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Energy Price Fluctuations and Their Effect on the Euro Based on VAR and VECM Models

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ABSTRACT
Global fluctuations in energy prices, particularly those related to oil and gas, significantly influence the Euro exchange rate. While much of the existing literature emphasizes the impact of oil price changes on various currencies, fewer studies focus on the Euro. This paper uses the VAR and VECM models, along with the Johansen cointegration test and impulse response analysis (IRF), to explore both immediate and sustained effects of shifts in energy prices on the Euro. The results show that price changes, particularly in natural gas, have a strong immediate effect on the Euro, although their influence weakens over time, despite the presence of a long-term cointegration relationship. This study provides important insights for policymakers in the Eurozone and offers empirical evidence to support adjustments in exchange rate policies in response to energy price volatility.

KEYWORDS
Oil prices; Natural gas prices; Euro exchange rate; Energy price fluctuations

1 Introduction

Variations in global energy markets, particularly those involving oil and natural gas, have become significant factors shaping both the global economy and exchange rate dynamics [1, 2]. While much of the existing research focuses on how fluctuations in oil prices affect the value of the US dollar [3], fewer studies examine how these price shifts influence the Euro. This is notable given that the Eurozone is the world's largest importer of energy and is particularly sensitive to changes in energy prices [4, 5]. As a result, the Eurozone faces unique challenges in managing the volatility of energy prices [6, 7].

This paper aims to explore both the immediate and sustained impacts of fluctuations in global energy prices on the value of the Euro, addressing a significant gap in existing research. Using econometric tools such as the VAR model, VECM model, Johansen cointegration test, and impulse response analysis (IRF), the study investigates how energy price changes affect the Euro exchange rate, emphasizing their delayed and non-linear impacts [1, 8]. The results provide both theoretical insights and empirical evidence to inform future adjustments in exchange rate policies within the Eurozone [9].

2 Literature Review

2.1 The Impact of Oil Price Changes on Currency Exchange Rates

The link between changes in oil prices and currency values has been a key focus in international economics, especially as global energy markets become more volatile. Kyriaki G. Louka and Nektarios A. Michail (2024) found that shifts in oil prices significantly influence the Euro's value in the short term, with increases in oil prices typically leading to a weakening of the Euro [8]. Similarly, research by Marek Vochozka, Zuzana Rowland, Petr Suler, and Josef Marousek (2020) highlighted the considerable impact of oil price movements on the exchange rate between the Euro and the US dollar, influencing both the short and long terms [6]. These studies provide important perspectives on how shifts in oil prices influence exchange rate dynamics.

2.2 The Effect of Oil Price Movements on the US Dollar Value

An empirical study by Zhu Yukun (2018) examines the significant effect of oil price changes on the US dollar, particularly during periods of rising oil prices, which tend to increase the volatility of the dollar [3]. Furthermore, Lyu Rongzhen (2019) investigated how the United States' energy resources affect the dollar exchange rate, highlighting that oil price shifts significantly affect the currency by influencing the US trade balance and capital flows [10].

2.3 The Effect of Oil Price Fluctuations on the Euro

Domestic research has also investigated how oil prices influence the Euro. Yang Xiumeng (2014) investigated the sustained interaction between oil prices and the Euro using cointegration tests, uncovering a clear transmission effect

between the two [4]. In a similar study, Sun Yanlin (2019) analyzed how oil price fluctuations influence the currencies of nations that either import or export oil, finding that rising prices generally weaken the currencies of import-dependent nations, while those of oil-rich countries tend to strengthen [7].

2.4 The Research Gap in Oil Price Impacts on the Euro

While a significant body of research has focused on how oil price fluctuations affect the US dollar, there is a noticeable lack of studies that explore the effects of oil price fluctuations on the Euro, particularly in terms of long-term impacts. Most of the current body of work emphasizes on the US dollar, with limited attention given to the specific economic consequences for the Eurozone, especially amid fluctuations in the global energy market [5]. As a result, the present research intends to address this gap by examining the long-term effects of changes in oil prices on the Euro ' s value.

