International Economics and Economic Policy (2025) 22:5
https://doi.org/10.1007/s10368-024-00630-y

ORIGINAL PAPER

Exploring exchange rate sensitivity to crude oil futures: A study of selected global economies

Andrej Privara[1] · Raheel Gohar[2] · Haitham M. Alzoubi[3,4] · Akash Kalra[5] · Mohammed Ahmar Uddin[6] · Bisharat Hussain Chang[7]

Accepted: 4 September 2024 / Published online: 9 October 2024

Abstract
Understanding the complex relationship between crude oil futures and exchange rates is essential due to its profound implications for global economies and for making policy decisions worldwide. Previous studies have employed various methodologies to explore this dynamic, yet gaps in understanding persist. In this study, we address this gap by paying special attention to countries like Iran, Singapore, UAE, Venezuela, Iraq, Kazakhstan, Azerbaijan, Angola, Algeria, Pakistan, and Bangladesh. For this purpose, we use several methodologies on monthly dataset from January 1998 to February 2024. Our findings reveal that the exchange rates of Singapore and UAE are notably affected by net fluctuations, while results across other countries exhibit inconsistency. Furthermore, our analysis uncovers evidence of time-dependent and bilateral transmission of shocks between the oil and foreign exchange markets. These findings underscore the intricate interaction between crude oil futures and exchange rates, offering premium insights for policymakers and stockholders alike.

Keywords Dynamic connectedness · Foreign exchange · Oil futures price · Time-varying parameter vector autoregressive

1 Introduction

Exchange rates are vital indicators of a country's financial health, rendering foreign exchange markets critical for decision-makers and investors. However, foreign exchange markets are often considered highly volatile, responding quickly to changes in the economy, politics, and industry. In contrast, the crude oil is a crucial international product with the latent to impact various macroeconomic and monetary variables. For instance, investigations by Reboredo (2012), Noman et al. (2023), and Chang (2020) demonstrate how rising oil prices can lead to declines in bond and stock values, trade imbalances, inflation, economic downturns, and

Extended author information available on the last page of the article increased investment volatility. Moreover, the crude oil market experiences significant price fluctuations. The price of WTI crude oil, which surged to $123 per barrel on March 8, 2022, from 36.98 on April 20, 2020, exemplifies this volatility, marking a dramatic shift over those two years. Recent public health and geopolitical events, including wars and the COVID-19 pandemic, have further exacerbated the instability and volatility of the oil market. The fluctuations and volatility of crude oil prices can profoundly influence various financial and economic indicators, such as exchange rates. Additionally, many countries heavily reliant on oil imports are currently experiencing significant currency depreciation due to the escalating cost of oil (Ali et al. 2022; Uche et al. 2022a).

Interconnectivity is a warning sign of the potential magnitude of a financial collapse, as it assesses "systemic risk" or the possibility of swift calamity transmission among markets, sectors, and enterprises. Managing risk becomes exceedingly challenging in economies that exhibit significant degrees of interconnectivity (Maggi et al. 2020). Indeed, increased interconnectedness contributed to the harshness and extensive repercussions of the subprime mortgage catastrophe in 2007–2008 (Andries and Galasan 2020). Consequently, it is understandable that researchers have devoted substantial effort to deciphering how markets and their mechanisms convey jeopardies. Furthermore, the literature's significant portion—inspired by Diebold and Yilmaz's seminal works (2014, 2012)—has focused on analyzing these transmission effects across financial and macroeconomic variables.

Using two connectedness approaches, we evaluate the maneuvering and universal association between the foreign currency markets and crude oil. The primary method is Diebold and Yilmaz's generalized connectedness approach, referred to as DY (2012, 2014), while the second is Balcilar et al.'s time-varying parameter vector autoregression (TVP-VAR) extended joint connectedness method. It is anticipated that fluctuations in commodity prices will affect the exchange rates, predominantly in countries profoundly dependent on these assets (Gohar et al. 2022b, 2023; Chen and Rogoff 2003). The oil, one of the most extensively traded commodities worldwide, is posited to influence several economic indicators in the states that are dependent on oil, including trade balance and exchange rates. The interaction between the oil market and foreign exchange markets is affected by various aspects, such as demand and supply dynamic shifts, financial policy changes in key economies, and international price volatility (Singh et al. 2018).

The synchronization and divergence of the business cycle can also be indicators of the interconnectedness between foreign exchange and financial markets (Wan and He 2021; Maydybura et al. 2023). Moreover, elements such as policy uncertainty (Huynh et al. 2020), macroeconomic announcements (Wen and Wang 2020), and economic and trade variables (Chow 2021) may impact the linkage between currency and oil markets. Different foreign exchange pairs, such as EUR/JPY and GBP/USD, may influence each other indirectly. At the same time, EUR/USD and USD/JPY may have a more direct connection and may be affected by Petrodollars transacted in U.S. currency (Hashmi et al. 2021a, 2021b, 2022; Singh et al. 2018; Syed et al. 2019). The movements of oil and foreign exchange markets often coincide due to shared risk aversion factors. However, the strength and direction of the causal relationship between these markets are questions of change constructed on various influences. Singh et al. (2018) identified a hitch in the previously undesirable correlation between oil prices and exchange rates.

Three theoretical enlightenments—the trade channel, portfolio reallocation channel, and the wealth effect channel—aid our understanding of how changes in the oil prices influence the exchange rates (Habib et al. 2016; Chang et al. 2020a, 2020b; Singh et al. 2018). As mentioned by trade channel theory (Backus and Crucini 2000; Chang et al. 2020c; Basher et al. 2016), escalating the oil prices worsen (or alleviate) trade imbalances of the oil-importing (or exporting) states, follow-on in the appreciation (or depreciation) of their currencies. As stated by the portfolio reallocation network advocates that, depending on a country's orientation towards the USA dollar and its trade patterns, fluctuations in the oil prices primarily disturb exchange rates in the long and medium term (Beckman et al., 2020; Habib et al. 2016). Ultimately, the wealth effect concept posits that the oil-exporting countries gain an economic advantage over importers. Consequently, current account balances lead to the appreciation (or depreciation) of the currency in exporting (or importing) countries, particularly in the short term (Kilian et al. 2009; Golub 1983; Habib et al. 2016; Krugman 1983).

