PRICE DYNAMICS OF FOSSIL FUEL COMMODITIES IN THE PERIOD 2014 - 2024

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Abstract: Over the last decade, the dependence on fossil fuels and their prices has been increasingly discussed. This paper aimed to assess the development of fossil fuel prices and their relationship to GDP in the Czech Republic. To achieve this objective, a VAR model and Granger causality test were used. All fossil fuel prices peaked in 2022. The causal relationship with GDP in the Czech Republic was confirmed for natural gas and coal prices. On the other hand, the causal relationship between oil and GDP in the Czech Republic was not confirmed during the period under study. Weak correlations were found with the Covid-19 pandemic, inflation, and unemployment in the EU. The only exception is the correlation between coal and inflation in the EU, which was moderately strong. A limitation of the paper is the length of the period studied, with data collection taking place only once a month.

Keywords: Oil, natural gas, coal, GDP, price development

1 Introduction

Over the past decade, fossil fuel sales have increased, leading to a discussion on the financial and environmental impacts on the general public (Abid et al., 2023). Fossil fuels account for 86% of global greenhouse gas emissions, raising the need for action to reduce their use despite the lack of direct reference to them in the Paris Agreement (Janzwood, Harrison, 2023). The introduction of carbon policy causes an increase in the cost of fossil fuels through emissions trading, carbon taxes, caps, and indirect regulations that lead to an increase in the price of fossil fuels (Zhang & Cross, 2020). The COVID-19 pandemic has caused a slowdown in the global energy market while changing the use of energy resources (Li & Huang, 2023). Furthermore, it has contributed to climate change, which may accelerate the transition to renewable energy commodities (Apanovych et al., 2023). However, fuel producers are unlikely to switch to a greener pathway, thus cementing dependence on fossil fuels (Le Billon et al., 2021). Since the Ukraine war outbreak, EU countries have been implementing emergency measures that lead to lower energy prices (Enescu et al., 2023). Furthermore, as a result of sanctions imposed on Russia, imports of oil, oil products, solid fossil fuels, and natural gas have declined, and in 2023, imports of oil products have almost ceased, while restrictions on natural gas are not as severe (Rokicki et al., 2023). Oil is one of the most important sources of fuel, and accurate price predictions impact the economy and society (Vochozka et al., 2023). However, several factors influence the price of oil, making future prices very difficult to predict (Deng et al., 2021). Economic, geopolitical, and climate policies cause fluctuations in oil prices, making oil even more volatile from a financial perspective (Ding et al., 2022). Liquefied natural gas is an essential element in the energy industry due to its characteristics, which include high energy density, low carbon emissions, and accessible transportation (Xu et al., 2022). As the largest consumer, China consumed 2,934.4 million tonnes of coal in 2021, which occupies an essential position in the market and industrial system, especially as a raw material in power, steel, and other industries (Zhu et al., 2022).

The aim of this paper is to assess the development of fossil fuel prices and their relationship to GDP in the Czech Republic. To achieve this, we have formulated the following research questions, which are crucial for understanding the dynamics of the fossil fuel market.

Understanding historical developments is essential for analyzing their trends and predicting future developments. This question will help us understand the interrelationship of fossil fuels and their response to various events.

RQ1: How has the price of fossil fuels evolved over the last 10 years, and what insights can we gain from this evolution?

Analyzing the relationship between fossil fuels and GDP in the Czech Republic will show us how a country's economic development affects the price of fossil fuels. The results of this question can be used to address policy issues in the energy sector.

RQ2: What is the relationship between fossil fuel prices and GDP in the Czech Republic?

Analyzing economic and political events will reveal how they affect the fossil fuel market. This is important for planning and risk management in energy security.

RQ3: What are the impacts of political and economic events on fossil fuel prices?

