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CYCLINACLITY EFFECTS OF EXCHANGE RATES AND OIL PRICES

Jassim Aladwani
Assistant Professor in Business Studies
Box Hill College of Kuwait
j.aladwani@bhck.edu.kw

ABSTRACT

Understanding the concept of time scales is crucial when modeling economic and financial decisions. Within the time-frequency domain, this study delves into the relationship between fluctuations in oil prices and exchange rates across major oil-importing and exporting countries. The investigation employs various cross-wavelet techniques within the continuous wavelet transform framework, with a particular focus on wavelet coherence and phase-difference over the period 2000 to 2020. The results underscore a notable diversity in the connection between the oscillations of oil prices and exchange rates across diverse countries. This relationship is subject to temporal variations and is contingent upon the specific time horizon under consideration. In particular, our analysis reveals strong co-movements between oil prices and exchange rates across various time intervals and frequencies. Importing oil countries like New Zealand, Singapore, Brazil, and Taiwan exhibit particularly pronounced co-movements. Similarly, exporting oil countries such as Kuwait, Mexico, Russia, and Canada also display strong associations between oil prices and exchange rates. These correlations are intricately tied to key macroeconomic events, further highlighting the complex interplay between oil prices and exchange rate movements in different global regions. While a robust connection is evident in numerous countries, the strength of the relationship appears significantly weaker in several others. This variance underscores the nuanced nature of the association between the fluctuations in oil prices and exchange rates across the global landscape.

Keywords: Continuous wavelet approach, Wavelet coherency approach, business cycle, oil prices, exchange rates, and wavelet power spectra.

JEL Classifications: C10 · C22 · G1 · G15

1. INTRODUCTION

The relationship between oil prices and exchange rates plays a pivotal role in international finance and macroeconomics, exerting influence on global economic dynamics, trade, investment, inflation, and overall economic growth. Exchange rates, which reflect the value of one currency relative to another, are shaped by factors such as inflation rates, interest rates, economic indicators, and political stability (Ito, 2018). In contrast, oil prices are contingent on the global demand and supply of crude oil, influenced by production levels, economic activity, and geopolitical events. As oil serves as a primary energy source and a critical input in various industries, it directly affects production costs and overall price levels, resulting in significant macroeconomic consequences for both oil-importing and oil-exporting countries. Understanding the intricate relationship between oil prices and exchange rates is indispensable for predicting and managing global economic behavior, financial market trends, and the transmission mechanisms of shocks. Recent seminal studies, including works by Kilian & Park (2009) and Garzón & Hierro (2022), have emphasized the need for a nuanced exploration of this relationship, underscoring its far-reaching implications on the broader economic landscape. Recognizing the intricate dynamics between oil prices and exchange rates is imperative not only for comprehending the forces driving global economic behavior but also for effectively managing financial market trends and the transmission mechanisms of economic shocks in today's interconnected world.

This nuanced comprehension is vital for analysts, policymakers, and market participants as they navigate the complexities of the international economic landscape. In this context, our study aims to explore the dynamic relationship between exchange rates and oil prices, delving into the theoretical framework, considering supply and demand factors, and reviewing empirical studies across various periods and economies. Gaining a deeper understanding of the interplay between exchange rates and oil prices empowers policymakers, investors, and market participants to make more decisions that are informed and develop effective risk management strategies in an interconnected and volatile global economy.

The intersection of exchange rates and oil prices necessitates sophisticated analytical tools, with the wavelet transform emerging as a particularly apt choice. The wavelet transforms, a powerful mathematical tool, enable simultaneous analysis of time and frequency domains, providing a nuanced perspective on the dynamics between these critical variables (see, e.g., Torrence & Compo, 1998; Percival & Walden, 2000). Ramsey (2002) argued that the wavelet transform proves to be a suitable analytical technique in situations where the time horizons of economic decisions and the strength of relationships between variables exhibit variations across time and frequency. This transformation decomposes time series data into its time-scale coefficients, each linked with specific frequency bands. The method effectively captures variations across frequencies and possesses the ability to identify events that are localized in time. Wavelet analysis, being more detailed, offers richer information compared to correlation, which does not consider the evolving relationship over time (Arnold *et al.*, 2018).

Wavelet analysis stands out as a model-free approach for estimating time-varying correlations, providing a powerful technique compared to standard methods relying on parameter estimation (Vacha & Barunik, 2012). Additionally, wavelet analysis proves especially relevant for analyzing non-stationary time series in economics and finance. Its capacity to track how different scales related to the periodic components of the signal change over time makes it a valuable tool (Cazelles *et al.*, 2008).

In this context, the wavelet transform has proven effective in investigating the interaction between exchange rates and oil prices. By utilizing the wavelet transform, researchers can identify different patterns in the relationship between exchange rates and oil prices, examining both long-term trends and short-term fluctuations, providing a comprehensive understanding of the complex interplay between these two variables. Empirical studies utilizing the wavelet transform have uncovered valuable insights into the nature of the relationship, emphasizing supply and demand factors, geopolitical events, and market sentiment. Examining wavelet coherency enables the identification of periods of strong correlation or decoupling between exchange rates and oil prices, shedding light on the underlying mechanisms governing their interaction.

Our study makes several significant contributions. Firstly, we employ two distinct wavelet methodologies, namely wavelet coherence and continuous wavelet transform, to investigate the relationship between oil prices and exchange rates. By utilizing wavelet-based decomposition across various time scales, our approach enables the concurrent identification of the oil price and exchange rate connection in both time domains (short-term and long-term co-movements) and frequency domains (low and high frequency). Secondly, we explore the connection between the returns of these two variables in countries significantly influenced by oil by contrasting the outcomes of two distinct groups—the major oil-importing and oil-exporting countries. Much of the existing literature on this topic does not differentiate between samples representing data from net oil-exporters and net oil-importers. Thirdly, in contrast to previous research, our study aims to provide more nuanced and detailed insights by simultaneously employing the continuous wavelet transform, primarily the wavelet coherence techniques, to examine the oil-exchange return linkage. The utilization of these two distinct wavelet analyses allows us to uncover specific features of the relationship between oil prices and exchange rates in a unique and comprehensive manner. The continuous and coherence wavelet methods complement each other, enabling us to derive findings that are more robust. For instance, we can visually examine the evolving interconnectedness over time with continuous frequency using the continuous wavelet transform technique, and simultaneously, we can statistically assess the lead-lag relationship within specific discrete time domains through the coherence wavelet technique. This dual approach enhances the depth and specificity of our research results.

Our findings reveal a robust correlation between oil prices and exchange rate returns in both importing oil countries, including New Zealand, Singapore, Brazil, and Taiwan, and exporting oil nations such as Kuwait, Mexico, Russia, and Canada. Furthermore, it is noteworthy that a robust relationship exists between exchange rates and oil prices, particularly evident during the global financial crisis period across a range of oil-importing and exporting countries.

The subsequent sections of this paper are structured as follows. In Section 2, we conduct a literature review pertinent to the topic. Section 3 provides an overview of the wavelet transform methods employed in this study. The data utilized for our analysis is detailed in Section 4. Experimental results are presented in Section 5. Lastly, Section 6 presents the conclusion of this paper.

2. LITERATURE REVIEW

2.1 Theoretical Foundations:

The theoretical foundation for the connection between oil and exchange rates revolves around three key principles: the law of one price (sometimes referred to as LOOP), the terms of trade effect, and the wealth effect. Firstly, the law of one price (LOOP) suggests that the uniform characteristics of oil imply that a depreciation of the U.S. dollar would result in lower oil prices in the global oil market. Supporting this proposition, Blomberg & Harris (1995), De Schryder & Peersman (2015), and Malik & Umar (2019) argue that a U.S. dollar depreciation would be advantageous for foreign consumers, as it would lead to reduced oil prices, thereby enhancing purchasing power and subsequently increasing the demand for oil. Second, the terms of trade channel play a crucial role in shaping and elucidating the connection between oil prices and exchange rates, contingent on how a country utilizes both traded and non-traded goods. By maintaining a constancy in non-traded goods across two economies, an escalation in oil prices amplifies the prices of traded goods in an oil-importing nation compared to the oil-exporting counterpart. Consequently, this dynamic prompt a devaluation of the domestic currency in the oil-importing country. This mechanism underscores the importance of trade dynamics and the terms of trade in influencing the impact of oil price fluctuations on exchange rates. This proposition is substantiated by various research endeavour, including the works of Brahmasrene *et al*. (2014), Mensi *et al*. (2017), and Ayadi *et al.* (2020). Their findings affirm that an elevation in oil prices correlates with a decline in the terms of trade for importing countries and an enhancement for exporting nations. This observation underscores the substantial influence wielded by the terms of trade channel in the intricate dynamics between oil prices and exchange rates. Third, the relationship between oil prices and exchange rates displays attributes of the wealth effect channel. According to analyses by Golub (1983), Caldara *et al.* (2019), and Boer *et al.* (2023), oil demand in countries importing oil tends to be inelastic. Consequently, a surge in oil prices results in the transfer of wealth from oil-importing nations to oil-exporting countries. This dynamic underscore the pivotal role played by wealth effects in shaping the impact of oil price fluctuations on exchange rates.

2.2 Empirical Literature

In this section, we delve into empirical literature, exploring three distinct strands of empirical methodologies employed to evaluate the relationship between oil prices and exchange rates. These

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methodologies encompass: (1) modelling the short- and long-term dynamics relationship between oil prices and exchange rates; (2) examining dependence and market asymmetries between both variables; and (3) exploring volatility spill over and risk transfer dynamics between both variables. Each approach contributes unique insights to the nuanced understanding of the intricate connection between oil prices and exchange rates.

