The Relationship Between Oil Prices and Stock Prices of the European Renewable Energy Companies: A Vector Autoregressive Analysis

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ARTICLE INFO

Original Scientific Article

Article History:
Received November 2023
Revised November 2023
Accepted December 2023

JEL Classification:
Q42, Q43, Q48

Keywords:
Renewable energy
Brent crude oil
Futures prices
ERIX index
VAR

UDK: 338.5:620.9
DOI: 10.2478/ngoe-2023-0019

Cite this article as: Slatina, E., Lazović-Pita, L., Abdić, Ademir, & Abdić, Adem (2023). The Relationship Between Oil Prices and Stock Prices of the European Renewable Energy Companies: A Vector Autoregressive Analysis. *Naše gospodarstvo/Our Economy, 69*(4), 1-11. DOI: 10.2478/ngoe-2023-0019.

Abstract

This article aims to examine the potential relationship between Brent crude oil futures prices and the index of the European renewable energy companies. After the overview of the European legislation and the most recent literature review on the topic, the article deploys a method of the Vector Autoregressive Model (VAR). The analysis includes weekly data over eight years (2015-2022). Our results indicate a positive correlation between Brent crude oil futures prices and the value of the European Renewable Energy Total Return (ERIX) index. The estimated bivariate VAR model indicates a statistically significant relationship, meaning that past values of the ERIX Index may be used to predict future Brent crude oil prices in the long run. Considering the most recent systemic disturbance in the world's commodity market, future research should consider longer time series and possible relationships of other macroeconomic factors.

Introduction

The current global energy landscape has been radically reshaped by the outbreak of three mutually independent recent systemic disturbances in the world market: the COVID-19 pandemic, the Russian-Ukrainian conflict, and the green transition (Abdić, Abdić & Rovčanin, 2023). These factors have radically reshaped the commodity markets of countries around the world. Throughout history, non-renewable or fossil fuels have been the primary source of energy that satisfied around 80% of the world's energy needs (Yilanci, Özgür & Altinsoy, 2022). In 2021 alone, 136,018 terawatt-hours of energy from fossil fuels were consumed worldwide, representing 82.3% of the total energy collected (Ritchie, Roser & Rosado, 2020). The consumption of a representative of non-renewable energy – crude oil per capita over 2000-2021 period worldwide was, on average, the highest in North America, closely followed by Australia and Europe (Ritchie, Roser, & Rosado, 2020).

Regarding (non) renewability, the energy sources may be classified as non-renewable and renewable (Rybár, Kudelas & Beer, 2015). Non-renewable energy sources are in place, and the time dimensions of human society within the context of social processes are exhaustible (Rybár, Kudelas & Beer,

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2015, p. 174). Energy from non-renewable sources includes crude oil, nuclear energy, gas, and coal.

However, growing negative externalities and emissions from non-renewable energy sources, such as carbon dioxide, are related to irreversible ecosystem damage, global warming, and climate change. Therefore, for the continuation of life on this planet, recognizing alternative – renewable energy sources is crucial (An et al., 2021). Renewable or clean energy sources are in place, and time dimensions of human society within the context of social processes are non-exhaustible (Rybár, Kudelas & Beer, 2015, p. 174). According to the revised European Union Directive (EU) 2018/2001, energy from renewable sources includes solar energy, wind energy, geothermal energy, environmental energy, hydropower, tidal energy and other energy of the ocean, biomass, gas obtained from waste processing, gas obtained from wastewater treatment plants and biogas. Renewable sources gained a more significant role at the beginning of this century. Between 2004 and 2017, there was a fast growth in clean energy investments (an increase from 62 billion US dollars to 280 billion dollars) (Pham, 2019).

The turning point in the development of international environmental politics was signed more than fifty years ago in Stockholm with the United Nations Conference on the Human Environment (United Nations, 1972). From that point onwards, several documents and protocols (for example, 1985 - Vienna Convention for the Protection of the Ozone Layer, 1987 - Environmental Perspective to the Year 2000 and Beyond, 1992 - the Earth Summit and the United Nations Framework Convention on Climate Change, etc.) have been brought and signed, serving as a legal basis for the undersigning countries to tackle environmental issues. The most essential internationally adopted document considered the cornerstone of climate change was the Kyoto Protocol signed in 1997, but it had little impact (Jackson, 2007). Even though 192 countries had initially signed it, the Protocol mandated that 37 industrialized countries, together with the EU, should reduce emissions of harmful gases by an average of 5% compared to the level of 1990 (Tardi, 2023; United Nations, 2022). However, as the negotiations on new legislation on climate change were lengthy and without much success in 2015, the Paris Agreement was signed, which repeals the Kyoto Protocol (United Nations, 2022).

