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Volatility and Spillover Effects between Central–Eastern European Stock Markets and Energy Markets: An Emphasis on Crisis Periods

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Abstract: The objective of this paper is to study the spillover effects between energy markets and stock markets with emphasis on the significant crisis periods of the last 15 years, the period of the financial crisis that officially started in 2008, the pandemic period, generically called COVID-19, and the recent confrontation in Eastern Europe. Understanding the volatility transmission mechanisms between the energy and capital markets and also from the energy markets back and the spillover effects that result is very important. We use multivariate GARCH models to highlight a spillover effect between energy commodities and equities in Central and Eastern Europe. The highest correlations are recorded for CEE stock markets with electricity and Brent, and the lowest for CEE stock markets with gas. The biggest symmetric shocks between energy and CEE stock markets occurred during the COVID-19 pandemic. In contrast, the biggest asymmetric shocks occurred during the financial crisis (for gas) and the Ukrainian invasion (for Brent). We also find that volatility is more sensitive to its lagged values in the marketplace than it is to new information. The impact and contagion of shocks caused by the oil market are greater than those of other energy markets.

Keywords: volatility; energy; stock markets; spillover; multivariate GARCH

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1. Introduction

The beginning of 2020 generated unprecedented shocks in both the energy and stock markets with the outbreak of the COVID-19 pandemic. In just a few weeks, many important companies listed on the stock exchange lost more than a third of their value and oil prices reached historic lows. The pandemic crisis caused a very high level of volatility in the markets, which led to a high level of uncertainty in the approach to finance at any level in society. Consequently, the geopolitical turmoil at the eastern borders of Europe caused unexplained shocks to energy markets. In a recent study, Sharif et al. [1] analysed the interdependence between the spread of COVID-19, oil price shocks, the stock market and geopolitical and economic uncertainty, with a focus on the US market. The combined shocks of the COVID-19 and oil volatility caused great sensitivity to the US stock market and the economy as a whole. These results were confirmed by Bekaert et al. [2], who studied how and why the financial crises of 2007 spread so violently across countries and economic sectors, and Syriopoulos et al. [3], who considered market reverberations to shocks, volatility transmission and spillover effects amidst the US and BRICS stock markets.

Of high importance is the understanding of the volatility transmission mechanisms between the energy and capital markets and also from the energy markets back and the spillover effects that result. These markets do not work independently in terms of these transmission mechanisms. Knowing the directions and degree of transmission of volatility following the application of econometric models, we want to be able to get closer to the ability to understand the markets, both the capital and energy markets, which operate to an unquantifiable extent due to human experiences and emotions, which are very difficult to predict, if not impossible. These unpredictable reactions with a particular impact on the markets were demonstrated by the pandemic crisis and even more so by the global East–West conflict at the edges of Europe.

A relevant study in the direction of understanding the transmission mechanisms of the spillover effects between different markets is that of Duan et al. [4], which deals with the dynamics of the spillover between traditional energy markets and emerging green energy markets with the implications for sustainable development. The study explores the spillover effects between China's traditional energy market and the emerging green markets and also the impact of the COVID-19 outbreak on these spillover effects. Taking into account a multitude of econometric models previously used in numerous studies, the authors conclude that the use of a combination of the vector autoregression model with time-varying parameters and the Diebold–Yilmaz spillover models (TVP-VAR-DY) is the right approach for their study. In order to provide a more precise comparison of structural and directional changes in spillover effects between markets, spillover networks were constructed before and after the pandemic of COVID-19. The principal conclusions that can be drawn from the study are that the spillover level between traditional energy and emerging green markets has obvious time-varying characteristics and that the green bond market was the largest spillover recipient in the network.

The present work aims to analyse the correlations and the covolatility spillover effects between main energies (oil, electricity and natural gas) and Central and Eastern European stock markets (proxied by the CETOP index). Energy resources are critical for the economic, social and environmental well-being of Central and Eastern European countries. They support industrial development, ensure comfortable living conditions, enhance energy security and contribute to the region's integration with broader European and global energy markets. We consider the commodity indexes chosen as of significant importance to the whole world. The indexes are the FTSE 350 Electricity Price Return Index, NYMEX Henry Hub Natural Gas Electronic Energy Future and ICE Brent Crude Energy Future c1. To examine this research hypothesis, we used the diagonal BEKK model, which was considered more reliable, according to Chang et al. [5]. Subsequently, we tested the robustness with non-linear combinations of univariate ARCH models (CCC-ARCH) in accordance with multiple studies addressing the issue of volatility spillovers between oil and stock markets that use the common econometric methodologies of the multivariate GARCH-type models [6–8]. Our results suggest the existence of covolatility spillover effects and are robust through the methods used.

A mixed and inconclusive empirical literature examines the relationship between energy prices and equity markets, with the prevailing relationship between oil prices and US stock markets [9]. However, our empirical work attempts to contribute to the existing literature in several ways. To the best of our knowledge, this is the first paper that deals with multivariate volatility between energy markets and CEE stock markets. Vrinceanu et al. [10] examine the exposure to the oil price risk of companies from the financial industry listed on stock exchanges from seven CEE countries from January 2010 to December 2019 using the GARCH model until December 2019 inclusive. We extend the empirical framework in terms of methodology (multivariate GARCH instead of univariate GARCH), variables (adding other energy markets, i.e., gas and electricity), sample (all industries instead of the financial industry) and period (up to December 2022, which includes recent international events). Moreover, the study focuses on the stock markets of Central and Eastern Europe, a region in which the focus was significantly reduced in the existing literature.