Within the first strand of analysis, the connection between oil prices and exchange rates is scrutinized by employing techniques that unveil both short- and long-term dynamics. Amano and Van Norden (1998), utilizing causality and co-integration analysis, demonstrate a unidirectional causality from oil prices to exchange rates. Similarly, Rautava (2004), employing VAR and co-integration techniques, discerns the impact of oil price fluctuations and real exchange rates on the Russian economy, both in the short-run and long run. More recently, Tian *et al.* (2021) studied the non-linear association between oil prices and exchange rates, examining both immediate and prolonged effects. The study uncovers evidence of bidirectional causality, indicating that oil prices influence exchange rates and vice versa. Furthermore, it reveals non-linear dynamics, elucidating distinct responses to decrease and increases in crude oil prices. Additional studies employing analogous methodologies encompass Kumeka *et al.* (2022) utilizing panel co-integration, *Iqbal et al.* (2023) employing panel co-integration and pooled mean group estimation methods, Wu *et al.* (2023) based on panel co-integration and fully modified ordinary least squares estimation methods, and Anjum (2019) and Baek *et al*. (2020) using wavelet cross-spectral analysis. Significantly, all of these investigations corroborate the existence of a long-term relationship between oil prices and exchange rates. The convergence of findings across diverse studies employing different techniques underscores the robustness of the identified link between oil prices and exchange rates over an extended period. However, contrary findings are presented by Buetzer *et al.* (2012), Chang *et al*. (2013), and more recently, Chowdury and Garg (2022) and Wang *et al.* (2022), as they identify no evidence of co-integration between crude oil prices and exchange rates. This result indicates the potential necessity for a clear demarcation between energy and financial policies in the policymaking process. The absence of co-integration suggests a nuanced and context-specific relationship that warrants careful consideration of separate policy approaches in the countries under consideration. Specifically, relevant to countries that rely on oil imports, Zhang *et al.* (2023) employ panel and VECM models to analyse the impact of an oil price shock on exchange rates in several oil importers. The study reveals distinct effects, with negative effects of oil price shocks on the exchange rates of numerous oil-importing countries.

Additional empirical work on the analysis the relationship between oil prices and exchange rates has been conducted, employing a diverse range of models that elucidate various temporal dynamics, encompassing both short- and long-run perspectives, as well as volatility considerations. Notably, Volkov and Yuhn (2016) delve into the impact of oil price shocks on exchange rate movements, focusing on five significant oil-exporting countries. In their empirical investigation, they employ a variety of techniques, such as the GARCH model to evaluate volatility spill over, causality tests, and the vector error correction model (VECM) to scrutinize the presence

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of a long-run relationship. This comprehensive approach allows for a thorough exploration of the dynamics between oil prices and exchange rates, encompassing both short-term volatility and potential long-term relationships. Their findings indicate a correlation between exchange rate volatility and oil price shocks in Mexico, Brazil, and Russia, although this connection is less pronounced in Canada and Norway. Additionally, the study reveals that the time required for the exchange rate to return to its initial equilibrium levels is significantly longer in Russia, Brazil, and Mexico compared to Norway and Canada. This nuanced analysis provides insights into the varying impact and recovery periods associated with oil price shocks on exchange rates in different countries. More recently, Rai and Garg *et al*. (2022) investigate the impact of the COVID-19 pandemic on the dynamic correlations and volatility spillovers between stock prices and exchange rates within the BRIICS economies. Employing volatility modelling techniques, we unveil substantial negative dynamic correlations and volatility spillovers between stock and exchange returns across the majority of BRIICS nations. Notably, this relationship intensified during the initial phases of pandemic-induced lockdowns. In essence, the findings suggest pronounced risk transfers between the stock and exchange markets during the COVID-19 outbreak. This phenomenon contributed to a decline in domestic stock returns and subsequent capital outflows, consequently exerting upward pressure on exchange rates in the affected BRIICS economies.

In the second strand of the empirical literature, numerous studies have been undertaken to analyze volatility spillover and risk transmission among different variables. The study conducted by Basher *et al.* (2012) and Nakajima & Hamori (2012) employed a cross-correlation method, concentrating on both causality-in-mean and causality-in-variance in their investigation. This method proves valuable in examining the relationship between oil prices and exchange rates, encompassing both the average impact and the dynamics of variance. Their results indicate a unidirectional causality from exchange rates to oil prices, signifying that changes in exchange rates influence oil prices. Furthermore, there is evidence of causality-in-mean between the variables, suggesting a relationship involving the average impact of one variable on the other. Recent investigations conducted by Belasen and Demirer (2019) and Nouira *et al*. (2019) utilize causality-in-variance employing a Lagrange Multiplier method. These studies unveil substantial causal effects, indicating a transfer of risk between commodity prices and exchange rates. These thorough analyses significantly contribute to a more profound comprehension of the intricate dynamics involving volatility spillover and risk transmission across diverse economic variables. Similarity, Ahmad *et al.* (2021) explores the factors influencing volatility in both oil prices and foreign exchange markets, along with examining jump spillovers between them. The study focuses on the currencies of two major oil-importing countries, China, and India, during the period from January 2013 to October 2019. The findings indicate a positive return spillover from the oil market to the foreign exchange market, with no corresponding spillover in the opposite direction. Furthermore, oil jumps exhibit a negative impact on exchange rate conditional volatility, and the response of the latter is asymmetrical to disentangled oil price jumps of both positive and negative nature. The study also highlights the significant impact of disentangled exchange rate jumps on conditional oil price volatility. Notably, these findings display asymmetry based on the nature of jumps and the specific oil price series. Importantly, the study does not identify evidence of co-jumps between the oil and foreign exchange markets.

Within the third strand of literature, researchers have employed both dependence and market asymmetry methodologies. In the empirical investigation conducted by Fowowe (2014), an examination of the correlation between oil prices and exchange rates in South Africa was undertaken. The study employed a model to analyse both volatility and jumps in exchange rate returns, utilizing the GARCH autoregressive conditional jump intensity model proposed by Chan & Maheu (2002). This model accounts for the impact of extreme news events in returns. The empirical findings from the study indicate that an increase in oil prices is associated with a depreciation of the South African rand relative to the U.S. dollar. Reboredo *et al.* (2014) investigated the correlation between oil prices and the US dollar exchange rate, employing detrended cross-correlation analysis. The authors systematically characterized the relationship between oil prices and exchange rates across various time scales for a diverse range of currencies, both preceding and following the onset of the recent global financial crisis. The study revealed two primary findings. Firstly, the cross-correlation analysis suggested consistently negative and low correlations between oil prices and exchange rates, with generally lower values observed for longer time scales. Secondly, the study noted an escalation in the negative dependence between oil prices and the US dollar after the initiation of the global financial crisis across all time scales, providing evidence of both contagion and interdependence in the relationship. Furthermore, the wavelet approach provides a nuanced understanding by capturing the time-varying dynamics and identifying potential lead-lag relationships between oil prices and exchange rates. Duna *et al.* (2021) aims to investigate the connection between geopolitics, exchange rates, and oil prices using Wavelet analysis on data spanning from 2008 to 2019. The findings suggest a mutual causal relationship between oil prices and exchange rates specifically during the period from 2017 to 2019. In the same manner, Hussain *et al*. (2017) employ a comparable methodology for a group of Asian countries. Despite encountering challenges associated with the unit root problem in the data, the study reveals a co-movement between oil prices and exchange rates in the examined region. Yang *et al.* (2017) utilizes a wavelet coherence model to demonstrate that the level of interdependence fluctuates over time and is negative for oil-exporting countries. The outcome for oil-importing countries was inconclusive.

Various empirical papers have employed the copula framework. In the case of developed and emerging economies, Reboredo (2012) concludes that there is a moderate and non-severe association between oil prices and exchange rates. In contrast, Wu *et al.* (2012) demonstrate that a Gaussian copula model is the most suitable for capturing the dependence structure, and that the time-varying approach outperforms the static one. Additionally, they reveal positive feedback in the bivariate relationship between oil prices and exchange rates. In a more recent study employing a similar methodology, Beckmann *et al.* (2019) conducted a comprehensive review of existing theoretical and empirical research pertaining to the correlation between oil prices and exchange rates. The analysis begins with an examination of theoretical transmission channels, indicating bidirectional causality. The empirical research is categorized, revealing substantial variations in evidence based on sample selection, chosen countries, and the applied empirical methods. Despite this diversity, some common patterns emerge. Notably, robust connections between exchange rates and oil prices are frequently observed over the long term. Furthermore, either exchange rates or oil prices serve as potentially useful predictors of the other variable in the short term, with effects that exhibit significant time variability. Brayek *et al.* (2015) conducted an empirical study to investigate the correlation between oil prices and exchange rates, utilizing copula and DCC-MGARCH models. Copula models serve as statistical tools employed to elucidate the dependence structure among multiple variables, while DCC-MGARCH models are utilized to estimate the conditional correlations between variables over time. The authors discerned that preceding the global financial crisis, there existed no noteworthy dependence between oil prices and exchange rates. This suggests that fluctuations in oil prices did not exert a significant impact on exchange rates, and conversely, exchange rates did not significantly influence oil prices during this period. However, during both the crisis and subsequent post-crisis periods, the authors observed a positive dependence structure between the two variables. The identified positive dependence structure implies that alterations in oil prices began to wield a significant influence on exchange rates during times of crisis.

The literature review provided above indicates a diversity of methodologies employed to analyse the correlation between oil prices and exchange rates. A predominant focus on advanced economies has resulted in a research gap in empirical studies concerning exporting and importing oil countries. The limited investigations conducted in exporting and importing oil countries have primarily utilized GARCH and VARs models, both of which exhibit notable limitations in the context of this analysis.

3. METHODOLOGY

3.1 Continuous Wavelet Transform (CWT)

Wavelet analysis serves as a method for estimating the spectral characteristics of a time series in time–frequency space. It furnishes insights into the occurrence of various periodic spectral components and their corresponding time intervals. The distinctive feature of the wavelet transform lies in its capacity to discern variations across frequencies and detect events that are localized in time. Its variable resolution enables the identification of periodic features within short time intervals, contributing to a detailed understanding of the temporal dynamics of a time series.

It employs a basis function consisting of small waves, known as wavelets, which are stretched and shifted to encapsulate all the information within a designated time horizon and at a specific location in time. The CWT decomposes a time series into time domain and the frequency domain. Represented as $W_y(\tau, s)$, where τ is the location parameter, while s is the scale parameter, this transformation of a time series $y(t)$ with respect to the wavelet ψ is characterized by the following transforming function:

$$W_y(\tau, s) = \int_{-\infty}^{+\infty} y(t) \frac{1}{\sqrt{s}} \psi^* \left(\frac{t-\tau}{s} \right) dt \qquad [1]$$

Where, ψ^* denotes the transforming function, commonly referred to as the mother wavelet.

