# ECONOMIC DETERMINANTS OF GASOLINE PRICES: A COINTEGRATION ANALYSIS FOR CZECHIA

**Jiří Alina[1,*], Jiří Nožička[2]**

[1]Department of Applied Economics and Economy, Faculty of Economics, University of South Bohemia in Ceske Budejovice, Ceske Budejovice, Czech Republic
[2]Department of Transport Management, Marketing and Logistics, Faculty of Transport Engineering, University of Pardubice, Pardubice, Czech Republic

*E-mail of corresponding author: jalina@ef.jcu.cz

Jiří Alina 0000-0002-3652-3597, Jiří Nožička 0000-0001-5427-1066

***Resume***
The long-term relationships between the N95 ("Natural 95") gasoline prices and economic factors, such as Brent crude oil prices, diesel fuel prices, and the CZK/USD exchange rate from 2014 to 2024, was investigated within this research. The Engle-Granger cointegration test was used to identify any stable long-term connections between these variables. Despite the comprehensive tests, facilitated by the Matlab software, no evidence of cointegration was consistently found, indicating that these economic factors do not significantly influence N95 gasoline prices over the long term. The findings suggest that, while the short-term fluctuations in these economic indicators may temporarily impact gasoline prices, they are not reliable predictors of the long-term trends.

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## 1 Introduction

Fuel prices have a significant impact on the development of both the global economy and national economies. Fuels price affects the level of logistics costs and thus enters all the market prices. In this way, it significantly affects the inflation rate and the development of GDP. The ability to estimate the development of fuel prices increases the competitiveness of both the state and the economy.

In economies with a market mechanism, fuel prices are to a certain extent dependent on the level of competition between gas station networks and also on the level of fuel taxation in individual economies. However, other factors, such as the geopolitical situation in the world, the OPEC cartel, and others, can also play a significant role.

The author's teams in China have been searching for factors affecting fuel prices for a long time. Research on this topic in the environment of European economies is not as widespread. With this article, the authors want to increase the level of knowledge in this issue for the market in the Czech Republic. Therefore, it was chosen to assess the relationship between the Natural 95 prices and diesel fuel in the Czech Republic from 2014 to 2024 against selected indicators, including the time shift.

### 1.1 Literature review

Investigating the relationship between the price of crude oil and fuel in Brazil, Gerrio et al. 2024 analysed the development of WTI oil by using statistical tools, such as nonlinear models of the self-exciting threshold autoregressive (SETAR) and logistic smooth transition autoregressive (LSTAR) [1].

Arun 2017 dealt with the sensitivity of fuel prices and their changes depending on oil prices. He tracked the development of fuel prices in India depending on the oil prices [2].

Ozdurak and Veysel 2020 investigated the relations between financial derivatives with crude oil prices. They were looking for intraday volatility interactions between crude oil futures and energy exchange traded funds. They did not identify the relationship where the spot market and the futures market would be affected. They

believe that causality is more likely to be bidirectional from the futures market to the spot markets for crude oil [3].

Choi et al. 2015 used the Granger causality to test the effect of crude oil spot prices on the crack spread futures market. They identified three periods (precrisis, crisis, and postcrisis periods). They found the unidirectional relationship between the precrisis and crisis periods from the crude oil spot market to crack spread futures. An interesting thing is that they found reverse relationships during the post-crisis period [4].

Arouri et al. 2011 also dealt with the difference between the price of oil and the price of fuel. They identified differences between price developments. They then explained these differences with current risks for the oil industry, as this will subsequently affect International portfolio management, which strongly reacts to developments on the level of return and volatility spillovers between world oil prices and GCC stock markets [5].

Borenstein and Kellogg 2014 investigated whether the fuel prices in the American Midwest change with the development of oil prices. They concluded that during the period under review, the decrease in crude oil prices in the Midwest market did not lead to a decrease in fuel prices. One of the reasons, they cited, is that the fuel is also imported into the Midwest from the Gulf of Mexico region, where crude oil prices were higher during the period under review [6].

An analysis of the types of demand and supply shocks that affect the oil prices was carried out by Li and Zhao 2011. Their structural vector autoregression model is based on the generalised supply and demand analysis of crude oil price fluctuation and performance the structural decomposition of price shocks with impulse response analysis of those factors. They found these kinds of structural shocks. First, the supply side shocks (the exogenous geopolitical shocks and other oil supply shocks) are the first group. The second group are the demand side shocks (the aggregate demand shock and the other oil market demand shock). This second group has a very strong effect on prices of oil. The next shocks are from the impact of the liquidity of the US dollar [7].