The structure of this paper is as follows. Section 2 provides the literature review. Section 3 explains the data and methodology. Section 4 reports the empirical results. Section 5 discusses the economic implications of the results. Finally, Section 6 concludes the paper.

2. Theoretical Background

In their paper, Lin et al. [11] point out the importance of the interaction between oil and stock markets, stating that it has become one of the most critical financial academic areas. In their study, a scientometric analysis of 1342 academic publications is considered. According to their results, this area experienced two development phases, with 2007 as the boundary, while many other subdivisions have emerged. Marin et al. [12] examine the broad literature on the dynamic association between oil prices and financial assets. They focus on the methodologies used to measure the dependence among oil prices, exchange rates, stock prices, energy markets and assets related to sustainable finance. One of their findings indicates that comovement and volatility analysis represents a promising area for further research in this field. Moreover, energy markets and assets related to sustainable finance represent, in their opinion, crucial trends in investigating dynamic comovements with oil prices.

On the other hand, Patel et al. [13] undertook a meta-literature review on the issue of financial market integration, covering 260 articles from 1981 to 2021. Their analysis consisted of a quantitative analysis of bibliometric citations and a qualitative analysis of content to identify primary research streams and propose directions for future research. Comovements and spillovers between commodities and financial markets represented one of the research directions. They consider integration among commodity and stock markets an underinvestigated topic, stating that comovements between oil and stock prices can be explored further, especially during extraordinary periods. The impact of changes in oil prices on integrations among financial markets is also found to be relatively underexplored by using asymmetric models or cyclical structures. They pose a future research question regarding the consistent integration (in the short and long term) between commodities and stock prices.

The financial crisis of 2008 and the COVID-19 pandemic severely affected both the energy and stock markets. Numerous scholarly articles and papers have addressed the subject of energy market volatility during economic and financial crises [14–16]. Energy market volatility is a subject of interest for public authorities, companies and households due to its direct impact on living costs and operating businesses [17]. Xu et al. [18], for example, show that in times of uncertainty, crude oil might serve, at least in the short term, as a hedging asset for underlying securities. An increasing number of works are coming to light dealing with the issue of volatility in the periods before and after the COVID-19 pandemic. Christopoulos et al. [19] show that the COVID-19 pandemic has impacted oil prices and volatility. Using the time-domain approach and the method used on frequency dynamics, Zhang and Hamori [20] study the connectedness between COVID-19, the crude oil market and the stock market, focusing on the returns and the volatility spillovers among these variables. Their findings showcase that the returns of IDEMVT, WTI and the three other stock indexes are not more closely connected with each other than the volatilities of these variables when using the time-domain approach. The method based on frequency dynamics shows that the return spillover mainly comes up in the short term. In contrast, the volatility spillover primarily occurs in the long term, consistent with the static analysis results.

Likewise, studying the spillover effects of volatility between stock and energy markets is a subject with increasing visibility. Oil, for example, has a major impact at the global level, being a fundamental resource for any component branch of the stock markets, thus impacting the economy as a whole. Numerous studies confirmed these causal shocks were confirmed over time [15,21–23]. Natural gas has also suffered moments of extreme volatility, sometimes inexplicable in known theoretical terms. The conflict between US and China, through their proxies Ukraine and Russia, caused more unexplained market volatility periods, shocks that caused further uncertainty in the human subconscious. Interconnectivity, global interdependence and the total lack of transparency regarding the world leadership structure cause shocks and periods of instability that will provide unlimited study material.

Xu et al. [16] investigated the dynamic asymmetric volatility spillover between oil and US/Chinese stock markets from 2007 to 2016. Their study uses intraday data of WTI future prices, the S&P 500 index and the Shanghai stock market composite index. Their results showcase the presence of asymmetric volatility spillovers between oil and stock markets, with bad volatility prevailing over good volatility for most of the period examined. The asymmetric generalised dynamic conditional correlation (AG-DCC) model is employed further to investigate the presence of asymmetric response to past shocks.

COVID-19 has influenced how oil, gas, electricity, etc., impact the global economy and the stock market in particular. In their work, Bouri et al. [24] present evidence of a fundamental shift in the structure and time-varying patterns of the return interdependence between various globally important assets (gold, crude oil, global equities, currencies and bonds) around the outbreak of the COVID-19 pandemic. These connections between the different analysed assets obviously impact both the political and the investment environment. The study results show that the interconnectivity structure between the assets above has changed, influencing both the global geopolitical and economic system and the interactions between assets at a particular level.

In their paper focused on spillovers between stock and energy markets during crises, Jebali et al. [14] compare the 2008 financial crisis and the COVID-19 pandemic crisis. The researchers examine the time-varying volatility spillovers between energy markets (crude oil and natural gas), the MSCI world stock market and regional stock markets equivalent to MSCI Emerging and MSCI Europe. The volatility spillovers are assessed based on the approach proposed by Diebold and Yilmaz [25], which is derived from a generalised vector autoregressive framework.

