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The Influence of the International Oil Price on the EUR/USD Exchange Rate

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Abstract

The study analyses the influence of the international oil price, focusing on the CBOE Crude Oil Volatility Index and Brent crude oil, on the main exchange rates: EUR/GBP, EUR/USD, GBP/USD, USD/CHF and USD/JPY. The analysis covers the period from 3 January 2022 to 8 December 2024 to examine the relationship between fluctuations in the oil market and the behaviour of exchange rates. The results show that the CBOE index directly impacts the EUR/GBP currency pair, reflecting the influence of global volatility on financial markets. The EUR/USD pair is influenced by the behaviour of the USD/JPY currency pair, showing the interconnection between the major currencies. Brent futures significantly affect the USD/CHF and USD/JPY currency pairs due to the importance of oil as a strategic commodity and the sensitivity of currencies such as the Yen and Swiss franc to fluctuations in energy prices. These relationships show the strong interconnectedness of global markets, highlighting the importance of informed risk management and decision-making strategies in interdependent environments.

Keywords: *CBOE Crude Oil Volatility, Exchange Rates, Movements, Volatility, Portfolio Rebalancing.*

Introduction

In recent years, global financial markets have been characterised by strong integration, which has increased their complexity and interdependence. As a result, these markets have faced several crises in recent decades, each marked by significant volatility and contagion effects (Hasanov et al., 2017). Energy prices, particularly oil, are among the most volatile assets in the financial markets. This extreme volatility makes energy prices a crucial macroeconomic element, capable of generating unstable economic conditions in the international economy. Continuous volatility, a measure of instability (Volkov & Yuhn, 2016), has attracted the attention of economists because evidence has suggested that economic crises and volatility are related phenomena (Teixeira et al., 2022).

The relationship between oil prices and foreign exchange markets has attracted growing interest due to its significant impact on global financial markets and on economies that depend on oil imports and exports. Oil price volatility is a key macroeconomic element, influencing both trade and financial flows and the stability of exchange rates, especially during global crises such as the COVID-19 pandemic and the conflict between Russia and Ukraine. Considered the world's main energy source, crude oil plays a vital role in international trade and finance, while exchange rates link domestic and foreign economies (Ben Salem et al., 2024).

Economists recognise that volatile oil prices can damage the economy and affect various macroeconomic indicators. The authors Czech and Niftiyev (2021) have shown that oil price volatility can infect the foreign exchange market, increasing exchange rate volatility (Donkor et al., 2022). For example, according to the nexus between oil prices and exchange rates, an increase in oil prices can cause currencies in oil-importing

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economies to depreciate, resulting in a transfer of returns from oil-importing to oil-exporting countries (Salisu et al., 2021). On the other hand, the exchange rate in oil-exporting countries can increase if oil prices rise (due to increased revenue).

The study's main objective is to analyse the influence of the international oil price on the main exchange rates. It will use two key oil market indicators to achieve this goal: the CBOE Crude Oil Volatility Index (which measures the implied volatility of crude oil futures prices) and the Brent crude oil price (one of the main global benchmarks for oil pricing). The study explores how variations in these indicators affect the EUR/GBP, EUR/USD, GBP/USD, USD/CHF and USD/JPY exchange rates, representing important currency pairs in the international financial markets. The analysis covers the period from 3 January 2022 to 8 December 2024, marked by significant economic and geopolitical events impacting the global energy and foreign exchange markets.

This study makes significant contributions to the existing literature. Firstly, it explores in detail the channels through which oil prices influence exchange rates, specifically considering the impact of oil price shocks on exchange rate volatility and adjustment mechanisms. Secondly, it incorporates the CBOE Crude Oil Volatility Index and Brent crude oil, with the main exchange rates: EUR/GBP, EUR/USD, GBP/USD, USD/CHF and USD/JPY. The analysis covers 3 January 2022 to 8 December 2024. This recent and specific time frame adds significant value to the literature by addressing the dynamics of global markets in a contemporary context marked by high economic and geopolitical uncertainty. Thirdly, another important contribution is the explicit incorporation of the role of speculative behaviour in oil prices, which amplifies exchange rate fluctuations. By observing that speculative oil price shocks disproportionately affect countries dependent on oil revenues, this study provides an in-depth view of the interaction between oil prices, financial systems and exchange rate volatility.

In terms of structure, this study is organised into 5 sections. In addition to this introduction, section 2 presents a state-of-the-art analysis of articles on integration in international financial markets, section 3 describes the methodology and section 4 contains the data and results. Section 5 presents the general conclusions of the work.

Literature Review

The relationship between oil price volatility and exchange rates is a central theme in the global economy, especially for understanding the interactions between financial markets and commodities in periods of instability. Oil, as one of the most traded assets in the world, plays a crucial role in economic dynamics, directly affecting production costs, trade flows and monetary policies in various economies. On the other hand, exchange rates reflect the balance between currencies and are a determining factor in international competitiveness and macroeconomic stability (Nam Li & Yeonho Lee, 2014; Reboredo et al., 2014; Vochozka et al., 2020; Lyu et al., 2021).

The studies by Reboredo (2012) and Hasanov et al. (2017) address the relationship between oil prices and exchange rates but from different perspectives and contexts. Reboredo (2012) uses correlations and copulas to analyse the dependence between these variables globally, revealing that the relationship is generally weak but intensifies after the global financial crisis, especially during economic instability. In contrast, Hasanov et al. (2017) focus on specific economies (Azerbaijan, Kazakhstan and Russia) and use the ARDL model to identify oil prices as a determining factor in the exchange rate valuation of these economies during 2004-2013. At the same time, Reboredo (2012) emphasises the absence of extreme dependence on oil and the exchange rate in a global scenario. Hasanov et al. (2017) show that oil prices significantly influence exchange rates in oil-exporting countries, reflecting the direct impacts of oil revenues on economies. These studies suggest that the impact of the oil-exchange rate relationship varies according to the context: weak and moderate globally but more pronounced and structural in economies highly dependent on oil exports.

The authors Anjum (2019), Salisu et al. (2021), and Czech and Niftiyev (2021) converge in investigating the relationship between oil prices and exchange rates, highlighting the different approaches and economic contexts. Anjum (2019) analyses the volatility transmission between oil prices and the US dollar exchange rate, identifying that considering structural breaks in the bivariate GARCH model is crucial to highlight the existence of significant volatility transmission. The focus is on the dynamics between the two variables from a global perspective, without differentiating between exporting and importing economies. Salisu et al. (2021) extend this approach by examining the predictability of exchange rate returns in BRICS countries, showing that oil prices are important predictors for net exporters (Brazil and Russia) and net importers (South Africa and China). Using a long-term perspective, the study emphasises the structural influence of oil on economies dependent on its exports or sensitive to fluctuations in their import costs (1973 to 2020). Czech and Niftiyev (2021) in turn, focus on specific oil-dependent economies, the countries of Azerbaijan and Kazakhstan, using the SVAR model to show that increases in oil prices lead to an appreciation of their currencies (MANAT and TENGE) and an increase in international reserves in Azerbaijan, with differentiated impacts between the two economies.

