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The Contemporaneous and Lagged Interconnectedness Among Crude Oil, Gold, Currency, and Stock Market in Iran

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Highlights

- The contemporaneous and lagged components exhibit distinct results.
- On average, gold is the main net transmitter of shocks, followed by the USD, while oil is the main net receiver of shocks within the network.
- The average connectedness indicates that, in the long term, stocks represent the most effective asset for portfolio diversification and risk management.
- In the contemporaneous structure, the USD is the primary net transmitter of shocks, and stocks are the main net receiver of shocks within the network.
- In the lagged interdependencies, gold is the primary net transmitter of shocks, whereas oil is the main net receiver of shocks within the network.

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Abstract

This study conducts a comprehensive examination of the interlinkages among four key financial markets—crude oil, gold, currency, and equities—over the period from July 23, 2013, to March 12, 2025. It employs the Contemporaneous and Lagged R^2 Decomposed Connectedness approach recently introduced by Balli et al. (2023), which enables the decomposition of connectedness among variables into lagged and contemporaneous components. As previous approaches provide only overall or contemporaneous results, this novel method fills an important gap in the literature. The findings reveal that most spillovers occur contemporaneously, with the U.S. dollar playing a central role in propagating contemporaneous shocks. In contrast, gold emerges as a significant transmitter of long-term shocks, underscoring its importance for strategic risk management. Furthermore, crude oil is identified as the main receiver of shocks in both the average and lagged connectedness within the network. Dynamic analyses indicate heightened market sensitivity during periods of geopolitical tension, particularly under intensified sanctions and currency volatility in Iran. By uncovering the evolving structure of cross-market dependencies, this research provides valuable insights for portfolio allocation, systemic risk assessment, and the formulation of responsive economic policies during periods of financial stress.

Keywords: Contemporaneous and lagged effects, Crude oil, Risk spillover, Stock market

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1. Introduction

Globalization and financial integration have led to increasing interdependence among global commodity, currency, and equity markets (Mensi et al., 2022; Xu et al., 2023). Two vital investment assets that are actively traded worldwide are crude oil and gold (Batten et al., 2019; Liu et al., 2024). Crude oil prices have a direct impact on business profitability and overall economic activity. As production costs rise, firms' expected cash flows decline, which in turn pushes stock prices lower (Park & Ratti, 2008; Sadorsky, 1999). Additionally, fluctuations in oil prices can stimulate inflation and prompt central banks to adjust interest rates, thereby creating an indirect linkage between oil markets and stock performance (Park & Ratti, 2008).

Gold, on the other hand, is widely regarded as a safe-haven asset. Investors turn to gold to preserve wealth during periods of severe inflation or stock market volatility (Baur & Lucey, 2010; Baur & McDermott, 2010). Empirical evidence supports gold's role as a hedge during turbulent periods, demonstrating its ability to protect against significant stock market losses (Baur & Lucey, 2010; Baur & McDermott, 2010). Furthermore, because gold and oil are predominantly priced in U.S. dollars, gold has also been shown to serve as a safe haven against U.S. dollar currency risk (Capie et al., 2005; Diebold & Yilmaz, 2012).

Consequently, currency markets represent another essential element of this relationship: changes in the value of dollar-denominated commodities such as gold and oil influence trade competitiveness and equity valuations across countries (Chang et al., 2013; Ding et al., 2021). Taken together, the price dynamics of gold, oil, exchange rates, and stock markets are intricately connected through financial and economic channels, making their interactions a compelling subject for academic researchers and industry practitioners.

It is critical to understand how these markets are interconnected for several reasons. According to Diebold and Yilmaz (2012) and Filis et al. (2011), cross-market spillovers illustrate how shocks propagate throughout the financial system. For instance, a shock to oil prices may trigger currency depreciation or stock market volatility. These spillovers influence systemic risk and financial stability (Mensi et al., 2021; Xu et al., 2023). Moreover, recent research has increasingly examined how geopolitical tensions and sanctions affect financial market integration, particularly in oil-exporting countries (Fattahi & Nafisi-Moghadam, 2023; Rudari et al., 2025).

Second, from an investment perspective, the benefits of diversification depend on the degree of connectedness: assets that move inversely or exhibit weak linkages can serve as safe havens or hedges within portfolios (Baur & Lucey, 2010; Baur & McDermott, 2010). For example, incorporating gold into a stock portfolio has traditionally reduced risk during crises without reducing returns (Arouri et al., 2011). Conversely, when markets display a high level of correlation, the advantages of diversification diminish precisely when they are needed most.

Third, regulators monitor these interconnections to anticipate how contagion might spread during periods of financial stress. Events such as the COVID-19 pandemic and the 2008 global financial crisis have demonstrated how disruptions in one market can quickly spill over into others, exacerbating economic downturns (Bakas & Triantafyllou, 2020; Sharif et al., 2020). Thus, a comprehensive understanding of the linkages among oil, gold, foreign exchange, and equity markets can inform improved risk management practices, regulatory policies, and contingency planning (Diebold & Yilmaz, 2012; Mensi et al., 2024).

While extensive research has examined pairwise relationships—such as correlations between oil and stocks or gold and stocks—a thorough assessment of the multivariate connectedness among oil, gold,

currency, and equities is required to capture their simultaneous interactions. By analyzing the linkages among these four major markets over a broad sample period, this study aims to address this gap. Specifically, it measures how return shocks in one asset (stocks, gold, oil, or currency) influence other assets and how these interactions evolve under different market conditions. The study builds on the seminal connectedness framework of Diebold and Yilmaz (2012, 2014) while addressing certain limitations by applying a VAR-based spillover approach that decomposes connectedness into contemporaneous (instantaneous) and lagged effects (Diebold & Yilmaz, 2014). This methodology offers a more nuanced understanding of shock transmission within the system.