Another paper that focuses on analysing the time-varying volatility and spillover effects is the one published by Karali et al. [26]. They study these effects in crude oil, heating oil and natural gas. In their paper, the authors adopt the multivariate GARCH-BEKK model developed by Engle and Kroner [27] and modify it to include exogenous variables, like macroeconomic and major political and weather-related events, that might impact conditional volatility. The authors also enable asymmetric responses to random disturbances. Their results showcase the impact of asymmetric effects in both random disturbances and macroeconomic variables.

The third millennium, marked by the financial crisis of 2007 and the COVID-19 pandemic crisis, generated constant volatility in Central and Eastern Europe's stock markets and the global energy markets. The quantification of the measure in which the energy shock impacts this region of Europe becomes a need for the expression of the independence of the states in this much-tried part of the world. Our study tries to improve the understanding of how the stock market in Central and Eastern Europe is affected by the volatility of the energy market and vice versa—a necessary objective, given that the EU obliges its members to adopt fundamental energy production and consumption measures. Renewable energy is predicted to represent the future, but a rather distant future, compared to the EU's 2035 target of achieving zero carbon emissions.

The impact of the energy markets on the stock markets is a subject that has received particular attention from the academic and private sectors. The pandemic crisis has generated new studies regarding the interrelationship between these two markets. Still, the main focus is on the developed stock markets of the US, Europe or Asia and less on the markets located on the periphery of Europe. The focus is constantly on the strong actors and less on the emerging markets. This work wants to broaden the horizons of the specialised literature by studying the spillover effects between the Central and Eastern European markets and the global energy market.

A relevant study focusing on developed markets is that of Elgammal et al. [28]. The paper aims to present new evidence on the dynamic interrelationships, both at the return and volatility levels, between the global equity, gold and energy markets before and during the outbreak of the 2020 pandemic crisis. The authors use in their study the S&P Global Broad Market Stock Index (BMI), the S&P GSCI gold index and the S&P GSCI energy index over a period of time between 13 January 2015 and 15 May 2020, a time horizon that analysed only a fraction of the impact of COVID-19 on the world. The study applied a set of multivariate GARCH models to investigate the spillover in main returns and volatility, using the residual after controlling the main common drivers for the equity, gold and energy markets. The impact conclusions are that the transmission relationship of profitability and volatility has strengthened after the onset of the pandemic crisis, generating unprecedented fluctuations in energy prices. The results confirm bidirectional spillover effects between energy market returns as well as equity and gold market returns and unidirectional return transmissions from gold to equity markets, in accordance with our own study. Interesting results capture the attention of investors in the mentioned markets and less so that of investors active in markets from other less attractive regions.

This paper adds to the current literature by being the first to investigate the interactions between the Central–Eastern European equity markets and energy markets during and after the COVID-19 period. Our work also contributes to the financial markets literature by offering new evidence on the interactions between the regional financial sector and commodity markets bearing the economic brunt of the COVID-19 crisis and also past crises like the 2007 financial crisis.

3. Data and Methodology

In order to examine the volatility between several energy markets and CEE stock markets, we considered significant data and variables. The data consisted of daily closing prices of several variables from 2 January 2007 to 29 December 2022. Based on representative criteria, the variables were chosen in terms of the most used and most influential commodities nowadays. For CEE stock markets, we used an aggregated index that reflects the performance of the companies with the biggest market value and turnover within the area. In this respect, the variables analysed were the FTSE 350 Electricity Price Return Index (labelled "E" for the electricity market), NYMEX Henry Hub Natural Gas Electronic Energy Future (labelled "GAS" for the gas market), ICE Europe Brent Crude Electronic Energy Future (labelled "Brent" for the oil market) and the Central European Blue Chip Index (labelled "CETOP" for CEE stock markets). We considered this time frame for the data horizon because it comprises several international events that the world has experienced in the last two decades, the financial crisis (2007–2008), the Euro Sovereign Debt Crisis (2010–2012) with the golden age of gas consumption, the COVID-19 pandemic (2020) and the Ukrainian invasion (2022) that has sparked a global energy crisis. The daily prices were obtained from Refinitiv, and the daily return was computed in line with the existing literature [29] as a continuous compounding return using the following formula: $R_t = \ln(P_t/P_{t-1})$.

In accordance with the existing literature [29], both direct generalisations of the univariate models (diagonal BEKK) and a non-linear univariate ARCH model (CCC-ARCH) were employed. The benchmark was the diagonal BEKK model, known for its main advantages, whereas the CCC model was employed for robustness purposes.

The BEKK models of Baba et al. [30] and Engle and Kroner [27] require that the conditional variance matrices are positive definite and are viewed as over-parameterised models. For the BEKK model, the natural multivariate extension of the GARCH (1,1) model in Equation (1) is:

$$H_t = C'C + A'u_{t-1}u'_{t-1}A + B'H_{t-1}B \quad (1)$$

where C is a lower triangular matrix with $(n/(n+1)/2)$ parameters and A and B denote $(n \times n)$ matrices with $n = 2$ parameters each.