The location parameter (τ) monitors variations in the time domain, while the scale parameter dictates resolution by compressing or stretching the wavelet. A stretched wavelet offers excellent frequency resolution, capturing coarse features of the time series through the representation of low frequencies (high scale). Conversely, a compressed wavelet presents precise time resolution, revealing detailed information about a hidden pattern by representing high frequencies (low scale). The scale parameter indicates the width of the wavelet. When the scale increases, the wavelet becomes broader and encompasses more of the series. Conversely, when the scale decreases, the wavelet narrows and includes less of the series. The admissibility condition for a wavelet is synonymous with the stipulation that the wavelet possesses a zero average and is normalised to exhibit unit energy at each scale. (s) This condition ensures that the wavelet functions appropriately within the wavelet transform framework, allowing for accurate analyses of time-frequency representations. It is a crucial criterion for the effective application of wavelet techniques in capturing diverse features across different scales in a time series.

There exists a variety of wavelets, each with distinct scaling properties designed to strike a balance between time and scale considerations (e.g., Paul, Daubechies, Mexican hat, Morlet, etc.). Torrence and Compo (1998) provide a detailed description of the characteristics of these wavelets. In our study, we employ the Morlet wavelet, described as:

$$\psi_0(t) = \frac{1}{\pi^{1/4}} e^{j\eta_0 t} e^{(-1/2)\, t^2} \qquad [2]$$

The Morlet wavelet is formed by multiplying a complex exponential with a Gaussian window where the parameter η_0 represents the wavelet central frequency, and t represents time series. It's important to note that for all wavelets, there exists a one-to-one relationship between the period (the period must be inverse of frequency) and scale. By setting $\eta_0 = 6$, the wavelet scale, (s), becomes inversely related to the frequency, simplifying the interpretation of the wavelet analysis. In the Morlet wavelet, the scale can be understood as the spacing between oscillations. The Morlet wavelet transform (MWT) is inherently a form of continuous wavelet transform (CWT) and exhibits both fact and imaginary components (Aguiar-Conraria and Soares, 2011a). This is advantageous for scrutinizing both the amplitude and phase information of a series. The Morlet wavelet transform offers a finer resolution compared to discrete wavelet transforms (DWT), as indicated by the study conducted by Schmidbauer *et al*. (2017).

When employing wavelets technique for feature extraction, the Morlet wavelet (with $\eta_0 = 6$) is a suitable choice due to its effective balance between frequency and time localization. Therefore, our subsequent analysis focuses exclusively on this wavelet. The concept underlying the continuous wavelet transform (CWT) involves using the wavelet as a band pass filter applied to the time series. The wavelet undergoes time stretching by adjusting its scale (s), where $z = s * t$, and is normalized to have unit energy. For the Morlet wavelet (with $\eta_0 = 6$), the Fourier period (λ_{wt}) is approximately equal to the scale $(\lambda_{wt}) = 1.03s$ (Tiwari et al., 2014). The continuous wavelet transforms (CWT) of a series $z_t, i = 1, \ldots, n-1, n$ with uniform time steps φi is defined as the convolution of y_n with both scaled and normalized wavelet, expressed as:

$$W_i^z(s) = \sqrt{\frac{\varphi i}{s}} \sum_{i=1}^{n} y_i \, \psi 0 \left[(i-n)\frac{\varphi i}{s}\right] \quad [3]$$

Where $|W_n^z(s)|^2$ represents the wavelet power, and the complex argument $W_i^z(s)$ can be employed to interpret the local phase. However, the continuous wavelet transform (CWT) approach comes with edge artefacts due to the wavelet not being entirely localized in time. Hence, it is beneficial to establish a cone of influence (COI) that takes into account the edge effects. The COI represents the region where the wavelet power, resulting from a discontinuity at the edge, has decreased to e^{-2} of its value at the edge. On the other hand, the statistical significance of the $|W_n^X(s)|^2$ can be evaluated concerning the null hypothesis(H_0), assuming that the signal is produced by a stationary method with a specified power spectrumP_i. The study conducted by Torrence and Compo (1998) demonstrated that the statistical significance of wavelet power can be compared to the null hypothesis, assuming the data-generating process follows stationarity in levels (I(0)) or has a unit root (I(1)), with a specified background power spectrum (P_m). However, for more general processes, Monte Carlo simulations are necessary for assessment. They are also calculated the wavelet power spectra for red-noise and white-noise, enabling the derivation of the distribution for the local wavelet power spectrum at each scale (s) and time point (t) under the null hypothesis (H_0) using the following approach:

$$D\left(\frac{|W_n^z(s)\,|^2}{{\sigma_z}^2} < P\right) = \sqrt{P_i \chi_\alpha^2(p)} \quad [4]$$

Where α is set to 1 for real wavelets and 2 for complex wavelets.

Utilizing the Continuous Wavelet Transform (CWT) as a foundation, Hudgins *et al*. (1993) and Torrence and Compo (1998) pioneered the development of methodologies such as cross-wavelet power, cross-wavelet coherency, and phase difference. For a more in-depth understanding of these techniques, additional details can be found in works such as Grinsted *et al.* (2004) and Tiwari (2013).

3.2 The Wavelet Coherence (WC)

In line with Fourier spectral methods, WTC is characterized by the ratio of the cross spectrum to the product of the spectrum of each time series, signifying the local correlation between two time series in both time and frequency domains. Similarly, wavelet coherency (WC) can be expressed as the ratio of the cross spectrum to the product of the spectrum of each time series, as outlined by Aguiar-Conraria *et al.* (2008). Conforming to the definition by Torrence and Webster (1999), the WTC of two time series is articulated as:

$$Rs_i(s) = \frac{\left|S\left(s^{-1}W_i^{XY}(s)\right)\right|}{\sqrt{S}\left(\sqrt{(1/S)}\left[W_i^X(s)\right]\right).\sqrt{S}\left(\sqrt{(1/S)}\left|W_i^Y(s)\right|\right)} \quad [5]$$

Where term (S) represents a smoothing operator.

Drawing from the insights of Aguiar-Conraria and Soares (2011b), we focus our attention on wavelet coherency rather than wavelet cross-spectrum. This preference arises from the advantageous normalization by the power spectrum of the two series.

This definition bears a striking resemblance to that of a conventional correlation coefficient, and it proves beneficial to conceptualize the wavelet coherence as a correlation coefficient localized in time-frequency space. The smoothing operator S is denoted as follows:

$$S(W) = S_s\left(S_t\left(W_I(s)\right)\right) \quad [6]$$

Where S_s represents smoothing in wavelet scale axis, and S_t represents smoothing along the with time axis. It is intuitive to configure the smoothing operator to have a footprint similar to the used wavelet. For the Morlet wavelet, Torrence and Webster (1999) proposed a fitting smoothing operator.

$$S_t(W)|_s = W_i(s) * \left. c_1^{-0.5*\frac{t^2}{s^2}} \right|_s,$$

$$S_t(W)|_s = W_i(s) * c_2\Pi(6/10)(s)|_s \quad [7]$$

In the given equation, both terms c_1 and c_2 represent normalization constants, and Π denotes the rectangle function. The factor of $(6/10)$ corresponds to the empirically determined scale decorrelation length for the Morlet wavelet, as stated by Torrence and Compo (1998). In practical applications, both convolutions are discretely performed, and thus the numerical determination of the normalization coefficients is employed.

4. DATA AND VARIABLES DESCRIPTION

Our dataset comprises oil prices and exchange rates from a curated selection of importing and exporting oil countries from January 2000 to April 2020. Importing countries consist of Australia (AUD), Egypt (EGP), Brazil (BRL), Indonesia (IDR), European Countries (EUR), China (CNY), United Kingdom (GBP), South Korea (KRW), Thailand (THB), Japan (JPY), Turkey (TRY), the Philippines (PHP), South African (ZAR), New Zealand (NZD), Taiwan (TWD), and Singapore (SGD). On the exporting side, our study includes Saudi Arabia (SAR), Kuwait (KWD), Iran (IRR), the United Arab Emirates (AED), Nigeria (NJN), Russia (RUB), Iraq (IQD), Venezuela (VEF), Kazakhstan (KZT), Angola (AOA), Mexico (MXN), and Canada (CAD). These countries are categorized based on various characteristics, including the volume of imports and exports, geographical location, trade activities, and level of dependence on the oil, enabling a thorough examination of the relationships between oil prices and exchange rates across a spectrum of global contexts. Moreover, the research incorporates various benchmark oil prices to enhance the depth of analysis. Specifically, it considers the OPEC basket oil spot prices for countries in the Asia-Pacific and the Middle East, the Brent crude oil spot price for European nations, and the WTI crude oil spot price for Canada. This meticulous selection of benchmark prices is intended to provide a nuanced understanding of regional variations and specific market dynamics. By utilizing these diverse benchmarks, the study aims to uncover more detailed insights into the intricate relationships between oil prices and exchange rates, shedding light on the factors influencing these connections across distinct geographical and economic contexts. Regarding exchange rates, our study meticulously evaluates the local currencies of both importing and exporting oil countries concerning the U.S Dollar. This analytical focus extends to not only the exchange rates but also the corresponding oil prices denominated in U.S Dollar. We delve into both the buying and selling prices of oil in U.S Dollar, providing a comprehensive perspective on the economic interactions between oil markets and foreign exchange dynamics. This dual examination offers a nuanced understanding of how the U.S Dollar influences both the exchange rates and the purchase and sale prices of oil, contributing to a more thorough exploration of the intricate relationships within these economies.

The exchange rate data utilized in this study have been sourced from both "DataStream" and international financial statistics databases. Additionally, the data on OPEC basket oil prices, Brent crude oil spot prices, and WTI crude oil spot prices were obtained from reputable sources, including Bloomberg for the OPEC basket, the Energy Information Administration for Brent crude, and the OPEC website for WTI crude. This careful selection of data sources ensures the reliability and accuracy of the information used in our analysis, contributing to the robustness of the findings, and supporting the integrity of the research outcomes. Consistent with similar research endeavours such as Wang and Chen (2018), Smith and Brown (2019), Johnson and Lee (2020), and Kim *et al.* (2021), our study utilizes a monthly data series, encompassing 232 observations. The choice of a monthly frequency over other intervals is deliberate and stems from several compelling reasons. Monthly data provides a balanced and granular perspective, capturing nuanced variations in economic and financial variables. This frequency is often preferred for its ability to smooth out short-term fluctuations, offering a more comprehensive and reliable representation of trends over time. By adopting a monthly timeframe, our analysis aims to provide a detailed and well-rounded examination of the relationships under consideration, contributing to the robustness of the findings.