Later, the authors Donkor et al. (2022) and Umoru et al. (2023) analyse the relationship between oil price volatility and exchange rates, converging on the evidence that oil prices play a crucial role in exchange rate dynamics, although with different matrices in terms of context, methodology and periods analysed. Donkor et al. (2022) highlight the presence of bidirectional and unidirectional relationships between the volatility of oil prices and exchange rates in oil-dependent economies, which are more pronounced in the post-financial crisis period of 2008-2009. On the other hand, Umoru et al. (2023) confirm that fluctuations in oil prices directly affect the appreciation or depreciation of the currencies of 21 developing economies. Although exchange rate volatility has little impact on oil prices, there is a significant volatility transfer from oil to exchange rates. This relationship reinforces the role of oil as a determining factor in exchange rate dynamics, particularly in exporting countries. Ben Salem et al. (2024) deepen this relationship by investigating the movements between oil and the exchange rate during recent global crises, such as the COVID-19 pandemic and the Russia-Ukraine war. The authors show that the connectivity between the markets was more intense at the beginning of the crises, decreasing over time but with increased sensitivity of exchange rates to oil price shocks in periods of extreme instability. In practical terms, the studies confirm that oil is a key factor in exchange rate dynamics, transmitting significant volatility in different contexts. Donkor et al. (2022), and Umoru et al. (2023) emphasise that the connectivity and sensitivity between oil and exchange rates increase during periods of crisis, although the impact varies in intensity and duration. While Donkor et al. (2022) analyse the patterns of causality, Umoru et al. (2023) focus on the direct transmission of volatility and Ben Salem et al. (2024) highlight the persistence of connectivity in recent crises.

More recently, the authors Bigerna (2024), Belanès et al. (2024), Mo et al. (2024) analyse the interactions between oil markets, exchange rates and macroeconomic variables in different contexts and periods, highlighting the impact of recent external shocks such as the COVID-19 pandemic and the Ukraine crisis. Despite different approaches, there are significant convergences in terms of objectives, methodologies and implications. Bigerna (2024) examines the relationship between energy prices, exchange rates and inflation in the countries of the MENA region, with monthly data from 2010 to 2022. The results show that the impact of oil prices varies between countries, depending on the direction and timing of the shock, and that the contagion effects on exchange rates and inflation are asymmetric and specific to certain countries. In addition, analysing spillovers reveals how shocks propagate between variables, with important implications for economic policies in the post-COVID-19 period. Belanès et al. (2024) investigate the dynamic relationship between oil prices, the US dollar exchange rate and the Saudi stock market index from 2010 to 2021. The results show a cointegrating relationship between oil prices and the Saudi stock market, which is highly sensitive to oil fluctuations in both the short and long term, while the exchange rate has a limited influence. The authors show that during the COVID-19 pandemic, the Saudi stock market suffered significant impacts due to the fall in oil prices. On the other hand, Mo et al. (2024) analyse the dynamic spillovers between global economic policy uncertainty, oil volatility and exchange rates in oil-importing countries. The results show that, in the short term, the oil market is the main transmitter of exchange rate spillovers due to its volatility. However, in the long term, global economic uncertainty becomes the main transmitter of spillovers, replacing oil as the main risk factor.

Method and Data

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Data

The data to be analysed is the CBOE Crude Oil Volatility Price Index, which measures the implied volatility of crude oil futures (ticker: OVX). The exchange rates considered were the EUR/GBP pair, which represents the relationship between the Euro and the British Pound (ticker: EURGBP=X); the EUR/USD pair, which measures the relationship between the Euro and the US Dollar (ticker: EURUSD=X); the GBP/USD, reflecting the relationship between the British Pound and the US Dollar (ticker: GBPUSD=X); the USD/CHF, measuring the relationship between the US Dollar and the Swiss Franc (ticker: USDCHF=X); and the USD/JPY, representing the relationship between the US Dollar and the Japanese Yen, (ticker: USDJPY=X). Finally, Brent futures were analysed, and contracts were based on Brent crude oil (ticker: BZ=F). The period analysed covers the years from 3 January 2022 to 8 December 2024, when the financial and energy markets faced a period marked by significant events. Global monetary restrictions, led by the FED and the ECB, which kept interest rates high to contain inflation, boosted the value of the US dollar (USD), leading to fluctuations in exchange rates such as EUR/USD and USD/JPY. In the oil markets, Brent prices fluctuated significantly due to production cuts by OPEC+ and uncertainties about global demand. Geopolitical tensions, such as the war in Ukraine and the rivalry between the US and China, aggravated volatility, affecting oil supplies and boosting demand for energy diversification.

Table 1. Description of financial assets and exchange rates under analysis from 3 January 2022 to 8 December 2024.

Asset	Description	Market Ticker
Bruto (CBOE Crude Oil Volatility)	Measures the implied volatility of crude oil futures.	OVX
EUR/GBP	Euro to Pound Sterling exchange rate.	EURGBP=X
EUR/USD	Exchange rate between the Euro and the US Dollar.	EURUSD=X
GBP/USD	Pound Sterling to US Dollar exchange rate.	GBPUSD=X
USD/CHF	Exchange rate between the US Dollar and the Swiss Franc.	USDCHF=X
USD/JPY	Exchange rate between the US Dollar and the Japanese Yen.	USDJPY=X
Brent Futures	Futures contracts based on Brent crude oi.	BZ=F

Tsay (2005) recommends using return series rather than price series to study the behaviour of financial markets. This approach reflects the focus of investors, who are primarily interested in the profitability of an asset or portfolio. In addition, yield series have statistical properties that facilitate analysis, such as stationarity, which is generally not found in price series. Based on these arguments, the price series of the indices were transformed into growth rates or differences of the Neperian logarithms between the current and previous returns, also known as logarithmic, instantaneous or continuously compounded returns, r_t calculated by the following formula:

$$r_t = \ln P_t - \ln P_{t-1} \quad [1]$$

where r_t is the rate of return on day t, P_t and P_{t-1} are the closing prices of the series at moments t and $t-1$, respectively.

Methodology

The methodology used to answer the research questions is structured as follows: in the first phase, descriptive statistics were carried out (mean, standard deviation, asymmetry and kurtosis). The Jarque and Bera (1980) test was used to validate the time series distributions. The panel unit root tests were used to validate the stationarity assumptions of the time series, namely the methods of Breitung (2000), Levin, Lin,

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and Chu (2002), and Im et al. (2003), which postulate the same null hypothesis (presence of unit roots). Dickey and Fuller (1981) and Phillips and Perron (1988) tests with Fisher's Chi-square transformation and Choi's (2001) unit root tests will also be used to strengthen the results. The diagnostic tests will be validated using the variance equality methodology, namely Bartlett's, Levene's, and Brown-Forsythe tests. Bartlett's test is used when the data is assumed to follow a normal distribution. This test is sensitive to deviations from this assumption and is best suited to scenarios where the normality of the data is strictly controlled. However, its sensitivity can generate distorted results when this assumption is unmet ("Properties of Sufficiency and Statistical Tests," 1937; Waddel Snedecor, George & Gemmel Cochran, 1989). Levene's test (1960) adopts a more robust approach, using the absolute differences between the observed values and the group means as a measure of dispersion. As it is less sensitive to deviations from normality, it is widely applied when the data is not normally distributed. In addition, the test by Brown and Forsythe (1974) is a modification of Levene's test, which replaces the mean with the median when calculating absolute differences, making it even more robust against the presence of outliers or asymmetric data. This test is particularly suitable for high heterogeneity or non-linear data behaviour situations.