An alternative approach for creating a model which is easier to fit than the DVECH model is the Constant Correlation (or CC) model of Bollerslev [31].

4. Results

The descriptive statistics for daily return are reported in Table 1, suggesting that all variables record volatility and have a leptokurtotic distribution. In other words, extreme events are likely to occur, which is typical for financial time series. The unconditional non-normal distribution is not rejected by the Jarque–Bera statistics.

Table 1. Descriptive statistics.

	R_CETOP	R_E	R_GAS	R_ICE
Mean	−0.000111	8.40×10^{-5}	-7.81×10^{-5}	7.35×10^{-5}
Median	0.000000	4.84×10^{-5}	0.000000	0.000436
Maximum	0.103823	0.120248	0.332041	0.154487
Minimum	−0.128882	−0.122175	−0.229520	−0.308558
Std. Dev.	0.015210	0.013949	0.032917	0.023828
Skewness	−0.710404	−0.606533	0.415637	−1.003331
Kurtosis	14.11635	11.90458	9.712510	19.13711
Jarque–Bera	21743.10	13982.12	7920.262	45779.97
Probability	0.000000	0.000000	0.000000	0.000000
Sum	−0.462522	0.349206	−0.324655	0.305382
Sum Sq. Dev.	0.960981	0.808310	4.501106	2.358490
Observations	4155	4155	4155	4155

The preliminary analysis included the plotting of data for both prices (Figure 1a) and daily returns (Figure 1b). For the price series, several upside and downside trends and extreme values could be observed for globally impacting crises (i.e., the 2008 financial crisis and the 2020 pandemic crisis).

Given that the preliminary multivariate ARCH effects delivered the unsurprising result that the lack of ARCH was overwhelmingly rejected, we employed multivariate GARCH models. Given the presence of an extensive number of models in the existing literature, each with pros and cons, in this paper, we made use of the direct generalisations of the univariate models (diagonal BEKK) and non-linear combinations of univariate ARCH models (CCC-ARCH). The superiority of CC models is related to the fact that they deal with conditional correlations, either constant or dynamic [29]. The results for diagonal BEKK are reported in Table 2. The conditional variance parameters (i.e., GARCH coefficients) indicate high volatility persistence for all variables considered. The substituted coefficients are also estimated and reported in the last column, where we can observe that all mean estimated return shocks are positive, with the largest for Brent and the smallest for gas. Considering the significance of ARCH coefficients, the partial covolatility spillover effects can be calculated with the general formula $\alpha_{ii} \times \alpha_{jj} \times \varepsilon_{j,\,t-1}$. Several remarks could be made. First, there is a symmetry pattern for all pairs, given that the sign is positive for the spillover effects from any i to j. Second, the diagonal elements of matrix A are not similar; therefore, one can notice a diagonal pattern of spillover effect. Third, the highest magnitude difference of spillover effect is recorded for the pair gas with Brent (i.e., Brent is more impacted by gas than gas by Brent), and the lowest magnitude difference of spillover effect is recorded for the pair CETOP with electricity.

The plots of the conditional variances (main diagonal) and covariance (lower triangular), as well as conditional correlations (upper triangular) of the variables considered when using the diagonal BEKK model under the multivariate normal distribution, are depicted in Figure 2. It can be visually observed that gas and Brent exhibit higher conditional volatility, the largest spike being recorded for the Ukrainian invasion (gas), the COVID-19 pandemic (Brent and electricity) and the 2008 financial crisis (CETOP). The conditional covariance is time-varying and mostly positive, while one of the peaks is associated with the Ukrainian invasion for all pairs (highest for electricity with Brent). Regarding conditional correlation, a time-varying pattern was recorded, too, with positive and negative values.