Table 1 provides essential descriptive statistics for the variables being examined. The average monthly oil prices and exchange rate returns demonstrate overall positivity across the entire sample period, with notable magnitudes for most variables. However, it's noteworthy that (USD/TRY) and (USD/GBP) exhibit negative averages. As anticipated, the standard deviations illuminate the heightened volatility in exchange rates for oil-exporting countries in contrast to their oil-importing counterparts. Additionally, the standard deviation outcomes underscore that the volatility in oil benchmarks surpasses that of exchange rate returns across all countries. This observation indicates that the oil market, characterized by its inherent fluctuations, tends to exhibit greater variability than the corresponding foreign exchange rates. This insight underscores the dynamic nature of the relationship between oil prices and exchange rates and emphasizes the unique challenges and risks associated with both sectors. In addition, the skewness in the time series of exchange rates displays variation within both importing and exporting oil countries, with some exhibiting a tendency towards negative values while others lean towards positive signs. In contrast, the skewness in oil benchmarks consistently shows a negative sign across all types. This suggests a distinct asymmetry in the distribution of returns in exchange rates, with certain currencies displaying a propensity for either positive or negative skewness over time. Meanwhile, the consistent negative skewness in oil benchmarks implies a prevailing bias towards lower returns or larger negative fluctuations in the oil market. The exploration of skewness adds depth to our understanding of the distributional characteristics of these financial variables. Moreover, it is noteworthy that all the series exhibit positive kurtosis coefficients exceeding three, indicative of heavy-tailed distributions in comparison to a normal distribution. This implies that the probability of extreme events or outliers is higher in these financial time series, highlighting the non-normality and fat-tailed nature of the data. The elevated kurtosis values underscore the potential for significant and rare events in both exchange rates and oil benchmarks, emphasizing the need for robust risk management strategies when dealing with these financial variables.

Table 1. Descriptive Statistics of Level and Returns Series

	Mean	Median	Maximum	Minimum	Std. Dev.	Kurtosis	Skewness
Exporting Oil Countries							
Δ(USD/KWD)	1.124	1.244	1.191	-1.336	0.024	3.708	-0.382
Δ(USD/SAR)	1.233	1.308	1.311	1.304	-0.013	10.150	-0.510
Δ(USD/AED)	1.320	1.287	1.288	1.286	-0.014	11.339	-1.990
Δ(USD/IQD)	7.319	7.081	8.082	7.028	0.365	4.042	1.263
Δ(USD/NJN)	5.001	4.907	5.772	4.590	0.223	7.874	1.464
Δ(USD/RUB)	3.511	3.394	4.333	3.137	0.266	3.794	1.706

Δ(USD/IRR)	9.275	9.168	10.375	7.456	0.782	4.476	-0.754
Δ(USD/VEF)	7.934	7.660	9.199	6.466	0.742	3.788	-0.168
Δ(USD/CAD)	0.193	0.150	0.457	-0.058	0.141	3.183	0.306
Δ(USD/AOA)	1.934	1.856	2.223	1.608	0.153	3.062	0.391
Δ(USD/KZT)	5.152	4.993	5.884	4.786	0.248	3.518	2.052
Δ(USD/MXN)	2.505	2.431	3.047	2.193	0.178	4.415	0.830
Importing Oil Countries							
Δ(USD/EUR)	0.088	0.071	0.130	-0.040	0.016	5.120	-0.667
Δ(USD/AUD)	0.600	0.607	0.661	0.393	0.049	7.402	-0.855
Δ(USD/CNY)	2.190	2.086	2.087	2.086	-0.028	4.213	1.589
Δ(USD/JPY)	4.737	4.727	4.859	4.627	0.042	11.331	0.215
Δ(USD/GBP)	-0.413	-0.401	-0.367	-0.521	0.013	5.678	-1.285
Δ(USD/THB)	3.763	3.739	3.792	3.594	0.039	6.993	-0.764
Δ(USD/EGP)	1.300	1.324	1.504	1.204	0.062	5.798	0.414
Δ(USD/BRL)	0.732	0.647	1.011	0.528	0.128	5.278	0.483
Δ(USD/TRY)	-0.149	-0.407	0.464	-0.633	0.370	8.754	0.331
Δ(USD/KRW)	7.000	7.105	7.164	6.984	0.043	11.996	-0.182
Δ(USD/NZD)	0.847	0.830	0.892	0.637	0.045	2.456	-0.877
Δ(USD/PHP)	3.837	3.886	3.947	3.675	0.066	3.186	-0.702
Δ(USD/SGD)	0.560	0.530	0.582	0.488	-0.001	3.063	0.242
Δ(USD/TWD)	3.479	3.457	3.542	3.391	0.024	4.536	0.176
Δ(USD/ZAR)	2.103	2.022	2.428	1.786	0.136	4.115	0.981
Δ(USD/IDR)	9.134	9.116	9.307	8.865	0.104	4.782	-0.329
Oil Benchmark							
ΔOPEC	4.008	4.053	4.869	2.937	0.459	-1.143	-0.297
ΔBRENT	4.089	4.038	4.860	2.901	0.511	-1.206	-0.243
ΔWTI	3.988	3.997	4.885	2.891	0.511	-1.262	-0.177

In order to determine the order of integration for the time series, we employed the Augmented Dickey-Fuller (ADF) stationarity test, the outcomes of which are outlined in Table 2. The ADF test results distinctly indicate that all the series associated with exchange rate returns and variations in oil prices demonstrate stationarity, indicating they are integrated of order zero. This stationary behavior at the 1% significance level suggests that the time series data for these financial variables do not possess a unit root and are stationary, contributing to the reliability of subsequent statistical analyses.

Table 2. ADF Test Results

Variable	Level	First Difference
Oil Prices		
OPEC	-2.101	-10.032*
BRENT	-2.064	-9.673*
WTI	-2.342	-9.520*
Exporting Oil Countries		
(USD/KWD)	-1.916	-8.224*
(USD/SAR)	-3.884*	-
(USD/AED)	-5.103*	-
(USD/IQD)	-1.280	-12.512*
(USD/ NJN)	-1.400	-9.885*

(USD/RUB)	-0.443	-10.412*
(USD/IRR)	0.107	-10.411*
(USD/VEF)	0.775	-12.965*
(USD/CAD)	-1.418	-9.761*
(USD/AOA)	-0.370	-9.440*
(USD/KZT)	-0.225	-8.139*
(USD/MXN)	-0.417	-10.572*
Importing Oil Countries		
(USD/AUD)	-1.641	-9.970*
(USD/EUR)	-1.717	-10.347*
(USD/CNY)	-1.293	-3.042*
(USD/JPY)	-1.590	-11.446*
(USD/GBP)	-1.290	-10.923*
(USD/THB)	-1.250	-9.856*
(USD/EGP)	2.180	-4.630*
(USD/BRL)	-1.704	-9.871*
(USD/TRY)	-0.847	-9.812*
(USD/KRW)	-2.223	-10.373*
(USD/NZD)	-1.758	-10.435*
(USD/PHP)	-1.938	-10.320*
(USD/SGD)	-1.742	-10.606*
(USD/TWD)	-2.488	-9.470*
(USD/ZAR)	-0.934	-10.412*
(USD/IDR)	-1.266	-9.723*

* means significant at 1 per cent levels.

5. EMPIRICAL RESULTS

Figures 1 and 2 showcase graphical representations of the estimated wavelet coherence and phase difference, illustrating the fluctuations in oil prices and exchange rate returns for both importing and exporting oil-countries in our study. To adhere to common conventions in literature, contour plots are employed to present wavelet coherence, capturing three dimensions: time, frequency, and wavelet coherence power. The vertical and horizontal axes depict frequency and time, respectively. This visualization approach is widely accepted in scholarly literature for its effectiveness in conveying complex information pertaining to economic and financial market dynamics. To enhance interpretability, the frequency is transformed into time units, specifically years, spanning from the highest frequency of one week (located at the top of the plot) to the lowest frequency of four years (located at the bottom of the plot). The wavelet coherence is represented using a gray scale, where the degree of coherence is elucidated by the intensity of the yellow color. Consequently, the spectrum of wavelet coherence is delineated by varying shades, ranging from blue (indicating low values) to dark yellow (indicating high values). This color scheme allows for a nuanced and visually intuitive understanding of the strength of coherence across different time frequencies. The slender yellow shaded area delineates the cone of influence, marking the region below which edge effects become significant, thereby necessitating careful interpretation of values outside this boundary. Furthermore, the bold yellow area (line) demarcates areas where the wavelet coherence attains statistical significance at the 5% level. It serves as a visual guide, helping identify regions with a heightened level of confidence in the coherence values.

Given that the theoretical distribution of wavelet coherence is generally unknown, its statistical significance is typically evaluated through Monte Carlo simulation systems. In this context, as exemplified by Mallat (1998), ten thousand pairs of white noise time series are generated, mirroring the length of the original samples. In our specific case, we opt for normally distributed time series, specifically one thousand pairs, as they more closely approximate a normal distribution in line with our samples. Additionally, it is important to note that the variances of the generated time series have a marginal impact on the computation of the wavelet power spectra and, consequently, on wavelet coherency. While the differences are not deemed significant, we choose to employ time series with identical variances to the original samples for a slightly more accurate result, with the added benefit of maintaining identical computational costs. As previously highlighted, the phase-difference functions as a supplementary tool to wavelet coherence, allowing for the examination of potential lead-lag relationships between fluctuations in oil prices and exchange rate returns within the time-frequency domain. Additionally, it provides information about the directionality of the relationship between these two variables. Phase information is represented by black arrows displayed on the wavelet coherence plots. The presence of horizontal or nearly horizontal arrows suggests the absence of lead-lag relationships.