2 Literary research

Substitutability and complementarity between fuel inputs are affected by price efficiency, where imperfect price efficiency implies that if the price of fuels increases, demand for fuels will decrease (Wang et al., 2022). After developing an autoregressive model, Carfora et al. (2022) argue that switching from fossil fuels to renewable energy helps combat energy poverty by promoting economic development and contributing to the Sustainable Development Goals, thus meeting one of the United Nations goals. As a result of prolonged high inflation, central banks have been forced to change their approach to monetary policy and raise interest rates. This could also affect the correction in the price of emission allowances. In this context, it might be appropriate to consider reforming the EU Emissions Trading Market to address upcoming challenges better and thus support the EU's climate change objectives (Heijmans, 2023). Fullat et al. (2021) analyzed the relationship between emission allowances and economic and energy factors in the EU using a vector autoregressive model. They pointed to a surplus of emission allowances and reduced price efficiency in limiting CO2 emissions. Using the ARDL method, it is possible to evaluate the impact of both long- and short-term effects (Kripfganz & Schneider, 2023). This method was used by Samour and Pata (2022), who found a relationship between interest rates in the US and Turkey. Their results show the negative impact of interest rates on the use of renewable resources in Turkey and prove that a significant increase in oil prices can reduce the demand for goods that consume fossil fuels, thus reducing the demand for fossil fuels. The ARDL method was also used by Zimon et al. (2023), who investigated the impact of fossil fuels, renewable energy, and nuclear energy on the environment of South Korea. The results indicate stable equilibrium linkages between GDP, population, fossil fuels, renewable energy, nuclear energy, and the environment. It was also found that GDP and population growth increase CO2 emissions, but using renewable energy helps reduce emissions.

Higher coal prices have less impact on consumption in emerging countries than developed countries, and the impacts on GDP are less pronounced, especially in poorer countries (Smith et al., 2021). Atuahene and Sheng (2023) used a vector autoregression model to analyze the relationship between variables in Ghana's energy sector and energy consumption from 2002 to 2021. They revealed a direct correlation between the GDP growth rate and fossil fuel electricity consumption, and Granger causality showed a feedback relationship between these factors. Zhang (2021) examined the main factors affecting coal prices using neural networks and found that the most influential factor affecting prices is national economic development, followed by national policy, coal production, and imports and exports.

Dependence on natural gas imports increases the risk to EU energy security, especially in geopolitical conflicts. Therefore, the EU's efforts to diversify its natural gas sources and seek alternative supply routes are key to reducing vulnerability (Zakeri et al., 2023). Martínez-García et al. (2023) investigated the changes in oil and gas prices in EU countries during the war

in Ukraine by building an input-output price model. The results show that the increase in oil prices had the most meaningful impact on Austria, the Czech Republic, Croatia, Finland, Romania, Slovakia, and Lithuania, and the most significant increase in natural gas prices was found in the Netherlands and Poland. Hence, the increase in oil and gas prices led to price increases in the manufacturing and service sectors.

Using a vector autoregression model, Tang and Aruga (2021) analyzed the effects of the 2008 financial crisis and the COVID-19 pandemic on the dynamic relationship between the Chinese and international fossil fuel markets. They found that the cointegration relationship between the Chinese and international fossil fuel markets was more affected during the 2008 financial crisis than by the COVID-19 pandemic, which did not significantly impact the relationship. Zhu et al. (2024) investigated the effects of energy imports on environmental innovation in the EU in the context of the ongoing war in Ukraine. An analysis using panel data from 1999-2022 found that natural gas imports promote innovation in renewable and environmentally friendly energy sources, while oil imports may slow down potential progress. Stajic et al. (2021) analyzed natural gas price volatility using the Pearson correlation coefficient. They found correlations between natural gas prices, oil prices, natural gas production, renewable energy production, and coal production. The highest positive correlation was recorded with coal production and oil prices, while high negative correlations were recorded with gas production and renewable energy production. Dehhaghi et al. (2022), using qualitative content analysis to obtain a large amount of information, examined Iran's five-year renewable energy policy development plans and found that Iran has the necessary capacity to develop a sustainable renewable energy policy. Using quantitative content analysis, Pierre et al. (2023) found that hybrid models such as ARIMA-LMTS or ARIMA-GRU are more appropriate for predicting peak energy consumption than single models such as ARIMA, GRU, and LMTS.