The Structural Vector Auto-Regressive (SVAR) model, an extension of the VAR model designed to identify and interpret causal relationships between endogenous variables in a dynamic system, will be used to answer the research question. While VAR captures statistical relationships between variables, SVAR adds a structure based on economic or theoretical assumptions, allowing for the identification of structural shocks and their implications. The main difference between VAR and SVAR is in the identification of shocks. While in traditional VAR, the residuals are treated as reduced shocks with no direct interpretation, in SVAR, they are broken down into structural shocks, allowing for more detailed analyses of how different types of shocks (for example, monetary policy shocks or demand shocks affect the system's variables). Identifying the SVAR requires imposing restrictions on the matrix or other components of the model. These restrictions can be based on theoretical assumptions, such as the order of causality or restrictions on the signs of the variables' responses to shocks. The process of estimating an SVAR includes several steps. First, the traditional VAR model is estimated to determine the appropriate number of lags and capture the dynamic relationships between the variables. Next, the necessary theoretical restrictions are imposed to identify the structural model. Once identified, the structural shocks can be extracted, and the impulse-response functions can be analysed to understand how the shocks affect the variables over time. In addition, variance decomposition can be carried out to assess the contribution of each shock to the variability of the variables in the short and long term. For a better understanding, see the studies by Dias et al. (2023), Dias, Chambino, et al. (2023), Dias et al. (2024), Dias, Galvão, and Alexandre (2024).

Results

Figure 1 shows the markets analysed, which show different dynamics over the period. In the case of crude oil volatility (CBOE Crude Oil Volatility), there is an initial high volatility, followed by stabilisation at lower levels. With regard to exchange rates such as EUR/GBP, EUR/USD, GBP/USD, USD/CHF and USD/JPY, regular fluctuations predominate, indicating short-term variations, although some show stability and others assume high trends in USD/JPY. With regard to Brent oil futures, there was a sharp initial drop, followed by stabilisation at lower levels. Overall, the markets reflect heterogeneous behaviour, with a strong initial oscillation in the oil market and moderate variation patterns in exchange rates, indicating a possible adaptation to the conditions of the period analysed.

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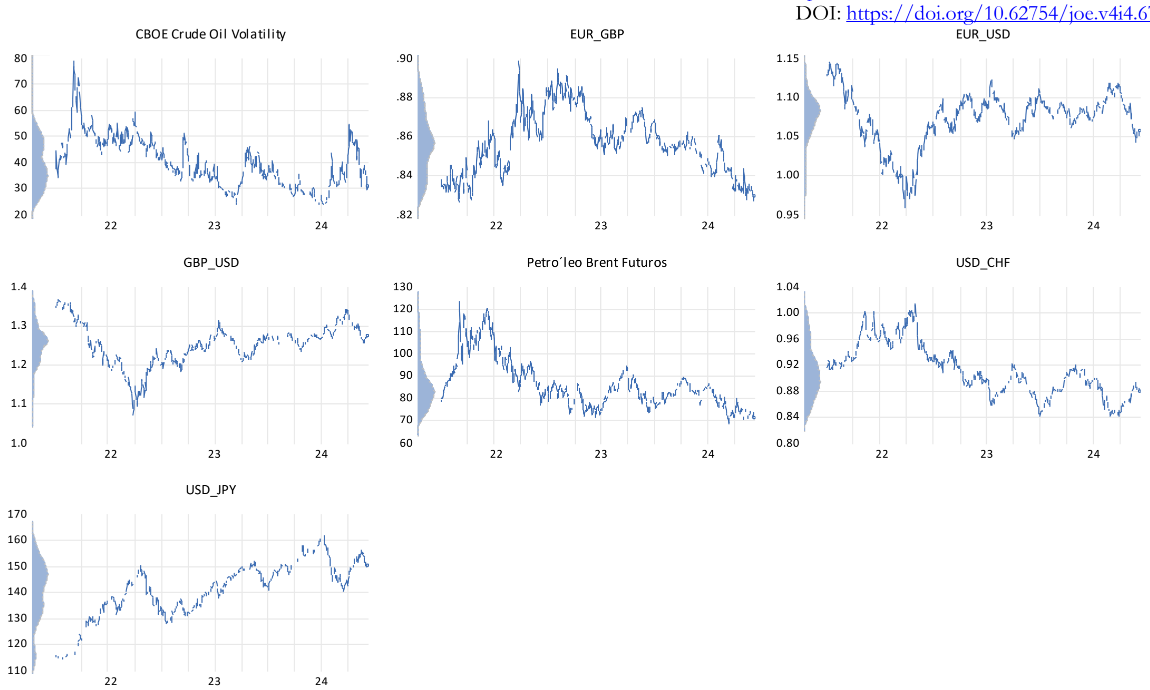

Figure 1. Evolution, in levels, of oil and exchange rates from 3 January 2022 to 8 December 2024.

Figure 2 shows the returns analysed, which show varying dynamics in terms of volatility and dispersion, reflecting different characteristics of risk and uncertainty in the markets. In the case of the CBOE Crude Oil Volatility, there are significant peaks and a high dispersion around the average, indicating the strong volatility associated with the oil market. The EUR/GBP and EUR/USD exchange rates show moderate dispersion around the average, with controlled volatility, suggesting that price fluctuations are more predictable and less extreme. On the other hand, the GBP/USD pair stands out for showing more uniform returns, with less dispersion and low volatility, indicating that it is a more stable market. In Brent futures, we identified spikes in volatility in the initial moments, followed by stabilisation at lower levels, which shows that the market could absorb the initial shocks, resulting in an average dispersion over time. Concerning the USD/CHF pair, the low dispersion around the average and the absence of large variations show low volatility, indicating that returns are predictable and stable. Finally, the USD/JPY pair shows moderate volatility, with controlled dispersion and regular movements, without large peaks. Overall, the results suggest that the oil market presents the highest levels of risk, while the currency markets tend to be more stable, with predictable behaviour and lower dispersion in relation to the average.