Choi et al. 2021 investigated the long-term and short-term dependencies between the price of crude oil and the price of fuels in the cities of Shenzhen, Hong Kong and Macao. They used an asymmetric error correction model (AECM). They found a long-term relationship between the fuel and crude oil prices in all three cities. For Hong Kong and Macao, they also found that fuel prices are rising faster than they are falling. For this reason, they hypothesised that the fuel market in these cities does not have a very strong competitive environment. For the city of Macao, the difference between the increase rate and the decrease of prices was not demonstrated [8].

The same method was used by Yufeng et al. 2017, who analysed monthly crude oil and fuel prices in China, in the observed period between 2006 and 2013. They found a strong dependence and confirmed that fuel prices rise faster when oil prices rise than they fall when oil prices fall. They also found a stronger effect on diesel prices than on gasoline prices. They also demonstrated that the Chinese government's interventions in oil prices during their longer-term growth led to significant market asymmetry [9].

Szomolanyi et al. 2022 based on the assumption from the results of many researches, i.e., that fuel prices rise faster than they subsequently fall. In their work, they analyse weekly US fuel prices and their response to oil prices. For their research, they used an empirical approach based on the linear exponential adjustment costs formulation. They found that US retail gasoline and diesel prices react asymmetrically to changes in WTI crude oil spot prices. However, they could not estimate statistically significant coefficients of specification with the input price c representing the WTI crude oil price time series and with the output price representing the time series of the gasoline and diesel price at the time [10].

Adrangi et al. 2001 used the VAR methodology and bivariate GARCH model in finding the relationship between the prices of crude oil (Alaska North Slope crude oil) and diesel prices in California. They confirmed a strong relationship between these prices [11].

Manera and Grasso 2005, carried out an econometric study of the sensitivity of gasoline price changes to oil price changes. They used a multi-model investigation in which they followed the development of monthly prices in France, Germany, Italy, Spain, and the UK between 1985 - 2003. They also worked with different time lags of reactions in the models. Their results demonstrated a long-term asymmetry of gasoline prices with oil prices for all the examined countries, in the given period [12].

Cheng 2024 examined the lag in price increases for selected energy market commodities. He created an updated time-delay function. He claimed that most of the impact of change occurs in the first 6 months. According to his results in the first 3 months, there is 50% of the effect of oil price change. Therefore, in this initial phase there are the most significant price changes [13].

## 2 Methods

### 2.1 Research questions

The authors asked four main research questions, which are:

Research Question 1 (RQ1). Is the price of gasoline "Natural 95" (N95) affected by the price of Brent crude oil, the price of diesel fuel and the CZK/USD exchange rate?

Research question 2 (RQ2). Is the price of N95 affected by the price of Brent crude oil and the CZK/USD exchange rate?

Research question 3 (RQ3). Is the price of N95 affected by the price of Brent crude oil and the price of diesel?

Research question 4 (RQ4). Is the price of N95 affected by the price of Brent crude oil?

The authors' interest in RQ 4 was the influence of the time shift and its results.

### 2.2 Data and tests

Data used for analysis were mainly extracted from the website kurzy.cz. It was necessary to recalculate them for months of the year. Collecting data over a 10-year period from 2014 to 2024 proved to be a complex and time-consuming task. The primary challenge was ensuring the consistency and reliability of data throughout such an extended timeframe, as data reporting standards and availability can vary significantly over the years. Additionally, the economic landscape during this period included numerous market events and fluctuations, such as oil price shocks and changes in currency exchange rates, which added layers of complexity to the data collection process. Those factors required meticulous attention to detail and rigorous validation to ensure that the data accurately reflected the economic conditions relevant to N95 gasoline prices. Furthermore, the integration of diverse datasets, including those for Brent crude oil prices, diesel fuel prices, and exchange rates, required a comprehensive approach to manage inherent volatility and potential discrepancies in the data sources. In general, the process was not only labour-intensive, but required significant expertise in data analysis tools like Matlab, as well, to handle and analyse large volumes of data effectively.