In the European context, as the Kyoto Protocol had been signed, the European Union also brought several documents, such as the White Paper for a Community Strategy and Action Plan, followed by the 2001 Directive 2001/77/EC of the European Parliament and of the Council on the promotion of electricity produced from renewable energy sources in the internal electricity market, 2009 Directive 2009/28/EC on the rise of the use of energy from renewable sources, 2019 Clean energy for all Europeans package to the most important - Directive EU 2018/2001 – the Renewable Energy Directive 2018 (Carella, 2020; Nouicer et al., 2020) and the following 2020 European Green Deal. The Renewable Energy Directive 2018 requires 32% of the energy consumed within the EU to be renewable by 2030, and together with the European Green Deal, it emphasizes the need for more ambitious action to address climate change and meet environmental objectives. It highlights the essential role of energy in the transition to a net-zero greenhouse gas emissions economy, particularly the importance of decarbonizing the energy system (European Commission, 2019). To finance the ambitious goals set in the European Green Deal, the European Commission adopted the European Green Deal Investment Plan (EGDIP) in January 2020, which represents a financing plan for Green Deal activities, through which it is planned to mobilize at least 1,000 billion Euros in the current and next decade (European Commission, 2020).

Apart from the policy-related mechanisms for achieving more significant investments in renewable energy, one of the ways of financing is possible through the capital markets. The great interest and increasing investment in renewable energy sources as a substitute for fossil fuels has encouraged researchers to investigate and examine potential relationships between these variables. Crude oil is the most common fossil fuel used to generate energy (Wu & Chen, 2019). Hence, changes in the crude oil market may lead to changes and oscillations in many markets, including renewable energy stock markets, and vice versa.

After the introduction and a literature review, the article is organized into the following sections: the research design and methodology section, followed by the results and discussion section. We focus on the importance of the results we obtained before we conclude.

Literature Review

Clarifications on the relationship between the price of (crude) oil as the most important representative of non-renewable energy and the price of stocks on traditional stock markets have been analyzed in several studies (Arouri & Nguyen, 2010; Broadstock, Cao & Zhang, 2012; Naser & Rashid, 2018; Shao et al., 2021; Yilanci, Özgür & Altinsoy, 2022).

In their research, Naser and Rashid (2018) find that crude oil is one of the most critical production factors and that any increase in the price of crude oil will lead to a rise in production costs. These higher costs will be passed on to consumers through higher product prices. Inflationary pressures will reduce aggregate demand, including investment spending and final consumption, leading to a slowdown in overall economic activity. According to this approach, the stock market will react oppositely to changes in crude oil prices.

Oil prices can affect stock markets through the principle of cash flow discounting (Arouri & Nguyen, 2010). The cost of any asset/liability is determined by the discounted value of the expected future cash flows associated with that asset. Therefore, it should be expected that any factor that could affect the discounted value of the assets' cash flows could significantly impact the price of that asset/liability. From the producer's perspective, any increase in oil prices should result in a fall in stock prices because higher oil prices would increase production costs, which would result in a decrease in company earnings, and this would reduce the value of the company that investors evaluate when making investment decisions (Shao et al., 2021).

Another channel through which oil prices could potentially affect the financial markets in general, especially the stock market, is the uncertainty created by oil price fluctuations and investors' expectations. Changes in inflation rates resulting from oil price shocks would cause an increase in uncertainty regarding future price variations, distort the signals that prices send, and thus reduce the efficiency of the entire economic and financial system (Yilanci, Özgür & Altinsoy, 2022).

The results of examining the relationship between crude oil future prices and renewable energy companies' stock prices are ambiguous.

Kumar, Managi, and Matsuda (2012) and Managi and Okimoto (2013) investigated the relationship between oil prices and clean energy firms. The authors hypothesize and show that the relationship between oil and alternate energy prices is positive because rising oil prices encourage substituting alternate energy sources for conventional energy sources (Kumar, Managi & Matsuda, 2012, p. 216). Research results from Dutta (2017), Ahmad (2017) & Xia et al. (2019) are also affirmative of these results, indicating a substitution relationship between oil and renewable energy (an increase in oil prices may lead to greater demand for renewable energy). They find that oil prices and returns on renewable energy stocks move in the same direction, which implies that the rise in oil prices leads to an increase in the stock prices of renewable energy companies. Zhao (2020) also finds that oil shocks positively impact the price movements of renewable energy stock indices.

Kocaarslan and Soytas (2019) examine the short and long-term relationship between oil prices and clean energy stock prices. As clean energy is considered a promising alternative to fossil fuels, oil prices are found to impact clean energy stock prices in the short term positively. In contrast, this relationship is reversed in the long run.

Similar conclusions are drawn from the early works of Henriques and Sadorsky (2008) and Sadorsky (2012), whose research examined the relationship between clean energy stock prices and oil prices, technology stock prices, and interest rates. Both studies find that all four variables have a statistically weak impact on clean energy stock prices; however, Sadorsky (2012) found that the correlation between clean energy stock prices and technology stock prices is higher than between clean energy stock prices and oil prices. Analyzing the relationship between oil prices and different renewable energy sectors, Pham (2019) and Lv, Dong, and Dong (2021) provide information on a solid heterogeneous relationship between oil prices and different renewable energy subsectors. Pham (2019, p. 356) indicates that biofuel and energy management stocks are the most connected to oil prices compared to other clean energy sectors.

Several other authors dealt with the relationship between oil prices and renewable energy stock prices in different market conditions and under changing investment structures. Dawar et al. (2021), examining the relationship between the West Texas Intermediate crude oil price index and three clean energy stock indices, concluded that when the market is bearish, there is a higher dependency of clean energy stock prices from crude oil prices and that during bullish markets, the dependence of pure energy stocks on crude oil prices decreases.