According to our empirical analysis, there are substantial differences between contemporaneous and lagged interdependencies, and the overall connectedness among the variables under study is moderate. Most of the connectedness is contemporaneous, underscoring the rapid transmission of shocks, particularly those originating from the USD. Conversely, although smaller in magnitude, lagged connectedness highlights the role of gold as a major long-term transmitter of shocks and its relevance for portfolio-level risk management strategies. Notably, the dynamic connectedness analysis indicates that the network becomes more sensitive during periods of geopolitical stress, particularly when sanctions intensify and Iran's currency experiences heightened volatility. By emphasizing the need for continuous monitoring of interconnectedness for effective risk management and policy formulation, these findings add important nuance to our understanding of asset interactions.

This study pursues three primary objectives. First, it provides a comprehensive assessment of return spillovers among crude oil, gold, the exchange rate, and the stock market in order to evaluate the overall interconnectedness of these markets. In addition to estimating the magnitude of these linkages, it identifies the direction of spillovers by determining which markets serve as dominant shock transmitters and which operate as net receivers. Second, by distinguishing between lagged and instantaneous (contemporaneous) spillover effects, the methodology clarifies whether shocks are primarily transmitted through delayed responses or propagate rapidly across markets. This decomposition allows for a more precise inference regarding the timing of cross-market interactions. As prior studies (e.g., Madani & Ftiti, 2022) have primarily focused on overall or contemporaneous connectedness, this study fills an important gap by decomposing these relationships into lagged and contemporaneous components, thereby enhancing our understanding of the underlying transmission mechanisms. Third, the study investigates the stability of these interdependencies across various market regimes. The sample period includes numerous economic and geopolitical events—such as the COVID-19 pandemic, currency regime adjustments, and oil price collapses—which are used to evaluate how periods of turmoil or extreme conditions may intensify, weaken, or redirect cross-asset relationships. These findings have implications for both portfolio allocation and policy measures aimed at mitigating systemic risk.

These objectives align with recent empirical research that employs regime-sensitive and nonlinear models to analyze Iranian markets. For example, Amiri et al. (2025) show that foreign exchange uniquely provides both hedging and safe-haven characteristics for the Tehran Stock Exchange, whereas gold and Bitcoin serve as strong safe havens during periods of elevated volatility. Their results highlight the increasing importance of alternative assets in domestic risk management practices. Our approach extends and complements this line of research by further decomposing connectedness into contemporaneous and lagged structures, particularly in identifying long-term transmitters of systemic risk.

The remainder of this study is organized as follows. Section 2 reviews the literature. Section 3 presents the methodology. Section 4 describes the data. Sections 5 and 6 provide the empirical findings, discussion, and conclusions.

2. Literature review

2.1. Spillovers among oil, gold, currency, and stock markets

The financial literature has long recognized the relationship between oil prices and stock market returns. Early studies documented a strong correlation, often attributed to the influence of oil prices on corporate profitability and macroeconomic fundamentals (Jones & Kaul, 1996; Park & Ratti, 2008; Sadorsky, 1999). Illustrating oil's role as a systematic risk factor, Sadorsky (1999) shows that oil price shocks can explain a substantial portion of the variation in U.S. stock returns. Additional research across various countries confirms that rising oil prices generally exert a negative effect on stock markets—particularly in oil-importing economies—by increasing inflation and production costs (Filis et al., 2011; Park & Ratti, 2008). However, the dynamics differ in oil-exporting countries, where higher oil revenues may stimulate economic activity and enhance equity valuations, resulting in distinct oil–stock relationships (Filis et al., 2011). Several studies further indicate that oil–stock correlations vary over time or depend on specific market regimes, often strengthening during periods of economic uncertainty (Filis et al., 2011).

The behavior of gold differs markedly from that of stock or currency markets. Owing to its monetary characteristics, gold is commonly viewed as a hedge or safe haven (Baur & Lucey, 2010; Baur & McDermott, 2010). Historical episodes such as the 2008–2009 financial crisis demonstrate that gold tends to move inversely to stocks during market downturns, with its price rising as equity markets fall (Baur & McDermott, 2010). In certain contexts, gold also functions as an inflation hedge (Beckmann & Czudaj, 2013). With respect to currencies, gold typically exhibits an inverse relationship with the U.S. dollar: when the dollar depreciates, international investors find dollar-denominated gold more affordable, leading to higher gold prices (Capie et al., 2005). Although gold and oil continue to be priced in dollars, their explicit links to currency movements weakened following the dissolution of the Bretton Woods system in 1971 (Capie et al., 2005; Chang et al., 2013). Exchange rate fluctuations often spill over into other asset classes, especially in commodity-dependent economies (Singhal et al., 2019). To deepen the understanding of systemic risk and cross-asset linkages, researchers have also examined the joint behavior of stocks, gold, oil, and currency markets.

Some studies have examined the four markets jointly to capture their collective dynamics, moving beyond simple pairwise linkages. For example, Mensi et al. (2021) analyze equities in the oil, gold, and Chinese sectors and find that no market is completely isolated; shocks in one market frequently spill over into others, indicating a high degree of integration. Similarly, Liu et al. (2024) show that in G20 economies, equities, currency, gold, and oil are interconnected within a global risk network, with certain assets acting as net transmitters of shocks. Although some studies report episodes of partial independence or temporary decoupling (Chang et al., 2013), the prevailing view is that the stock, currency, gold, and oil markets are sufficiently intertwined to merit joint analysis. Importantly, these relationships are not static, and many researchers emphasize their time-varying and asymmetric nature.