The kurzy.cz database is not an international database like Eurostat or OECD, it is a widely recognised Czech financial portal that aggregates data directly from authoritative institutions such as the Czech National Bank (CNB) and the major commercial banks. This ensures the accuracy and reliability of the information provided. The comprehensive historical coverage of the platform was essential for the ten-year analysis (2014-2024), and its open data policy allows transparent and reproducible research. To ensure the data reliability and consistency, authors cross-validated a sample of kurzy.cz data points with official CNB records and, where possible, with Eurostat. Authors also conducted completeness checks to identify missing or inconsistent records. Any gaps in the data were addressed using standard imputation methods (such as linear interpolation for time-series data), following best practices in economic research. The data handling procedures included programmatic extraction from kurzy.cz's API, systematic data cleaning, outlier detection, and thorough documentation of all preprocessing steps. Those procedures, along with the availability of the scripts and documentation as supplementary materials, ensure transparency and reproducibility. In summary, kurzy.cz provides reliable, granular and long-term economic data for the Czech context. Rigorous data validation and preprocessing steps address concerns about data credibility and ensure the robustness of the analysis. Authors are happy to provide additional details or documentation upon request.

To investigate the four research questions, the Engle-Granger test was used. The Engle-Granger test is a method used to test for cointegration between two or more time series. It is a two-step procedure that involves two steps: the first of which is to estimate the cointegrating regression, and the second is to test the residuals for stationarity.

The Engle-Granger test, which was first proposed by Robert F. Engle and Clive W.J. Granger in 1987, is a statistical method that can be employed to test for cointegration between two or more time series. The term "cointegration" is used to describe a situation in which a linear combination of nonstationary series yields a stationary series. This indicates a stable long-term relationship between variables [14]. One possible approach to the two-step Engle-Granger procedure is to first estimate the long-term relationship using ordinary least squares (OLS) and then apply the augmented Dickey-Fuller (ADF) test to the residuals to determine their stationarity [15-16].

One of the primary applications of the Engle-Granger test is in the field of econometrics and financial studies, particularly for modelling the relationships between economic variables over time. For example, researchers often use the test to examine long-term relationships between the stock prices and economic indicators, which can inform investment decision making [17]. Despite its limitations, including its applicability mainly to systems of two variables [18], this test is popular among economists due to its simplicity and efficiency.

The Engle-Granger test has been the subject of both praise and criticism in numerous studies. While some researchers have found the test to be effective in identifying cointegration, others have identified potential issues related to the dependence of the test on estimated residuals [19].

The Engle-Granger test is particularly suitable for systems involving two variables due to its simplicity and efficiency, making it a popular choice among economists. This method is effective in identifying cointegration, indicating a long-term equilibrium relationship between time-series data. The straightforward application of the test involves estimating residuals from a regression model and checking for their stationarity, thus determining if the variables move together over time. Despite some criticisms regarding its dependence on estimated residuals, the Engle-Granger test remains a valuable tool for initial cointegration analysis, especially when dealing with smaller datasets or when computational resources are limited. Its implementation in software like Matlab further enhances its accessibility and ease

of use, allowing researchers to quickly assess potential long-term relationships between economic variables.

The Engle-Granger two-step method is a classic approach to testing cointegration between non-stationary time series. It first estimates a long-term equilibrium relationship using ordinary least squares and then checks whether the residuals are stationary. Its main strengths are simplicity and ease of implementation. However, it has notable limitations: it can only detect a single co-integrating relationship and is sensitive to errors in the first regression step, which can bias results. Furthermore, the critical values of the method depend on the number of variables, which complicates inference in larger systems [20]. The Johansen test addresses many of these issues by using a vector autoregressive (VAR) framework to test multiple co-integrating vectors simultaneously. This makes it more suitable for multivariate systems and is generally more powerful when the model is correctly specified. However, the Johansen method is computationally more complex and sensitive to model misspecification, such as incorrect lag length or the presence of structural breaks. In some cases, it may detect spurious cointegration if the underlying assumptions are violated [21]. Other alternatives include the Phillips-Ouliaris test, which improves upon Engle-Granger by better accounting for uncertainty in residual estimation, and Bayesian methods that allow for more flexible modelling, especially in the presence of structural breaks or uncertain cointegration ranks [18]. In practice, researchers often use Engle-Granger and Johansen tests to cross-check results, as they can sometimes yield different conclusions. While Johansen is preferred for systems with several variables and potential co-integrating relationships, Engle-Granger remains valuable for its simplicity and robustness, especially in bivariate settings or when model assumptions are in doubt. Ultimately, careful model specification and diagnostic checking are crucial regardless of the chosen method [20].