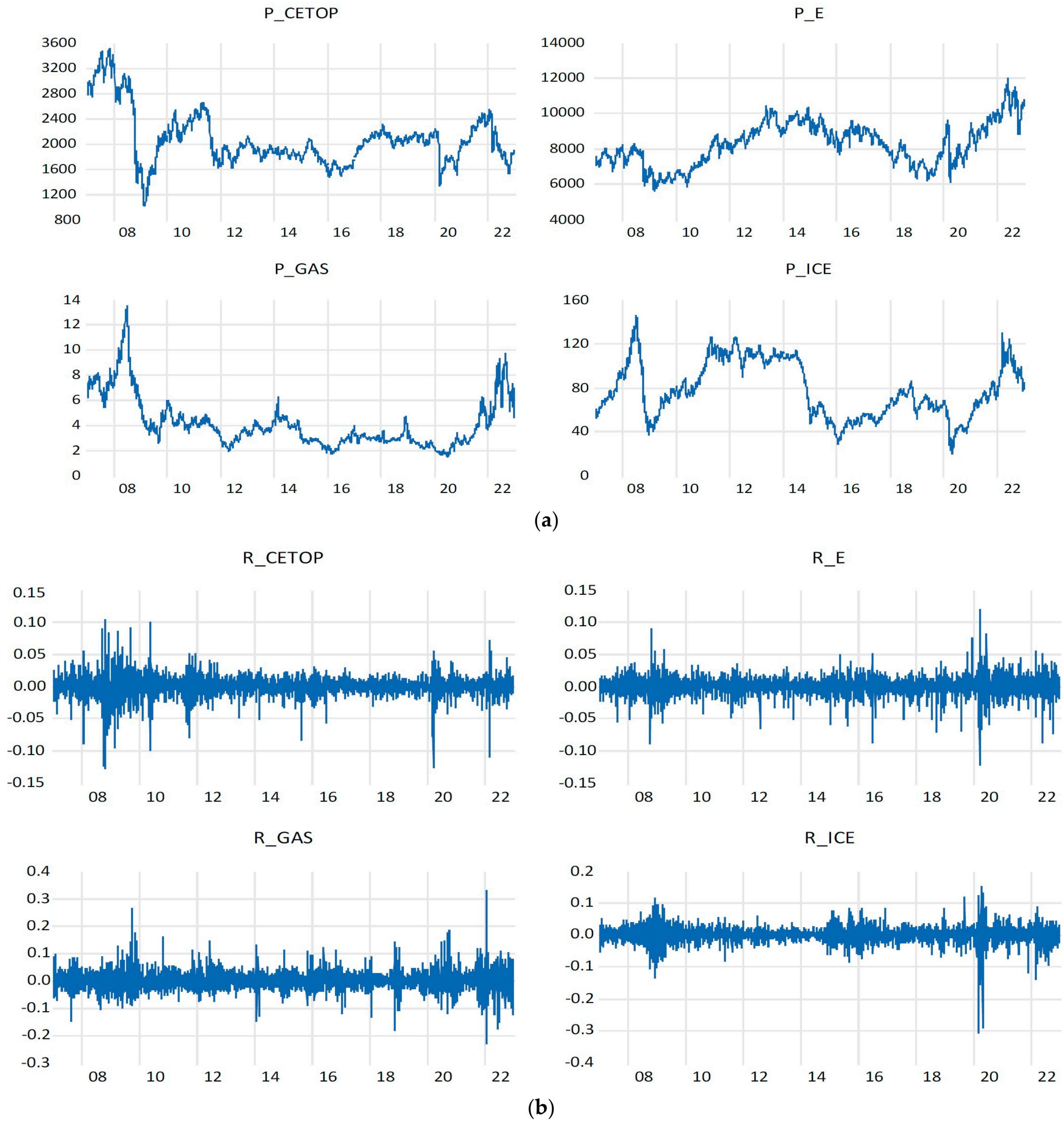

Figure 1. Daily plots of prices (**a**) and returns (**b**).

Table 2. Diagonal BEKK model results.

Variables	**A**	**B**	$\overline{\varepsilon}_i$
CETOP	0.219248 ***	0.969614 ***	0.000306
	(0.004851)	(0.001522)	
Electricity	0.19973 ***	0.967478 ***	0.000259
	(0.004674)	(0.00187)	
Gas	0.231872 ***	0.968164 ***	0.000171
	(0.007747)	(0.00207)	
Brent	0.275398 ***	0.956033 ***	0.000509
	(0.005574)	(0.002053)	

Notes: Robust standard errors in parentheses. A and B are the diagonal coefficient matrices for ARCH and GARCH; $\overline{\varepsilon}_I$ values are the substituted coefficients. *** $p < 0.01$, and the covariance coefficients are in Table 3.

Table 3. CCC GARCH model results.

Variables	A	B	A + B	$\bar{\varepsilon}_i$
CETOP	0.076864 ***	0.905139 ***	0.9820	0.000393
	(0.004699)	(0.005669)		
Electricity	0.095848 ***	0.83048 ***	0.9263	0.000336
	(0.007241)	(0.01103)		
Gas	0.082468 ***	0.913533 ***	0.9960	0.00026
	(0.005656)	(0.005439)		
Brent	0.098276 ***	0.889496 ***	0.9878	0.000661
	(0.004621)	(0.005599)		

Notes: Robust standard errors in parentheses. *** $p < 0.01$.