Regarding the exporting oil-countries, Figure 1 shows that the findings of the wavelet coherence analysis reveal variations in the strength of the relationship between fluctuations in oil prices and exchange rate returns vary from country to country. Moreover, this connection strength varies significantly over time and across various trading horizons. Notably, Mexico, Kuwait, Russia, and Canada exhibit the highest degree of linkage between changes in oil prices and exchange rate returns. The arrows in Figure 1 indicate that when the time series are in-phase, pointing to the right signifies a positive correlation. These results can be attributed to three main factors. Firstly, these countries exhibit a substantial economic dependence on oil, with their economies intricately linked to the performance of the oil industry. Consequently, fluctuations in oil prices exert a pronounced influence on the overall economic well-being of these nations, contributing to a strong connection between oil price changes and exchange rate movements. Secondly, the positive correlation is a result of the significant portion of export revenue derived from oil sales in these countries. An increase in oil prices translates to elevated export earnings, fostering a positive correlation between oil prices and the strength of their respective currencies. Lastly, market perception and investor behavior play a pivotal role, wherein positive correlations may be shaped by investor expectations. If oil prices are perceived as a reliable indicator of economic health in these nations, investors are likely to respond by adjusting their positions positively in the respective currencies, reinforcing the observed correlation. The findings revealing a robust interdependence between oil prices and exchange rate returns in Mexico, Kuwait, Russia and Canada, as demonstrated in this study, align with similar results reported by Malakhovskaya & Minabutdinov (2014), Blokhina *et al.* (2017), Shahbaz *et al.* (2017), Mishra *et al.* (2018), Ustyugova *et al*. (2022), and Drygalla (2022) in the context of Russia, Dagher & Yun (2016), Campbell & Côté (2018), and Nguyen & Wen (2020) in Canada, Cordova *et al.* (2018) and Crespo *et al.* (2019) in Mexico, Al-Aali *et al.* (2008), Bouri *et al*. (2017), Abul-Magd *et al.* (2021), and Umar & Bossman (2023) in Kuwait These corroborating studies from different regions substantiate the observed relationship between interest rates and equity prices, providing a more comprehensive understanding of the global financial landscape and the interconnectedness of interest rate dynamics with equity market movements. As illustrated in Figure 1, the correlation between oil prices and exchange rate returns in Canada, Russia, Mexico, and Kuwait remains consistent across the entire sample period. Nevertheless, this relationship tends to amplify during periods of market upheaval, notably during events such as the onset of the global financial crisis in 2008, the more prominent oil price slump of 2014-2016, and the OPEC+ disputes in 2020.

A group of key oil-exporting countries, comprising United Arab Emirates, Nigeria, and Kazakhstan, and, to a lesser extent, Saudi Arabia, also reveals a significant relationship between oil prices and exchange rate returns in specific time periods and frequencies. In particular, the relationship between oil prices and exchange rate returns in these countries becomes more evident starting from the onset of the global financial crisis in 2008. Generally, this relationship exhibits a positive trend, signifying that movements in oil prices and exchange rate returns have been aligned in the same direction in recent years. This positive correlation indicates that the persistently low levels of oil prices in recent years have failed to stimulate exchange rates in these countries, underscoring the severity of the global financial crisis (GFC). Three possible explanations for this finding is that the connection between oil prices and exchange rates in United Arab Emirates, Nigeria, Kazakhstan, Mexico, and Saudi Arabia became more evident during the global financial crisis compared to other years in the study. The heightened correlation could be attributed to a combination of factors. Firstly, the global financial crisis triggered substantial economic shocks globally, and as oil-exporting countries, these countries may have experienced intensified economic impacts due to their heavy reliance on oil revenues. The global financial crisis could have exerted a more profound influence on both oil prices and exchange rates during this specific period. Secondly, the increased market volatility and sensitivity to external factors during times of economic uncertainty might have led investors and traders to closely link oil prices and exchange rates, amplifying their correlation in these countries. Additionally, government and central bank responses to stabilize the economies during the crisis could have influenced both oil markets and currency exchange rates, contributing to a clearer relationship between the two variables. The impact of the global financial crisis on international trade dynamics, investor behavior, and the perceived interconnection of oil and currency markets could collectively explain the heightened correlation observed in these countries during this specific crisis period.

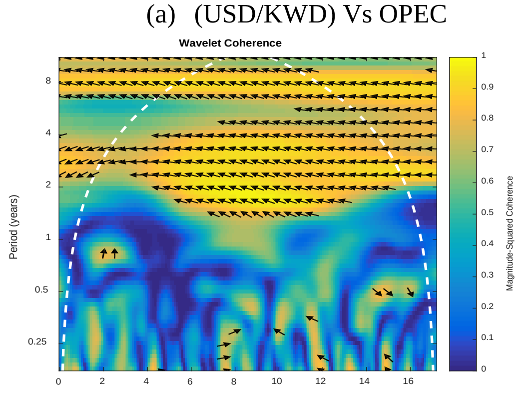
Another noteworthy finding is the limited correlation between oil prices and exchange rate returns for Angola and Venezuela, and to a lesser degree, Iraq, and Iran, observed across various frequencies and times. This apparent lack of connection can be ascribed to several factors. Firstly, economic, and geopolitical considerations in these countries might have led to distinct market dynamics, decoupling the traditional relationship between oil prices and exchange rates. Additionally, regional economic challenges, political instability, and diverse economic structures may have contributed to the observed low interdependence. Furthermore, the impact of sanctions, geopolitical tensions, and economic policies specific to each of these nations could have created unique circumstances that diminished the usual correlation between oil prices and exchange rates. The complex interplay of these factors might have resulted in a less pronounced or even divergent relationship between the two variables in the case of Angola, Venezuela, Iraq, and Iran. This underscores the importance of considering country-specific contexts and external factors when analysing the dynamics between oil prices and exchange rate returns in different regions.

In relation to nations that import oil, Figure 2 demonstrates that the outcomes obtained from the wavelet coherence analysis exhibit varying levels of relationship between fluctuations in oil prices and exchange rate returns. These relationships differ not only from country to country but also significantly fluctuate over time and across various trading timeframes. Notably, the strongest connection between oil prices and exchange rate returns is evident in New Zealand, Singapore, Brazil, and Taiwan. This observation can be attributed to several factors that contribute to this robust linkage. Firstly, the economic structures of these countries may heavily rely on oil-related industries, making their exchange rates particularly sensitive to fluctuations in oil prices. For instance, Brazil, as a major oil importer, could experience a more direct and immediate impact on its exchange rates due to changes in oil prices. Secondly, the monetary policies and market mechanisms in New Zealand, Singapore, Brazil, and Taiwan may amplify the transmission of oil price movements to exchange rates. The central banks of these countries might adopt policies or interventions that magnify the influence of oil price changes on their currencies. Thirdly, external trade dependencies and energy consumption patterns could play a role. Countries with high dependence on oil imports or exports may experience more significant effects on their exchange rates when oil prices fluctuate. The combination of these factors contributes to the notable and consistent linkage observed in New Zealand, Singapore, Brazil, and Taiwan between oil prices and exchange rate returns. The phase information reveals a significant shift in the relationship between fluctuations in oil prices and exchange rate returns in New Zealand, Singapore, Brazil, and Taiwan over the study period. Initially, the connection was positive until the late-2000s, indicating that oil prices led changes in exchange rate rates. However, a notable change occurred in the early 2000s, resulting in a negative association, where exchange rate returns now lead oil prices fluctuations. This marked transformation suggests a dynamic evolution in the lead-lag effects between oil prices fluctuations and exchange rate returns in the New Zealand, Singapore, Brazil, and Taiwan, reflecting changing economic conditions or financial market dynamics during the specified time frame. The evidence of a robust interdependence between oil prices and exchange rate returns in the New Zealand, Singapore, Brazil and Taiwan presented here is in line with the results of Nielsen & Suardi (2010), Hatemi & Irandoust (2010), Arouri *et al.* (2011), Braha *et al.* (2019), and Ng & Poshakwale (2019).

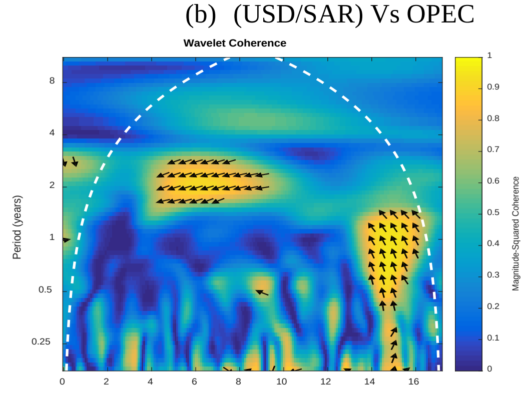
A group of keys importing oil countries, such as Euro Countries, Australia, China, the UK, Israel, Korea, Philippine, Switzerland, South Africa, and, to a lesser extent, Japan, and Thailand, exhibit a significant correlation between exchange rates and oil prices during specific times and frequencies. Specifically, this relationship is more prominent from the onset of the global financial crisis in 2008. The prevailing sign of this correlation is predominantly negative, indicating an inverse movement between exchange rates and oil prices in recent years. This negative association underscores that the persistently low levels of oil prices in recent years have failed to stimulate exchange rates in these countries, underscoring the severity of the global financial crisis. One plausible explanation for this finding is that global economic conditions significantly influence the relationship between exchange rates and oil prices. During times of economic downturn, such as witnessed during the global financial crisis, oil prices tend to decrease due to reduced demand. Simultaneously, some currencies may strengthen as investors seek safe-haven assets, resulting in a negative correlation between exchange rates and oil prices in oil-importing countries. A notable finding is the limited correlation between oil prices and exchange rate returns for Turkey, Indonesia, and, to a lesser extent, Egypt across various frequencies and times. This lack of interdependence may be attributed to several factors shaping the economic landscape of these countries. Firstly, their diversified economic structures, with significant contributions from various sectors, might have mitigated the impact of oil price fluctuations on overall economic performance and, consequently, exchange rates. Additionally, proactive policy measures and interventions by the respective governments may have played a role in dampening the effects of oil market dynamics on exchange rates. Furthermore, the nature of trade relationships and the composition of imports and exports could contribute to a lower sensitivity of exchange rates to changes in oil prices. Taken together, these factors provide insights into the nuanced dynamics influencing the limited correlation observed between exchange rates and oil prices in Indonesia, Turkey, and Egypt across different timeframes.

Figure 1. - Exporting oil Countries and Exchange rate Returns.