## 3 Results

The authors obtained the main results by using Matlab software. Figure 1 shows the time series of all four variables (their prices), such as Brent crude oil, diesel, CZK/USD exchange rate and gasoline 'natural 95'. The horizontal axis shows the months and the vertical axis shows the values of the variables in CZK. This chart was generated in Matlab.

The first three research questions led to the creation of hypothesis, which is given as follows:

Null hypothesis: There is no cointegration between the time series.

After running all tests, authors got results as can be seen in Tables 1, 2 and 3.

The research question No 4 was answered using the Engle Grenger test in Matlab software. Table 4 shows the results of the Engle-Granger test used for analysis.

The authors included lagged (time shift) values (1-3 months) in their analysis for RQ1-RQ3 to better assess whether cointegration is truly absent or if it

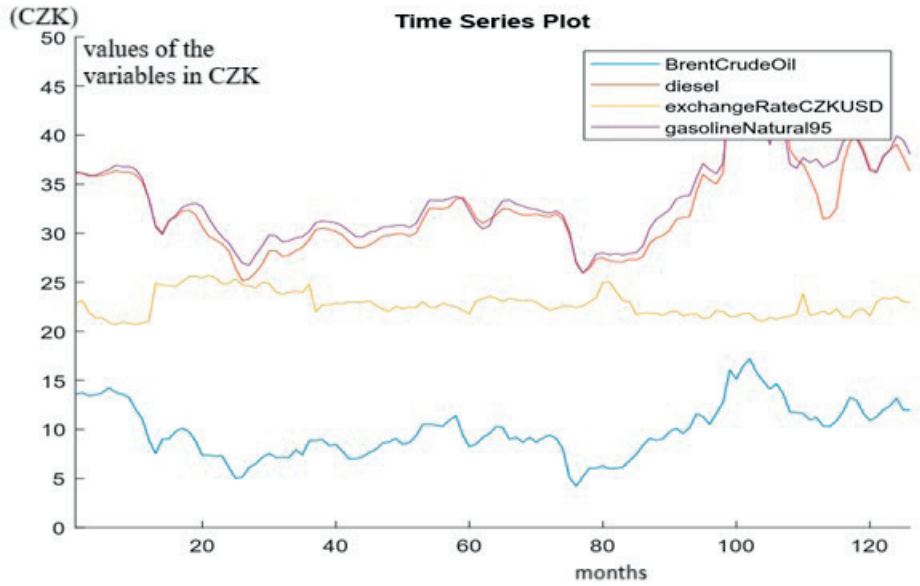


***Figure 1*** *The time series plot*

***Table 1*** *Results of the Engle-Granger test, RQ1*

| Null Rejected | P-Value | Test Statistic | Critical Value |
|---|---|---|---|
| false | 0.23086 | -3.4493 | -3.8799 |

***Table 2*** *The results of the Engle-Granger test, RQ2*

| Null Rejected | P-Value | Test Statistic | Critical Value |
|---|---|---|---|
| false | 0.27212 | -4.3551 | -3.5034 |

***Table 3*** *The results of the Engle-Granger test, RQ3*

| Null Rejected | P-value | Test Statistic | Critical Value |
|---|---|---|---|
| false | 0.10818 | -3.4676 | -3.5034 |

***Table 4*** *The results of the Engle-Granger test, RQ4*

| Shift in months | P - value | Null Rejected |
|---|---|---|
| 0 | 0.0039119 | True |
| 1 | 0.001 | True |
| 2 | 0.001 | True |
| 3 | 0.0053748 | True |
| 4 | 0.060452 | False |
| 5 | 0.15605 | False |
| 6 | 0.22785 | False |
| 7 | 0.36603 | False |
| 8 | 0.49718 | False |
| 9 | 0.50359 | False |