Using a nonparametric causality-in-quantiles approach, Shao et al. (2021) examine the causal relationship between oil price uncertainty and the returns and volatility of Chinese clean energy metal stocks and show that oil price uncertainty on stock returns mainly appears in bear markets.

Using the quantile autoregressive distributed lag approach of the US and Europe clean energy stock returns and oil prices, He et al. (2021) find, among other things, that the fluctuations in oil prices have a positive effect on clean energy stocks in higher quantiles. Maghyereh and Abdoh's (2021) research confirms the finding in the short term regarding the connectedness between oil supply shocks and the returns of clean energy firms being at the highest level for higher quantiles.

Similarly, using endogenous break tests and sub-sample estimation methods, Caporale, Spagnolo, and Almajali (2023) showed connectedness between fossil and renewable energy stock indices and market reaction to climate policy measures. Geng, Liu, and Zhang (2021) previously found that crude oil and European clean energy firms' stock returns system shows a dynamic, highly integrated degree.

The results of the academic research become more complex in the context of the possible differences and effects of oil prices on net oil exporting and importing countries. The study is primarily done to examine the relationship between Brent Crude oil prices and stock market indices in several oil-importing and exporting countries considering the impact of the Global Financial Crisis.

Creti, Ftiti and Guesmi (2014), in the examination of the monthly stock and oil prices from oil-importing (the US, Germany, Italy, the Netherlands, France) and exporting countries (United Arab Emirates, Kuwait, Saudi Arabia, and Venezuela) find that interdependence between the oil price and the stock market is more vital in exporters' than in the importers' markets. Authors conclude that oil shocks are more persistent in the long run in the importing countries than in the exporting countries. Similarly, in the analysis of the top ten oil-importing and top ten oil-exporting countries, Aydoğan, Tunç and Yelkenci (2017) find that the time-varying correlation of oil and stock prices for oil-importing countries is more pronounced than that for oil-exporting countries.

In the investigation of the interrelationship between Brent and West Texas Intermediate crude oil indices for the Nordic countries, Germany (oil importing) and Russia (oil exporting) countries, Bein and Mehmet (2016) find, among other things, that the two oil exporting countries (Norway and Russia) have higher integration with both oil indices.

Finally, a positive relationship between Brent crude oil price and the sustainability of stock returns has been examined and found in the works of Maraqa and Bein (2020). A higher correlation was found between sustainability stock indices and European oil-importing countries (UK, Germany, France, Italy, Switzerland, and The Netherlands). In comparison, oil-exporting countries (Norway and Russia) correlate more with the oil market. Again, for the sample of European countries, Ali (2022) confirms that sustainability stock indices have a more significant correlation with oil-importing countries than oil-exporting countries.

Research Design and Methodology

Bearing in mind the European strategic documents and the determination towards a more significant share of clean/renewable energy consumption, we wanted to examine the potential relationship between oil futures prices and the stock prices of the European renewable energy companies presented in the value of the ERIX index. This type of research has not yet been conducted for European renewable energy companies. Hence, as previous academic research regarding the direction of the potential relationship between the variables is not unanimous, our primary motive was to contribute to this study area. Furthermore, the most recent research using Diebold & Yılmaz (2014) methodology in the works of Caporale, Spagnolo, and Almajali (2023) tested connectedness and the possible presence of significant static and dynamic linkages between stocks issued for fossil fuels and renewable energy markets in the form of benchmark model comprising of several indices (ERIX index was included). Their results indicate that spillovers between the two sets of needs are sizeable. Finally, unlike available academic research, our analysis does not have other potential variables such as tech companies' indices, macroeconomic variables, the prices of gold, etc., in the investigation since we wanted to examine the sole relationship between the selected variables bearing in mind its potential significance at the level of (European) supranational economic policy implications. However, establishing only two variables also represents the most significant research limitation. Previously, an investigation of Brent oil spot price and global monetary policy uncertainty in the time-varying characteristics of net-oil exporting and net-oil importing countries showed heterogeneity in fluctuation range, fluctuation intensity, and stage in the works of Feng, Failler, and Li (2020).

Therefore, we set two research questions:

1. Is there a relationship between oil futures prices and the value of the ERIX index?
2. Is there a long-term relationship between oil futures prices and the value of the ERIX index?

Apart from descriptive statistics, the bivariate vector autoregressive model (VAR) was used. VAR is one of the most successful and flexible multivariate time series analysis models. VAR is an extension of the univariate autoregressive model (AR), which consists of one equation, to a dynamic multivariate time series model with a system of multiple equations (Zivot & Wang, 2003). The empirical part of the research has been done using Stata 13.

Due to the importance of Brent crude oil future prices in Europe and in academic research, it has been used to represent the price movement of non-renewable energy sources. Similarly, as a representative of renewable energy companies in Europe, the value of the ERIX index, which consists of the ten most significant and most liquid stocks from the list of eligible companies, was used. Provided by the Societe Generale and contracted with S&P Opco, LLC, the ERIX index tracks the performance of the European renewable energy companies that are active in either or several of the following six investment clusters: biofuels, geothermal, marine, solar, water, and wind. It is rebalanced every quarter and reviewed every six months (Caporale, Spagnolo & Almajali, 2023). Even though it is an index, the value of ERIX has been denominated in Euros since its introduction in 2005. For our analysis, the value of ERIX denominated in Euros has been converted to USD at the official weekly EUR/USD exchange rates.