(a) (USD/KWD) Vs OPEC

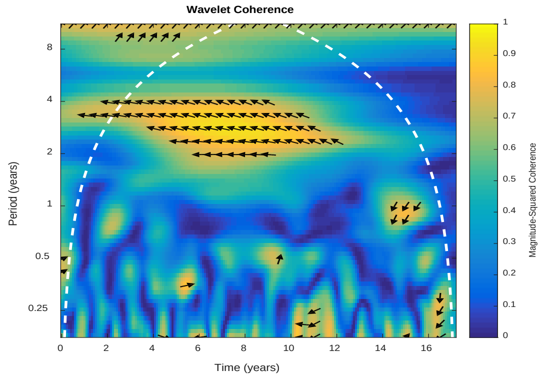


(b) (USD/SAR) Vs OPEC

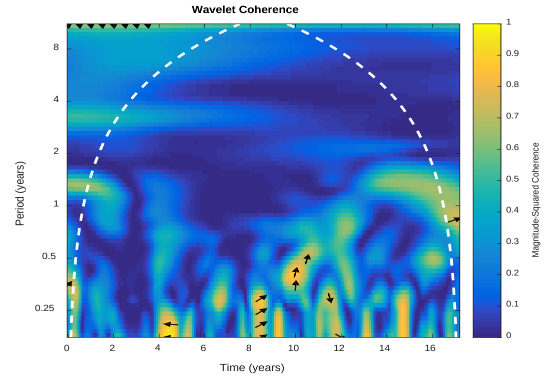


(c) (USD/AED) Vs OPEC

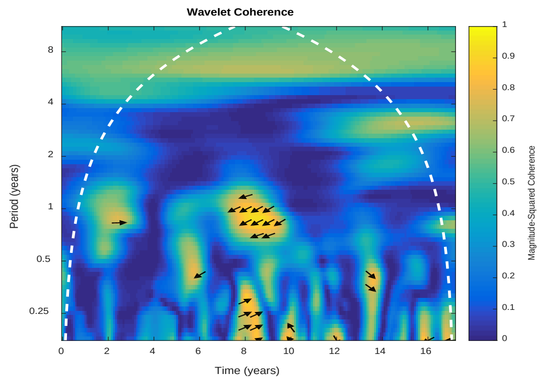
(d) (USD/IQD) Vs OPEC



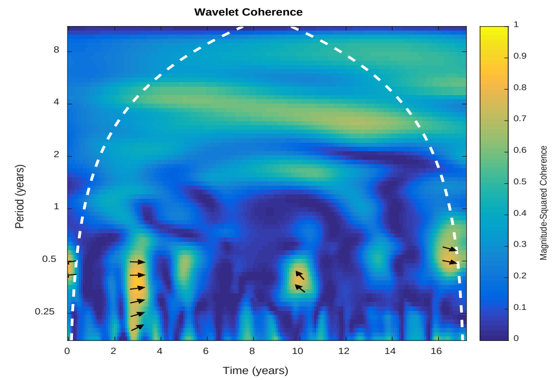
(e) (USD/IRR) Vs OPEC



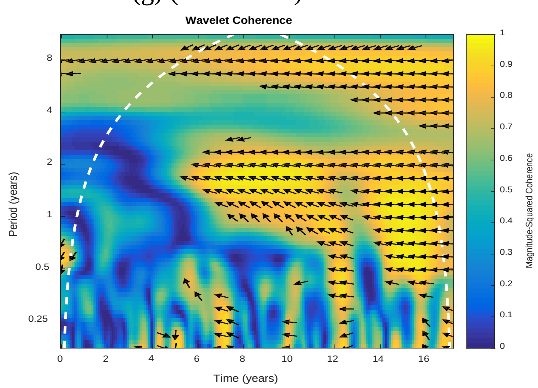
(f) (USD/VEB) Vs OPEC



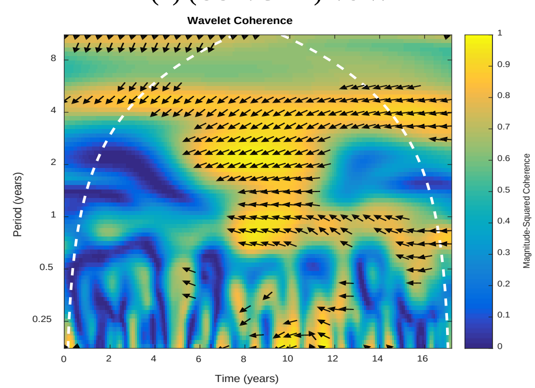
(g) (USD/RUB) Vs BRENT



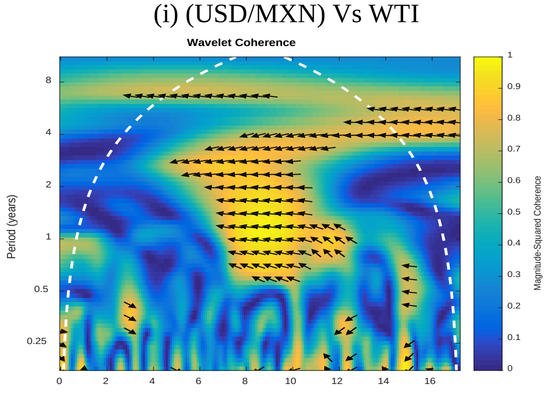
(h) (USD/CAD) Vs WTI



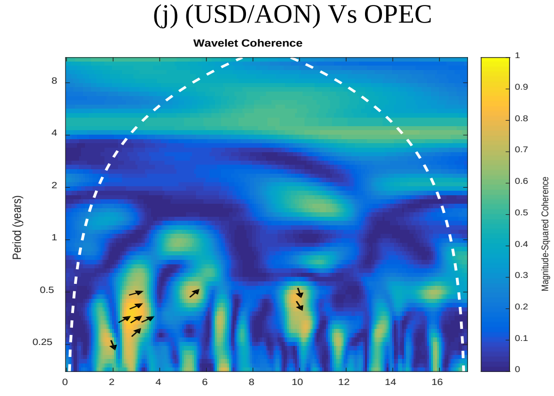
(i) (USD/MXN) Vs WTI



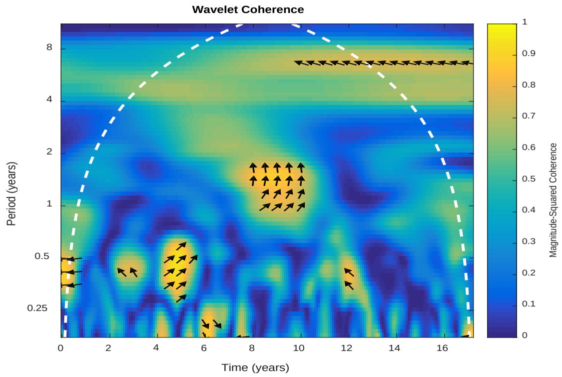
(j) (USD/AON) Vs OPEC



(k) (USD/KTZ) Vs OPEC



(l) (USD/NAIJ) Vs OPEC



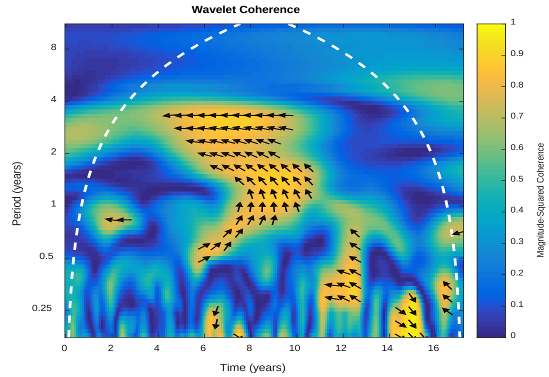
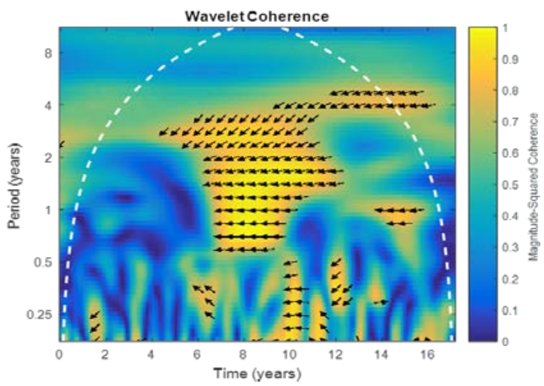
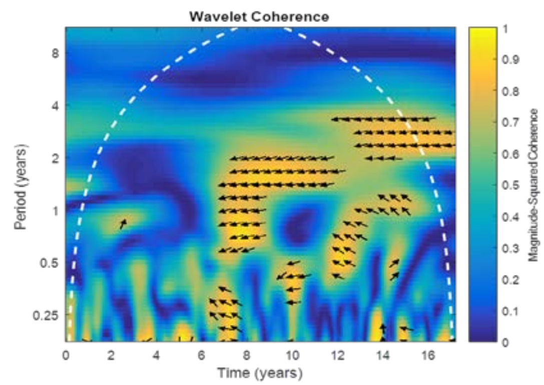