***Table 5*** *The results of the Engle-Granger test for RQ1, RQ2, RQ3 with time lag (-1,-2,-3)*

| RQ 1 | | | |
|---|---|---|---|
| Null Rejected | P-Value | Test Statistic | Critical Value |
| false (t -1) | 0.0641 | -5.5741 | -4.1905 |
| false (t -2) | 0.0884 | -4.869 | -4.1913 |
| false (t -3) | 0.0721 | -4.0333 | -4.1920 |
| RQ 2 | | | |
| Null Rejected | P-Value | Test Statistic | Critical Value |
| false (t -1) | 0.0915 | -5.0714 | -3.8125 |
| false (t -2) | 0.0534 | -4.8450 | -3.8131 |
| true (t -3) | 0.0488 | -4.1091 | -3.8137 |
| RQ 3 | | | |
| Null Rejected | P-Value | Test Statistic | Critical Value |
| false (t -1) | 0.0715 | -5.5359 | -3.8125 |
| false (t -2) | 0.0832 | -4.8725 | -3.8131 |
| false (t -3) | 0.1322 | -4.1156 | -3.8137 |

only manifests with a time delay. For all three Research questions (RQ - 1 -3), the authors used the Engle-Granger cointegration test with shifts of 1, 2 and 3 months. The results are shown in Table 5. Only one time lag, for RQ 2, time lag -3 months has results as the slide cointegration, and all other results confirmed no cointegration.

## 4 Results description

The Engle-Granger cointegration tests conducted in the attached file provide insight into the relationships between the price of N95 gasoline and various economic factors, specifically Brent crude oil prices, diesel fuel prices, and the CZK/USD exchange rate. The following are the most significant implications of the test results for each research question.

### 4.1 Results of research question 1

Objective: To assess whether the price of N95 gasoline is influenced by the price of Brent crude oil, diesel fuel, and the CZK/USD exchange rate.

Implications: The test results did not find evidence of cointegration, as the null hypothesis was not rejected (p-value = 0.23086).

Significance: This implies that, collectively, these three factors do not exhibit a stable long-term relationship with the prices of N95 gasoline.

Consequences: Policymakers and market analysts may consider that changes in these factors, when combined, do not predict long-term trends in N95 gasoline prices. This suggests that other variables or combinations may be more relevant to understand and forecast gasoline price movements.

### 4.2 Results of research question 2

Objective: Determine if the price of N95 gasoline is affected by the price of Brent crude oil and the CZK/USD exchange rate.

Implications: The test results did not show evidence of cointegration, and the null hypothesis was not rejected (p-value = 0.27212).

Significance: This finding indicates that there is no significant long-term relationship between N95 gasoline prices and the combination of Brent crude oil prices and the CZK/USD exchange rate.

Consequences: This relationship cannot be crucial for stakeholders, such as energy traders and policymakers, who need to consider these factors in their strategic planning and forecasting. It suggests that fluctuations in Brent crude oil prices and exchange rates are unlikely to have a lasting impact on N95 gasoline prices, making them key indicators for market analysis.

### 4.3 Results of research question 3

Objective: To evaluate whether the price of N95 gasoline is influenced by the price of Brent crude oil and the price of diesel.

Implications: The test results did not find evidence of cointegration, as the null hypothesis was not rejected (p-value = 0.10818).

Significance: This suggests that the combination of Brent crude oil prices and diesel prices does not exhibit a stable long-term relationship with the prices of N95 gasoline.

Consequences: This outcome indicates that these two factors, when considered together, may not be reliable predictors of long-term trends in N95 gasoline prices. Stakeholders might need to explore other variables or combinations to better understand and anticipate changes in gasoline prices.

### 4.4 Results of research question 4

Objective: Determine if the price of N95 gasoline is affected by the price of Brent crude oil with some time shift.

Implications: The test results divide the time shifts into two groups. The first group is for time shifts 0,1,2 and 3 months. The second group is for time shifts of 4 months and more. For time shifts in the first group, there is evidence of cointegration, with the null hypothesis being rejected (p-value = 0.0039119, 0.001, 0.001 and 0.0053748). For the time shifts in the second group, there is no evidence of cointegration, and the null hypothesis can not be rejected (p-value = 0.060452, 0.15605, 0.22785, 0.36603, 0.49718, 0.50359).

Significance: This finding indicates that the N95 gasoline prices absorb the change in the price of Brent crude oil gradually and this change is statistically demonstrable in the first 3 months.

Consequences: These results mean that changes in crude oil prices do not have a one-off effect on fuel prices, but are gradual. The change will be felt by auto users in the first few months. From the industry perspective, this is a relatively short period, and therefore it can be expected that the change will affect mainly the first stages of production, which will gradually absorb the price change into their prices. It suggests that fluctuations in Brent crude oil prices have almost no effect in long-term relationship with N95 gasoline prices.