Based on the literature search, the vector autoregressive model (VAR) and Granger causality test will be used to meet the objective. The VAR model will address the first and third research questions, and the Granger causality test will address the second research question. Quantitative content analysis will collect data for all three research questions.

3 Data and Methods

The data on the price trends of different fossil fuels, used to answer the first research question, will be obtained from the Trading Economics website. The period from January 1, 2014, to January 1, 2024, will be monitored. The data obtained will then be projected onto a graph.

The data on the development of GDP in the Czech Republic and fossil fuel prices necessary to answer the second research question will be recorded from the Trading Economics website for current fossil fuel prices and from the CSO website for GDP development in the Czech Republic. Data will be recorded at the end of every third month from 2014 to 2024.

Data on EU inflation, EU unemployment, the COVID-19 pandemic, and fossil fuel prices will be used to answer the third research question. Data on the COVID-19 pandemic will be obtained from the WHO website, data on the prices of different fossil fuels from the Trading Economics website, and data on inflation and unemployment in the EU will be obtained from the Eurostat website. The impact of economic and political events on fossil fuel prices will be monitored during the selected period. The data will be monitored at the end of each month.
To answer all the research questions, quantitative content analysis will be used to collect quantitative data for all variables. All data will be processed using the statistical software R.

The VAR method will answer the first and third research questions. This method involves lagged values of all variables, allowing each variable to influence the other variables in the model. Several steps must be taken to calculate a VAR model:

1. Upload the data and install the necessary packages.

Figure 1. Installed packages

```
install.packages("readxl")
install.packages("ggplot2")
install.packages("urca")
install.packages("vars")
install.packages("mFilter")
install.packages("tseries")
install.packages("tidyverse")
install.packages("tsDyn")
```

(Source: Authors elaboration in Rstudio)

2. Convert the data to stationary using the *adf*. test function.
3. Name the data using the d*ata.frame* function.
4. Select the number of lags using the *VARselect* function.
5. Name the model and add the appropriate number of lags.
6. Use the summary function to display the results of the model.
7. For the first research question, use the *fevd* function and display the results using the plot function.

Figure 2. Example of VAR model processing procedure

```
ropa<-ts(ceny_palivšropa, start = c(2014,01,01), frequency = 12)
zemni_plyn <-ts(ceny_palivšzemni_plyn,start = c(2014,01,01),frequency = 12)
uhlí<-ts(ceny_palivšuhlí, start = c(2014,01,01), frequency = 12)
autoplot(cbind (ropa,zemni_plyn))

adf.test(ropa)
ropax <- diff(ropa)
adf.test(ropax)

adf.test (zemni_plyn)
zemni_plyn1 <- diff(zemni_plyn)
adf.test(zemni_plyn1)

adf.test(uhlí)
uhlí3<-diff(uhlí)
adf.test(uhlí3)
uhlí4<-diff(uhlí3)
adf.test(uhlí4)

ropax2 <- diff(ropa, differences = 2)
zemni_plyn2<-diff(zemni_plyn, differences = 2)

vliv_paliv<-data.frame(ropax2,zemni_plyn2,uhlí4)
View(vliv_paliv)
VARselect(vliv_paliv,lag.max = 10,type = "both")
model1=VAR(vliv_paliv,p=10)
summary(model1)

fossil <-fevd(model1,n.ahead = 10)
plot(fossil)
```

(Source: Authors elaboration in Rstudio)

The Granger causality test, a practical tool, will be used to answer the second research question. Granger causality is used to determine the relationship between two time series. It addresses whether the past values of one variable can provide relevant information for predicting the values of the other variable. It is usually tested using regression analysis. Next, the relationship between two time series is evaluated using a regression model. Finally, it is examined whether the inclusion of lagged values of one variable improves the prediction of the other variable; if so, there is evidence of Granger causality between the variables. In a Granger causality test, the interpretation of the results depends on the null and alternative hypotheses, where:

HO: No causal relationship between the variables.
H1: The existence of a relationship between the variables.