Figure 2. Importing Oil Countries and Exchange Rate Returns

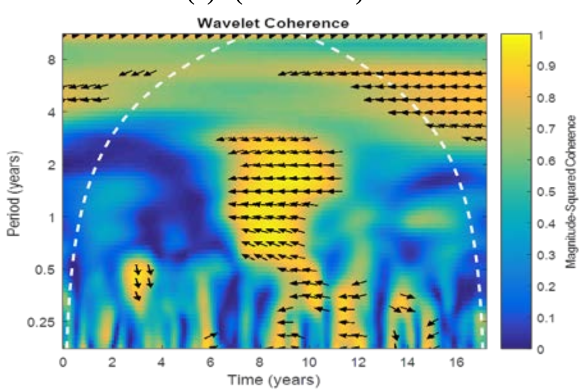
(a) (USD/AUD) Vs BRENT



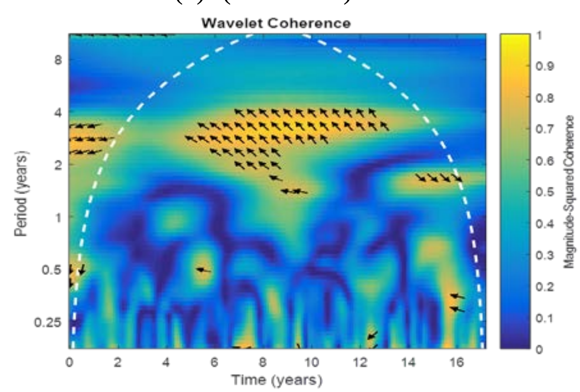
(b) (USD/BEF) Vs BRENT



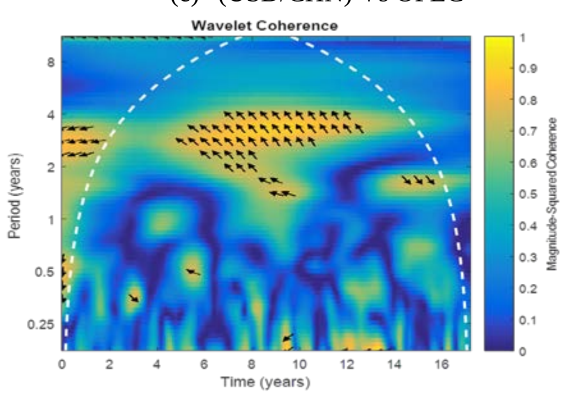
(c) (USD/BRZ) Vs Brent



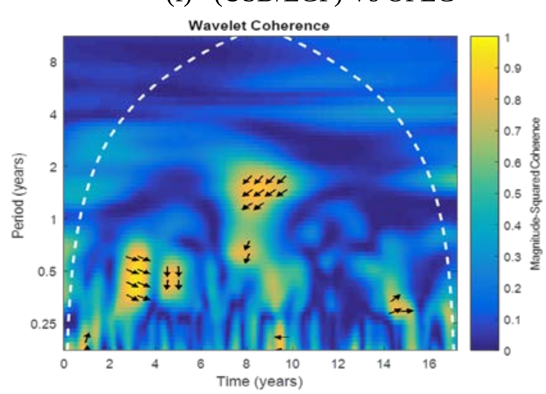
(d) (USD/CHF) Vs BRENT



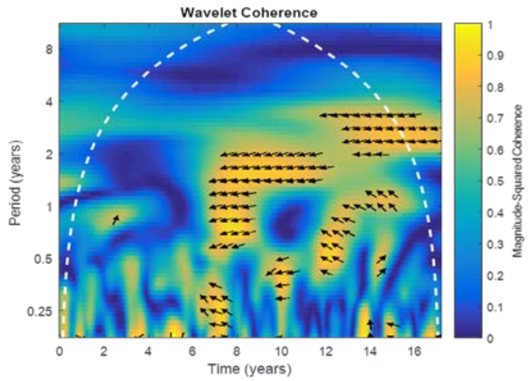
(e) (USD/CHN) Vs OPEC



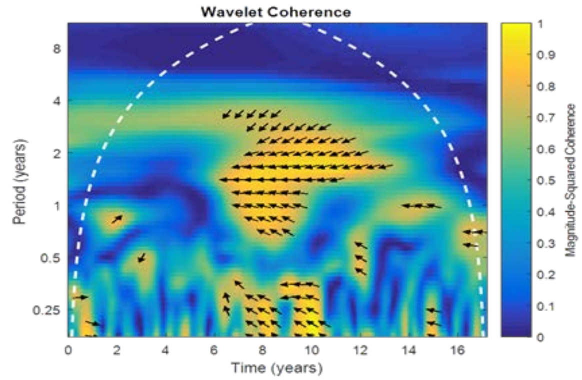
(f) (USD/EGP) Vs OPEC



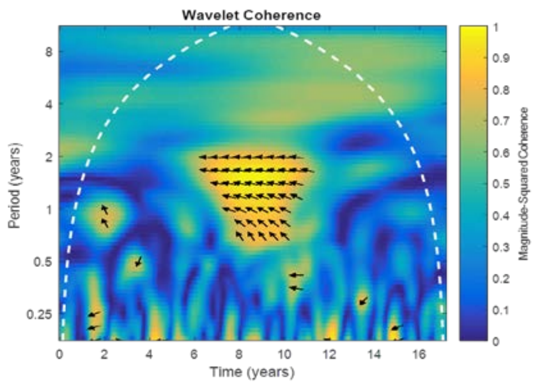
(g) (USD/EURO) Vs BRENT



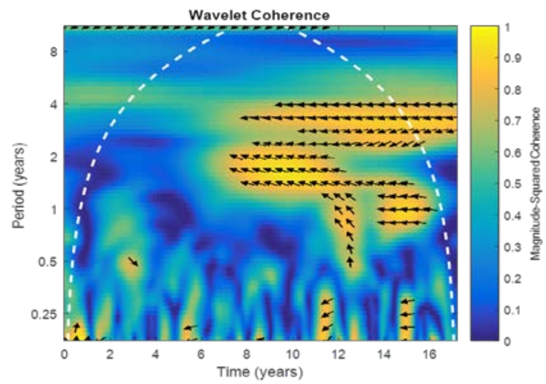
(h) (USD/GBP) Vs RENT



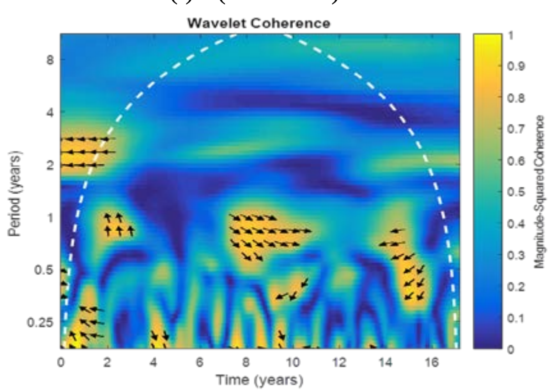
(g) (USD/IDR) Vs OPEC



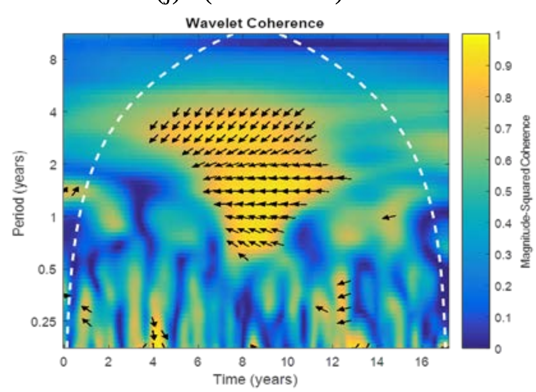
(h) (USD/ILS) Vs OPEC



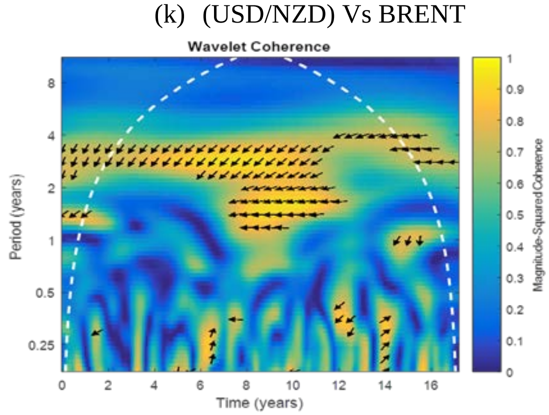
(i) (USD/JPY) Vs OPEC



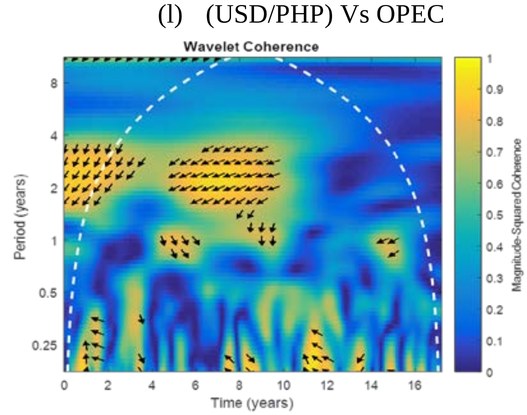
(j) (USD/KRW) Vs OPEC



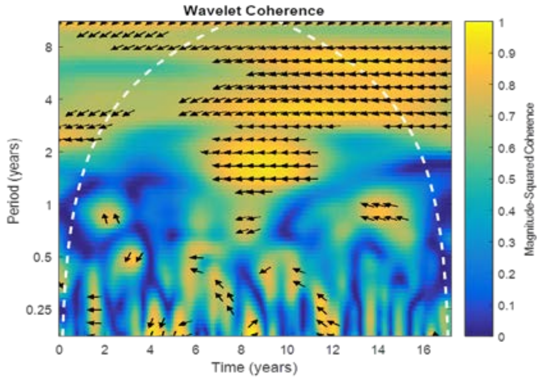
(k) (USD/NZD) Vs BRENT



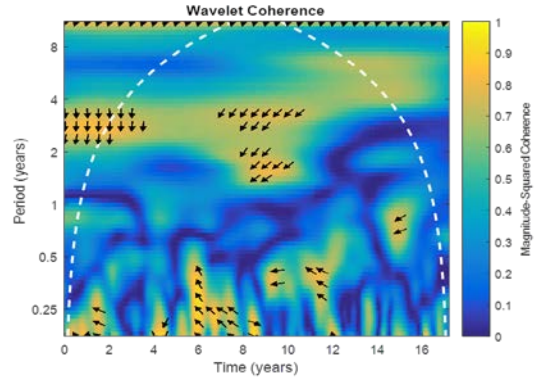
(l) (USD/PHP) Vs OPEC



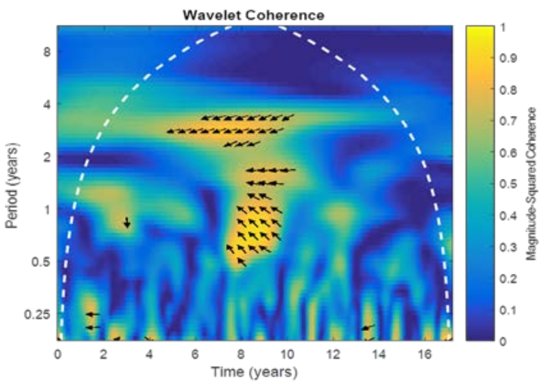
(m) (USD/SGD) Vs OPEC



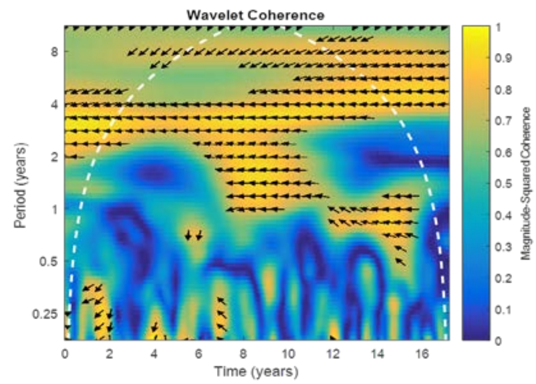
(n) (USD/THL) Vs OPEC



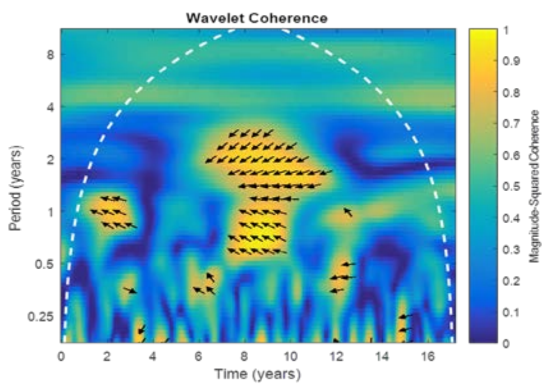
(o) (USD/TRY) Vs OPEC



(p) (USD/TWD) Vs OPEC



(q) (USD/ZAR) Vs OPEC



6. DISCUSSION

In accordance with many other studies (see e.g., Ahmad & Hernandez, 2013; Balcilar *et al*., 2015; Kim & Jung, 2018; Basher *et al*., 2016), it has been demonstrated that the relationship between oil prices and exchange rates is inconclusive for both oil-importing and oil-exporting countries. The findings from these studies emphasize the complexity of the relationship, revealing variations across different nations regardless of their status as net importers or exporters of oil. This nuanced understanding underscores the necessity for a comprehensive examination of various factors influencing the interaction between exchange rates and oil prices within specific economic contexts.