Recent evidence shows that connectedness is highly dynamic and often asymmetric with respect to positive versus negative shocks. To track evolving spillovers, many studies employ time-varying parameter or rolling-window frameworks. Correlations across markets tend to be weaker during tranquil periods and stronger during times of market stress. Mensi et al. (2021), for instance, document that short-term spillovers across stocks, gold, and oil generally dominate long-term effects, suggesting that markets respond more strongly to abrupt shocks. Moreover, several studies report asymmetry in transmission, with negative shocks spreading more extensively than positive ones (Mensi et al., 2021, 2022). In other words, adverse news tends to exert a broader market impact than favorable news. Xu et al. (2023) find that negative spillovers prevail in their sample, although gold remains relatively less

affected than currency or oil. This pattern has practical implications for risk management, as investors face greater downside exposure when markets decline simultaneously. The phenomenon is particularly relevant during financial crises, which often alter both the magnitude and direction of spillovers.

Crises can profoundly reshape the direction and intensity of cross-market transmissions. Major events such as the 2008–2009 global financial crisis, the European debt crisis of the early 2010s, and the COVID-19 pandemic of 2020 have increased interdependence across oil, gold, currency, and equity markets (Bakas & Triantafyllou, 2020; Mensi et al., 2022; Sharif et al., 2020). During the Great Financial Crisis, for instance, gold prices surged in a flight-to-quality response, while oil and stock prices declined concurrently. Comparable patterns emerged during the 2014–2016 oil price collapse, particularly in oil-exporting economies (Mensi et al., 2024). Research on the COVID-19 period reveals a distinctive dynamic: the simultaneous decline in oil and stock prices in early 2020 suggests synchronized bearishness (Ali et al., 2022; Xu et al., 2023). Several studies conclude that short-run co-movements peaked between March and May 2020, reflecting the rapid spread of pandemic-induced shocks. Elevated volatility persisted even after initial lockdowns, indicating that the pandemic continued to reshape the connectedness structure. These findings reinforce the notion that crises can strengthen existing relationships, invert lead-lag patterns, and fundamentally alter cross-asset transmission. Thus, understanding the evolution of these linkages requires not only crisis-specific insights but also robust methodological frameworks.

Advanced R^2-based deconstructed linkage techniques have been increasingly employed in 2025 research to capture both lagged and contemporaneous shock transmissions across interconnected asset classes (Akıncı Tok & Tarkun, 2025; Ha & Thanh, 2025; Huang et al., 2025). These studies show that spillovers intensify during periods of geopolitical stress and energy-price volatility, underscoring the importance of analyzing sectoral indices, investor sentiment, and currency–commodity linkages from a dynamic, system-wide perspective. Collectively, this evidence illustrates that conventional pairwise approaches may overlook critical dimensions of volatility transmission, particularly when market conditions become highly turbulent.

Beyond the global context, several recent works have focused specifically on Iran's financial markets. A substantial body of domestic literature has examined the intricate interactions among financial assets, socio-political shocks, and macroeconomic variables. Using nonlinear Smooth Transition Regression (STR) models, Amiri et al. (2025) investigated the hedging and safe-haven properties of Bitcoin, gold, and foreign exchange for the Tehran Stock Exchange. Their findings indicate that although gold and Bitcoin provide some safe-haven characteristics, only foreign exchange consistently serves as both an effective hedge and a reliable safe haven during periods of market stress. Similarly, employing a TVP-QVAR framework, Jamshidi et al. (2024) showed that the volatility of Iran's currency, stock, and gold markets shapes the dynamics of social unrest over time, with the stock market exerting the most persistent influence. In another strand of research, Rudari et al. (2025) analyzed dynamic risk spillovers among housing, gold coins, exchange rates, and equities across sanctioned and non-sanctioned periods, finding markedly stronger volatility transmission during episodes of geopolitical instability. These results align with the wavelet-based analysis of Fattahi and Nafisi-Moghadam (2023), which demonstrated that political uncertainty and oil-related sanctions heighten the interconnectedness of Iran's financial markets—most notably between gold and foreign exchange.

Earlier empirical work relied primarily on simple cointegration or standard GARCH frameworks. To capture pairwise volatility spillovers, initial studies typically employed multivariate GARCH models and vector autoregression (VAR) (Arouri et al., 2011; Sadorsky, 1999). With the introduction of the Diebold and Yilmaz (2012, 2014) connectedness indices—based on forecast error variance decomposition—researchers gained the ability to quantify both the magnitude and direction of

spillovers. Using rolling-window estimation, these methods allow identification of net transmitter and net receiver assets, as well as the construction of time-varying measures of total connectedness (Diebold & Yilmaz, 2014; Mensi et al., 2022). Subsequent methodological extensions include quantile-based connectedness (Ando et al., 2022) and frequency-domain decompositions (Baruník & Křehlík, 2018). These advanced approaches highlight tail-dependent behavior and distinguish between short- and long-term spillover dynamics—features that become particularly salient during periods of market stress.

Aligned with the broader spillover literature, this study employs a VAR-based framework similar to that of Diebold and Yilmaz, focusing on both contemporaneous and lagged dimensions of interconnectedness. Accordingly, the results offer updated evidence on the interrelationships among oil, gold, foreign exchange, and equity markets, generating insights relevant to investors, policymakers, and researchers concerned with market stability and cross-asset integration.

This study specifically adopts the R^2-decomposed connectedness method proposed by Balli et al. (2023), which extends recent developments in connectedness modelling by separating contemporaneous and lagged spillover effects within a multivariate VAR environment. Unlike conventional connectedness indices that aggregate all spillovers into a single measure, this approach provides a richer depiction of shock propagation mechanisms over time. Applying this methodology to stock, currency, oil, and gold markets yields novel insights into the direction, timing, and persistence of return spillovers under varying macroeconomic and geopolitical conditions. For investors and portfolio managers, the decomposition is particularly valuable, as it reveals whether markets react immediately or with delay to systemic shocks—information that is essential for real-time risk management, hedging strategies, and the formulation of effective policy responses.