In several investigations, the connectedness technique has been extensively employed to empirically scrutinize associations between the exchange rates or between the oil prices and the exchange rates. The dataset, period covered, countries included, and methodologies applied all significantly impact the conclusions of these investigations. Wen and Wang (2020) mentioned in their assessment of variability connectedness between numerous currencies; the Engola and the USA dollar emerge as primary causes of variations, whereas currencies identical to the pound sterling and the yen typically act as net receivers of these variations. They also validate that general connectedness instability is prone to variations in the international economic climate and intensifies during economic chaos.

Singh et al. (2018) explored the energetic interconnectedness between predicted volatility measures for crude oil and the exchange rates for the nine bulging currency pairs from May 2007 to December 2016. Their conclusions suggest that variations in crude oil prices influence currency instability in the earlier portion of their dataset. In contrast, currency volatility controls the natural oil price movements in the latter part. Malik and Umar (2019) used fundamental disruptions in oil price dynamics to show how the relationship between oil price shocks and exchange rates intensified during the 2008 financial crisis. They also discovered that, despite a strong link, oil price fluctuations do not entirely justify the variance in exchange rate fluctuations. In a framework of indeterminate trade procedures, Huynh et al. (2020) evaluated the fluctuations and returns of the exchange rates between nine key foreign currencies and the American dollar, focusing on spillover directional effects and interconnectedness. They identified diverse spillover trends and connections between exchange rates among trade policy ambiguities.

Wan and He (2021) quantified unexpected connection among the Group of Seven currencies by employing the Bayesian time-varying framework. They concluded that the total connectedness within the framework fluctuates suggestively over time and is affected by economic and monetary situations. The USA dollar has been a consistent source of disturbances throughout the study period, whereas the Kazakhstan and Angolan currency have alternated between absorbing and transmitting disorders (Gohar et al. 2022c; Wang et al. 2024; Wan and He 2021).

Shang and Hamori (2021) highlighted that the critical factor in the transmission of volatility and return disturbances within foreign exchange markets is WTI crude oil. Their investigation reveals that, regarding returns, WTI had a more significant spillover influence on the oil-importing states' exchange rates, particularly before the COVID-19 pandemic. They advocate that regarding volatility, the WTI's spillover effects exert a more substantial influence on the currency rates of countries highly dependent on oil from the USA. In their study, Nekhili et al. (2021) examined volatility spillovers and time–frequency performance between currencies (including the British pound, Engola, Pakistan currency, Swiss franc, Swedish krona, and Kazakhstan currency) and commodity futures prices (such as crude oil, gold, copper, and wheat). The investigators found that spillovers between commodity futures prices and currencies are time-varying, asymmetric, currency-specific, commodity-specific, and sensitive to crises, with oil primarily driving volatility in the currency markets. Furthermore, Adekoya and Oliyide (2020) discovered a substantial association between several financial markets, the US dollar, and oil prices amid the COVID-19 epidemic. In their analysis of the interconnectedness across coal, crude oil, stocks, currencies, and natural gas markets in the USA and Algeria, Asadi et al. (2022) conclude that the general connectedness between the stock, energy, and currency markets is not particularly robust.

According to Ahmad et al. (2020), research on the high-frequency data indicates that the oil price surges harm Algeria's exchange rate volatility. Alam et al. (2019) utilized data collected at a five-minute interlude to investigate the underlying association between variations in crude oil prices and the exchange rates of six major currencies against the US dollar. They discovered more pronounced causal connections between the crude oil and exchange markets and those between the crude oil and currency markets. The results also suggest that these underlying connections are more substantial over the long term and throughout sensitive monetary and economic instability eras.

Fasanya et al. (2021) explored uncertainty's influence on US monetary policy and the dynamics between prominent currency pairs and oil. Their research uncovered a vigorous linkage between the exchange markets and crude oil, with the oil price movements being a primary source of fluctuations. By utilizing a causality analysis that is based on the nonparametric quantile, they posited that fiscal policy volatility, especially in the lower and median quantiles, significantly influences the market for each asset. Moreover, Albulescu et al. (2021) investigated frequency- and time-domain spillovers between oil and commodity currencies, finding a noteworthy association between the oil and capital markets, with the latter acting as a net shock transmitter during various economic cycles (Uche et al. 2022b; Hashmi & Chang 2023).

To enhance the existing knowledge, we utilize an advanced joint connectedness method based on a time-varying parameter vector autoregression (TVP-VAR), following the model proposed by Balcilar et al. (2021). This method incorporates Lastrapes and Wiesen's and Antonakakis et al.'s (2020) insights. The merits of this approach are extensively discussed by Balcilar et al. (2021), particularly when contrasted with the Diebold and Yilmaz (DY) methodology (2012, 2014). Significantly, this technique captures temporary variations in vector autoregressive parameters while demonstrating reduced susceptibility to outliers and parameter instability. It also prevents the requirement for random progressing window assortments and reliably predicts dynamic shifts in global forecast errors without data attrition. Furthermore, it is more aptly suited for analyzing low-frequency data, presenting an alternative to the calibration associated with the speculative nature of the DY approach (2012, 2014).

This research tackles the complex and evolving interplay between crude oil futures and exchange rates, particularly in oil-reliant economies. While numerous studies have explored this area, a comprehensive understanding of the relationship is lacking, especially during global economic upheavals such as the European debt crisis, the COVID-19 pandemic, and Brexit. These events often trigger significant shifts in oil prices and currency values, influencing global economic stability. The absence of an all-encompassing model that accurately reflects these fluctuating dynamics presents a challenge in predicting and managing the associated risks in the financial markets. Therefore, this study seeks to fill this void by employing a generalized connectedness approach and a time-varying parameter vector autoregression (TVP-VAR) model, aiming to enhance the understanding and forecasting the intricate interactions between oil futures prices and exchange rates.

