Heliyon 9 (2023) e22974

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Interconnectedness dynamic spillover among US, Russian, and Ukrainian equity indices during the COVID-19 pandemic and the Russian–Ukrainian war

Bashar Yaser Almansour [a], Sabri Elkrghli [a], Jesus Cuauhtemoc Tellez Gaytan [b], Rajesh Mohnot [c,*]

[a] *Faculty of Business Administration, Libyan International Medical University, Benghazi, Libya*
[b] *School of Business, Tecnologico de Monterrey, San Luis Potosí, Mexico*
[c] *Ajman University, Ajman, United Arab Emirates*

A R T I C L E I N F O

Keywords:
COVID-19
Dynamic connectedness
Network approach
Russian–Ukrainian war

A B S T R A C T

We examine the dynamics and spillover effects of interconnectedness among equity indices during the COVID-19 pandemic and the Russian–Ukrainian war. Using daily data from June 2010 to May 2023, we consider five major equity indices, namely, the Dow Jones Industrial Average (DJIA), National Association of Securities Dealers Automated Quotations (Nasdaq), Standard and Poor's 500 (S&P 500), PFTS (Ukraine), and Moscow Exchange (MOEX; Russia). The results demonstrate a 45 % level of the total connectedness index to explain the interconnectedness among these indices. The findings indicate that the DJIA, Nasdaq, Small Cap 100, and MOEX are net receivers of spillovers, whereas the S&P 500 and PFTS are significant net transmitters. Moreover, analysis of different periods, including before and during COVID-19 and before the Russian–U war, provides insights into the changing patterns of interconnectedness and spillover effects during these events. This study contributes to a better understanding of the interdependency and transmission mechanisms among equity markets and highlights the importance of considering external factors and geopolitical events in formulating risk management and investment strategies.

1. Introduction

The global financial landscape has become increasingly interconnected with financial markets worldwide experiencing dynamic spillover and interconnectedness. This phenomenon is particularly evident in equity markets in which the performance of one market can exert profound effects on others. Understanding these dynamic spillovers and connectedness is crucial for investors, policymakers, and financial institutions in managing risks and making informed decisions on investment [1–5].

Financial contagion theory provides a framework for understanding the transmission of financial shocks and disturbances across countries and markets. It suggests that financial interconnectedness and links among equity markets can amplify the effects of shocks, which leads to contagion and spillover effects [6–8]. In the context of the war between Russia and Ukraine, financial contagion theory

* Corresponding author
E-mail addresses: bashar.almansour@limu.edu.ly (B. Yaser Almansour), sabri.elkrghli@limu.edu.ly (S. Elkrghli), cuauhtemoc.tellez@tec.mx (J.C. Tellez Gaytan), r.mohnot@ajman.ac.ae (R. Mohnot).

https://doi.org/10.1016/j.heliyon.2023.e22974
Received 7 June 2023; Received in revised form 20 November 2023; Accepted 23 November 2023
Available online 28 November 2023

posits that this conflict can trigger shocks and disturbances that can propagate through the interconnected global financial system. These shocks can emerge from various sources, such as geopolitical uncertainty, disruption in trade and supply chains, economic sanction, and investor sentiment.

First, geopolitical uncertainty related to the war can significantly impact investor sentiment and risk perception [9]. Specifically, uncertainty regarding the duration, intensity, and potential escalation of the conflict can lead to heightened risk aversion among investors, which may result in widespread sell-offs in equity markets. The reason is that investors intend to reduce exposure to risky assets and move toward safe investments [10]. Selling pressure can trigger a downward spiral in asset prices, which affects not only the equity markets of Russia and Ukraine but also those of other countries. Second, disruptions in trade and supply chains due to the war can exert a cascading effect on global financial markets [11]. Russia and Ukraine are major players in international trade with extensive linkages to global supply chains. Disruptions in trade flows, export restrictions, or import disruptions can impact not only the countries directly involved but also their trading partners and multinational corporations operating in the region. These disruptions can lead to decreased corporate earnings, reduced business confidence, and potential default on cross-border obligation, which creates a ripple effect across financial markets. Furthermore, the economic sanctions imposed on Russia or Ukraine by other countries can exacerbate financial contagion. Sanctions can restrict access to global financial markets, limit trade opportunities, and increase the borrowing costs of affected countries. The resultant economic pressure can spill over into financial markets, which causes increased volatility, currency devaluation, and capital flight [12].