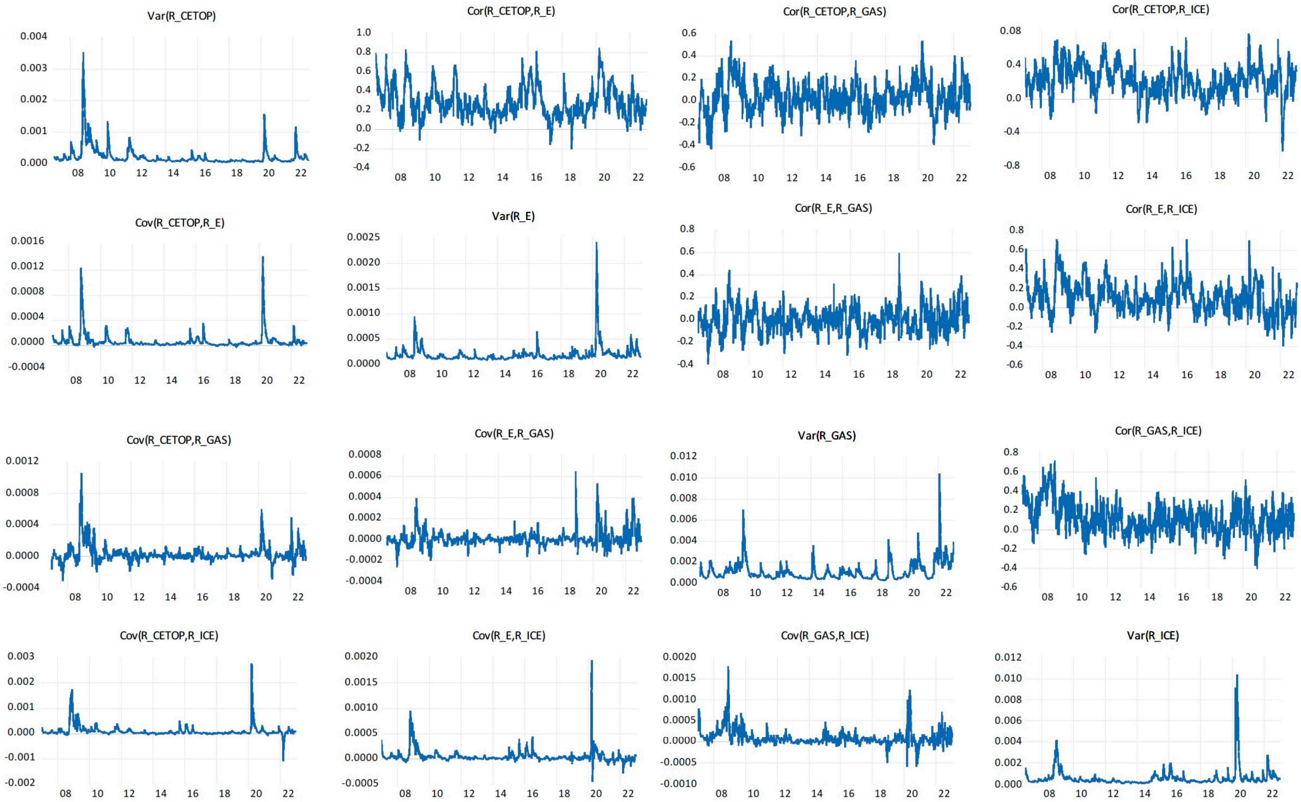

Figure 2. Covariance and correlation representation.

Next, for robustness purposes, the CCC model was used as an alternative method for the diagonal BEKK by reducing the number of parameters. The results are reported in Table 3, and one can argue that they support previous results in terms of both persistence and partial covolatility spillover effects.

When looking at the off-diagonal elements of H_t reported in Table 4, one can notice that conditional correlations are predominantly significant except for one pair: gas with electricity.

Table 4. Conditional correlation coefficients.

Variables	CETOP	Electricity	Gas	Brent
CETOP		0.312553 ***	0.038792 **	0.250814 ***
		(0.012055)	(0.016309)	(0.012941)
Electricity			0.010629	0.12904 ***
			(0.016158)	(0.014659)
Gas				0.13275 ***
				(0.015397)
Brent				

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$.

The table of correlation coefficients exposes the dependence situations between the CETOP index and all the analysed variables, with both maximum (with electricity, 0.31) and minimum values (with gas, 0.03). These results could be explained by the fact that several utility companies are also listed on stock markets. Therefore, both direct and indirect correlations could be recorded. Also, crude oil is correlated with both gas and electricity with a similar magnitude. The lack of dependence between gas and electricity can be observed and explained by the fact that both resources are generally used to ensure the amount of energy in similar fields (i.e., a substitution role for the heating process). Gas reserves and constant production have made this resource not disturbed by past major crises, like the 2007 financial crisis or the COVID-19 pandemic. Uncontrolled market movements due to the Eastern European conflict generated periods of extreme volatility.

5. Discussion

In this section, we discuss the policy implications of our econometric results by considering correlation structure and covolatility spillover effects.

Figure 2 shows the correlation between energy markets and CEE stock markets. On average, the highest correlations were recorded for CETOP with electricity and with Brent and the lowest correlation was recorded for CETOP with gas. The results are robust compared to those reported in Table 4.

For the pair of CETOP with electricity, the correlation range is between −0.18 (19 May 2017) and 0.82 (16 March 2020). For the pair of CETOP with Brent, the correlation range is between −0.61 (10 March 2022) and 0.77 (10 March 2020). For the pair of CETOP with gas, the correlation range is between −0.44 (29 June 2007) and 0.61 (6 March 2020). For all cases, one can notice that the biggest symmetric shocks between energy markets and CEE stock markets occurred during the COVID-19 pandemic period, whereas the biggest asymmetric shocks occurred during the financial crisis (for gas) and the Ukrainian invasion (for Brent). These results are in line with economic theory, given that oil has a close relationship with the macroeconomy, with a significant role in pricing and creating other energy markets.

For the pairs between energy markets, the least correlated is the pair electricity with gas, while the pairs with Brent have a similar level, 0.13 and 0.13, respectively. The correlation for the pair electricity with gas ranges between −0.38 (13 August 2007) and 0.52 (16 November 2018). For electricity with Brent, the correlation ranges between −0.34 (2 March 2022) and 0.70 (30th June 2016). For gas with Brent, the correlation ranges between −0.39 (4 April 2020) and 0.73 (2 September 2008). Once again, all energy markets exhibited big asymmetric shocks during major events.