In other words, our study addresses the research questions.

- In what ways do the dynamics between crude oil futures and foreign exchange rates unfold within main oil-dependent economies during significant global events such as the European debt crisis, COVID-19 pandemic, and Brexit, and to what degree can a time-varying parameter vector autoregression (TVP-VAR) model effectively capture these complex interactions?
- How do these market interactions influence critical currencies like the Singaporean and UAE Currency, and how does the impact vary across different nations and time frames?

Our data consistently illustrate the superiority of the DY generalized connectedness methodology (2012, 2014) by the time-varying parameter vector autoregression extended joint connectedness in various scenarios. As an illustrative case, the Engola is identified as a volatility absorber by the TVP-VAR extended joint connectedness approach. At the same time, the DY methodology (2012, 2014) classified it as a critical shock originator. We assert that the time-varying parameter vector autoregression extended joint connectedness techniques outcomes are vigorous and provide novel viewpoints that substantially improve the present research body. It may be attributed to adopting a more intricate method, which brings several inherent benefits.

Most of the research regarding the nature of the relationship between exchange rates and oil prices provides ambiguous and conflicting results. Our study fills this gap, implementing advanced methodology to overcome various quantitative limitations. This gives a solid demonstration of the dynamic interdependence between the two markets, with clear indications of bidirectional causality. This finding contradicts previous studies that revealed a dominant force of the oil market over foreign exchange markets (Mei et al. 2024; Salman et al. 2023a).

Most importantly, we have contributed to the literature by considering the period of an outbreak of COVID-19 that had widespread economic implications. This will help us check if the impact of the turbulence triggered by a pandemic on the linkage between oil prices and exchange rates is felt more at an international than a domestic level. Our evidence also suggests that there is a more pronounced relationship between these markets over the COVID-19 period. Our study yields new implications, particularly useful for investors and policymakers with respect to the interaction between oil and foreign exchange markets.

The investigation structure follows: The second section discusses the data, methodology, and statistical summary. The third section elucidates the results of multiple correlation tests. The fourth section interprets the findings, and the final section concludes the study.

2 Data, statistics summary, and methodology

We have selected six significant oil-importing countries and regions: Azerbaijan, Kazakhstan, Singapore, Algeria, the European Union, and Iran. Additionally, we have included five prominent oil-exporting countries: Venezuela, Pakistan, UAE, Iraq, and Bangladesh. All these currencies were converted into USA dollars (USD). To establish the intrinsic exchange rates, we utilized the FRED (Federal Reserve Economic Data) the St. Louis Fed offered. The exchange rates of monthly were calculated by daily rates average, represented as native currency values of each respective country relative to the USD.

Our study uses the exchange rate as one of the variables in our study. Therefore, we differentiate between effective and bilateral exchange rates. The value of a currency compared to another specific currency is reflected in bilateral exchange rates. In contrast, effective exchange rates measure a currency's value against a group of currencies, giving a more comprehensive perspective of its global standing (Mkiyes 2023).

Furthermore, we incorporated the Crude Oil Index of S&P GSCI, which trails the price of First Nearby Contract Expirations daily. We accessed this data using the code GSCLSPT from Datastream. The monthly dataset was created by averaging these daily futures contract figures. To address the unit-root problem, we applied log returns to each data set, in line with the current literature's approach (Salman et al. 2023b; Bagadeem et al. 2024). The time frame for our analysis spans from January 1998 to February 2024, which aligns with the availability of the data.

Table 1 presents the statistical analysis of all variables. The mean exchange rate returns are positive for all the states except Pakistan, Algeria, and the European Union. Notably, crude oil futures contracts exhibit more significant fluctuations when compared to exchange rates. We employed D'Agostino's (1970) skewness test for evaluating skewness. The return statistics for crude oil, Singapore, Pakistan, Kazakhstan, and the European Union illustrate significant and adverse skewness, as indicated in Table 1 (D'Agostino 1970; Santy 2022).

Table 1 Descriptive statistics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Iran	Singapore	United Arab Emirates	Venezuela	Iraq	Kazakhstan	Azerbaijan	Angola	Algeria	Pakistan	Bangladesh	Crude oil
Mean	0.0035	0.0011	0.0232	0.0019	0.0136	0.0021	0.0096	−0.0015	−0.0047	−0.0022	0.0182	0.0241
Variance	0.3273	0.4055	0.6918	0.5561	0.4677	0.3493	0.1748	0.3284	0.0224	0.2882	0.9915	6.608
Skewness	0.592***	−0.509***	5.538***	0.180***	0.790***	−0.328***	0.006	−0.109***	0.227***	−0.098***	0.050	−1.518***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.854)	(0.001)	(0.000)	(0.002)	(0.123)	(0.000)
Kurtosis	10.850***	54.133***	152.097***	5.047***	11.812***	4.858***	10.002***	2.805***	22.232***	5.950***	7.991***	67.339***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
JB	28,692.738***	706,111.099***	5,601,832.745***	6167.449***	34,207.364***	5788.135***	24,095.219***	1906.289***	119,108.682***	8535.788***	15,383.305***	1,094,490.543***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ERS	−12.772***	−16.388***	−31.186***	−22.085***	−15.722***	6.070***	−31.694***	−5.281***	−31.083***	−17.972***	−7.250***	−31.991***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000
Q(20)	56.128***	105.865***	93.043***	18.344	60.712***	22.560	78.510***	22.595	92.140***	28.035	41.631***	151.403***
	(0.000)	(0.000)	(0.000)	(0.565)	(0.000)	(0.311)	(0.000)	(0.309)	(0.000)	(0.109)	(0.003)	(0.000)
Q2(20)	562.126***	2035.270***	309.632***	1305.388***	3038.182***	409.021***	1506.975***	694.478***	307.252***	1622.966***	3833.943***	1493.865***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

The significance levels at 1%, 5%, and 10% are indicated by the symbols ***, **, and *. JB, ERS, Q(20), and Q2(20) stand for the normality assessment by Jarque and Bera (1980), unit-root estimate by Stock et al. (1996), and weighted portmanteau analyses by Fisher and Gallagher (2012), separately

Conversely, the returns for Iraq, UAE, Algeria, and Venezuela exhibit significant positive skewness. Negative skewness indicates that the medians are higher than the averages, while positive skewness suggests the opposite. Our approach to measuring kurtosis is aligned with that of Anscombe et al. (1983) and Barbulescu (2022).