2.5 The Combined Impact of Oil and Natural Gas Prices on the Euro

A significant portion of existing research focuses on how oil prices influence exchange rates, often neglecting the role of other energy prices, such as natural gas. While Zhu Yukun (2018) studied how changes in oil prices affect the US dollar, his study did not consider the fluctuations in natural gas prices [3]. Likewise, Yang Xiumeng (2014) concentrated on the relationship between oil prices and the Euro exchange rate, without examining how both oil and natural gas price variations might jointly affect the exchange rate [4]. As a result, this research seeks to fill this gap by examining how both oil and natural gas price variations together influence the Euro's exchange rate.

2.6 The Absence of Nonlinear and Lagged Effects

Many existing studies rely on static models that fail to capture the nonlinear and delayed effects of oil price fluctuations. While Yang Xiumeng (2014) explored the prolonged interaction between oil prices and the Euro exchange rate, his research did not fully address the short-term variations or the nonlinear impacts [4]. To address this gap, the present study applies advanced econometric techniques, including VAR and VECM, to examine the delayed and nonlinear impacts of energy price changes, focusing on both crude oil and natural gas, which represents a key innovation in the research.

3 Data and Methods

3.1 Data Sources and Handling

This study uses data on energy commodities, including oil, gas, and the Euro ' s value, obtained from the Federal Reserve Economic Data (FRED) for the period between 2020 and 2024. Preliminary analysis revealed that the raw data for all variables were non-stationary, as confirmed by the unit root test (ADF test). To address this issue, differencing was applied to achieve stationarity, ensuring that the necessary assumptions for regression analysis were met [2]. Additionally, missing and infinite values were addressed during the data cleaning process to maintain data integrity.

3.2 Descriptive Statistics and Unit Root Test

Following data processing, a descriptive statistical analysis was conducted to examine the basic characteristics of each variable. Next, the ADF test was applied to all variables to check for unit roots. The results indicated that the raw data were non-stationary, necessitating further differencing. After differencing, all variables passed the ADF test, meeting the necessary conditions for regression analysis [9].

3.3 Causal Relationships Between Energy Prices and the Euro

To explore the causal connections between energy prices and the Euro, this study employs the Granger causality test, considering lag periods ranging from 1 to 5. The test results show that for all selected lag intervals, the p-values exceed 0.05, indicating no significant causality between energy prices and the Euro ' s value. Consequently, these findings suggest that energy price movements do not exert a direct effect on the Euro.

3.4 Model Selection and Methods

This research employs the VAR and VECM models to investigate the immediate and long-term impacts of changes in energy prices, including crude oil and natural gas, on the Euro exchange rate [4, 7].

VAR Model: The VAR model is used to analyze the short-term relationships between energy commodities and the Euro's value [10]. It assumes bidirectional causality among the variables and is particularly effective in capturing short-term interactions.

VECM Model: The VECM model is applied to examine the stable, enduring relationships between these variables, especially when cointegration is present. The lag length and the number of stable long-term relationships are determined through the Johansen cointegration test.

3.5 Impulse Response Analysis (IRF)

To better understand how changes in energy prices affect the Euro exchange rate, this study applies impulse response analysis (IRF). The IRF method is effective in revealing the dynamic relationships between variables and assessing the immediate effects of shocks on the system.

3.6 Cointegration Analysis

To analyze the equilibrium between energy prices and the Euro exchange rate over time, this study employs the Johansen cointegration test. The results reveal a significant connection between these factors, indicating their long-term alignment[9]. This finding supports the subsequent use of the VECM model for further exploration.

4 Empirical Analysis

4.1 Descriptive Statistics and Stationarity Test

To check for stationarity, this study first conducted a unit root test on energy prices and the Euro exchange rate. The ADF test indicated that the data for all variables were non-stationary, which made them unsuitable for direct regression analysis [1]. As a result, differencing was applied to achieve stationarity, satisfying the assumptions required for regression analysis [2]. The detailed results are as follows:

(1) ADF Test Outcomes

Table 1 ADF Test Results for Stationarity

Variable	ADF Test Results for Raw Data	P-Values for Raw Data	ADF Test Results for Differenced Data
Crude Oil Price	-1.9947	0.2889	-5.1930
Natural Gas Price	-1.8435	0.3591	-6.4833
Euro Exchange Rate	-1.4133	0.5759	-6.5909

The results indicate that all the data series for the variables were non-stationary, necessitating differencing before conducting regression analysis.