We use a bivariate VAR model to analyze the existence of a relationship between Brent oil futures prices and the value of the ERIX index with the following equations:

$$BRENT_t = cons + \sum_{j=1}^{p} \beta_j BRENT_{t-j} + \sum_{j=1}^{p} \phi_j ERIX_{t-j} + u_{1t} \quad (1)$$

$$ERIX_t = cons + \sum_{j=1}^{p} \beta_j BRENT_{t-j} + \sum_{j=1}^{p} \phi_j ERIX_{t-j} + u_{2t} \quad (2)$$

The analysis covers eight years, from the beginning of 2015 to the end of 2022. The starting year of our research is 2015, primarily due to the undersigning of the currently most important legally binding international treaty on climate change, namely the Paris Agreement. As presented in the introduction section, the European Union has since 2015 intensified its activities to address the issues related to climate change. The data were collected weekly and contained information at the time of closing the stock exchanges every Wednesday, from 7 January 2015 until 28 December 2022, with a total of 416 observations. The reason for closing prices on Wednesdays is that there are fewer holidays and non-working days on Wednesdays than Fridays (Henriques & Sandorsky, 2008). All data is collected from the Investing (2023a; 2023b) website and is denominated in USD.

Figure 1 shows the weekly values of the ERIX index and Brent crude oil futures prices over the observed period.

The value of the ERIX index has been growing steadily since 2015 and reached peak values during the COVID-19 pandemic until early 2021, but afterward, it indicated greater volatility. Volatility can be observed in the value of Brent oil futures prices over the marked period, whereby prices plummeted due to the COVID-19 pandemic but reached the highest peak in 2022 due to the Russian-Ukrainian conflict and the outbreak of inflationary pressures.

Results and Discussion

We begin our analysis by presenting the results of descriptive statistics and a correlation coefficient, as presented in Table 1.

Table 1

Descriptive statistics and correlation coefficient for variables of interest

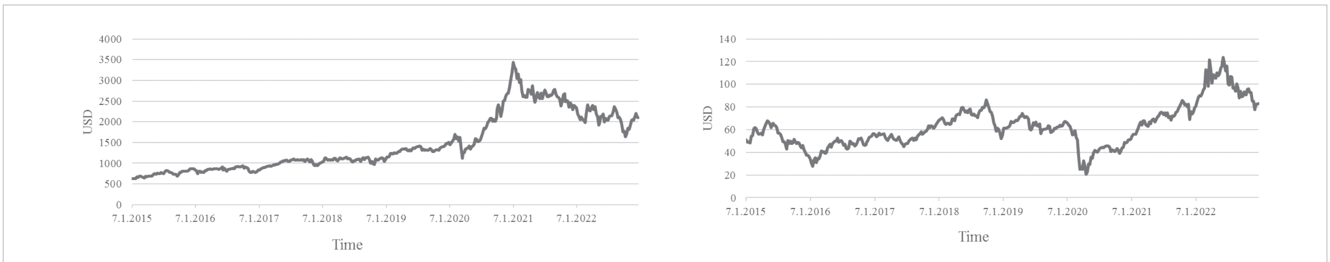
	ERIX	BRENT
Mean	1,455.07	62.74
Standard deviation	675.96	18.68
Min.	623.23	20.37
Max.	3,439.28	123.58
Correlation coefficient	0.4301	0.4301

Source: Authors

From Table 1, we can determine that the mean value of the ERIX index over the 2015-2022 period was 1,455.1 USD, with a standard deviation of almost 676 USD. The lowest value of the ERIX index amounted to 623.2 USD on 14 January 2015, while the highest price was 3,439.3 USD on 6 January 2021. Over 2015-2022, the mean value of Brent oil futures prices was 62.7 USD with a standard deviation

Figure 1

Weekly values of ERIX index (left) and Brent crude oil futures prices (right, 2015-2022)



Source: Authors, based upon Investing (2023a; 2023b) of 18.7 USD. The lowest price of 20.4 USD Brent oil futures was on 22nd April 2020, and the highest value of 123.6 USD was on 8th June 2022. The positive correlation coefficient between the ERIX index and Brent oil futures prices is 0.4301. These results are somewhat consistent with the findings of Kumar, Managi and Matsuda (2012), Managi and Okimoto (2013), Dutta (2017), and Ahmad (2017).

We estimated the VAR model based on equations (1) and (2) to test causal relationships between variables and answer our first research question. Before VAR estimation, we must test whether time series are stationary, so unit root tests have been deployed. The most common unit root tests are the Dickey-Fuller and the Philips and Perron tests, as presented in Table 2. The p-values of both tests are more significant than the 5% significance level, indicating that time series has a unit root; that is, they are not stationary.