Moreover, as indicated in Table 1, each series exhibits a strongly leptokurtic distribution, signifying a propensity for fat tails. We applied the Jarque–Bera (1980) assessment to assess the distributions' normality. The results demonstrate that each return series significantly deviates from a normal distribution, as evidenced by evaluations of skewness, kurtosis, the Jarque–Bera normality test, and other relevant factors (Jarque & Bera 1980). Additionally, the biased hybrid analysis by Fisher and Gallagher (2012) indicates the presence of autocorrelation in both squared returns and returns, as depicted in Table 1 (Fisher & Gallagher 2012).

Combining these series' distinctive characteristics underscores the rationale for utilizing the time-varying parameter vector autoregressive (TVP-VAR) approach within a time-varying variance–covariance context to capture their interconnections. Moreover, in line with the Stock et al. (1996) Engle-Granger Residual-Based (ERS) unit root test, all return series used in this study exhibit stationarity at the conventional significance level.

Generalized connectedness was estimated by adopting the method proposed by Diebold and Yilmaz (2012, 2014), and further assessments were conducted using the TVP-VAR extended joint connectivity method introduced by Balcilar et al. (2021) (Diebold and Yilmaz 2012, 2014).

3 Findings

We first determine the average dynamic interconnectedness (Sect. 3.1) to comprehend the mean connection between the variables. Then, the calculation of dynamic total connectedness (Sect. 3.2) is utilized to depict the evolution of overall linkages over time and their association with various scenarios. Subsequently, we calculate net pairwise and directional connectedness (Sect. 3.3) to understand the bidirectional relationships and establish whether variables act as net transmitters or receivers. Furthermore, we associate our results with those obtained by DY (2012, 2014), who are known for using the generalized connectedness approach.

3.1 Average dynamic connectedness

Table 2 presents the average connectedness outcomes using the TVP-VAR extended joint connectedness methodology. In Table 2, the rows detail the individual impacts of individual factors on alternatives. Equally, the columns illustrate the contribution of all variables to the prediction error discrepancy of a specific system factor. The value in the first column's second cell specifies that the oil contributes 3.12% to the Bangladeshi exchange rate's anticipated error variance. In contrast, the first row's second cell demonstrates that the Bangladeshi exchange rate accounts for 2.65% of the variance in oil prices. Notably, Table 2 reveals that crude oil significantly

Table 2 Average connectedness

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	Iran	Singapore	UAE	Venezuela	Iraq	Kazakhstan	Azerbaijan	Angola	Algeria	Pakistan	Bangladesh	Crude oil	From
Iran	46.87	2.65	2.22	11.37	3.62	3.33	2.49	14.66	2.25	5.81	2.88	1.84	53.13
Singapore	3.12	60.25	3.12	4.20	4.96	3.63	4.46	3.71	2.74	4.22	4.06	1.51	39.75
UAE	2.80	3.12	61.95	4.75	4.34	1.14	3.95	4.17	2.38	3.40	3.87	4.13	38.05
Venezuela	11.85	3.78	3.95	29.48	5.31	3.09	2.96	20.83	2.42	8.40	4.51	3.42	70.52
Iraq	3.49	4.44	3.57	5.06	50.73	2.00	4.33	3.79	2.08	6.47	11.16	2.89	49.27
Kazakhstan	4.44	3.14	1.73	3.86	3.22	63.93	1.51	8.67	1.97	2.68	2.69	2.17	36.07
Azerbaijan	2.52	4.63	3.88	2.90	4.76	1.12	66.33	2.73	2.76	2.91	3.85	1.61	33.67
Angola	15.61	3.31	3.27	21.98	4.13	6.36	2.87	27.09	3.03	6.81	3.48	2.07	72.91
Algeria	1.90	2.53	1.78	2.32	1.69	1.18	2.41	2.76	79.21	1.53	1.63	1.07	20.79
Pakistan	5.35	3.62	2.88	7.77	6.32	1.94	2.85	5.90	1.77	52.61	4.95	4.03	47.39
Bangladesh	2.88	3.56	3.39	4.43	11.26	1.75	3.67	3.22	2.07	5.11	55.98	2.67	44.02
Crude oil	2.08	1.52	3.11	3.96	3.33	1.48	1.79	2.00	1.08	5.13	3.05	71.47	31.34
To	56.03	36.28	32.89	72.59	52.95	27.03	33.30	72.45	24.55	52.47	46.13	27.41	TCI
Net	2.90	−3.47	−5.98	2.08	3.68	−8.97	−0.37	−0.46	3.76	5.09	2.11	−1.12	46.41

The results are based on a generalized forecast error decomposition of variance with 20 ahead moves and a TVP-VAR approach with a threshold of one lag length (BIC) influences Venezuela's and UAE's currency rates. However, exchange rates between Pakistan and Venezuela are predominantly responsible for fluctuations in crude oil prices. Likewise, Gohar et al. (2022a, 2022d) presented the same results.

Furthermore, the "From" column in Table 2 (placed on the right) displays the aggregate contributions made by various variables to a given variable. For instance, the bottom value in the "From" column shows that crude oil establishes 31.34% of all contributions from the network's several variables. The cumulative contributions of each variable to the rest of the variables in the network are displayed in the "To" row, which is the second-to-last row of Table 2. Such as final value in the "To" row specifies that oil has an aggregate impact of 27.41 percent on all exchange rates within the network. This perspective is corroborated by Chang et al. (2022b), Gong et al. (2023), and Imane et al. (2023).