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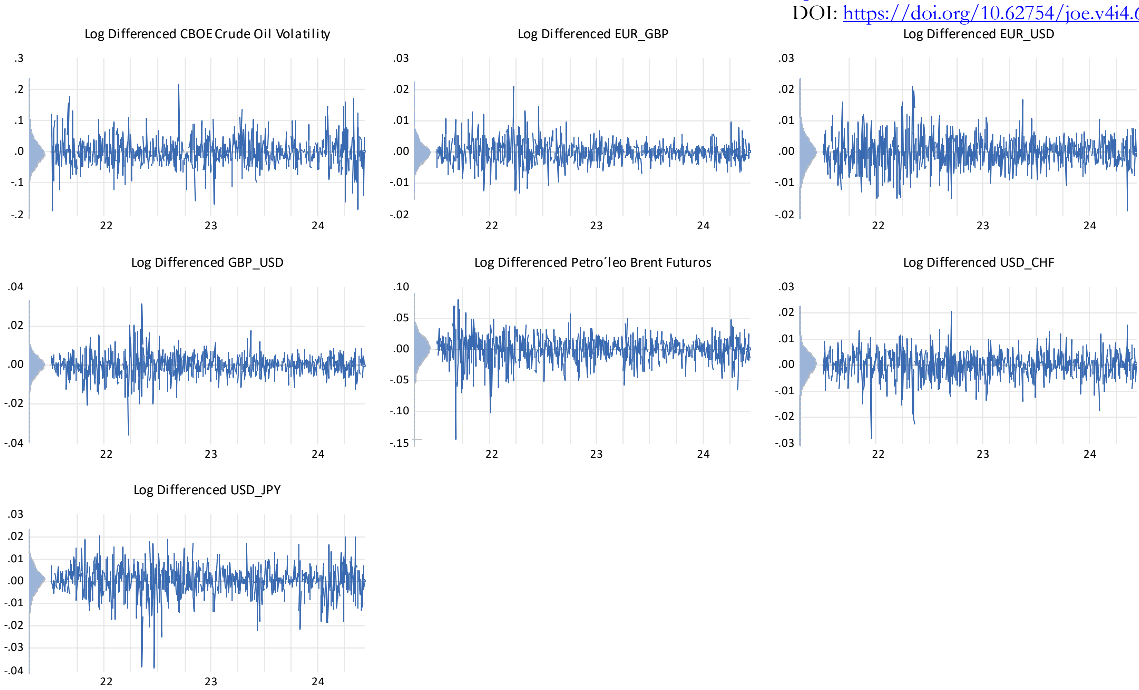

Figure 2. Evolution, in returns, of oil and exchange rates from 3 January 2022 to 8 December 2024.

Figure 3 shows the mean returns of the markets analysed. The GBP/USD exchange rate pair shows an average return of practically zero (-0.00006), which indicates that the returns are concentrated around zero. This suggests the absence of any significant upward or downward trend, reflecting a relatively balanced market over the period analysed. On the other hand, the CBOE Crude Oil Volatility index shows negative average returns (-0.00040), which points to a slight downward trend. Although the magnitude is small, it may indicate that, on average, returns have shown losses over time, possibly reflecting adverse conditions or regular adjustment movements in the oil markets. The mean return of the EUR/GBP pair is practically zero (-0.00002), highlighting the absence of a clear trend in returns. This behaviour is common in currency pairs from stable economies, where daily movements are balanced and often cancel out any consistent long-term direction. As a complement, the EUR/USD pair has slightly negative average returns (-0.00008), showing a slight downward bias. This result can be interpreted as a sign of stability, with unfavourable swings for the European currency, but without much impact on the general behaviour of the market. The mean return on Brent Oil futures is slightly negative (-0.00015), suggesting a slight downward return trend. Although low, this average may reflect periods of pressure in the market, perhaps related to fluctuations in supply and demand and/or geopolitical uncertainties affecting this asset. The mean return on the USD/CHF pair is also very close to zero (-0.00007), indicating no significant trend in the asset's movements. This is characteristic of a market with relative equilibrium, generally influenced by macroeconomic factors that cancel out major variations over the long term. On the other hand, unlike the other assets analysed, the USD/JPY pair has a positive average (0.00034), indicating a slight upward trend in returns. This behaviour can be interpreted as a marginal dollar appreciation against the Yen, potentially explained by economic or monetary factors favouring the American currency.

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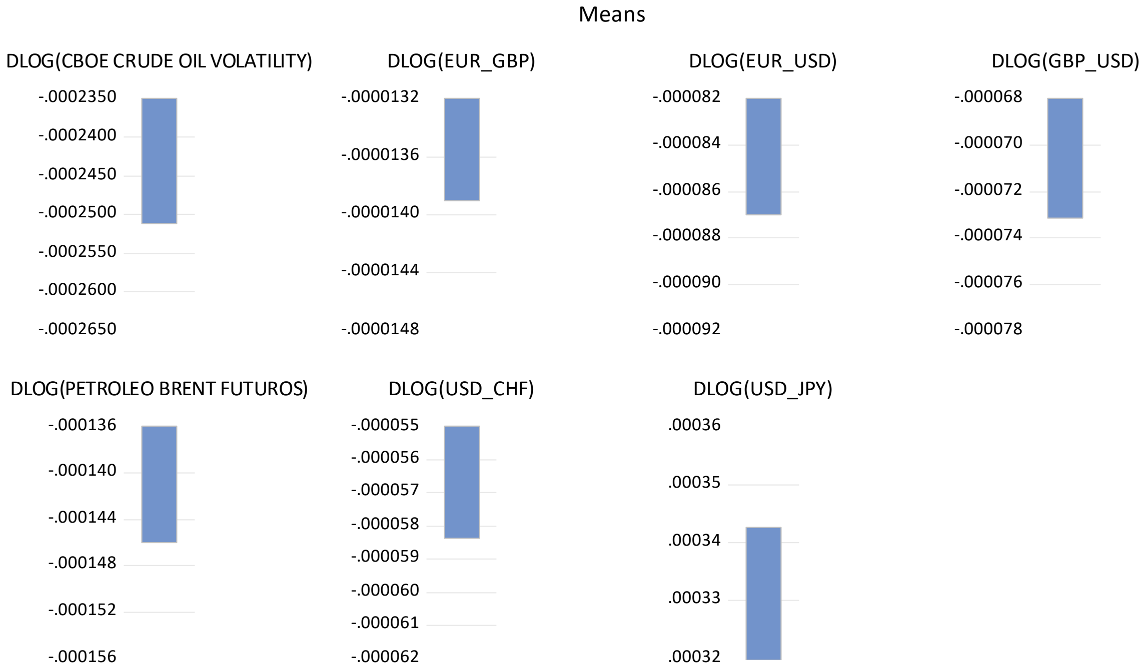

Figure 3 Evolution of mean returns for oil and exchange rates from 3 January 2022 to 8 December 2024.

Figure 4 shows the standard deviations of the assets analysed and shows significant differences in the volatility of each market, reflecting the unique characteristics of each asset. The CBOE Crude Oil Volatility index has the highest standard deviation (0.04619), indicating high volatility and distinct returns behaviour, typical of assets linked to oil volatility, which respond strongly to external events. In contrast, the EUR/GBP has the lowest standard deviation (0.00358), showing great stability in the market, a common characteristic of currency pairs from stable economies. Among the currency pairs, USD/JPY has the highest standard deviation (0.00671), indicating greater sensitivity to market conditions compared to GBP/USD (0.00582) and USD/CHF (0.00508), which show moderate and relatively similar volatilities. Brent Oil (Futures) has a standard deviation of 0.02158, reflecting moderate volatility, which is to be expected in an energy commodities market that often reacts to geopolitical and economic factors. The EUR/USD, on the other hand, has a standard deviation of 0.00497, showing low volatility, similar to that of the EUR/GBP, but still slightly higher, suggesting that the pair is marginally more sensitive to movements in the global market. In comparative terms, we can suggest that assets linked to volatility (such as the CBOE Crude Oil Volatility) and energy commodities (Brent Oil) show the most significant swings in returns. In contrast, currency pairs show lower volatility, thus reflecting greater stability in markets in developed economies.