Table 2

Unit root tests for ERIX and BRENT

Unit root tests	ERIX (level)		BRENT (level)	
	test statistic	p-value	test statistic	p-value
Dickey-Fuller test	-1.210	0.6693	-1.827	0.3672
Phillips and Perron test	-1.220	0.6648	-1.745	0.4079

Source: Authors

Results in Table 3 show the second essential criterion for VAR estimation is related to a number of lags, whereby the information criteria used to determine lags are Akaike (AIC), Schwartz Bayesian (SBIC), and Hannan and Quinn (HQIC).

The information criteria HQIC and SBIC suggest that one shift should be used in our model, while the criterion AIC suggests that 5 shifts should be used. Considering the number of our observations (416), we will use one lag, as indicated in the works of Ivanov and Kilian (2001).

Table 4 presents the results of the estimated VAR model.

The results in Table 4 indicate that the estimated VAR model is statistically significant (at a 1% significance level). The coefficient of determination (R2) is 0.9648 for the first equation, while for the second equation, it is 0.9890. From the first equation, we can determine that an increase in the Brent crude oil futures prices of one USD in the previous week leads to an increase in the oil futures price of 0.9754 USD in the current period. An increase in the value of the ERIX index by one USD in the previous week leads to an increase in the Brent oil futures prices of 0.00049 USD in the current period (at a 10% significance level). Similar methods and results may be found in the works of Kumar, Managi and Matsuda (2012) and Managi and Okimoto (2013).

From the second equation, an increase in the value of the ERIX index by one USD in the previous week leads to an increase in the value of the index of 0.997 USD in the current period.

The results in Table 4 also indicate that the average value of the residuals is close to zero. Graphical interpretation (not presented) of the residuals indicates that they were stable until the beginning of 2020 when the period of instability began, most likely due to the COVID-19 pandemic and the Russian-Ukrainian conflict. LM test for serial correlation (chi2=5.12; p-value=0.2473) indicates no autocorrelation in the residuals in the estimated model with one lag.

In Table 5, we present the results of Granger causality test.

From Table 5 and the upper panel of results, we can reject the null hypothesis of no causality from ERIX to BRENT at the 10% significance level. We cannot reject the null hypothesis of no causality from BRENT to ERIX from the lower panel at the 10% significance level. The latter finding implies that past values of Brent oil futures

Table 3

Information criteria results for number of lags

lag	*LL*	*LR*	*df*	*p*	*FPE*	*AIC*	*HQIC*	*SBIC*
0	-4958.2				1.30E+08	24.3745	24.3823	24.3942
1	-3399.4	3117.5	4	0	63491.3	16.7344	16.7578*	16.7935*
2	-3396.5	5.8161	4	0.213	63833	16.7398	16.7788	16.8383
3	-3394.2	4.7636	4	0.312	64342.9	16.7477	16.8023	16.8856
4	-3385.8	16.708	4	0.002	62981.4	16.7263	16.7965	16.9036
5	-3381.6	8.4831	4	0.075	62907.5*	16.7251*	16.8109	16.9418

Source: Authors

Table 4

Results of the estimated VAR model

Sample: 2015w2 - 2023w1			
Log likelihood	-3469.23	No. of observations	416
FPE	61826.58	AIC	16.70784
Det(sigma_ml)	60068.57	HQIC	16.73083
		SBIC	16.76598

Equation		Parms	RMSE	R-sq	chi2	P>chi2
BRENT		3	3.517	0.9648	11390.59	0.0000
ERIX		3	70.966	0.9890	37464.87	0.0000
		Coef.	Std. Err.	z	P>|z|	[95% CI]
BRENT	L1. BRENT	0.97544	0.01019	95.66	0.000	[0.95546 - 0.99543]
	L1. ERIX	0.00049	0.00028	1.74	0.081	[-0.00006 - 0.00104]
	cons	0.90252	0.61757	1.46	0.144	[-0.30789 - 2.11292]
ERIX	L1. BRENT	-0.30702	0.20575	-1.49	0.136	[-0.71027 - 0.09624]
	L1. ERIX	0.99739	0.00568	175.51	0.000	[0.98625 - 0.00853]
	cons	26.56301	12.46123	2.13	0.033	[2.13945 -50.98657]

Descriptive statistics of residuals	Mean	St. Dev.	Min	Max
	-2.85E-08	70.7948	-282.112	259.6688
Langrage-multiplier test (LM)	lag	chi2	df	prob>chi2
	1	5.4151	4	0.2473

Source: Authors

prices do not contain useful information for predicting future movements in the ERIX index. Economically, it suggests that changes in Brent oil futures prices do not cause Granger-caused changes in the ERIX index. The lack of Granger causality means that historical oil prices may not provide reliable signals for anticipating changes in the value of the ERIX index. For the stock and oil market participants, this implies a need for caution in relying on historical oil prices to predict the value of ERIX index movements, potentially leading to adjustments in trading and risk management strategies.

Table 5

Granger causality test for variables of interest

Equation	Excluded	chi2	df	Prob>chi2
BRENT	ERIX	3.0445	1	0.081
BRENT	ALL	3.0445	1	0.081
ERIX	BRENT	2.2266	1	0.136
ERIX	ALL	2.2266	1	0.136

Source: Authors

Using cointegration tests, our second research question examines the possible long-term relationship between future BRENT oil futures prices and the ERIX index. Table 6 presents the results of the Johansen cointegration test. Our results are complementary to those of Kocaarslan and Soytas (2019).