To obtain the results, the following steps must be performed:

1. Build a VAR model.
2. Use the causality function to determine the existence of the causal relationship, with GDP in the Czech Republic as the influencing variable.

Figure 3. Example of Granger causality test procedure

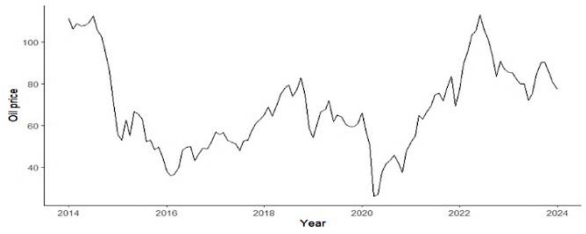
```
ropa<-ts(ceny_palivŠropa, start = c(2014,01,01), frequency = 12)
zemni_plyn <-ts(ceny_palivŠzemni_plyn,start = c(2014,01,01),frequency = 1
uhli<-ts(ceny_palivŠuhli, start = c(2014,01,01), frequency = 12)
autoplot(cbind (ropa,zemni_plyn))

adf.test(ropa)
ropax <- diff(ropa)
adf.test(ropax)

adf.test (zemni_plyn)
zemni_plyn1 <- diff(zemni_plyn)
adf.test(zemni_plyn1)

adf.test(uhli)
uhli3<-diff(uhli)
adf.test(uhli3)
uhli4<-diff(uhli3)
adf.test(uhli4)

ropax2 <- diff(ropa, differences = 2)
zemni_plyn2<-diff(zemni_plyn, differences = 2)

vliv_paliv<-data.frame(ropax2,zemni_plyn2,uhli4)
View(vliv_paliv)
VARselect(vliv_paliv,lag.max = 10,type = "both")
model1=VAR(vliv_paliv,p=10)
summary(model1)

fossil <-fevd(model1,n.ahead = 10)
plot(fossil)
```

(Source: Authors elaboration in Rstudio)

4 Results

Chart 1 shows the evolution of oil prices from January 2014 to January 2024. Oil prices are quoted in USD/Bbl. The chart shows that the oil price peaked in 2022, with similar values also seen in 2014. In contrast, the lowest oil price was recorded in 2020.

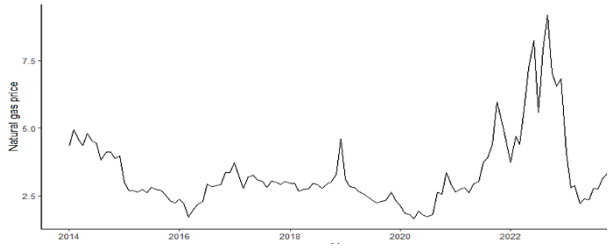
Figure 3. Oil price development



(Source: Authors elaboration based on data from Trading Economics)

Chart 2 shows the evolution of natural gas prices from January 2014 to January 2024. Prices are quoted in USD/MMBtu. The highest natural gas price was recorded in 2022. On the other hand, the lowest prices were recorded in 2020, with very similar natural gas prices in 2016.

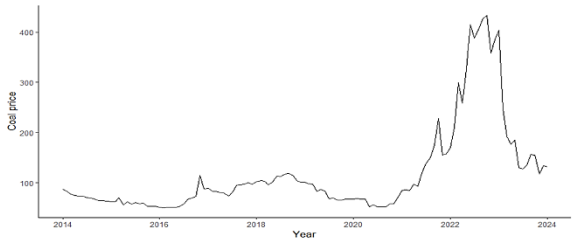
Figure 4. Natural gas price development



(Source: Authors elaboration based on data from Trading Economics)

Chart 3 shows the evolution of coal prices from January 2014 to January 2024. Coal prices are quoted in USD/T. The chart shows that coal prices peaked in 2022, while the lowest coal price was recorded in 2016, with similar prices recorded in 2020.