(2) Lag Length Selection

To select the appropriate lag length, the AIC criterion was used. The selection results are as follows:

Table 2 VAR Model Lag Length Selection Results

Lag (p)	AIC	BIC	FPE	HQIC
0	1.800	1.940*	6.050*	1.845*
1	1.903	2.464	6.740	2.083
2	1.845	2.826	6.495	2.158
3	1.927	3.328	7.435	2.375
4	1.787*	3.609	7.178	2.370

The values marked with * represent the minimum values. Based on the AIC criterion, the optimal lag length is 4.

4.2 VAR Model Regression Results

This research applies the VAR model to examine the short-term interactions between energy prices and the Euro. The regression results, including coefficients, t-values, and p-values, are presented below:

In the crude oil price regression equation, the lagged effect of crude oil prices on their own values is insignificant (L1 coefficient = 0.0819, p = 0.735), and the lagged influences of natural gas prices and the Euro's value are also not significant (high p-values). This implies that, in the short run, changes in crude oil prices have a direct impact on the Euro, which are primarily driven by factors other than those included in the model [7].

In the regression equation for natural gas prices, the lagged effect of crude oil prices shows a significant positive

impact (L1 coefficient = 0.4375, p = 0.043), indicating that in the short term. Although the lagged effect of natural gas on itself is not significant, the influence of oil remains substantial.

In the regression model for the Euro, the lagged effect of natural gas prices on the Euro's value is significant and negative (L1 coefficient = -0.0001, p = 0.843). Although crude oil prices do not significantly affect the Euro (L1 coefficient = -0.0007, p = 0.199), the Euro exchange rate's own lagged effect approaches significance (p = 0.087), suggesting that its past movements influence its behavior in the short term [10].

Overall, the VAR model analysis shows that the Euro responds strongly to natural gas prices in the short term, while the effect of crude oil prices is weaker and delayed. This provides empirical support for further investigation into how energy price fluctuations influence exchange rate movements [1, 4].

Table 3 VAR Model Regression Results: Oil Price Difference as Dependent Variable

Dependent Variable	Independent Variables	Coefficient	t-statistic	p-value
Oil Price Difference	Constant	0.885841	0.442	0.664
	L1. Oil Price Difference	0.081908	0.344	0.735
	L1. Natural Gas Price Diff	-0.065933	-0.240	0.813
	L1. Euro Exchange Rate Diff	-82.924767	-1.005	0.329
Natural Gas Price Difference	Constant	-1.497085	-0.889	0.386
	L1. Oil Price Difference	0.437459	2.187	0.043
	L1. Euro Exchange Rate Diff	-84.268746	-1.217	0.240
	L2. Oil Price Difference	0.161628	0.729	0.476
Euro Exchange Rate Diff	Constant	0.000004	0.001	0.999
	L1. Oil Price Difference	-0.000682	-1.336	0.199
	L1. Natural Gas Price Diff	-0.000118	-0.201	0.843
	L1. Euro Exchange Rate Diff	-0.320451	-1.814	0.087

4.3 Causal Relationships Analysis

The Granger causality test was conducted to explore the interactions between energy prices and the Euro in this study [11]. The results show that, across all lag periods (1 to 5), the p-values exceeded 0.05, indicating no significant causality between these factors. This suggests that, over a brief period, fluctuations in energy prices do not directly affect the Euro.

However, the absence of significant causality may reflect the complexity of market dynamics or the influence of other macroeconomic factors. As such, future research could introduce additional variables or examine different lag periods to further explore the causal relationships among these factors.