The results indicate that the trace statistic for rank one is less than the critical value (2.4031<3.76), there is at least one cointegration, and that the long-term relationship between the importance of the ERIX index and Brent crude oil futures price exists. Cointegration suggests a stable long-term relationship between Brent oil futures prices and the value of the ERIX index. This means that, over time, these two variables move together so that any deviations from their long-term relationship are expected to be corrected. For market participants, this implies informed decision-making regarding investment strategies, risk management, and dynamic hedging, considering the long-term movements of these critical variables. Therefore, market participants may adjust their strategies to reflect this information, contributing to market efficiency.

VAR model results also showed a statistically significant relationship, meaning that past values of the ERIX index may be used to predict Brent crude oil future prices.

To test the possible existence of a long-term relationship between Brent oil futures prices and the ERIX index, we have deployed the Johansen cointegration test and showed that there is at least one cointegration, indicating a long-term relationship between the values of the ERIX index and Brent crude oil futures prices.

Our research limitations relate to the use of the time frame (2015-2022), possible further measurement of the impact of the Russian-Ukrainian conflict and inflationary pressures on the selected variables as representatives of the economic policy uncertainty measures. Furthermore, a research limitation might be examining the impact of only two variables (Brent crude oil and the value of the ERIX index). Hence, further research might include exploration of volatility by using the GARCH model, investigation of possible implications of other variables of interest, such as the tech companies' indices, stock market indices with differentiation between oil importing and exporting countries, macroeconomic indicators, the prices of gold and, most importantly, the possible impact that the European Green Deal Investment Plan financing activities could have on ERIX companies and the value of the ERIX index. Another research limitation relates to selecting the ERIX index, which selects only 10 European renewable energy companies without analyzing their financial performance.

Table 6

The results of the Johansen cointegration test

Trend: constant			Number of observations = 416		
Sample: 2015w2 - 2023w1			Lags = 1		
maximum rank	parms	LL	Eigenvalue	Trace statistic	5% critical value
0	2	-3473.98	.	9.4921	15.41
1	5	-3470.43	0.01690	2.4031*	3.76
2	6	-3469.23	0.00576		

** Indicates the rejection of the null hypothesis at a 5% level.*
Source: Authors

Conclusion

This paper examined the potential relationship between Brent oil futures prices and the ERIX index. After the overview of the European legislation and the most recent literature review on the topic, our analysis included a bivariate VAR estimation model on weekly data over eight years (2015-2022). Our results indicated a positive correlation between Brent crude oil futures prices and the ERIX index. The estimated bivariate

References

Abdić, A., Abdić, A., & Rovčanin, A. (2023). Izazovi upravljanja robnim rizikom u doba energetske krize. *Business Consultant / Poslovni Konsultant, 14* (127), 6-22.

Ahmad, W. (2017). On the dynamic dependence and investment performance of crude oil and clean energy stocks. *Research in International Business and Finance*, *42*, 376-389. DOI: https://doi.org/10.1016/j.ribaf.2017.07.140

Ali, M. (2022). Nonlinear Spillover and Dynamic Connectedness Between International Crude Oil and Dow Jones Islamic Market. *Economics and Business Quarterly Reviews*, *5*(3), 82-89. DOI: 10.31014/aior.1992.05.03.438

An, H., Razzaq, A., Haseeb, M., & Mihardjo, L. W. (2021). The role of technology innovation and people's connectivity in testing environmental Kuznets curve and pollution heaven hypotheses across the Belt and Road host countries: new evidence from Method of Moments Quantile Regression. *Environmental Science and Pollution Research*, *28*, 5254-5270. DOI: https://doi.org/10.1007/s11356-020-10775-3

Arouri, M. E. H., & Nguyen, D. K. (2010). Oil prices, stock markets and portfolio investment: Evidence from sector analysis in Europe over the last decade. *Energy policy*, *38*(8), 4528-4539. DOI: https://doi.org/10.1016/j.enpol.2010.04.007

Aydoğan, B., Tunç, G., & Yelkenci, T. (2017). The impact of oil price volatility on net-oil exporter and importer countries' stock markets. *Eurasian Economic Review*, *7*, 231-253. DOI: https://doi.org/10.1007/s40822-017-0065-1

Bein, M. A., & Mehmet, A. G. A. (2016). International crude oil price and stock markets: Evidence from the Nordic and other European oil importing and oil exporting countries. *Romanian Journal of Economic Forecasting*, *19*(4), 115.