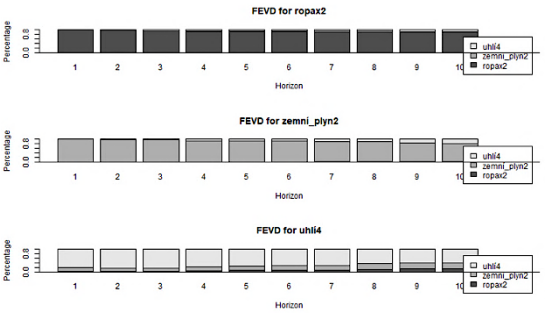
Figure 5. Coal price development



(Source: Authors elaboration based on data from Trading Economics)

In Chart 4, it is possible to see how the variables influence each other. Oil prices do not significantly affect natural gas and coal prices. The same applies to natural gas prices, where price trends depend on internal factors. Coal prices show the most significant dependence on oil and natural gas prices, although this dependence is not very high.

Figure 5. Forecast deviation distribution



(Source: Authors elaboration based on data from Trading Economics)

Table 1 shows the results of the Granger causality test. The significance level was set at 0.05. This implies that the GDP development in the Czech Republic directly affects the development of natural gas and coal prices since the values of the Granger causality test do not exceed the significance level. Therefore, the alternative hypothesis can be accepted. On the other hand, the alternative hypothesis is rejected for oil prices because the result is greater than the significance level. This means that GDP development in the Czech Republic does not affect the development of oil prices.

Table 1. Granger causality test

Fossil fuels	Granger causality test
Oil	0,946
Natural gas	0,0195
Coal	1,077e-07

(Source: Authors elaboration based on data from Trading Economics and CZSO)

Table 2 shows the results of the correlation matrix of residuals. Oil is the only variable directly correlating with all the other variables studied, with the highest correlation observed during the ongoing COVID-19 pandemic. Suppose the variables have a direct correlation with each other. In that case, it means that if the value of one variable increases, the value of the other variable will also increase. Natural gas has an inverse correlation with inflation, and coal has an inverse correlation with unemployment in the EU. If the variables have an inverse correlation, it means that if one variable's value increases, the other variable's value will decrease.

Table 2. Matrix of correlation residuals

	Inflation	Unemployment	Covid – 19
OIl	0,2140	0,1404	0,23465
Natural gas	-0,01479	0,004467	0,06082
Coal	0,6926	-0,01594	0,32435

(Source: Authors elaboration based on data from Eurostat, Trading economics, WHO)

5 Discussion

RQ1: How has the price of fossil fuels evolved over the last ten years, and what insights can we gain from this evolution?

At the beginning of the period under review, a downward trend in fossil fuel prices can be observed, with prices gradually declining until 2016. More pronounced volatility in fossil fuel prices can be observed since the beginning of the COVID-19 pandemic when prices rose significantly faster than in the earlier part of the period under review. For oil and natural gas, the lowest prices were recorded in 2020, while the lowest coal price in 2020 was not much different from its low in 2016. For all fossil fuels, the highest prices within the period under review were in 2022, when the war in Ukraine began. The analysis of the forecast variance decomposition showed that individual fossil fuels mainly depend on internal factors, though it can be argued that individual fossil fuels partially influence each other. Zakeri et al. (2023) examined the role of natural gas in electricity pricing in Europe and its reliance on imports. With Russia being a major natural gas supplier to Europe and fossil fuel prices surging post the Ukraine war, it's evident that fossil fuel imports can significantly impact prices until a new supplier is found and market conditions stabilize.

RQ2: What is the relationship between fossil fuel prices and GDP in the Czech Republic?