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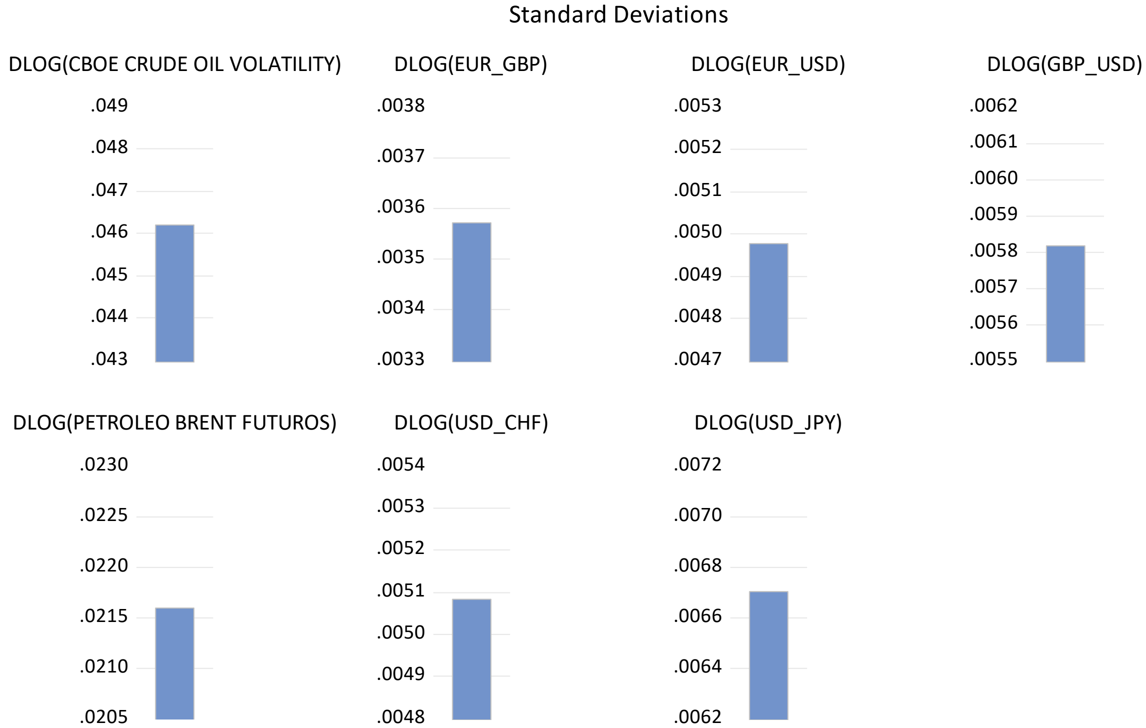

Figure 4. Evolution of the standard deviation, in returns, for oil and exchange rates from 3 January 2022 to 8 December 2024.

Figure 5 shows the asymmetries of the markets analysed and shows that they exhibit positive and negative asymmetries, characteristics that reflect different slopes in the distributions of returns and provide significant information about the risk of each asset. Positive asymmetry, observed in the CBOE Crude Oil Volatility index (0.30018) and the EUR/GBP exchange rate pair (0.39982), indicates that above-average events are more frequent. This can attract investors looking for above-average market returns and with a higher propensity to risk. In the case of the CBOE Crude Oil Volatility, the positive slope suggests a greater likelihood of spikes in returns at times of uncertainty in the oil market, although it can also generate periods of softer losses in adverse scenarios.

On the other hand, markets with negative asymmetries, such as USD/JPY (-0.70036), Brent Oil (Futures; -0.65744) and USD/CHF (-0.52593), show a higher frequency of below-average returns, implying a significant risk of extreme losses. For example, the high negative asymmetry in the USD/JPY pair reflects the market's sensitivity to economic or monetary shocks, mainly when the Yen acts as a safe haven asset. Similarly, the negative asymmetry in Brent Oil can be explained by geopolitical factors or supply shocks that put downward pressure on prices more frequently and intensely. In practical terms, assets with positive asymmetries, such as the CBOE Crude Oil Volatility Index and EUR/GBP, are more likely to attract speculative traders or investors who want to capture extreme bullish movements. However, these markets can be challenging in scenarios of low stability.

On the other hand, markets with negative asymmetries, such as USD/JPY and Brent Oil, are looking for more robust hedging strategies. Overall, analysing asymmetry highlights the importance of adjusting investment strategies according to the characteristics of each market, i.e. markets with positive asymmetries offer the potential for high returns but require some caution due to their unpredictability. On the other hand, markets with negative asymmetries require greater attention to risk, as they are more vulnerable to unfavourable extreme events that can significantly impact a portfolio's performance.

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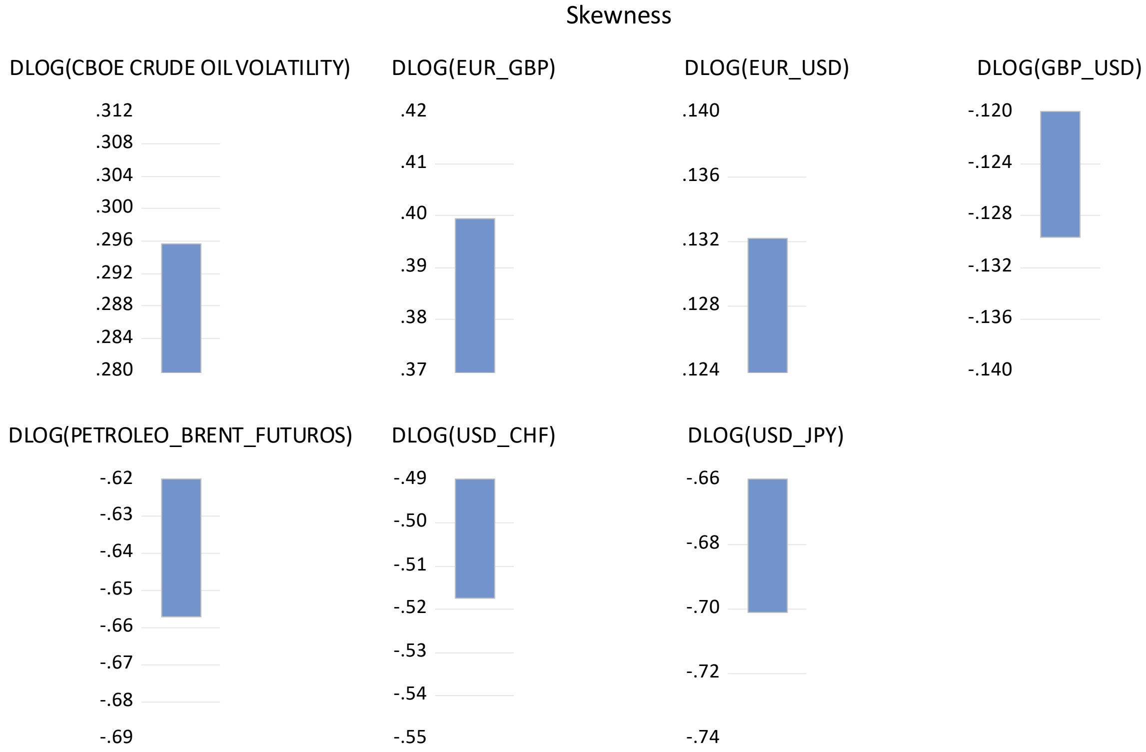

Figure 5. Evolution of asymmetries, in returns, for oil and exchange rates from 3 January 2022 to 8 December 2024.