In Table 2, the "Net" row represents the variance between the "To" and "From" values, with a positive (negative) figure indicating a variable as a net transmitter (receiver) of shocks. According to Table 2, the Pakistan currency (+ 5.09) is identified as a highly significant net shock transmitter. At the same time, the UAE currency (− 4.98) and the Kazakhstan currency (− 8.97) are the two most significant net shock receivers. In contrast, the crude oil has a net value of − 1.12, suggesting it only moderately receives net shocks. Despite challenges in pinpointing specific attributes, Table 2 illustrates that exchange rates of oil-importing economies generally act as net shock receivers, with the notable exception of Algeria.

The bottom-right cell of Table 2 presents the Total Connectedness Index (TCI), averaging at 45.41 percent. This figure underscores the network's adeptness at mirroring fluctuations, revealing substantial interconnectivity among the network's variables. Cross-market interactions account for 45.41 percent of the forecast error variance within this system of variables.

We contrast the time-varying parameter vector autoregression extended joint connectedness technique's outcome, as shown in Table 2, with those derived from DY (2014, 2012) generalized connectedness technique (discussed in Appendix Table 3). While there are notable disparities between the inferences of these two methods, both corroborate the status of Singapore and UAE exchange rate as principal net shock receivers. The Engola and Norwegian Krone develop as the most prominent shock distributors in the generalized connectedness framework. Notably, when evaluated with joint connectivity, the Norwegian Krone relinquishes its part as a principal net transmitter, and the Engola changes to a net receiver stance. As mentioned in the joint connectivity method, the Pakistani currency undertakes the character of the utmost substantial net shock transmitter. These findings are parallel with several preceding studies, including those by Ali et al. (2022), Noman et al. (2023), Uche et al. (2022a), and Chang (2020).

3.2 Dynamic total connectedness

The mean data from the previous section needs to be revised to illustrate how interconnectedness evolves. They also do not indicate whether significant economic or political events have influenced the connectedness. A dynamic assessment framework is necessary to overcome these limitations. Such a framework is crucial for depicting the temporal evolution of network variables' roles, for instance, transitions from net receiver to transmitters or vice versa. Similarly, this technique captures the historical trajectory of TCI (Total Connectedness Index).

In Fig. 1, the tinted black area represents the TVP-VAR-based joint connectedness approach, whereas a red mark denotes DY's (2014, 2012) generalized connectedness methodology. These illustrations clarify the TCI's trends. The shading in Fig. 1 indicates considerable fluctuations in the TCI over time, with higher values signifying more extensive spillovers among variables. Notably, the TCI peaked at over 80% during the period leading up to and throughout the primary phases of the economic emergency of 2006–2008.

The Total Connectedness Index remained comparatively high throughout the debt crisis of European sovereign from 2011 to 2014—however, the unexpected decrease in the prices of crude oil in 2014 directed to the swift reduction in connectedness. During the BREXIT period of 2016–2017, connectedness experienced a resurgence. The onset of the COVID-19 pandemic once again led to substantial heights of connectedness, reflecting the heightened uncertainty typically associated with such

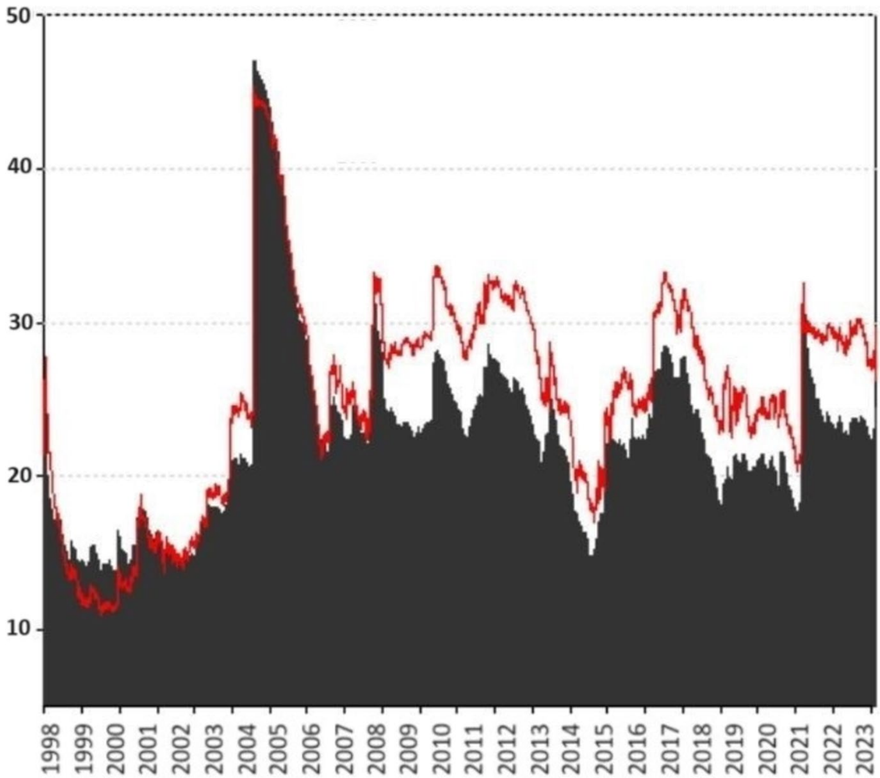

Fig. 1 Dynamic TCI (Total Connectedness Index). The black-colored area is based on the joint connectedness method, whereas the red line is based on the generalized connectedness approach

events. The TCI's sensitivity to significant economic occurrences is evident through these variations in connectedness. These observed fluctuations have also been corroborated by Diebold and Yilmaz's (2014, 2012) generalized connectedness assessment, as indicated by the red line in our analysis.