The Granger causality test results provide crucial insights into the relationship between GDP in the Czech Republic and natural gas and coal prices. While the test couldn't confirm a causal relationship between GDP and oil during the study period, it's important to note that the data was collected quarterly from January 31, 2014, to January 31, 2024. With a larger dataset and a longer observation period, a causal relationship between these variables could be established. Given the existence of a causal relationship between coal and GDP, one can agree with Smith et al. (2021), who argued that the impacts on GDP are less pronounced, especially in poorer countries.

RQ3: What are the impacts of political and economic events on fossil fuel prices?

There are weak correlations for all variables examined, except for the relationship between coal and inflation in the EU, where a moderately strong correlation was found. An inverse correlation was only observed for the relationship between natural gas and EU inflation and for the relationship between coal and EU unemployment. Based on the finding of correlations with EU inflation, especially with coal, one can agree with Heijmans (2023), who argues that central banks are forced to raise interest rates due to prolonged high inflation, which may also affect the price of emission allowances.

6 Conclusion

The aim of this paper is to to assess the development of fossil fuel prices and their relationship to GDP in the Czech Republic. Regarding the development of oil prices, it was found that the highest price during the period under study reached 113.140 USD/barrel in 2022. The lowest price was in 2020, when the price of oil dropped to 25.990 USD/barrel. The Granger causality test did not confirm that GDP in the Czech Republic directly affects oil prices. However, direct correlations were found with EU inflation, EU unemployment, and the COVID-19 pandemic, with the highest correlation found with the COVID-19 pandemic. This unexpected finding piques further interest in the research. In contrast, the lowest correlation was found with EU unemployment.

For natural gas prices, it was found that the highest price was in 2022, when the price climbed to 9.1940 USD/MMBtu. On the other hand, the lowest price was found in 2020, when the COVID-19 pandemic broke out, with natural gas costing 1.6480 USD/MMBtu. The Granger causality test, a crucial tool in this research, confirmed the existence of a causal relationship between natural gas prices and GDP in the Czech Republic, indicating that GDP in the Czech Republic directly influences fossil fuel prices. This robust finding provides a solid foundation for the research. Furthermore, the correlation between fossil fuel prices and EU inflation, EU unemployment, and the COVID-19 pandemic was analyzed. A weak direct correlation was found for all variables except EU inflation, where an inverse correlation was observed.

Regarding coal prices, it was found that the price of coal peaked in 2022, reaching 433.70 USD/T. The lowest coal price was recorded in 2016 when the price dropped to 49.95 USD/T. The Granger causality test confirmed a causal relationship between coal prices and GDP in the Czech Republic, indicating that GDP in the Czech Republic directly influences coal prices. When examining the correlation between EU inflation, EU unemployment, and the COVID-19 pandemic, direct correlations were found between EU inflation and the COVID-19 pandemic, with inflation showing the highest correlation. In contrast, an inverse correlation was found with EU unemployment.

For all fossil fuels, the highest price volatility was observed between 2020 and 2022, indicating that the COVID-19 pandemic and the ongoing war in Ukraine greatly impacted fossil fuel prices. Increasing the frequency of data collection to, for example, weekly or daily data may lead to more accurate results.

Literature:

1. Abid, I., Benlemlih, M., El Ouadghiri, I., Peillex, J., & Urom, C. (2023). Fossil fuel divestment and energy prices: Implications for economic agents. Journal of Economic Behavior & Organization, Volume 214, 1-16. ISSN 0167-2681. https://doi.org/10.1016/j.jebo.2023.07.033.
2. Atuahene, S. A., & Sheng, Q. X. (2023). Powering Ghana's future: Unraveling the dynamics of electricity generation and the path to sustainable energy. Environmental Sciences Europe, Volume 35 (1). ISSN 2190-4715. https://doi.org/10.1186/s12302-023-00732-5.
3. Apanovych, Y., Líšková-Dvořáková, Z., Burghauserová, M., & Kovač, V. (2023). Insights into Gold Investing: Exploring Investor Behavior. Acta Montanistica Slovaka, Volume 28 (4), 807-818.
4. Carfora, A., Passaro, R., Scandurra, G., & Thomas, A. (2022). The causal nexus between income and energy poverty in EU Member States. Energies, Volume 15 (8), 2822.
5. Dehhaghi, S., Choobchian, S., Ghobadian, B., Farhadian, H., & Viira, A.-H. et al. (2022). Five-Year Development Plans of Renewable Energy Policies in Iran: A Content Analysis. Sustainability, Volume 14 (3). ISSN 2071-1050. https://doi.org/10.3390/su14031501.
6. Deng, C., Ma, L., & Zeng, T. (2021). Crude oil price forecast based on deep transfer learning: Shanghai crude oil as an example. Sustainability, Volume 13 (24), 13770.
7. Ding, Y., Liu, Y., & Failler, P. (2022). The impact of uncertainties on crude oil prices: Based on a quantile-on-quantile method. Energies, Volume 15 (10). ISSN 1996-1073. https://doi.org/10.3390/en15103510.
8. Enescu, A.-G., & Szeles, M. R. (2023). Discussing energy volatility and policy in the aftermath of the Russia–Ukraine conflict. Frontiers in Environmental Science, Volume 11. ISSN 2296-665X. https://doi.org/10.3389/fenvs.2023.1225753.
9. Fullat, M. B., Martín, P. A., & Alarcón, S. (2021). CO2 emission allowances and their interaction with economic and energy factors in the European Union. Revista de la Facultad de Ciencias Agrarias UNCuyo, Volume 53 (1), 182-195.