Interconnectedness between the equity markets of the United States, Russia, and Ukraine holds significant implications. The United States represents a major global economic powerhouse, because its equity market serves as a benchmark for investors worldwide [13]. Alternatively, Russia and Ukraine are emerging markets that experienced various economic and geopolitical events, which can potentially generate spillover effects [14]. Thus, examining the dynamic spillovers and connectedness among these equity markets using the time-varying parameter vector autoregression (TVP-VAR) approach enables a comprehensive analysis. The TVP-VAR framework captures the time-varying nature of relationships and permits the detection of shifts in spillover patterns. By accounting for changing dynamics, the TVP-VAR approach offers an accurate estimation of the interconnectedness between these markets.

The current study aims to contribute to the existing literature on financial contagion and spillover effects by focusing on the interconnectedness among the US, Russian, and Ukrainian equity indices. Including Russia and Ukraine provides a unique perspective, because these markets have experienced significant economic and geopolitical events that potentially generate spillover effects.

2. Literature review

Financial contagion theory explores the transmission of shocks and disturbances across financial markets, which leads to the spread of distress and instability. Specifically, it focuses on the interconnectedness and interdependence of financial institutions, markets, and economies, and the manner in which disturbances in one area can rapidly propagate to others [15]. The concept of financial contagion emerged from the observation that financial crises frequently spread beyond their initial source, which affects domestic and international markets. The manifestation of financial contagion takes on different forms such as the spillover of shocks from one market to another, amplification of market disturbances, and transmission of distress from one institution to others within the financial system [16]. It may occur through various channels such as asset price linkage, information asymmetry, herding behavior, and investor panic [17–19]. Empirical research on financial contagion theory used various methodologies to examine its occurrence and dynamics. Examples of these methods include statistical analysis of market data, network analysis of financial linkages, and econometric modeling of contagion transmission mechanisms [14,20–23].

Particularly [14], investigated volatility spillovers between dirty and clean energy markets and global stock indices under the conditions of the escalating geopolitical risk during the Russian–Ukrainian war. To examine significant changes in shock transmission between August 1, 2014, and May 27, 2022, the authors employed volatility connectedness indices based on the innovative methodology proposed by Diebold and Yilmaz [24,25], which considers structural breaks. Additionally, they explored the advantages and disadvantages of heterogeneous diversification in green energy for hedging strategies and calculated optimal weights and hedge ratios to facilitate portfolio diversification and risk management. The findings suggested that clean energy indices generally exhibit lower risk levels compared with those of global equity markets. Notably, however, hedging costs in renewable energy assets tended to be higher compared with those of nonrenewable energy indices.

Moreover [23], investigated the return and volatility spillover dynamics between agricultural commodities and emerging stock markets during various crises, including the COVID-19 pandemic and the Russian–Ukrainian war. The authors utilized the approach proposed by Refs. [24,25] to estimate return and volatility spillovers. The findings suggested a weak connectedness between agricultural commodities and emerging stock markets. Among the commodities, corn exhibited the highest transmission, whereas sugar displayed the lowest. Similarly, the study identified soya bean and coffee as the largest and smallest recipients of spillover over time, respectively. The majority of equity indices were net recipients of spillover, except for India, China, Indonesia, Argentina, and Mexico, throughout the sample period. In terms of volatility spillover, the majority of commodities served as net transmitters, except for coffee and soya bean. Furthermore, the major equity indices are net recipients of volatility spillover, except for India, Indonesia, China, Argentina, Malaysia, and Korea. Additionally, return and volatility spillovers increase during crises, such as the COVID-19 pandemic and the Russian–Ukrainian war, in which the most significant increase was observed during the COVID-19 pandemic. In that sense, a recent study by Ref. [26] analyzes the interconnectedness among major cryptocurrencies and exchange rates between 2017 and 2022 where the TVP-VAR approach is applied to capture connections and spillover dynamics during the Covid-19 pandemic. The main findings suggest that major cryptocurrencies have been transmitters of shocks to alternative coins, and that EUR/USD, AUD/USD and NZD/USD have been also transmitters to other exchange rates.