In figure 6 we can see the results of the kurtosis measure applied to the markets under analysis, and we can see that the assets analysed indicate a very significant degree of fat tails in the distribution of returns, i.e. the frequency with which extreme events (positive or negative) occur in relation to a normal distribution.

The CBOE Crude Oil Volatility Index shows significant kurtosis (5.54059), indicating that returns tend towards extreme positive and negative movements compared to a normal distribution. This characteristic reflects the volatile and unpredictable nature of the oil volatility market, which geopolitical and economic events or market shocks can strongly influence. Similarly, Brent Oil (Futures) also has a high kurtosis (6.47725), suggesting that returns in the oil market tend to be more extreme than would be expected.

Currency pairs such as GBP/USD (6.79242), EUR/GBP (6.08336) and USD/JPY (6.41104) have high kurtosis, highlighting the existence of a significant frequency of extreme movements when compared to a normal distribution. The high kurtosis of the USD/JPY, in particular, can be explained by its sensitivity to changes in monetary and economic policies in the United States and Japan, which often generate abrupt swings in the exchange rate.

On the other hand, assets with lower kurtosis, such as the EUR/USD pair (4.25097), have fewer fat tails, indicating a lower probability of extreme events, although they are still subject to sharp fluctuations, especially during global crises or market shocks. The kurtosis of the GBP/USD is remarkably high, suggesting that, despite its relative stability, the foreign exchange market can experience significant movements of uncertainty stemming from political or economic uncertainty in the UK.

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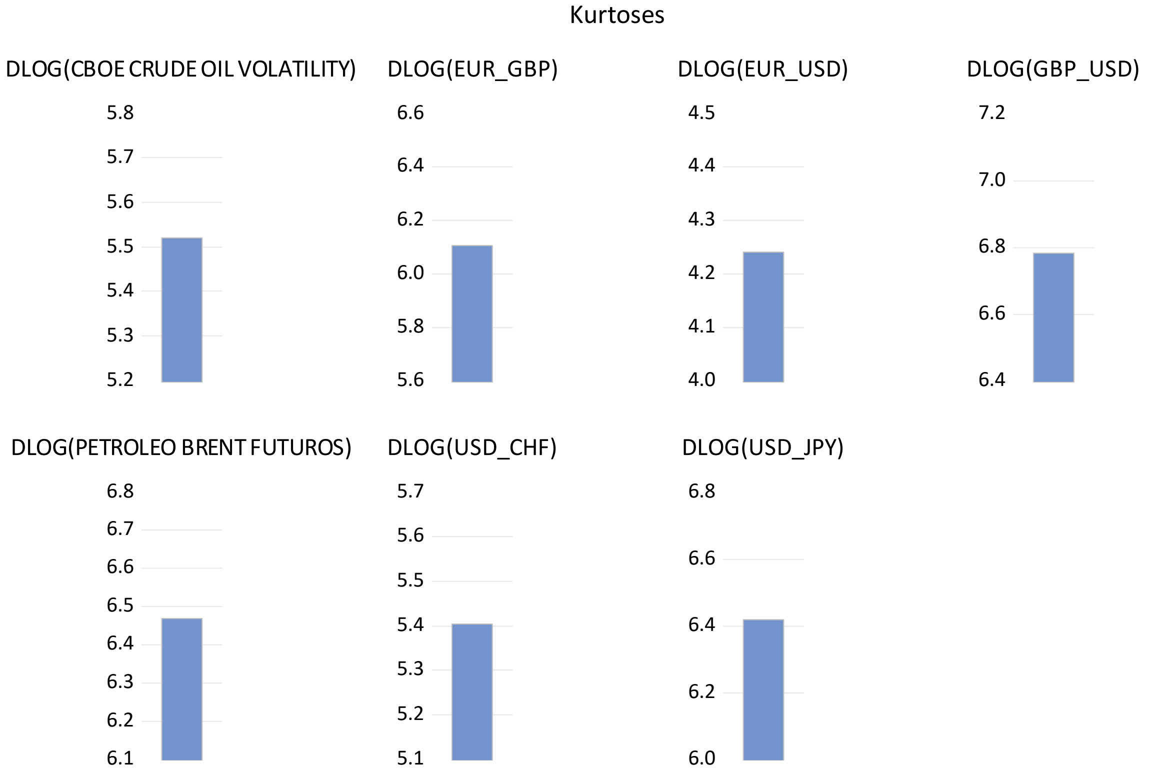

Figure 6. Evolution of Kurtoses, in returns, regarding oil and exchange rates, from 3 January 2022 to 8 December 2024.

Table 2 shows the results of the panel root tests, namely the methods of Breitung (2000), Levin, Lin, and Chu (2002), and Im et al. (2003), which postulate the same null hypothesis (presence of unit roots). In order to strengthen the results, the Dickey and Fuller (1981) and Phillips and Perron (1988) tests with Fisher's chi-square transformation and Choi's (2001) unit root tests will also be estimated. The results of the unit root tests applied to oil and exchange rates for the period from 3 January 2022 to 8 December 2024 indicate that the series are stationary. In the Levin, Lin, and Chu (2002) test, which evaluates the null hypothesis of a unit root with a common process, the statistical value is -126.78, with significance at 1%, and the rejection of the null hypothesis is confirmed.

The Breitung (2000) test, which considers the heterogeneity of the coefficients, shows a statistical value of -57.74 and a p-value of 0.000, reinforcing the stationarity of the series. The test by Im et al. (2003), which analyses the individual unit roots for each cross-section, shows a statistical value of -79.72 and a p-value of 0.0000, supporting the rejection of the null hypothesis. In the ADF-Fisher and PP-Fisher tests, based on combinations of individual series statistics, the high Chi-squared values (1757.24 and 1843.73, respectively) and p-values of 0.0000 confirm the stationarity of the series. Thus, all the tests applied consistently reject the unit root hypothesis, showing that the data series analysed are stationary over the period considered, a fundamental characteristic for applying appropriate econometric models.

Table 2. Summary table of the panel root tests applied to oil and the exchange rates under analysis from 3 January 2022 to 8 December 2024

Group unit root test: Summary				
Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-126.78	0	7	5359
Breitung t-stat	-57.74	0	7	5352

Journal of Ecohumanism
2025
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https://ecohumanism.co.uk/joe/ecohumanism
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Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-79.72	0	7	5359
ADF - Fisher Chi-square	1757.24	0	7	5359
PP - Fisher Chi-square	1843.73	0	7	5363

Note:** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Table 3 shows the results of the equality tests of variances applied to oil and exchange rates from 3 January 2022 to 8 December 2024, revealing significant differences between the variances of the series analysed. The Bartlett test, which is sensitive to the normality of the data and tests the equality of variances that assume normal distributions, the statistical value of 30944.15 and the p-value of 0.0000 suggest rejection of the null hypothesis of equal variances. This means that the variances of the series are significantly different. On the other hand, Levene's test, which is less sensitive to normality and more robust to deviations from the normal distribution, also shows a statistically significant result, with an F-value of 894.5 and a p-value of 0.0000. This reinforces the conclusion that the variances of the series are not equal. Finally, the Brown-Forsythe test, a variation of the Levene test that uses medians instead of averages, obtained an F-value of 733.92 and a p-value of 0.0000, corroborating the rejection of the hypothesis of homogeneity of variances. In short, the three statistical tests consistently reject the hypothesis of equality of variances between the series. This suggests significant volatility differences between the data from the oil series and the exchange rates.