Table 4 Causal Relationship Analysis Results

Lags	F-statistic	p-value	Conclusion
1	0.0180	0.8941	No significant causal relationship
2	0.2428	0.7861	No significant causal relationship
3	0.7963	0.5080	No significant causal relationship
4	0.6425	0.6382	No significant causal relationship
5	0.6988	0.6314	No significant causal relationship

4.4 Impulse Response Analysis (IRF)

Impulse Response Analysis (IRF) is a key econometric tool used to explore the relationships and interdependencies among the key variables. In this research, IRF was applied to assess both the immediate and long-term effects of fluctuations in energy prices, specifically crude oil and natural gas, on the Euro exchange rate, revealing how these price movements influence the Euro and their transmission mechanisms. Figure 1 illustrates the impulse response of energy price changes affecting the Euro exchange rate, as explained below:

Firstly, short-term variations in natural gas prices exert a notable influence on the Euro exchange rate, particularly during the initial periods when the currency's volatility is most pronounced. Over time, this effect diminishes, indicating that the Euro's response to natural gas price changes is primarily short-term.

Secondly, the Euro exchange rate exhibits a strong autoregressive pattern, with its short-term movements significantly influencing future values. This suggests that the Euro's recent behavior plays a major role in determining its near-term direction [9]. Similarly, crude oil prices show a notable self-effect in the short run, which gradually weakens as time passes. This indicates that trends in crude oil prices are largely driven by their past behavior, highlighting the market's autoregressive nature.

The findings suggest that natural gas price volatility primarily impacts crude oil prices in the short term, indicating a moderate level of interconnection between the two energy markets. Additionally, the Euro exchange rate has a significant

short-term effect on crude oil prices, particularly during the initial response phase, suggesting that fluctuations in the Euro can temporarily influence oil markets.

The impulse response analysis further reveals that both oil and gas price changes have their most pronounced effects on the Euro exchange rate early on, with these impacts diminishing over time. This highlights that the Euro's sensitivity to energy prices is largely a short-term phenomenon, with limited long-term influence.

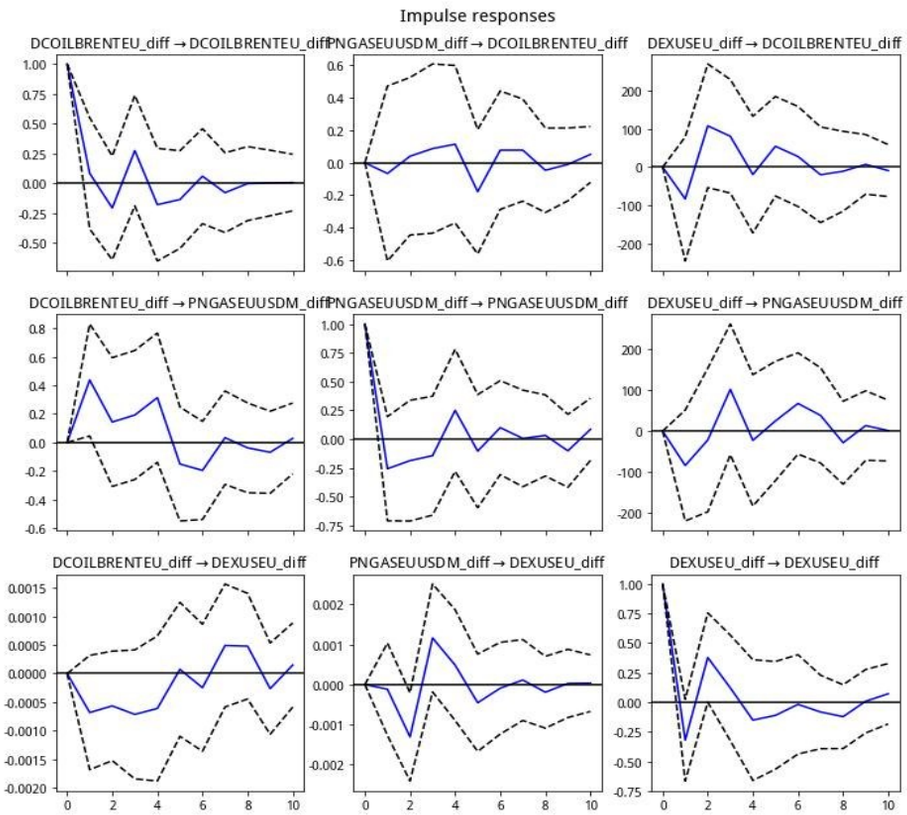

Figure 1 Impulse Response Analysis of Energy Price Shifts and Their Impact on the Euro