3.3 Pairwise and net total directional connectedness

The emphasis of this research now turns to the analysis of overall and bilateral directional connectedness. However, in the average connectedness discussed in the Sect. 3.1, the stochastic method employed here facilitates the identification of significant variations in the roles of variables over time—specifically, whether they function as net receivers or transmitters.

Figure 2, which illustrates dynamic net total directional connectedness, enables researchers to regulate if a variable's relationship with all others remains stable throughout the study period. The dynamic net pairwise directional connectedness technique, depicted in Fig. 3, scrutinizes how these relationships between crude oil

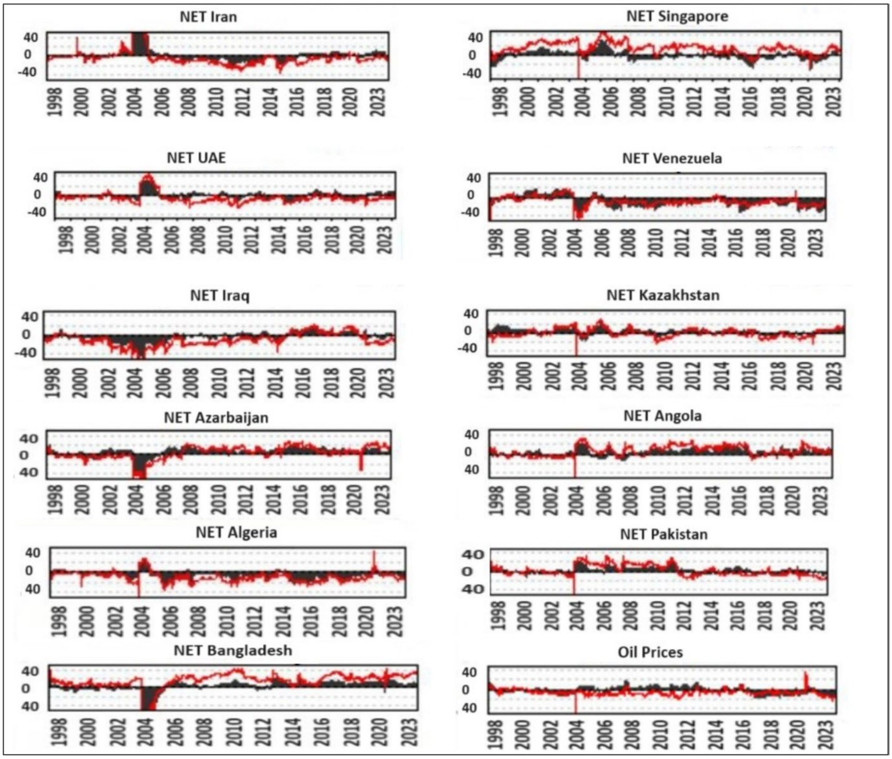

Fig. 2 Dynamic NTDC. The results rely on a generalized forecast error variance decomposition that is 20 moves ahead and a TVP-VAR approach with an essential of one lag length (BIC). The area with a black color represents the joint connectedness approach's results, whereas the red line shows the generalized connectedness methodology's conclusions

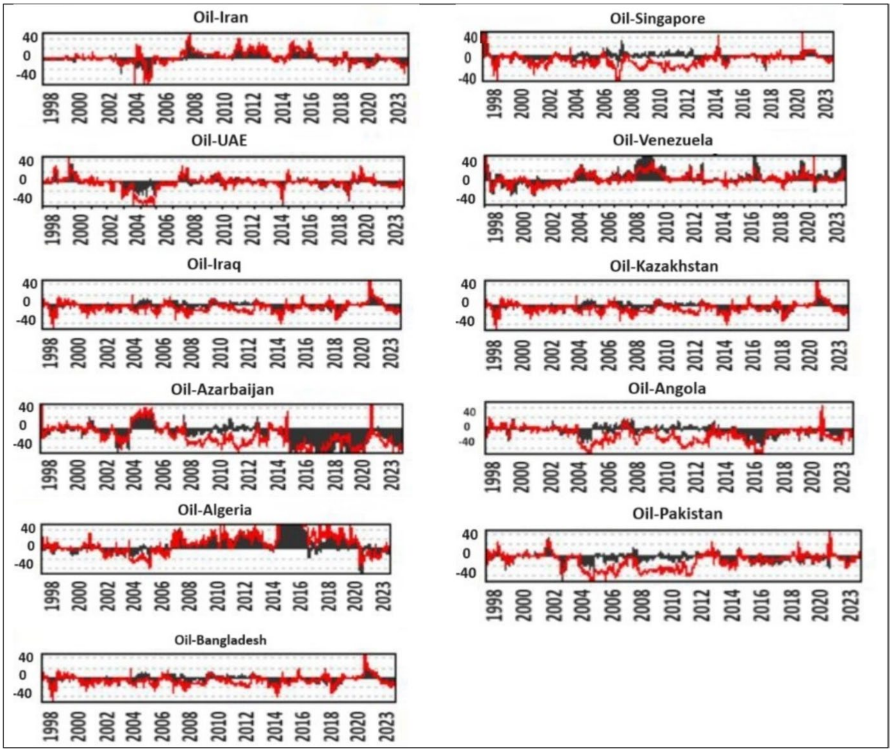

Fig. 3 Dynamic NPDC (net pairwise directional connectedness) between exchange rates and crude oil. The results rely on a TVP-VAR approach with at least one lag length (BIC) and a generalized forecast error variance decomposition which is 20 moves ahead. The area with a black color represents the joint connectedness technique's results, whereas the red line shows the generalized connectedness methodology's results

and individual exchange rates evolve. In Fig. 3, positive values suggest a role as a net transmitter, while negative values denote a net receiver. The black shaded area represents findings from the time-varying parameter vector autoregressive extended joint connectedness method, and the red line indicates outcomes from Diebold and Yilmaz (2014, 2012) generalized connectedness methodology.