Table 3. Summary table of the variance tests applied to oil and the exchange rates analysed from 3 January 2022 to 8 December 2024.

Test for Equality of Variances Between Series			
Method	df	Value	Probability
Bartlett	6	30944.15	0.0000
Levene	(6, 5362)	894.15	0.0000
Brown-Forsythe	(6, 5362)	733.92	0.0000

Table 4 shows the results of the VAR Lag Order Selection Criteria test, used to determine the ideal number of lags in VAR models, which identified lag 7 (days) as the most appropriate according to the LR test. This means that the model considers seven previous periods to capture the dynamic relationships between the variables, avoiding overfitting and loss of relevant information. The choice reflects a balance between accuracy and simplicity, ensuring the model is robust and suitable for forecasting the series analysed, such as oil and exchange rates.

Table 4. Summary table of the VAR Lag Order Selection Criteria, applied to oil and the exchange rates analysed, from 3 January 2022 to 8 December 2024.

VAR Lag Order Selection Criteria						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	20009.14	NA	9.08e-33	-53.91413	-53.87064*	-53.89736
1	20149.74	278.1811	7.09e-33	-54.16104	-53.81317	-54.02693
2	20246.87	190.3211	6.23e-33*	-54.29076*	-53.63849	-54.03930*
3	20280.64	65.54226	6.49e-33	-54.24971	-53.29306	-53.88091
4	20335.00	104.4701	6.40e-33	-54.26416	-53.00311	-53.77801
5	20387.49	99.88141	6.34e-33	-54.27356	-52.70812	-53.67006
6	20419.91	61.08931	6.63e-33	-54.22888	-52.35905	-53.50803
7	20460.36	**75.44451***	6.79e-33	-54.20583	-52.03161	-53.36763
8	20488.11	51.23880	7.20e-33	-54.14855	-51.66994	-53.19301

Journal of Ecohumanism
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9	20519.76	57.83773	7.55e-33	-54.10178	-51.31878	-53.02890
10	20549.20	53.25382	7.97e-33	-54.04907	-50.96168	-52.85884

Note: *Indicates the lag order selected by the criterion. LR represents the sequential modified LR test statistic (each test at the 5% significance level). FPE refers to the Final Prediction Error. AIC is the Akaike Information Criterion. SC is the Schwarz Information Criterion. HQ corresponds to the Hannan-Quinn Information Criterion.

The Lagrange LM test checks for the presence of serial autocorrelation in the residuals of a VAR model. It tests whether the correlations between the lagged residuals are significant. If the p-value is greater than 0.05, there is no autocorrelation; otherwise, it indicates problems in the model. This test is crucial for validating the VAR model, ensuring reliable forecasts and the appropriate number of lags chosen. If there is autocorrelation, the model may need to be adjusted, such as adding more lags.

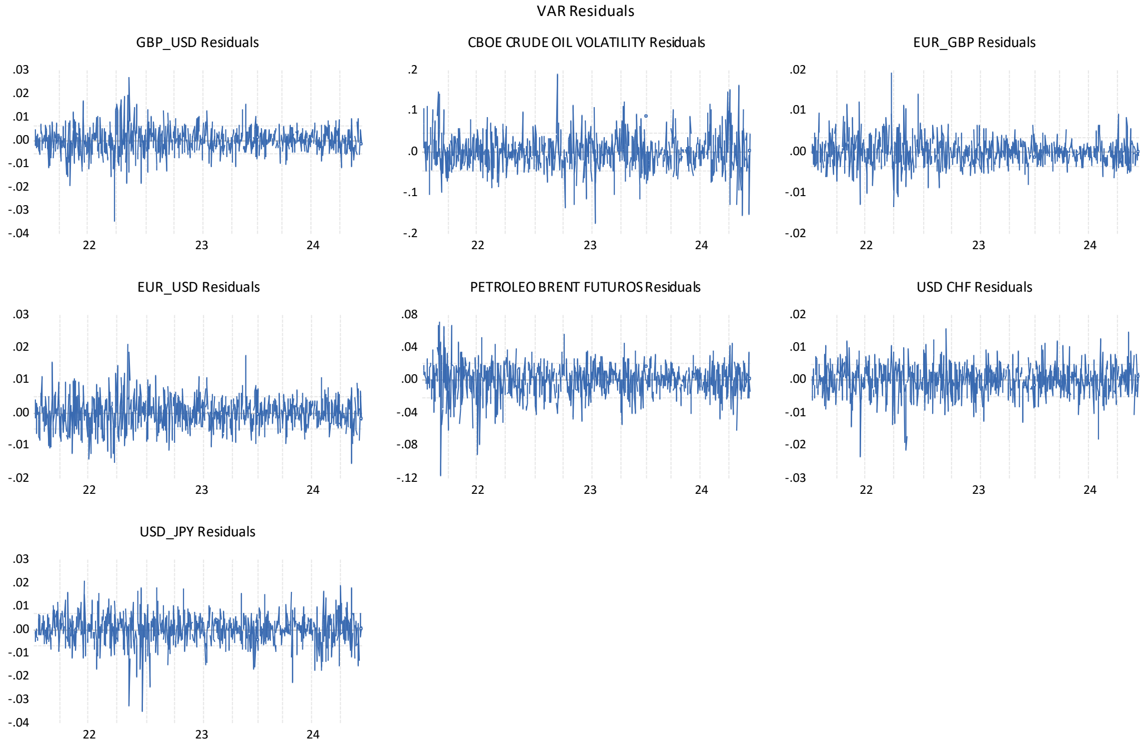

Figure 7. Lagrange's LM test to check the presence of serial autocorrelation in the residuals

Table 4 shows the results of the Granger causality test, which confirm the relevance of two key assets in price formation: the CBOE volatility index and Brent oil futures prices. These assets play central roles, establishing significant relationships with the main currency pairs analysed.

The CBOE index, recognised as a measure of financial market volatility, directly impacts the prices of the EUR/GBP currency pair. This relationship suggests that changes in the perception of global risk and uncertainty, captured by the index, have immediate repercussions on foreign exchange markets, particularly on the pair involving the single European currency and the pound sterling. This influence may be related to the sensitivity of the EUR/GBP to global macroeconomic and financial factors.

In the case of EUR/USD, its prices are influenced by the behaviour of the USD/JPY currency pair. This dynamic can be explained by the interconnection between the main currency markets, where the USD plays a central role as the global reserve currency, while the JPY acts as a safe haven currency. In practical terms,

Journal of Ecohumanism
2025
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movements in the USD/JPY pair can, therefore, have repercussions on the EUR/USD, reflecting the interaction between these leading economies.