Tables 2 and 3 report the volatility patterns and partial covolatility spillover effects using the diagonal BEKK model and CCC model, respectively. In terms of volatility, GARCH coefficients indicate high volatility persistence for all variables considered. In other words, volatility is more sensitive to its lagged values in the marketplace than it is to new information. In terms of the pair relationship of markets, one can notice that the pattern remains robust for both multiplicity and signs. The covolatility spillover effect is positive for all pairs considered. These values could be used for optimal hedging ratios, given that it is not recommended to combine two assets when covolatility is positive. The impact and contagion of shocks caused by the oil market are greater than the shocks of other energy markets. The economic interpretation of these shocks is related, on the one hand, to the fact that gas and electricity markets are smaller and, on the other hand, to the existence of derivative contracts for these two markets.

6. Conclusions

Europe has forced itself in the past years to embrace green energy as soon as possible. Our present and foreseeable future still holds Europe "enslaved" in conventional energy sources for its needs. Thus, energy prices and the volatility they exhibit are essential when looking for economic growth and portfolio management for professionals. In this paper, we analysed the relationship between energy markets and stock markets. Using daily data from 1 January 2007 to 31 December 2022, we highlight a spillover effect between energy commodities and equities in Central and Eastern Europe. The results can have implications for investors, policymakers and academics alike. Fiscal policy and investors' reactions to these policies, combined with the events in the stock and energy markets, are the most critical aspects of these implications. The subject of gas deserves greater attention and detailed analysis in the future in the academic environment. There is a need to recalibrate global priorities regarding the share of renewable energy consumption to the detriment of the usual ones. Most of the time, their costs have no economic justification because their global spread is a low percentage of the total energy production. A single "green" continent lacking energy "power" cannot make a difference globally.

The results of this work can impact the decisions of political factors and investors. These decisions are increasingly complex and challenging to take in the context of the continuous global crises of the last 15 years. From the political perspective, these relationships of interconnectivity between the capital and energy markets generate new fiscal policies with multiple consequences. Governments can support long-term investments with a view to sustainable development but with immediate negative consequences for the population, or they can print money indiscriminately, money used to support ordinary citizens to the detriment of sustainable development, for the benefit of immediate consumption, this second policy having been almost unanimously adopted globally during the recent COVID-19 crisis. Also, investors can use these results for portfolio management and hedging operations, their actions taking into account the correlation with the decisions of political factors and major fiscal decisions having an immediate impact on the stock markets. At the same time, it is possible to consider the choice of one of the commodities to the detriment of the other, for hedging activities, with gas being able to have a better position for such investment strategies due to the different volatility its impact has on the global economy compared to, for example, crude oil.

It is worth mentioning that our results should be interpreted with prudence, since certain limitations could be mentioned. Therefore, it could be extended by considering methodologies that examine full volatility/covolatility spillovers as well as by considering the sensitivity to proxies used for CEE stock markets.