### 4.5 Detailed breakdown of results

The research analysed three specific research questions:

1. Impact of Brent crude oil, diesel fuel, and the CZK/USD exchange rate on N95 price: The Engle-Granger test revealed no evidence of cointegration, indicating that the price of N95 gasoline does not exhibit a long-term dependency on the combined influence of Brent crude oil, diesel fuel, and the CZK/USD exchange rate. This implies that, although the short-term fluctuations in these economic variables may cause temporary price changes in N95 gasoline, there is no persistent and stable relationship between them.
2. Influence of Brent crude oil and the CZK/USD exchange rate on the N95 price: The analysis again did not produce cointegration, indicating that the price of N95 gasoline is not significantly influenced by the simultaneous variations in Brent crude oil and the CZK/USD exchange rate. This suggests that the relationship between these factors and the price of N95 gasoline is largely independent and short-lived.
3. Relationship between the Brent crude oil and diesel fuel prices and N95 price: The third research question, investigating the joint influence of Brent crude oil and diesel fuel prices on the price of N95 gasoline, also did not result in cointegration. This finding confirms that the price of N95 gasoline is not significantly influenced by long-term changes in the prices of these energy commodities.
4. Relationship between the Brent crude oil and the price of N95 with time changes: The fourth research question, investigating the influence of Brent crude oil on the price of N95 with monthly shifts, divides the results into two groups. For a short-term period (3 months and less) there was cointegration and for a longer-term period (4 months and more) there was no cointegration. This finding confirms that the price of N95 gradually reacts on crude oil changes in the first quatter. These results confirm the conclusions of Cheng [13], although a different approach was used for the test.

### 4.6 Consequences of the findings

The absence of cointegration between the price of N95 gasoline and the examined economic factors has several key consequences:

- Limited Influence of Economic Factors on N95 Prices: The findings suggest that the price of N95 gasoline is largely determined by other factors, such as supply and demand dynamics, manufacturing costs, and government regulations, rather than the fluctuations in Brent crude oil, diesel fuel, and the CZK/USD exchange rate. This implies that the price of N95 gasoline is relatively insulated from the volatility of these economic indicators.
- Independent Price Dynamics: The results suggest that the price of N95 gasoline follows its own independent trajectory, largely uninfluenced by the long-term movements of Brent crude oil, diesel fuel, and the CZK/USD exchange rate. This implies that market forces specific to the demand and supply of N95 gasoline play a more significant role in shaping its price.
- Uncertainty in Predicting N95 Prices: The lack of cointegration between the price of N95 gasoline and the economic factors examined makes it challenging to predict future price movements using these indicators. The price of N95 gasoline is likely influenced by a complex interplay of factors, making accurate forecasting difficult.
- Gradual Impact of Changes: Time shifts have shown that changes in N95 prices are short-term, so there is only a small chance that policymakers will be able to respond effectively. On the other hand, the impacts are unlikely to be long-term, so there is less risk of market jitters.

### 4.7 Future prediction and recommendations

Although the study provides information on the lack of cointegration between the price of N95 gasoline and the economic indicators examined, it does not negate the importance of these factors. It is essential to acknowledge that:

- Short-Term Fluctuations are Still Relevant: Although the study indicates a lack of long-term dependency, short-term price fluctuations in Brent crude oil, diesel fuel, and the CZK/USD exchange rate can still affect the short-term price of N95 gasoline. These factors might influence the transportation costs, raw material prices, and overall manufacturing costs, which can temporarily affect the price of N95 gasoline.
- Other Factors Can Influence Prices: The price of N95 gasoline is likely to be determined by a wide range of factors beyond those examined in this study. Factors, such as global demand, pandemic situations, government policies, and manufacturing capacity, play a crucial role in the shape of the price.
- More research is needed: The study provides valuable information, but it is just a starting point. Future research should investigate the influence of other potential factors on the price of N95 gasoline, including the role of government subsidies, supply chain disruptions, and consumer behaviour.

## 5 Conclusion

The findings of the research report highlight the complexity of the factors that influence the price of N95 gasoline. Although the absence of cointegration with Brent crude oil, diesel fuel and the CZK/USD exchange rate suggests a limited direct impact, it is important to remember that other economic factors and market dynamics can still influence prices. Further research is crucial to understand the intricate interplay of factors that ultimately shape the price of this essential item.

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### Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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