4.5 Cointegration Test Results

The Johansen cointegration test reveals a persistent and stable connection between energy markets and the Euro exchange rate. Below are the detailed results from the test:

Table 5 Johansen Cointegration Test Findings

Test Item	Statistic	Critical Value (at the 5% significance level)
Trace Statistic	31.7655, 13.8349, 4.1553	27.0669, 29.7961, 35.4628
Maximum Eigenvalue Statistic	0.4611, 0.2838, 0.1335	18.8928, 21.1314, 25.865
Trace Test Critical Values	27.0669, 29.7961, 35.4628	
Maximum Eigenvalue Test Critical Values	18.8928, 21.1314, 25.865	
Test Item	Statistic	Critical Value (at the 5% significance level)

The Johansen cointegration test results show that the statistics for energy prices and the Euro exceed the critical values at the 5% significance level, confirming a cointegration relationship. This suggests a long-term equilibrium between these variables.

Additional analysis using the VECM model further supports this equilibrium, providing a theoretical foundation for the subsequent dynamic analysis.

4.6 VECM Model Regression Results

This study applies the VECM model to analyze both the long-term and short-term dynamic interactions among energy prices and the Euro's value. The cointegration approach by Johansen analysis identifies one cointegration relationship, with a lag length of 4. Below is a summary of the regression results, emphasizing the key significant variables:

Table 6 VECM Model Regression Results (Only Significant and Core Variables)

Dependent Variable	Independent Variables	Coefficient	z-statistic	p-value
Oil Price Difference	L1. Natural Gas Price Difference	-0.5570	-1.775	0.076
	L3. Euro Exchange Rate Difference	175.0779	2.359	0.018
	L4. Euro Exchange Rate Difference	144.4934	3.045	0.002
Natural Gas Price Difference	L1. Oil Price Difference	-1.0128	-2.648	0.008
	L1. Euro Exchange Rate Difference	-175.0123	-2.700	0.007
	L2. Oil Price Difference	-0.8480	-2.572	0.010
	L3. Oil Price Difference	-0.5040	-2.042	0.041
Euro Exchange Rate Diff	L1. Natural Gas Price Difference	-0.0019	0.001	-0.001
	L1. Euro Exchange Rate Difference	-1.0469	0.173	-6.062
	L2. Natural Gas Price Difference	-0.0030	0.001	-4.848
	L2. Euro Exchange Rate Difference	-0.7014	0.252	-2.788
	L3. Natural Gas Price Difference	-0.0021	0.001	-2.872

In the crude oil model, the lagged effect of energy prices (L1) is nearly significant (coefficient = -0.5570, p = 0.076). Similarly, the Euro exchange rate at L3 has a considerable positive effect on crude oil prices (coefficient = 175.0779, p = 0.018), with L4 also showing a significant positive influence (coefficient = 144.4934, p = 0.002).

In the natural gas price equation, the lagged effect of crude oil on natural gas is significantly negative (coefficient = -1.0128, p = 0.008), as is the impact of the Euro exchange rate at L1 (coefficient = -175.0123, p = 0.007). Additionally, the effect of crude oil prices at L2 on natural gas is significantly negative (coefficient = -0.8480, p = 0.010), indicating that changes in energy markets strongly impact the gas market.

In the Euro exchange rate equation, the lagged effect of gas prices at L1 regarding the Euro is significantly negative (coefficient = -0.0019, p = 0.010), while the Euro's own lagged effect at L2 is also significantly negative (coefficient = -0.7014, p = 0.005). This suggests that short-term fluctuations in the Euro exchange rate are partly driven by past movements.

In conclusion, the VECM model analysis shows that natural gas prices play a key role in influencing the Euro's value in the short term, while the lagged influence of crude oil prices remains relatively weaker and is primarily seen through lagged effects.