Broadstock, D. C., Cao, H., & Zhang, D. (2012). Oil shocks and their impact on energy related stocks in China. *Energy Economics*, *34*(6), 1888-1895. DOI: https://doi.org/10.1016/j.eneco.2012.08.008

Caporale, G. M., Spagnolo, N., & Almajali, A. (2023). Connectedness between fossil and renewable energy stock indices: The impact of the COP policies. *Economic Modelling*, *123*, 106273. DOI: https://doi.org/10.1016/j.econmod.2023.106273

Carella, C. (2020). *Renewable Energy in the European Union - Florence School of Regulation*. Retrieved from: https://fsr.eui.eu/renewable-energy-in-the-european-union/

Creti, A., Ftiti, Z., & Guesmi, K. (2014). Oil price and financial markets: Multivariate dynamic frequency analysis. *Energy policy*, *73*, 245-258. DOI: https://doi.org/10.1016/j.enpol.2014.05.057

Dawar, I., Dutta, A., Bouri, E., & Saeed, T. (2021). Crude oil prices and clean energy stock indices: Lagged and asymmetric effects with quantile regression. *Renewable Energy*, *163*, 288-299. DOI: https://doi.org/10.1016/j.renene.2020.08.162

Diebold, F. X., & Yılmaz, K. (2014). On the network topology of variance decompositions: Measuring the connectedness of financial firms. *Journal of econometrics*, 182(1), 119-134. DOI: https://doi.org/10.1016/j.jeconom.2014.04.01

Dutta, A. (2017). Oil price uncertainty and clean energy stock returns: New evidence from crude oil volatility index. *Journal of Cleaner Production*, *164*, 1157-1166. DOI: https://doi.org/10.1016/j.jclepro.2017.07.05

European Commission. (2019). *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions - The European Green Deal*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2019%3A640%3AFIN

European Commission. (2020). *The European Green Deal Investment Plan and Just Transition Mechanism explained*. Retrieved from: https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_24

Directive (EU) 2018/2001. European Parliament and the European Council. *Directive (EU) 2018/2001 of 11 December 2018 on the promotion of the use of energy from renewable sources*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001

Directive 2001/77/EC. European Parliament and the European Council. *Directive 2001/77/EC of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market*. Retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2001L0077:20100401:EN:PDF

Directive 2009/28/EC. European Parliament and the European Council. *Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*. Retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:en:PDF

Directive 2018/2001. European Parliament and the European Council. *Directive 2018/2001 of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001

Regulation (EU) 2021/1119. European Parliament and the European Council. *Regulation (EU) 2021/1119 of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law')*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021R1119

Feng, Y., Xu, D., Failler, P., & Li, T. (2020). Research on the time-varying impact of economic policy uncertainty on crude oil price fluctuation. *Sustainability*, *12*(16), 6523. DOI: https://doi.org/10.3390/su12166523

Geng, J. B., Liu, C., Ji, Q., & Zhang, D. (2021). Do oil price changes really matter for clean energy returns? *Renewable and Sustainable Energy Reviews*, *150*, 111429. DOI: https://doi.org/10.1016/j.rser.2021.111429

He, X., Mishra, S., Aman, A., Shahbaz, M., Razzaq, A., & Sharif, A. (2021). The linkage between clean energy stocks and the fluctuations in oil price and financial stress in the US and Europe? Evidence from QARDL approach. *Resources Policy*, *72*, 102021. DOI: https://doi.org/10.1016/j.resourpol.2021.102021

Henriques, I., & Sadorsky, P. (2008). Oil prices and the stock prices of alternative energy companies. *Energy Economics*, *30*(3), 998-1010. DOI: https://doi.org/10.1016/j.eneco.2007.11.001

Investing.com (2023a). *Brent Oil Futures*. Retrieved from: https://www.investing.com/commodities/brent-oil (Accessed: 2.7.2023).

Investing.com (2023b*)*. *European Renewable Energy Total Return (ERIX)*. Retrieved from: https://www.investing.com/commodities/brent-oil (Accessed: 2.7.2023).

Ivanov, V., & Kilian, L. (2001). *A practitioner's guide to lag-order selection for vector autoregressions* (Vol. 2685). London: Centre for Economic Policy Research.

Jackson, P. (2007). *From Stockholm to Kyoto: A Brief History of Climate Change*. Retrieved from https://www.un.org/en/chronicle/article/stockholm-kyoto-brief-history-climate-change (Accessed: 16.7.2023).

Kocaarslan, B., & Soytas, U. (2019). Asymmetric pass-through between oil prices and the stock prices of clean energy firms: New evidence from a nonlinear analysis. *Energy Reports*, *5*, 117-125. DOI: https://doi.org/10.1016/j.egyr.2019.01.002

Kumar, S., Managi, S., & Matsuda, A. (2012). Stock prices of clean energy firms, oil and carbon markets: A vector autoregressive analysis. *Energy Economics*, *34*(1), 215-226. DOI: https://doi.org/10.1016/j.eneco.2011.03.002

Lv, X., Dong, X., & Dong, W. (2021). Oil prices and stock prices of clean energy: New evidence from Chinese subsectoral data. *Emerging Markets Finance and Trade*, *57*(4), 1088-1102. DOI: https://doi.org/10.1080/1540496X.2019.1689810

Maghyereh, A., & Abdoh, H. (2021). The impact of extreme structural oil-price shocks on clean energy and oil stocks. *Energy*, *225*, 120209. DOI: https://doi.org/10.1016/j.energy.2021.120209

Managi, S., & Okimoto, T. (2013). Does the price of oil interact with clean energy prices in the stock market? *Japan and the world economy*, *27*, 1-9. DOI: https://doi.org/10.1016/j.japwor.2013.03.003

Maraqa, B., & Bein, M. (2020). Dynamic interrelationship and volatility spillover among sustainability stock markets, major European conventional indices, and international crude oil. *Sustainability*, *12*(9), 3908. DOI: ttps://doi.org/10.3390/su12093908

Naser, H., & Rashid, A. (2018). Oil price shocks and stock market performance in the BRICs: some evidence using FAVAR models. *Economics Issues, 23*(2), 85-108.