10. Heijmans, R. J. R. K. (2023). Adjustable emissions caps and the price of pollution. Journal of Environmental Economics and Management, Volume 118. ISSN 0095-0696. https://doi.org/10.1016/j.jeem.2023.102793.
11. Janzwood, A., & Harrison, K. (2023). The political economy of fossil fuel production in the Post-Paris Era: Critically evaluating Nationally Determined Contributions. Energy Research & Social Science, Volume 102. ISSN 2214-6296. https://doi.org/10.1016/j.erss.2023.103095.
12. Kripfganz, S., & Schneider, D. C. (2023). Ardl: Estimating autoregressive distributed lag and equilibrium correction models. The Stata Journal: Promoting communications on statistics and Stata, Volume 23 (4), 983-1019. ISSN 1536-867X. https://doi.org/10.1177/1536867X231212434.
13. Vochozka, M., Škapa, S., & Apanovych, Y. (2023). Changes in Real Income of Households in the Czech Republic Due to the Russian Invasion of Ukraine. Entrepreneurship and Sustainability Issues, Volume 11 (2), 37–53. https://doi.org/10.9770/jesi.2023.11.2(3).
14. Le Billon, P., Lujala, P., Singh, D., Culbert, V., & Kristoffersen, B. (2021). Fossil fuels, climate change, and the COVID-19 crisis: Pathways for a just and green post-pandemic recovery. Climate Policy, Volume 21 (10), 1347-1356. ISSN 1469-3062. https://doi.org/10.1080/14693062.2021.1965524.
15. Li, Z., & Huang, H. (2023). Challenges for volatility forecasts of US fossil energy spot markets during the COVID-19 crisis. International Review of Economics & Finance, Volume 86, 31-45. ISSN 1059-0560. https://doi.org/10.1016/j.iref.2023.02.004.
16. Martínez-García, M. Á., Ramos-Carvajal, C., & Cámara, Á. (2023). Consequences of the energy measures derived from the war in Ukraine on the level of prices of EU countries. Resources Policy, Volume 86. ISSN 0301-4207. https://doi.org/10.1016/j.resourpol.2023.104114.
17. Pierre, A. A., Akim, S. A., Semenyo, A. K., & Babiga, B. (2023). Peak electrical energy consumption prediction by ARIMA, LSTM, GRU, ARIMA-LSTM and ARIMA-GRU approaches. Energies, Volume 16 (12), 4739. https://doi.org/10.3390/en16124739.
18. Rokicki, T., Bórawski, P., & Szebérenyi, A. (2023). The impact of the 2020–2022 crises on EU countries' independence from energy imports, particularly from Russia. Energies, Volume 16 (18). ISSN 1996-1073. https://doi.org/10.3390/en16186629.
19. Samour, A., & Pata, U. K. (2022). The impact of the US interest rate and oil prices on renewable energy in Turkey: A bootstrap ARDL approach. Environmental Science and Pollution Research, Volume 29 (33), 50352-50361. ISSN 0944-1344. https://doi.org/10.1007/s11356-022-19481-8.
20. Smith, L. V., Tarui, N., & Yamagata, T. (2021). Assessing the impact of COVID-19 on global fossil fuel consumption and CO2 emissions. Energy Economics, Volume 97. ISSN 0140-9883. https://doi.org/10.1016/j.eneco.2021.105170.
21. Stajic, L., Đorđević, B., Ilić, S., & Brkić, D. (2021). The volatility of natural gas prices – Structural shocks and influencing factors. Revista Internacional de Métodos Numéricos para Cálculo y Diseño en Ingeniería, Volume 37 (4). ISSN 0213-1315. https://doi.org/10.23967/j.rimni.2021.12.002.
22. Tang, C., & Aruga, K. (2021). Effects of the 2008 Financial Crisis and COVID-19 Pandemic on the Dynamic Relationship between the Chinese and International Fossil Fuel Markets. Journal of Risk and Financial Management, Volume 14 (5). ISSN 1911-8074. https://doi.org/10.3390/jrfm14050207.
23. Wang, X., Liang, S., Wang, H., Huang, S., & Liao, B. (2022). Do fossil-fuel price distortions impact the low-carbon transition in China's energy intensive industries? Frontiers in Energy Research, Volume 9. ISSN 2296-598X. https://doi.org/10.3389/fenrg.2021.805224.
24. Xu, J., Lin, W., Chen, X., & Zhang, H. (2022). Review of unconventional natural gas liquefaction processes. Frontiers in Energy Research, Volume 10. ISSN 2296-598X. https://doi.org/10.3389/fenrg.2022.915893.
25. Zakeri, B., Staffell, I., Dodds, P. E., Grubb, M., & Ekins, P. et al. (2023). The role of natural gas in setting electricity prices in Europe. Energy Reports, Volume 10, 2778-2792. ISSN 2352-4847. https://doi.org/10.1016/j.egyr.2023.09.069.
26. Zhang, J., & Cross, M. L. (2020). Carbon policies, fossil fuel price, and the impact on employment. Clean Technologies and Environmental Policy, Volume 22 (5), 1085-1095. ISSN 1618-954X. https://doi.org/10.1007/s10098-020-01850-x.
27. Zhang, W. (2021). Influencing factors and projections of coal price. IOP Conference Series: Earth and Environmental Science, Volume 632 (2). ISSN 1755-1307. https://doi.org/10.1088/1755-1315/632/2/022016.
28. Zhu, S., Chi, Y., Gao, K., Chen, Y., & Peng, R. (2022). Analysis of influencing factors of thermal coal price. Energies, Volume 15 (15). ISSN 1996-1073. https://doi.org/10.3390/en15155652.
29. Zhu, Z., Zhao, J., & Liu, Y. (2024). The impact of energy imports on green innovation in the context of the Russia-Ukraine war. Journal of Environmental Management, Volume 349. ISSN 0301-4797. https://doi.org/10.1016/j.jenvman.2023.119591.
30. Zimon, G., Pattak, D. C., Voumik, L. C., Akter, S., Kaya, F., Walasek, R., & Kochański, K. (2023). The impact of fossil fuels, renewable energy, and nuclear energy on South Korea's environment based on the STIRPAT model: ARDL, FMOLS, and CCR approaches. Energies, Volume 16 (17), 6198.

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