3. Methodology

We begin our analysis by introducing the R^2-based decomposed connectedness methodology, starting with a VAR(p) model that accounts for contemporaneous effects.

$$y_t = \sum_{i=0}^{p} B_i y_{t-i} + u_t \qquad u_t \sim N(0, \Sigma) \tag{1}$$

where y_t, y_{t-1}, and u_t are dimensional demeaned vectors in time t, and B_i as well as $\boldsymbol{\Sigma}$ are $K \times K$ dimensional matrices where $diag(B_0) = 0$. Thus, the left-hand side (LHS) variable is dropped from the right-hand side (RHS) variables. It is worth mentioning that if p = 0, the model decreases to the contemporaneous R^2 decomposed connectedness approach proposed by Naeem et al. (2023). Alternatively, the outlined model can be formulated as $y_{k,t} = b_k x_t + u_{k,t}$ where $x_t = [y_t, y_{t-1}, \dots, y_{t-i}, \dots, y_{t-p}]$ is a $K(p+1) \times 1$ dimensional vector and $b_k$is a $1 \times K(p+1)$ vector with zero on the kth position. Generally, the total R^2contributions from bivariate linear regressions (BLRs) will only equal the R^2 goodness-of-fit measure from a multivariate linear regression (MLR) if all right-hand side (RHS) variables are uncorrelated with one another. Thus, it is necessary to identify a transformation that converts the correlated series $x_{k,t}$ into orthogonal series. This can be achieved through principal component analysis (PCA), where the number of latent factors matches the number of right-hand side (RHS) variables. Thus, the R^2 decomposition for an MLR can be calculated as follows:

$$R_{xx} = V \Lambda V' = CC' \tag{2}$$

$$C = V\Lambda^{1/2}V' \tag{3}$$

$$R^{2,d} = C^2\left(C^{-1}R_{yx}\right)^2 \tag{4}$$

where $\boldsymbol{V}, \boldsymbol{\Lambda} = \text{diag}\left(\lambda_1, \dots, \lambda_{K(p+1)-1}\right)$, and R_{xx} represent $[K(p+1)-1] \times [K(p+1)-1]$ eigenvector, eigenvalue, and Pearson correlation matrices, respectively, while R_{yx} and $R^{2,d}$ illustrate $[K(p+1) \times 1]$ Pearson correlation and contribution vectors, respectively. With greater specificity, R_{xx} refers to Pearson correlation coefficients across RHS variables and R_{yx} to Pearson correlation coefficients between the LHS and RHS variables. The first K–1 values of $R^{2,d}$ represent the contemporaneous R^2 contributions, while the remaining highlight the lagged R^2 contributions. As a result, the vector sum of $R^{2,d}$ is equal to the MLR R^2 goodness-of-fit measure. In the next step, we stack the $R^{2,d}$ contribution of all K MLRs to obtain the $K\times(p+1)$ dimensional $R^{2,d}$ decomposition matrix, $\left[R_0^{2,d}; \dots; R_i^{2,d}; \dots R_p^{2,d}\right]$.

$R_0^{2,d}$ can be explained as the contemporaneous spillovers ($R_C^{2,d}$) while the sum of the lagged values $\left(R_L^{2,d} = R_1^{2,d} + \cdots + R_i^{2,d} + \cdots + R_p^{2,d}\right)$ represents the lagged spillovers.

With respect to the connectedness approach of Diebold and Yılmaz (2012, 2014), $R_C^{2,d}$and $R_L^{2,d}$replace the scaled GFEVD matrix. This indicates that the total connectedness index (TCI) is equivalent to the average $R^2$of the kMLRs.

$$TCI = \frac{1}{K}\sum_{k=1}^{K} R_k^2 \tag{5}$$

Since R_k^2 ranges between zero and one, the TCI also lies within the same bounds, thereby avoiding the connectedness normalization problem (see Lastrapes and Wiesen, 2021; Chatziantoniou and Gabauer, 2021; Gabauer, 2021). The application of our proposed methodology allows for the separate exploration of contemporaneous and lagged TCI.

$$TCI = \frac{1}{K}\sum_{k=1}^{K} R_k^2 \tag{6}$$

$$= \left(\frac{1}{K}\sum_{k=1}^{K}\sum_{j=1}^{K} R_{C,k,j}^{2,d}\right) + \left(\frac{1}{K}\sum_{k=1}^{K}\sum_{j=1}^{K} R_{L,k,j}^{2,d}\right) \tag{7}$$

$$= TCI^C + TCI^L \tag{8}$$

where TCI^{C}and TCI^{L}represent the contemporaneous and lagged TCI, respectively.

Ultimately, this framework can also be extended to the total directional connectedness measures, encompassing both “TO” and “FROM” others, as well as the net total directional connectedness indicators.

$$TO_j = \sum_{k=1}^{K} R_{C,k,j}^{2,d} + \sum_{k=1}^{K} R_{L,k,j}^{2,d} \tag{9}$$

$$= TO_j^C + TO_j^L \tag{10}$$

$$FROM_j = \sum_{k=1}^{K} R_{C,j,k}^{2,d} + \sum_{k=1}^{K} R_{L,j,k}^{2,d} \tag{11}$$

$$= FROM_j^C + FROM_j^L \tag{12}$$

$$NET_j^C = TO_j^C - FROM_j^C \tag{13}$$

$$NET_j^L = TO_j^L - FROM_j^L \tag{14}$$

$$NET_j = NET_j^C + NET_j^L \tag{15}$$

While the TO_j(TO_j^C/TO_j^L) total directional connectedness indicates the extent to which series $j$explains the overall (contemporaneous/lagged) variance in all LHS variables, the FROM_j(FROM_j^C/FROM_j^L) total directional connectedness reflects the extent to which all RHS variables explain the overall (contemporaneous/lagged) variance in series j—equivalent to the R^2 of the k MLR. If $\mathrm{NET}_j > 0$ ($\mathrm{NET}_j < 0$), series $j$is considered a net transmitter (receiver) of shocks, indicating that it explains more (less) of the variation in others than vice versa. The contemporaneous and lagged connectedness measures can be analyzed and interpreted in a similar manner.

