can significantly impact the oil market. The policy of reducing greenhouse gas emissions in the EU could have several consequences, including a potential decrease in overall demand for oil. This direction may reduce dependence on oil and diversify the market share of various energy sources. Subsequently, decreased demand may lead to a decline in oil prices on the global market. Due to restrictions in the production market of combustion engine vehicles, there may be an increased demand for electric vehicles and other alternatives. This shift can influence the oil market as electric vehicles do not use oil. These factors can be considered both a threat and an opportunity. In this study, this factor has been taken into account, and subsequently, in response to the development of the mentioned measures, the research will react to the external economic environment.

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