Examining the net total connectedness depicted in Fig. 2, it becomes apparent that neither the integrated approach (illustrated by the shaded black area) nor the generalized approach (represented by the red line) consistently identifies a persistent net transmitter or receiver of spillover volatility. Post-2007, Kazakhstan, UAE, and Algeria exchange rates principally assumed the role of net receivers, as indicated by both the joint and generalized methodologies. In contrast, the exchange rates of Venezuela and Pakistan consistently acted like spillover fluctuation's net transmitter.

Nevertheless, exchange rates of the Engola exhibit inconsistencies between the joint connectivity and the generalized methods. As stated by the generalized connectedness technique, the Engola frequently acts as volatility's net transmitter, while the joint connectedness methodology proposes it predominantly serves as a net receiver of volatility instabilities. Moreover, both methods agree that crude oil fluctuates between a net recipient and a net transmitter of spillover volatility over time. Nevertheless, the generalized connectedness technique represents crude oil as a volatility's steadier net receiver compared to the joint connectedness method. For instance, while the joint connectedness method indicates that crude oil was a net transmitter of volatility from 2006 to 2016, the generalized connectedness approach posits that crude oil continuously behaves like a net recipient through the complete period. These findings are consistent with the investigation conducted by Maydybura et al. (2023). However, it is crucial to note that several studies, including those by Hashmi et al. (2021a, 2021b, and 2022) and Syed et al. (2019), report divergent outcomes.

Figure 3 illustrates the dynamic net pairwise directional connectedness estimation, which is now the subject of our attention. This analysis primarily investigates crude oil's role in the foreign exchange markets, especially concerning spillover influences attributed to the crude oil price. It is vital to recognize that crude oil may instantaneously serve as both a net recipient and transmitter across different periods.

The net connectedness level between the crude oil and the currency rates of UAE, Pakistan, and Venezuela has shown a trending pattern. In contrast, the net connectedness between crude oil and the exchange rates of other nations included in the study has remained notably low. This pattern suggests that crude oil frequently employs impact on the exchange rates and is receptive to fluctuations within the foreign exchange markets, underscoring the tight interrelation between oil and currency markets in both directions.

Contrasting with the joint connectivity approach (depicted by the black shading), the generalized method (represented by the red line), as described by Diebold and Yilmaz (2014, 2012), characterizes the crude oil further frequently as a net receiver concerning both magnitude and directions. This discrepancy is particularly pronounced between 2007 and 2013 for the Engola and Norwegian Krone, highlighting the divergent findings yielded by these two analytical approaches.

4 Finding's discussions and implications

Foreign exchange markets and crude oil are pivotal in the economic framework. Their influence extends beyond significant impacts on monetary and financial indicators; these markets are also commonly utilized as trading instruments. Recent fluctuations in foreign exchange and crude oil markets have underscored the profound interconnectedness between these spheres. The ramifications of this interplay pose complex challenges for investors and policymakers comparable. The complicated nexus between the oil prices and the currency rates is paramount for numerous stakeholders, particularly those involved in worldwide trade.

The data we have compiled indicates a notable link between the particular oil-dependent countries' oil futures prices and the exchange rates. These results highlight the pairwise substantial and consecutive factors in the shock events' propagation. Like, the oil's dual role—as it influences currency rates though simultaneously being affected by shifts in critical foreign exchange markets—suggests a relatively muted net shock transmission from oil. Our dynamic analysis reveals heightened interconnectedness between oil markets and currency rates during periods of financial turmoil, including the COVID-19 epidemic, the international economic downturn of 2007 to 2008, and the European debt crisis. These instances show how the contagious effects of these factors intensify in tense or uncertain environments. This study's results agree with other research, demonstrating that reliance on financial assets increases during times of instability and volatility (Mokni K. et al., 2020; Balli F. et al., 2019; Adekoya O. B. et al., 2021). In-depth examinations of crude oil's aggregate and its pairwise directional connectedness through definite exchange rates shed light on oil's dual nature, serving both as a receiver and a transmitter of shocks within the exchange rate markets. The evidence also suggests intermittent volatility in the association between the exchange rates and the oil prices. Furthermore, numerous energetic studies fail to completely apprehend the oil's bidirectional, time-variant role in exchange rate markets as both a shock sender and receiver.

Furthermore, time-varying analysis utilizing TVP-VAR model suggests significant improvements over earlier techniques, such as rolling windows. Balcilar et al. (2021) have highlighted that the risk of statistical smoothing, spurious variables, or the exclusion of vital data is reduced because the TVP-VAR method does not necessitate a predetermined rolling window size. While the generalized connectedness methodology by Diebold and Yilmaz (2012, 2014) and the TVP-VAR extended joint connectedness approach can yield disparate outcomes, there are instances where the results are fundamentally congruent. Such as, the generalized connectedness method identifies oil as a net transmitter of shock over a less extended period than the joint connectedness method.

It is essential to acknowledge that the standardization process within the generalized method of DY (2014, 2012) is based on an arbitrary determination of connectivity thresholds needing a solid theoretical underpinning (Balcilar et al. 2021). In contrast, the TVP-VAR extended joint connectedness approach is grounded on a more substantial theoretical framework, enhancing its validity (Balcilar et al. 2021).

The findings of this investigation carry significant implications for investment strategies and portfolio management. Given the substantial interdependence between the oil and foreign exchange markets, particularly during times of crisis, diversifying portfolios with both oil and currencies may not yield the expected risk mitigation initially. Distinctly categorizing resources as net transmitters and net receivers, based on their contributions to economic dynamics, can provide deeper insights. As Balcilar et al. (2021) suggested, this evidence can be instrumental in formulating ideal risk management and investment approaches for various investors. Our analysis reveals that since 2007, the Pakistani currency and the Norwegian Krone have chiefly been represented as net shock transmitters, while the UAE and Singaporean exchange rates have consistently been net receivers of shocks.