4. Data

Our study utilizes a daily dataset comprising oil prices [oil], currency [USD], gold prices [gold], and the stock market index [stock]. The data sample spans the period from July 23, 2013, to March 12, 2025. The data were obtained from the OPEC website, TGJU, and TSETMC, respectively.

Several significant events occurred during this period, including the US sanctions in 2013, the JCPOA agreement in 2014–2015, the US withdrawal from the JCPOA in 2018 accompanied by a surge in the USD, a historic stock market crash in 2020–2021, and another notable USD surge in the current year. The period also encompasses four critical presidential elections. The stock market is expressed in terms of its index, the exchange rate in Rials, and gold and oil prices in US dollars.

Given that the raw series are non-stationary, the growth rate of all series was computed. Table 1 presents the summary statistics for the variables. As shown, gold exhibits the highest mean, followed by the stock market and USD. Oil displays the highest variance, followed by USD and gold. All variables are non-normally distributed but stationary according to the Jarque–Bera and ERS tests. The skewness of all variables, except for oil, is positive, indicating higher-than-usual returns, particularly for the stock market. The excess kurtosis values for all variables are positive and significant at the 1% level, demonstrating that all distributions are leptokurtic.

Table 2 presents the correlations between the series. As shown, the highest correlation is observed between gold and USD, whereas the lowest correlation occurs between gold and the stock market, followed by oil and the stock market. Furthermore, no significant correlation is observed between gold and oil, oil and USD, or USD and the stock market.

Table 1

Summary statistics

	Gold	**Oil**	**Stock**	**USD**
Mean	0.280***	0.025	0.250***	0.233***
Variance	5.41	9.437	3.341	5.959
Skewness	0.368***	–0.052	1.111***	0.127**
Ex. Kurtosis	21.921***	19.251***	7.306***	19.167***
JB	33415.479***	25741.490***	4050.529***	25522.872***
ERS	–6.262***	–16.109***	–11.262***	–11.527***

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Skewness was assessed using the D'Agostino (1970) test; kurtosis was evaluated with the Anscombe and Glynn (1983) test; JB refers to the Jarque–Bera (1980) normality test; and ERS denotes the Elliott et al. (1996) unit-root test.

Table 2

Kendall rank correlation coefficients

Kendall	**Gold**	**Oil**	**Stock**	**USD**
gold	1.000***	0.017	0.044***	0.406***
oil	0.017	1.000***	0.050***	0.005
stock	0.044***	0.050***	1.000***	0.022
USD	0.406***	0.005	0.022	1.000***

An overview of the research data is presented in Figure 1. As illustrated, USD and stock returns exhibited greater volatility than the other variables over the sample period. A notable surge in gold, stock, and USD returns is observed in 2018–2019, corresponding to the US withdrawal from the JCPOA. All series experienced substantial fluctuations during 2020–2021, likely attributable to the COVID-19 pandemic. Finally, an increase in volatility is evident in 2023 for the stock market and USD, coinciding with the national currency devaluation and the Iran–US political tensions in the same year.

5. Results

We begin by interpreting the averaged connectedness measures presented in Table 3, which represent the overall R^2-decomposed measures. Our results indicate that the total connectedness index (TCI) is 21.25%. According to Balli et al. (2023), this value implies that, on average, 21.25% of the variance of the LHS variables can be explained by the RHS variables. Decomposing the TCI into contemporaneous and lagged connectedness reveals that contemporaneous dynamics account for 19.65% of the TCI, whereas lagged interdependencies contribute only 1.59%. Moreover, the contemporaneous FROM and TO connectedness are substantially larger than the lagged effects for all variables.

As shown in Table 3, oil emerges as the primary net receiver of shocks from the network, indicating that it is the most dependent variable among the assets and may not be an optimal investment. In contrast, gold serves as the main net transmitter of shocks, followed by USD. The stock market, however, is the least net contributor to the network, suggesting its suitability for portfolio diversification. These findings are consistent with those of Shakeel et al. (2023), who also identified gold as an effective transmitter of shocks and oil as the primary receiver; however, they did not differentiate between contemporaneous and lagged interdependencies.