Nouicer, A., Kehoe, A., Nysten, J., Fouquet, D., Hancher, L., & Meeus, L. (2020). *The EU clean energy package* (ed. 2020), European University Institute. Retrieved from: https://data.europa.eu/doi/10.2870/58299. DOI: doi:10.2870/58299

Pham, L. (2019). Do all clean energy stocks respond homogeneously to oil price? *Energy Economics*, *81*, 355-379. DOI: https://doi.org/10.1016/j.eneco.2019.04.010

Ritchie, H., Roser, M., & Rosado, P. (2020). *Energy.* Retrieved from: https://ourworldindata.org/energy

Rybár, R., Kudelas, D., & Beer, M. (2015). Selected problems of classification of energy sourc es - What are renewable energy sources? *Acta Montanistica Slovaca*, *20*, 172-180. DOI: https://doi.org/10.3390/ams20030172

Sadorsky, P. (2012). Correlations and volatility spillovers between oil prices and the stock prices of clean energy and technology companies. *Energy economics*, *34*(1), 248-255. DOI: https://doi.org/10.1016/j.eneco.2011.03.00

Shao, L., Zhang, H., Chen, J., & Zhu, X. (2021). Effect of oil price uncertainty on clean energy metal stocks in China: Evidence from a non-parametric causality-in-quantiles approach. *International Review of Economics & Finance*, *73*, 407-419. DOI: https://doi.org/10.1016/j.iref.2021.01.00

Tardi, C., Brown, J. R., & Velasquez, V. (2023). *What Is The Kyoto Protocol? Definition, History, Timeline, and Status*. Investopedia. Retrieved from https://www.investopedia.com/terms/k/kyoto.asp (Accessed: 15.9.2023).

United Nations Climate Change. (2022). *The Rio Conventions*, Retrieved from https://unfccc.int/process-and-meetings/the-rio-conventions (Accessed: 16.7.2023)

United Nations. (1972). *Report of the United Nations Conference on the Human Environment*. Retrieved from https://daccess-ods.un.org/tmp/2335596.82965279.html.

United Nations. (2022). *Marking the Kyoto Protocol's 25th anniversary*. Retrieved from https: //www.un.org/en/climatechange/marking-kyoto-protocol%E2%80%99s-25th-anniversary

Wu, X. F., & Chen, G. Q. (2019). Global overview of crude oil use: From source to sink through inter-regional trade. *Energy Policy*, *128*, 476-486. DOI: https://doi.org/10.1016/j.enpol.2019.01.022

Xia, T., Ji, Q., Zhang, D., & Han, J. (2019). Asymmetric and extreme influence of energy price changes on renewable energy stock performance. *Journal of Cleaner Production*, *241*, 118338. DOI: https://doi.org/10.1016/j.jclepro.2019.118338

Yilanci, V., Özgür, O., & Altinsoy, A. (2022). The Dependence of Clean Energy Stock Prices On The Oil And Carbon Prices: A Nonlinear Perspective. *Economic Computation and Economic Cybernetics Studies and Research*, *56*(2), 115-132. DOI: http://dx.doi.org/10.24818/18423264/56.2.22.08

Zhao, X. (2020). Do the stock returns of clean energy corporations respond to oil price shocks and policy uncertainty? *Journal of economic structures*, *9*, 1-16. DOI: https://doi.org/10.1186/s40008-020-00229-x

Zivot, E., & Wang, J. (2003). *Vector Autoregressive Models for Multivariate Time Series. In: Modelling Financial Time Series with S-PLUS.* Springer Science, 385-429. DOI: https://doi.org/10.1007/978-0-387-21763-5_11

Povezava med cenami nafte in cenami delnic evropskih podjetij za obnovljive vire energije: vektorska avtoregresijska analiza

Izvleček

Cilj tega članka je proučiti morebitno povezavo med cenami surove nafte Brent po terminskih pogodbah in indeksom evropskih podjetij za obnovljive vire energije. Po pregledu evropske zakonodaje in pregledu najnovejše literature na to temo je v članku uporabljena metoda vektorskega avtoregresijskega modela (VAR). Analiza vključuje tedenske podatke za obdobje osmih let (2015-2022). Naši rezultati kažejo na pozitivno korelacijo med terminskimi cenami surove nafte Brent in vrednostjo indeksa ERIX (European Renewable Energy Total Return). Ocenjeni bivariatni model VAR kaže na statistično značilno povezavo, kar pomeni, da je mogoče pretekle vrednosti indeksa ERIX uporabiti za dolgoročno napovedovanje prihodnjih cen surove nafte Brent. Glede na zadnje sistemske motnje na svetovnem trgu blaga bi bilo treba v prihodnjih raziskavah upoštevati daljše časovne vrste in morebitne povezave drugih makroekonomskih dejavnikov.

Ključne besede: obnovljiva energija, surova nafta Brent, terminske pogodbe, indeks ERIX, VAR