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References

1. Sharif, A.; Aloui, C.; Yarovaya, L. COVID-19 pandemic, oil prices, stock market, geopolitical risk and policy uncertainty nexus in the US economy: Fresh evidence from the wavelet-based approach. *Int. Rev. Financ. Anal.* **2020**, *70*, 101496. [CrossRef]
2. Bekaert, G.; Ehrmann, M.; Fratzscher, M.; Mehl, A. The global crisis and equity market contagion. *J. Financ.* **2014**, *69*, 2597–2649. [CrossRef]
3. Syriopoulos, T.; Makram, B.; Boubaker, A. Stock market volatility spillovers and portfolio hedging: BRICS and the financial crises. *Int. Rev. Financ. Anal.* **2015**, *39*, 7–18. [CrossRef]
4. Duan, X.; Xiao, X.; Ren, X.; Taghizadeh-Hesary, F.; Duan, K. Dynamic spillover between traditional energy markets and emerging green markets: Implications for sustainable development. *Resour. Policy* **2023**, *82*, 103483. [CrossRef]
5. Chang, C.L.; Liu, C.P.; McAleer, M. Volatility spillovers for spot, futures, and ETF prices in agriculture and energy. *Energy Econ.* **2019**, *81*, 779–792. [CrossRef]
6. Hammoudeh, S.; Yuan, Y.; Chiang, T.; Nandha, M. Symmetric and asymmetric US sector return volatilities in presence of oil, financial and economic risks. *Energy Policy* **2010**, *38*, 3922–3932. [CrossRef]
7. Guesmi, K.; Fattoum, S. Return and volatility transmission between oil prices and oil-exporting and oil-importing countries. *Econ. Model* **2014**, *38*, 305–310. [CrossRef]
8. Kang, S.H.; Mclver, R.; Yoon, S.-M. Dynamic spillover effects among crude oil, precious metal, and agricultural commodity futures markets. *Energy Econ.* **2017**, *62*, 19–32. [CrossRef]
9. Zolfaghari, M.; Ghoddusi, H.; Faghihian, F. Volatility spillovers for energy prices: A diagonal BEKK approach. *Energy Econ.* **2020**, *92*, 104965. [CrossRef]
10. Vrinceanu, G.; Horobet, A.; Popescu, C.; Belascu, L. Financial industry and oil price volatility: An analysis on Central and Eastern Europe. In *The Changing Financial Landscape. Contributions to Economics*; Karanovic, G., Polychronidou, P., Karasavvoglou, A., Eds.; Springer: Cham, Switzerland, 2021; pp. 41–63.
11. Lin, B.; Su, T. Mapping the oil price-stock market nexus researches: A scientometric review. *Int. Rev. Econ. Financ.* **2020**, *67*, 133–147. [CrossRef]
12. Marín-Rodríguez, N.J.; González-Ruiz, J.D.; Botero Botero, S. Dynamic co-movements among oil prices and financial assets: A scientometric analysis. *Sustainability* **2022**, *14*, 12796. [CrossRef]
13. Patel, R.; Goodell, J.W.; Oriani, M.E.; Paltrinieri, A.; Yarovaya, L. A bibliometric review of financial market integration literature. *Int. Rev. Financ. Anal.* **2022**, *80*, 102035. [CrossRef]
14. Jebali, I.; Kouaissah, N.; Arouri, M. Volatility spillovers between stock and energy markets during crises: A comparative assessment between the 2008 global financial crisis and the Covid-19 pandemic crisis. *Financ. Res. Lett.* **2022**, *46*, 102363. [CrossRef]
15. Wen, X.; Wei, Y.; Huang, D. Measuring contagion between energy market and stock market during financial crises: A copula approach. *Energy Econ.* **2012**, *34*, 1435–1446. [CrossRef]
16. Xu, W.; Ma, F.M.; Chen, W.; Zhang, B. Asymmetric volatility spillovers between oil and stock markets: Evidence from China and the United States. *Energy Econ.* **2019**, *80*, 310–320. [CrossRef]
17. Min, H. Examining the Impact of Energy Price Volatility on Commodity Prices from Energy Supply Chain Perspectives. *Energies* **2022**, *15*, 7957. [CrossRef]
18. Xu, S.; Du, Z.; Zhang, H. Can Crude Oil Serve as a Hedging Asset for Underlying Securities? Research on the Heterogenous Correlation between Crude Oil and Stock Index. *Energies* **2020**, *13*, 3139. [CrossRef]
19. Christopoulos, A.G.; Kalantonis, P.; Katsampoxkis, I.; Vergos, K. COVID-19 and the energy price volatility. *Energies* **2021**, *14*, 6946. [CrossRef]
20. Zhang, W.; Hamori, S. Crude oil market and stock markets during the COVID-19 pandemic: Evidence from the US, Japan and Germany. *Int. Rev. Financ. Anal.* **2021**, *74*, 101702. [CrossRef]
21. Hamilton, J.D. What is an oil shock? *J. Econom.* **2003**, *113*, 363–398. [CrossRef]
22. Hammoudeh, S.; Dibooglu, S.; Aleisa, E. Relationships among US oil prices and oil industry equity prices. *Int. Rev. Econ. Financ.* **2004**, *13*, 427–453. [CrossRef]
23. Ji, Q.; Zhang, H.-Y.; Geng, J.-B. What drives natural gas prices in the United States?—A directed acrylic graph approach. *Energy Econ.* **2018**, *69*, 79–88. [CrossRef]
24. Bouri, E.; Lei, X.; Jalkh, N.; Xu, Y.; Zhang, H. Spillovers in higher moments and jumps across US stock and strategic commodity markets. *Resour. Policy* **2021**, *72*, 102060. [CrossRef]
25. Diebold, F.X.; Yilmaz, K. Better to give than to receive: Predictive directional measurement of volatility spillovers. *Int. J. Forecast.* **2012**, *28*, 57–66. [CrossRef]
26. Karali, B.; Ramirez, O. Macro determinants of volatility and volatility spillover in energy markets. *Energy Econ.* **2014**, *46*, 413–421. [CrossRef]
27. Engle, R.F.; Kroner, F.K. Multivariate Simultaneous Generalized ARCH. *Econ. Theory* **1995**, *11*, 122–150. [CrossRef]
28. Elgammal, M.M.; Ahmed, V.M.A.; Alshami, A. Price and volatility spillovers between global equity, gold, and energy markets prior to and during the COVID-19 pandemic. *Resour. Policy* **2021**, *74*, 102334. [CrossRef]
29. Botoc, C. Univariate and Bivariate Volatility in Central European Stock Markets. *Prague Econ. Pap.* **2017**, *26*, 127–141. [CrossRef]

30. Baba, Y.; Engle, R.F.; Kraft, D.F.; Kroner, K.F. *Multivariate Simultaneous Generalized ARCH*; Department of Economics, University of California: San Diego, CA, USA, 1991.
31. Bollerslev, T. Modelling the Coherence in Short-Run Nominal Exchange Rates: A Multivariate Generalized ARCH Model. *Rev. Econ. Stat.* **1990**, *72*, 498–505. [CrossRef]