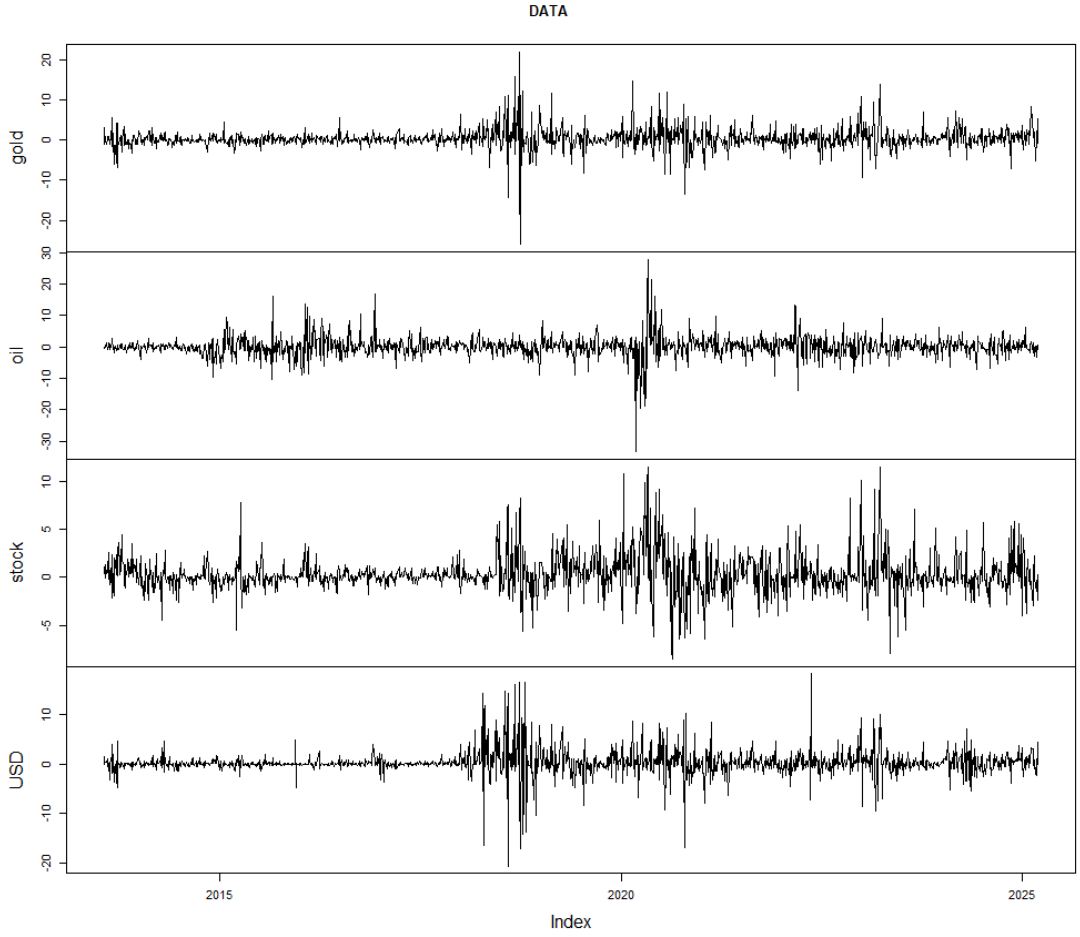

Figure 1

Dynamics of network indices

Table 3

Averaged Connectedness.

	Gold	**Oil**	**Stock**	**USD**	**FROM**
gold	0.78	0.98	3.32	31.64	35.94
oil	1.18	1.66	2.28	1.3	4.76
stock	3.88	1.8	3.56	3.29	8.97
USD	31.82	0.44	3.07	2.97	35.33
TO	36.88	3.22	8.67	36.22	84.99
Inc. Own	37.66	4.88	12.23	39.2	cTCI/TCI
NET	0.94	–1.54	–0.3	0.9	28.33/21.25
NPT	3	0	1	2	

Table 4 presents the contemporaneous connectedness measures. From a contemporaneous perspective, USD emerges as the primary transmitter of shocks within the network. In contrast, the stock market is the main receiver of shocks, followed by oil. Gold exhibits the smallest contribution to the network, suggesting that it may serve as a suitable short-term asset for portfolio diversification.

Table 4

Contemporaneous Connectedness.

	Gold	**Oil**	**Stock**	**USD**	**FROM**
gold	0	0.72	2.91	30.82	34.46
oil	0.84	0	1.63	0.37	2.84
stock	3.12	1.55	0	2.98	7.65
USD	30.54	0.31	2.81	0	33.66
TO	34.5	2.58	7.36	34.18	78.61
Inc. Own	34.5	2.58	7.36	34.18	cTCI/TCI
NET	0.04	–0.27	–0.29	0.51	26.20/19.65
NPT	2	0	1	3	

Table 5 presents the lagged interdependencies. As shown, oil is the primary net receiver of shocks from the network, whereas gold is the main net transmitter, followed by USD. The stock market contributes the least to the network, indicating its suitability as a long-term asset for portfolio diversification and risk management.

Furthermore, the results suggest that gold transmits a larger share of shocks in the long term compared to its contemporaneous effects. In contrast, USD primarily transmits shocks contemporaneously. The data also indicate that oil receives the most shocks in the lagged connectedness measures relative to its contemporaneous interdependencies.

Table 5

Lagged connectedness

	Gold	**Oil**	**Stock**	**USD**	**FROM**
Gold	0.78	0.26	0.41	0.81	1.48
Oil	0.34	1.66	0.64	0.92	1.91
Stock	0.76	0.25	3.56	0.31	1.32
USD	1.28	0.13	0.26	2.97	1.67
TO	2.38	0.64	1.31	2.05	6.38
Inc. Own	3.16	2.3	4.87	5.02	cTCI/TCI
NET	0.9	–1.27	–0.01	0.38	2.13/1.59
NPT	3	0	1	2	

As the examination of average connectedness may overlook time-varying dynamics, we also investigate dynamic connectedness. Figure 2 illustrates the dynamic TCI, highlighting two notable peaks. The first peak occurs at the end of 2021, coinciding with the tightening of US sanctions against Iran, as well as

a surge in the USD due to political issues and unfavorable economic policies. The second peak is observed at the end of 2023 and the beginning of 2024, when Iran faced a similar situation with the collapse of the national currency as in 2021. A surge in the TCI is also evident in 2013, potentially linked to stricter sanctions during that period. Furthermore, a more pronounced surge occurred in 2018, corresponding to the US withdrawal from the JCPOA. These observations underscore the significant impact of sanctions on risk transmission in Iranian markets. Notably, the all-time lowest TCI is observed between 2016 and 2018, coinciding with the JCPOA period. As shown in Figure 2, the contemporaneous TCI remains substantially higher than the lagged TCI throughout the sample period.

Figure 3 illustrates the time-varying net total directional connectedness. As shown, oil serves predominantly as a net receiver of shocks throughout the period, although it temporarily becomes a transmitter at the onset of the COVID-19 pandemic. Similar studies (Hung and Vo, 2021; Mensi et al., 2021) also found that oil was a net receiver of shocks prior to COVID-19 and shifted its role in 2020; however, these studies did not differentiate between contemporaneous and lagged interdependencies. Our results indicate that, while oil remained a net receiver of contemporaneous shocks, it transmitted shocks to the network via lagged interdependencies during this period.