Brent futures prices, meanwhile, demonstrate their significant influence on the USD/CHF and USD/JPY exchange rate pairs. In the case of USD/CHF, the relationship can be attributed to the importance of oil as a strategic commodity and the role of the Swiss franc as a currency associated with financial stability. In the case of USD/JPY, the influence of Brent futures may be related to Japan's energy dependence and Yen's sensitivity to fluctuations in oil prices.

This evidence underlines the interconnected nature of global financial markets. Shocks to specific assets, such as oil or market volatility, can propagate through economic and financial channels, affecting the prices of currencies and other financial instruments. Identifying these relationships not only enriches the understanding of market dynamics but is also key to formulating risk management strategies and informed decision-making in an environment of interdependent markets.

Table 5. Summary table of the Pairwise Granger Causality Tests applied to oil and the exchange rates under analysis for the period from 3 January 2022 to 8 December 2024.

Pairwise Granger Causality Tests		
Null Hypothesis:	F-Statistic	Prob.
CBOE does not Granger Cause GBP/USD	0.6811	0.6881
GBP/USD does not Granger Cause CBOE	1.6405	0.1207
EUR/GBP does not Granger Cause GBP/USD	1.5778	0.1386
GBP/USD does not Granger Cause EUR/GBP	0.4411	0.8763
EUR/USD does not Granger Cause GBP/USD	1.5647	0.1426
GBP/USD does not Granger Cause EUR/USD	1.3004	0.2470
BRENT FUTUROS does not Granger Cause GBP/USD	1.4229	0.1927
GBP/USD does not Granger Cause BRENT FUTUROS	1.0191	0.4161
USD/CHF does not Granger Cause GBP/USD	1.0431	0.3992
GBP/USD does not Granger Cause USD/CHF	1.5401	0.1503
USD/JPY does not Granger Cause GBP/USD	1.1635	0.3214
GBP/USD does not Granger Cause USD/JPY	0.8360	0.5575
EUR/GBP does not Granger Cause CBOE	1.5101	0.1603
CBOE does not Granger Cause EUR/GBP	**2.7371**	**0.0082**
EUR/USD does not Granger Cause CBOE	1.1554	0.3267
CBOE does not Granger Cause EUR/USD	1.3883	0.2067
BRENT FUTUROS does not Granger Cause CBOE	1.1896	0.3061
CBOE does not Granger Cause BRENT FUTUROS	0.7934	0.5924
USD/CHF does not Granger Cause CBOE	1.0343	0.4058
CBOE does not Granger Cause USD/CHF	1.0042	0.4268
USD/JPY does not Granger Cause CBOE	0.7786	0.6053
CBOE does not Granger Cause USD/JPY	0.5410	0.8035
EUR/USD does not Granger Cause EUR/GBP	0.4583	0.8646
EUR/GBP does not Granger Cause EUR/USD	1.4444	0.1842
BRENT FUTUROS does not Granger Cause EUR/GBP	1.1297	0.3421
EUR/GBP does not Granger Cause BRENT FUTUROS	1.3246	0.2355
USD/CHF does not Granger Cause EUR/GBP	0.4337	0.8816
EUR/GBP does not Granger Cause USD/CHF	1.8685	0.0719

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2025
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USD/JPY does not Granger Cause EUR/GBP	0.8046	0.5834
EUR/GBP does not Granger Cause USD/JPY	1.1964	0.3022
BRENT FUTUROS does not Granger Cause EUR/USD	1.2193	0.2893
EUR/USD does not Granger Cause BRENT FUTUROS	0.6114	0.7467
USD/CHF does not Granger Cause EUR/USD	0.7421	0.6362
EUR/USD does not Granger Cause USD/CHF	0.6464	0.7175
USD/JPY does not Granger Cause EUR/USD	**1.9145**	**0.0645**
EUR/USD does not Granger Cause USD/JPY	0.5932	0.7617
USD/CHF does not Granger Cause BRENT FUTUROS	0.6265	0.7341
BRENT FUTUROS does not Granger Cause USD/CHF	**1.8280**	**0.0788**
USD/JPY does not Granger Cause BRENT FUTUROS	1.4470	0.1832
BRENT FUTUROS does not Granger Cause USD/JPY	**2.1213**	**0.0392**
USD/JPY does not Granger Cause USD/CHF	1.3027	0.2462
USD/CHF does not Granger Cause USD/JPY	1.5809	0.1376

Note: The Granger causality test assesses whether one variable helps predict another, rejecting the null hypothesis of 'no causality' if the ppp value is less than the critical levels: p<0,01 (strong evidence), p<0,05 (moderate) ou p<0,10 (weak). Otherwise, it is concluded that there is no causal relationship in the Granger sense.

Conclusions

The main objective of this study was to analyse the influence of the international oil price, namely the CBOE Crude Oil Volatility Index and Brent crude oil, on the main exchange rates: EUR/GBP, EUR/USD, GBP/USD, USD/CHF and USD/JPY. The analysis covers the period from 3 January 2022 to 8 December 2024 to examine the relationship between fluctuations in the oil market and the behaviour of exchange rates.

The findings show that the international price of oil, represented by the CBOE Crude Oil Volatility index and Brent oil futures, play a crucial role in shaping the prices of the main exchange rates. The analysis shows that global volatility, as measured by the CBOE index, directly impacts the EUR/GBP currency pair, reflecting how risk perception and uncertainty changes affect financial markets sensitive to macroeconomic factors. In addition, there is a strong interconnection between leading currencies such as EUR/USD and USD/JPY, where the behaviour of the Japanese Yen against the dollar directly influences the Euro against the dollar, highlighting the dynamic and interconnected nature of the main global currency pairs. Brent oil futures impact the price formation of the USD/CHF and USD/JPY currency pairs, highlighting the importance of oil as a strategic commodity for the global economy. In the case of the USD/CHF, this relationship reflects the stability attributed to the Swiss franc as a safe haven currency that responds to fluctuations in the energy markets. The impact on the USD/JPY pair can be associated with Japan's energy dependence, which makes the Yen highly sensitive to fluctuations in oil prices.

On the other hand, the results show that certain assets do not significantly influence the relationships between the variables studied. Specifically, no direct causal relationship was identified between Brent futures or the CBOE index and the GBP/USD currency pair, suggesting that the movements of this currency pair are less sensitive to fluctuations in oil prices and market volatility, possibly due to factors specific to the United Kingdom and the United States playing a predominant role.

These results underline the interdependence between the financial and commodities markets, such as oil, but also indicate that some relationships are not universal and depend on the specific characteristics and fundamentals of each asset or currency pair. In practice, these findings highlight the need for robust and informed strategies for risk management and decision-making in an environment of interdependent global markets. Individual and institutional investors, portfolio managers and policymakers should carefully observe oil volatility and exchange rate movements, integrating these variables into their analyses to improve the forecasting of market movements and protect against the risks arising from external shocks.

Future research could extend the analysis period to include additional economic shocks, such as the 2020 pandemic, explore other volatility indices, such as the VIX and OVX, and study the currency pairs of emerging economies. Conduct analyses with advanced methods, such as non-linear models and machine learning, which can capture complex relationships, differentiate between short- and long-term impacts, and compare developed and emerging markets.

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Volume: 4, No: 4, pp. 160 – 176
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