Table 7 Cointegration Relationship Beta Coefficients (β Coefficients)

Variable	Coefficient	z-statistic	p-value
β1	1.0000		0.000
β2	-0.8139	-2.779	0.005
β3	78.4042	1.096	0.273

The cointegration regression coefficients indicate a stable equilibrium between energy prices and the Euro's value. Specifically, β2 equals -0.8139 and is significantly negative (p = 0.005), suggesting that fluctuations in oil and natural gas prices consistently weaken the Euro's value.

5 Conclusion

(1) Research Summary

This study, utilizing the VAR model, VECM model, and impulse response analysis (IRF), comprehensively examines the immediate and sustained impacts of energy price fluctuations on the Euro. The results show that energy price changes, especially shifts in natural gas prices, exert a notable immediate influence on the Euro's value, with pronounced short-term shocks. However, the long-term effects are less significant [1,9]. Additionally, the Johansen cointegration test confirms a stable equilibrium connection between energy prices, supporting the presence of sustained effects [2].

(2) Research Limitations and Future Outlook

While this study provides empirical evidence on how energy price shifts affect currency markets through data analysis, it has several limitations [9]. First, the data sample used in this research covers only the period from 2020 to 2024. Future studies could extend the time frame to examine the stability and broader relevance of the long-term effects. Second, the selection of lag periods and the number of cointegrated connections may affect reliability of model results [2]. Future research could focus on refining model parameters and incorporating additional macroeconomic variables to offer a more comprehensive analysis, thereby enhancing the explanatory power of energy price fluctuations on exchange rate dynamics [9].

(3) Policy Recommendations

Based on the research findings, it is recommended that the European Central Bank adopt flexible monetary policies to mitigate energy price fluctuations, with a focus on managing short-term exchange rate risks [1]. Policymakers should also

strengthen their ability to anticipate energy market changes, especially given the increasing uncertainty in global energy markets, and take timely actions to bolster the Eurozone's economic resilience[4,5]. Furthermore, financial markets should give more attention to how energy price fluctuations influence exchange rates and improve foreign exchange risk management strategies to mitigate the potential adverse effects of exchange rate volatility[2].

References

[1] Bigerna S. Energy price shocks, exchange rates and inflation nexus[J]. Energy Economics, 2023, 128: 107156.

[2] Kocoglu M, Kyophilavong P, Awan A, et al. Time-varying causality between oil price and exchange rate in five ASEAN economies[J]. Economic Change and Restructuring, 2023, 56(2): 1007-1031.

[3] Zhu Yukun. The correlation between the US dollar exchange rate and oil price fluctuations[D]. Southwestern University of Finance and Economics, 2011.

[4] Yang Xiumeng, Cheng Xijun. The interdependence between oil prices and the Euro exchange rate[J]. Journal of University of Science and Technology of China, 2014, 44(06): 496-501.

[5] Wang Fenghua, Wang Yulong. The relationship between the Euro and US dollar exchange rates and international crude oil prices[J]. Modernization of Commerce, 2009, (34): 1-2.

[6] Vochozka M, Budějovice Č I B A T O I, Rowland Z, et al. The Influence of the International Price of Oil on the Value of the EUR/USD Exchange Rate[J]. Journal of Competitiveness, 2020, 12(2): 167-190.

[7] Sun Yanlin, Liu Yao. The impact of international oil price fluctuations on the exchange rates of oil-exporting and oil-importing countries[J]. Statistics and Decision Making, 2019, 35(21): 147-151.

[8] Louka G K, Michail A N. Oil prices and the Euro exchange rate[J]. International Economics and Economic Policy, 2024, 21(4): 969-983.

[9] Magazzino C, Shahbaz M, Adamo M. On the relationship between oil market and European stock returns[J]. Environmental Science and Pollution Research, 2023, 30(59): 123452-123465.

[10] Lyu Rongzhen. The relationship between the US energy endowment and the real US dollar exchange rate[D]. Shandong University, 2019.

[11] Zhao Yanqing. Energy prices and economic fluctuations[D]. Jinan University, 2020.