Gold functions as the primary net transmitter of shocks for most of the period, except between 2014–2016 and 2017–2018, which may be associated with the JCPOA. The stock market is generally a net receiver of shocks, but it becomes a transmitter during 2014–2016 and 2017–2018. Finally, USD predominantly acts as a transmitter of shocks, although it functions as a net receiver between late 2018 and 2020, likely reflecting the impact of the US withdrawal from the JCPOA and the COVID-19 pandemic.

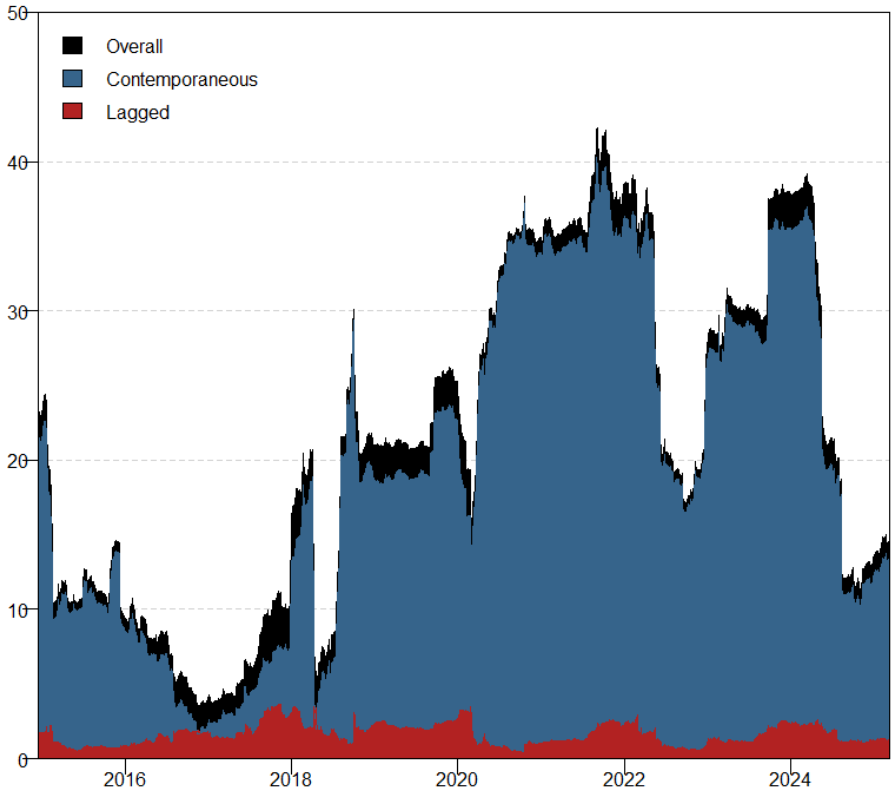

Figure 2

Dynamic TCI

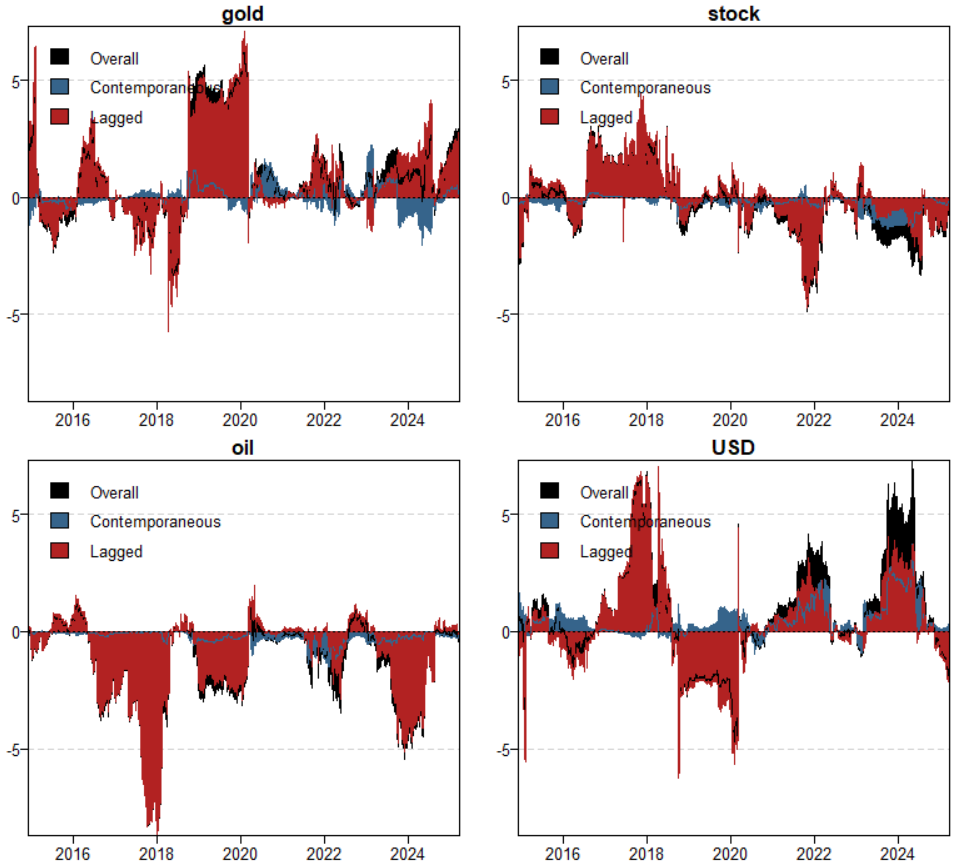

Figure 3

Net total directional connectedness

Figure 4 presents the average contemporaneous, lagged, and overall connectedness. A higher degree of contemporaneous interdependencies is observed from USD to oil and from gold to the stock market. The results further indicate that lagged interdependencies are stronger from USD to gold, followed by USD to the stock market and from gold to the stock market. Overall, oil emerges as the primary receiver of shocks, with the majority of shocks being transmitted from USD to oil.