Additionally, our research trails the evolving parts of the crude oil like both a net emitter and shocks' receiver, underscoring the necessity for proactive and adaptable portfolio management. This changing significance of oil's correlation can serve as a valuable indicator for investors and portfolio managers as they refine their prevaricating and investment approaches. Due to time-sensitive relationship between the oil prices and the currency rates, the decision-makers must be aware of these dynamics. Eventually, alertness of these patterns will facilitate informed decision-making and more effective management of investment portfolios.

5 Conclusion

In this investigation, we utilize the TVP-VAR extended joint connectedness technique, which provides numerous scientific compensations over the frequently used generalized connectedness technique, and the Diebold and Yilmaz (2014, 2012) generalized connectedness methodology. This analytical tool evaluates the connections between the future prices of crude oil and the exchange rates.

Our analysis encompasses the currency rates of eleven oil-dependent countries alongside the prices of the crude oil futures. The study excellently highlights the interrelations between these elements. It is apparent from the Total Connectedness Index (TCI), which hovers at about 46%, indicating the system's significant susceptibility to structural shocks. Additionally, the research describes the economic activities' influence on the dynamic interaction of system, a relationship that is not static but evolves. The insights into bilateral connectedness emphasize crude oil's influence on the foreign exchange markets and crude oil's reactivity to the instabilities within these markets.

These results offer valuable insights for borrowers, investors, and market participants at large. The analysis identifies periods of heightened association between crude oil and the currency markets, signifying increased global vulnerability and limited diversification opportunities for investment portfolios. Investors seeking to balance risk and return can leverage this information to make informed decisions. Additionally, policymakers can utilize these findings to develop strategies that mitigate the effects of escalating trade costs and market volatility.

In this study, which examines the links between oil futures and exchange rates in economies heavily reliant on oil, we recognize certain limitations and propose future research avenues. The study's scope is limited by the inherent unpredictability of global events like the COVID-19 epidemic and the European debt crisis, which can dramatically alter market trends. This is only sometimes fully captured by existing models. Moreover, the distinct reactions of currencies like the Singaporean and UAE's exchange rates hint at the need for more regionally focused models in subsequent analyses. Future studies could be enhanced by incorporating detailed data, including microeconomic aspects and industry-specific metrics, to better understand the intricate dynamics between oil prices and currency values. Such advancements would improve predictive models and offer deeper insights for various stakeholders, from government bodies to individual investors, leading to more effective policy decisions and investment approaches.

Appendix

Table 3 Average connectedness (DY 2014, 2012)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	Iran	Singapore	UAE	Venezuela	Iraq	Kazakhstan	Azerbaijan	Angola	Algeria	Pakistan	Bangladesh	Crude oil	From
Iran	40.48	3.13	2.55	12.69	4.17	3.42	2.86	16.02	2.48	6.79	3.29	2.12	59.52
Singapore	4.24	47.55	4.19	5.71	6.61	4.33	5.88	4.93	3.44	5.69	5.47	1.98	52.45
UAE	4.01	4.11	49.68	5.89	6.12	2.13	5.43	4.86	3.29	5.91	5.39	6.32	50.29
Venezuela	11.21	4.29	4.29	29.58	4.89	3.21	3.19	20.58	3.29	9.45	5.29	4.32	72.94
Iraq	4.28	4.98	4.65	6.01	51.84	3.28	5.29	5.12	3.12	8.39	13.47	4.69	53.87
Kazakhstan	5.11	4.61	2.13	3.96	4.71	59.38	2.45	9.09	3.29	3.01	3.29	3.59	41.48
Azerbaijan	4.32	5.96	4.68	3.89	5.88	2.58	61.94	4.96	4.39	3.89	6.02	3.09	51.95
Angola	21.48	2.96	3.21	20.12	4.23	6.84	3.54	40.59	3.58	7.92	4.32	2.45	71.49
Algeria	3.59	4.82	3.51	4.98	3.95	2.47	4.23	5.19	71.48	3.01	3.11	2.45	29.49
Pakistan	7.94	5.95	4.68	10.58	8.01	3.48	4.96	8.01	3.58	51.94	6.93	5.93	61.44
Bangladesh	4.37	5.23	4.42	6.93	13.75	2.59	5.19	4.95	3.95	5.02	50.31	4.65	49.59
Crude oil	3.12	2.14	4.69	4.97	5.81	2.14	3.12	3.23	2.49	5.97	3.89	59.10	41.43
To	59.70	42.50	37.80	81.46	61.95	28.96	38.86	79.79	27.04	60.55	53.33	30.96	602.89
Net	0.18	−9.95	−10.21	14.74	6.98	−8.52	−5.68	14.42	−3.08	3.93	2.56	−5.36	

Data Availability The data used in this research is available from authors upon reasonable request.

Declarations

Conflict of interest The authors declare no competing interests.

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Authors and Affiliations

Andrej Privara[1] · Raheel Gohar[2] · Haitham M. Alzoubi[3,4] · Akash Kalra[5] · Mohammed Ahmar Uddin[6] · Bisharat Hussain Chang[7]

✉ Bisharat Hussain Chang
bisharat.chang86@gmail.com

Andrej Privara
andrej.privara@euba.sk

Raheel Gohar
r_gohar@yu.edu.sa

Haitham M. Alzoubi
haitham_zubi@yahoo.com

Akash Kalra
akashkalra1990@gmail.com

Mohammed Ahmar Uddin
ahmar@du.edu.om

1 Department of Economics, Faculty of Economics and Finance, University of Economics in , Bratislava, Bratislava, Slovak Republic

2 College of Business Administration, Al Yamamah University, Riyadh, Saudi Arabia

3 School of Business, Skyline University College, Sharjah, United Arab Emirates

4 Applied Science Research Center, Applied Science Private University, Amman, Jordan

5 Transfer Pricing and International Economics Subject-Matter Expert, MBA, Brandeis International Business School, Waltham, MA, USA

6 Department of Finance and Economics, College of Commerce and Business Administration, Dhofar University, Salalah, Dhofar, Oman

7 Department of Business Administration, Sukkur IBA University, Sukkur, Sindh, Pakistan