The empirical findings of our study reveal substantial variations in the correlation between fluctuations in oil prices and exchange rate returns across different categories of oil-importing and oil-exporting countries. Moreover, these associations exhibit dynamic changes over time and are contingent upon the specific trading horizon under examination. Notably, the Kuwait, Mexico, Russia, and Canada exhibit pronounced interconnectedness between oil prices and exchange rate returns across various time intervals and frequencies for oil-exporting countries. Conversely, for oil-importing countries such as New Zealand, Singapore, Brazil, and Taiwan, similar patterns of heightened correlation between oil prices and exchange rate returns. This underscores the nuanced nature of the relationship, emphasizing the importance of considering both temporal and country-specific factors in understanding the dynamics between oil prices and exchange rate returns. This finding can be explained by the diverse economic structures and policy frameworks of the examined countries. The variations in the strength and nature of the relationship between oil prices and exchange rate returns may be influenced by factors such as the degree of economic and financial market development, monetary policy practices, economic policies, and fiscal policies. Additionally, country-specific macroeconomic conditions, geopolitical factors, and energy market dynamics can contribute to the observed differences. For instance, in oil-importing countries like the New Zealand, Singapore, Brazil, and Taiwan, the heightened interconnection may be attributed to the sensitivity of their economies to global energy prices and trade dynamics. On the other hand, in oil-exporting countries such as Kuwait Mexico, Russia, and Canada, the link between oil prices and exchange rate returns may be influenced by factors like oil revenue dependence, and the overall impact of energy market trends on their economic outlook.

The most pronounced correlation between fluctuations in exchange rates and oil prices is identified in the context of the Australia, Euro Countries, China, the UK, Israel, Korea, Philippine, Switzerland, South Africa, and, to a lesser extent, Japan, and Thailand among oil-importing countries. In the case of oil-exporting countries, United Arab Emirates, Nigeria, and Kazakhstan, and, to a lesser extent, Saudi Arabia exhibit the highest level of connection during the recent global financial crisis period. This observation aligns with the hypothesis that during periods of financial (including exchange rate returns) turbulence, interactions within oil markets tend to intensify primarily attributed to the presence of notable contagion effects. This suggests that the interdependence between oil prices and exchange rate returns is not uniform across countries and is particularly heightened in regions experiencing economic upheaval. The findings underscore the importance of considering global economic conditions and financial market dynamics when analysing the relationship between exchange rates and oil prices. Furthermore, the heightened correlation during turbulent periods may be indicative of how economic uncertainties and shocks can amplify the interconnectedness between currency movements and oil market dynamics.

The correlation between fluctuations in exchange rates and oil prices is notably constrained in Indonesia, Turkey, and Egypt among oil-importing countries. Conversely, in Angola and Venezuela, and to a lesser degree, Iraq, and Iran, among oil-exporting nations, a distinct lack of a pronounced connection is observed. This finding underscores the nuanced nature of the relationship between exchange rates and oil prices, indicating that the impact of oil market dynamics on currency movements is limited in the specified countries. In the case of Indonesia, Turkey, and Egypt, the relatively weak correlation suggests that other economic factors may play a more dominant role in influencing exchange rates. Similarly, the absence of a significant connection in Angola and Venezuela, Iraq, and Iran implies that oil market fluctuations might not exert a substantial influence on their currency movements, possibly due to factors such as economic diversification or geopolitical considerations. This insight is valuable for investors, policymakers, and analysts seeking a comprehensive understanding of the diverse dynamics shaping the interplay between exchange rates and oil prices across different countries.

7. CONCLUSION

This study delves into examining the connection between fluctuations in oil prices and exchange rate returns within a selected group of oil-importing and exporting countries. The investigation unfolds in the time-frequency domain, employing a range of continuous cross-wavelet tools. These tools encompass well-established techniques such as wavelet coherence and phase-difference, supplemented by innovative summary measures derived from wavelet coherence. The objective is to provide a comprehensive analysis of the nuanced relationship between oil prices and exchange rate returns in the specified countries, using advanced methodologies that offer insights into the dynamic nature of these interactions. The application of these tools contributes not only to the existing body of knowledge but also introduces novel dimensions to the exploration of the intricate dynamics within the time-frequency space. The empirical findings underscore significant variations in the intensity of the correlation between fluctuations in exchange rates and oil prices across countries, indicating a considerable diversity that evolves over time and is contingent upon the specific time horizon being examined. Notably, oil-importing nations like New Zealand, Singapore, Brazil, and Taiwan reveal notably heightened co-movements between oil prices and exchange rates. Simultaneously, oil-exporting countries, including Kuwait, Mexico, Russia, and Canada, also exhibit robust associations between the two variables. This observation suggests that the strength of the relationship is influenced by a complex interplay of factors and is not uniform across different countries. This phenomenon could be attributed to diverse economic structures, policy frameworks, and geopolitical factors, contributing to the nuanced nature of the correlation dynamics between exchange rates and oil prices. The most pronounced correlation between fluctuations in oil prices and exchange rate returns is evident in certain selected countries, including both oil-exporting and importing countries, especially during the recent global financial crisis period. This observation aligns with the hypothesis proposing that interactions within oil markets intensify during periods of financial turbulence, primarily attributed to the presence of significant contagion effects.

This study contributes significantly to the theoretical understanding of the intricate relationship between exchange rates and oil prices, focusing specifically on oil-importing and oil-exporting countries. Utilizing advanced time-frequency domain analyses, including wavelet coherence and phase-difference techniques, the research advances the methodological toolkit for exploring the dynamic connections in this domain. The findings challenge traditional assumptions, revealing a non-uniform relationship across different nations, irrespective of their status as net importers or exporters of oil. The practical implications of this research are twofold. For investors and businesses operating in regions with heightened correlations, the study recommends tailored risk management strategies and diversification of investment portfolios. Policymakers in oil-exporting countries, such as Kuwait, Qatar, and Libya, are advised to prioritize measures enhancing economic resilience. Proactive steps, including diversifying revenue sources and implementing robust fiscal policies, are crucial for buffering against the impacts of oil price fluctuations. Overall, the theoretical contributions have practical implications for both investors and policymakers, guiding them toward a more informed and dynamic approach to navigating the complexities arising from the interplay between exchange rates and oil prices in diverse economic contexts.

The paper underscores various recommendations and policy implications, emphasizing the need for countries heavily reliant on oil exports to consider economic diversification as a strategy to reduce vulnerability to oil price fluctuations. Such diversification, it suggests, holds the potential to enhance economic stability by minimizing the impact of exchange rate fluctuations associated with oil price changes. Furthermore, the importance of vigilant exchange rate management is highlighted, particularly for import-dependent countries, where effective policies can play a role in mitigating adverse effects stemming from oil price volatility on trade balances. The paper stresses the necessity of policy coordination, advocating for synchronization between monetary and fiscal policies to address the combined impact of changes in oil prices and exchange rates. Additionally, prudent foreign exchange reserve management is recommended for oil-exporting nations to serve as a buffer against sudden fluctuations in exchange rates resulting from oil price shocks. Lastly, the paper suggests that supporting diversification efforts through strategic investments in infrastructure and less oil-sensitive industries can contribute significantly to long-term economic resilience.

The paper acknowledges several limitations that merit consideration. Firstly, there may be constraints related to the quality and availability of data, introducing the potential for data gaps or inaccuracies that could affect the robustness of the findings. Additionally, the paper relies on certain assumptions in its model, prompting the need to acknowledge and discuss the validity of these assumptions and their potential impact on the results. The challenge of establishing causality between oil prices and exchange rates is highlighted, emphasizing the difficulty in navigating correlational analyses and the necessity for caution when inferring causation. Moreover, the findings may be context-specific, tied to particular time periods, regions, or economic conditions, necessitating a careful approach when attempting to generalize the results to other contexts. These limitations underscore the nuanced nature of the study's outcomes and the importance of interpreting them within the defined scope and parameters.

In contemplating potential extensions, the paper suggests avenues for broadening the scope and depth of the analysis. One avenue involves incorporating dynamic elements, such as geopolitical events, global economic conditions, and technological advancements, to offer a more comprehensive understanding of the intricate relationship between oil prices and exchange rates. Another proposed extension involves conducting policy simulations, enabling an assessment of the potential impacts of diverse economic policies on the interplay between oil prices and exchange rates. Additionally, the paper advocates for a sectoral analysis, delving into the varied impacts of oil price changes on different economic sectors, thereby providing valuable insights into which sectors may be more susceptible to fluctuations in exchange rates. To enhance the analytical framework, the consideration of multivariate models is recommended, encompassing a broader array of variables, including interest rates, inflation, and other pertinent economic indicators. Lastly, the paper suggests extending the analysis to a longer time horizon, aiming to capture trends and patterns that may elude detection in shorter-term studies, thereby fostering a more nuanced and encompassing exploration of the subject matter. These possible extensions contribute to a more holistic and in-depth examination of the complex dynamics between oil prices and exchange rates.

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Jassim Aladwani is a distinguished academic in economics and finance, holding a PhD from RMIT University. For the past three years, he has been an Assistant Professor at Box Hill College in Kuwait, where he has taught courses in macroeconomics, microeconomics, monetary policy, and applied econometrics. Passionate about advancing knowledge, Dr. Aladwani focuses on research related to consumer behavior, market trends, and fiscal policy. His impressive publication record includes studies on money supply impacts, consumer preferences for organic products, and transportation efficiency in developing economies. Committed to bridging economic theory and policy, Dr. Aladwani aims to address real-world challenges, particularly in emerging markets.