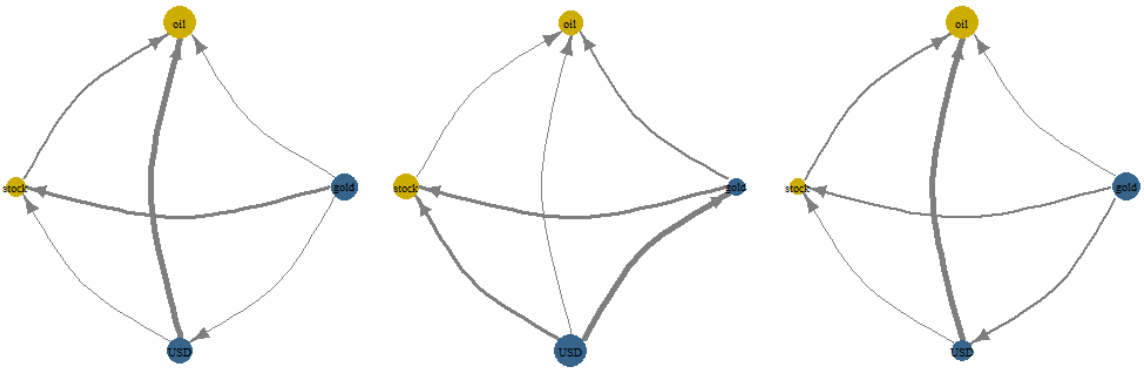

Figure 4

Network connectedness

Finally, robustness checks are presented in Figure 5 based on the dynamic total connectedness. Specifically, we replace the Pearson correlation coefficients with Spearman and Kendall rank correlation coefficients, which are less sensitive to outliers. Given the numerically similar results, we conclude that our empirical findings are robust.

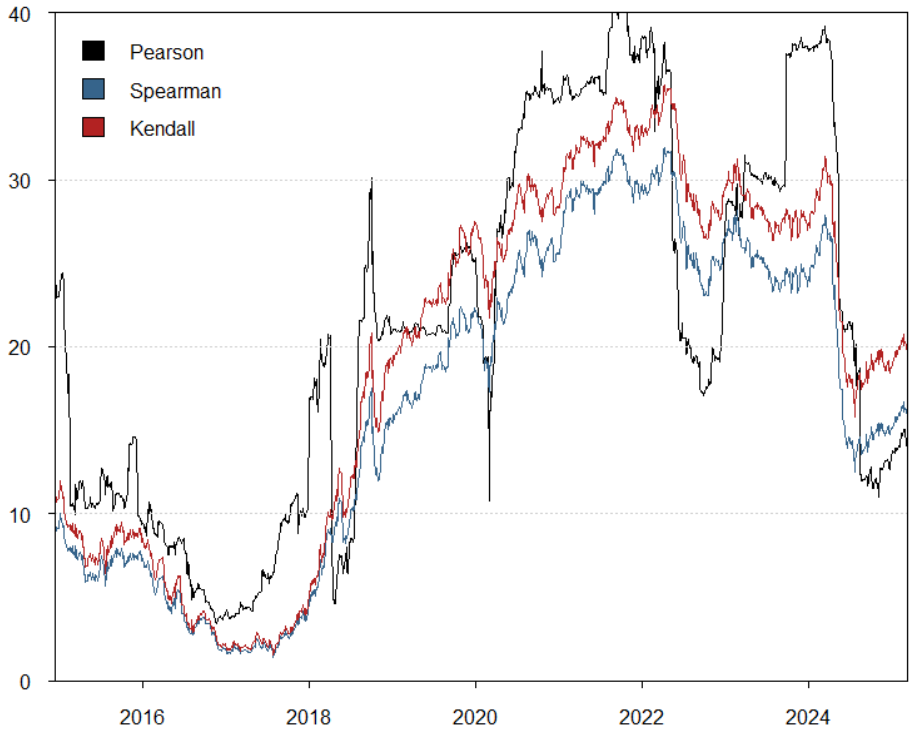

Figure 5

Robustness checks

6. Conclusions

This study investigates the connectedness among gold, oil, currency, and the stock market in Iran, using daily data spanning from July 23, 2013, to March 12, 2025. This period encompasses several significant events, including three presidential elections, the JCPOA agreement, the US withdrawal from the JCPOA, surges in the national currency, and a historic stock market crash in 2021. We employ the recently developed R^2-decomposed connectedness method by Balli et al. (2023), which allows for the separation of contemporaneous and lagged components of connectedness. This approach provides insights into the interrelationships among assets, currency, and the oil market—factors critical for portfolio diversification and hedging strategies, particularly during periods of political and economic turbulence. The findings of this research contribute to enhancing portfolio asset allocation and mitigating risk.

Our results indicate that gold was the primary net transmitter of shocks to the network during the study period, followed by the currency. In contrast, oil served as the net receiver of shocks, rendering it a vulnerable asset during extreme events. Moreover, the stock market exhibited the least contribution to the network, suggesting its potential as a safe asset for portfolio diversification.

While previous studies have primarily focused on overall connectedness, our research differentiates between overall, contemporaneous, and lagged interdependencies. In the contemporaneous period, the currency acts as the main net transmitter of shocks, whereas the stock market is the principal net receiver

and the most vulnerable asset, with gold contributing minimally to the network. Lagged interdependencies reveal that gold becomes the primary net transmitter over time, while oil remains the main net receiver of shocks. The stock market continues to exhibit minimal contribution in the lagged context, indicating its suitability as a long-term safe asset.

Accordingly, investors may consider including gold in their portfolios for short-term risk management and contemporaneous diversification, while allocating to stock market components for long-term portfolio diversification and risk mitigation.

Nomenclature

GARCH	Generalized Autoregressive Conditional Heteroskedasticity
JCPOA	Joint Comprehensive Plan of Action

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