The influence of recent global shocks is investigated by Ref. [22] such as the COVID-19 pandemic and the Russian–Ukrainian war, on the variability of major macroeconomic trends. These shocks displayed synchronized behavior across economies and elicited similar policy responses. The primary objective of the study was to examine the transmission of inflation among G20 economies and assess its contribution to domestic inflation. The authors employed the Diebold and Yilmaz spillover approach for this purpose. Unconditional analysis revealed notable disparity in inflation spillover patterns between advanced and emerging economies. Particularly, advanced economies were more susceptible to global shocks and experienced higher spillover rates compared with their emerging counterparts. Idiosyncratic shocks primarily drove inflation in emerging countries in which global shocks exerted a modest influence on domestic inflation. Furthermore, bilateral spillovers among G20 members indicated that the average pairwise directional spillovers between emerging economies are lower than those observed for advanced economies. Analysis of spillover dynamics demonstrated an increasing trend in total inflation spillover, which indicates an increasing interconnectedness among G20 countries over time. Moreover, the estimates revealed the increasing impact of received inflation spillovers from external shocks on advanced and emerging economies.

Utilizing the Baba, Engle, Kraft and Kroner-multivariate generalized autoregressive conditional heteroskedasticity (GARCH) model [21], examined the volatility transmission effects between the US stock market and the COVID-19 pandemic. The study investigated the relationship between the volatility of the US stock market and its previous shocks, including those associated with COVID-19. The findings indicated that its historical shocks and the impact of previous shocks related to COVID-19 influenced the volatility of the US stock market. Additionally, the study observed that death rate, which represents negative news, positively influenced this volatility, whereas the recovery rate, which represents positive news, exerts a negative impact on stock market volatility.

The presence of financial contagion from the US stock market to the Vietnamese and Philippine stock markets during two distinct crises, namely, the global 2007–2009 financial crisis and the COVID-19 pandemic is examined by Ref. [16]. Analysis utilized the dynamic conditional correlation (DCC)-GARCH model and daily data from Standard and Poor's 500 (S&P 500; United States), Vietnam Stock Index (VN-Index), and the Philippine Stock Exchange, Inc. The results indicated that no evidence of contagion exists from the US stock market to the Philippine stock market during the global financial crisis. However, the Vietnamese market did manifest the effect of this contagion. Moreover, the Vietnamese and Philippine stock markets were affected by the contagion effect during the COVID-19 pandemic. Another notable finding was that the contagion effect in Vietnam during the COVID-19 pandemic is less than that during the global financial crisis, while the opposite is true for the Philippines.

The nature and extent of spillover effects of the uncertainty of US economic policy on the stock markets of Gulf Cooperation Council (GCC) countries is examined by Ref. [20]. The GCC region is characterized by a risk-sharing-based financial system in which foreign investment, risk-free interest, and derivatives are less prevalent as those in western economies. The research employed monthly data from 1992 to 2018 and utilized linear and nonlinear VAR models along with an impulse response-based test to examine the spillover effects. The findings revealed that an unexpected increase in the uncertainty of the US economic policy significantly reduces the stock market index of all GCC countries. The study also identified a symmetric relationship, which indicates that the GCC stock market indices decrease and increase by the same magnitude with the rise and fall of the uncertainty in US economic policy, respectively.

Although previous research lacks an extensive examination of the connectedness among the US, Russia, and Ukraine equity indices, the current aims to fill this research gap by approaching the topic from various perspectives and by utilizing different samples, indices, and time periods. The primary objective is to address several key questions: (1) Does network connectedness play a role in driving the US, Russia, and Ukraine equity indices? (2) Which specific indices, if any, exhibit the strongest connectedness? (3) Are the US equity indices net receiver or transmitter of shocks? (4) Does the Russia equity index act as a net receiver or transmitter of shocks? (5) Does the Ukraine equity index serve as a net receiver or transmitter of shocks? (6) How does the COVID-19 pandemic impact the connectivity patterns among the US, Russia, and Ukraine equity indices? (7) What role does the Russian–Ukrainian war play in shaping the connectivity patterns among these indices? The answers to these inquiries could contribute to the existing literature and enhance the current understanding of the interrelationships among these equity indices.

2.1. Research methodology

2.1.1. Data Collection

Empirical analysis of connectedness across different groups of indices covers 13 years, from June 7, 2010, to May 24, 2023, which corresponds to the beginning of a relatively stable period after the 2007–2009 subprime credit crisis originated in the US and when the European Union and the International Monetary Fund supported the European countries that were engaged in a debt crisis. The period of study extends to May 2023, to capture the possible worldwide effects of the U.S regional banks crisis. To verify the volatility spillovers of equity indices, we include three countries, namely, the United States, Russia, and Ukraine, which represent geographical diversity. In this context, we utilize data from investing.com to analyze the daily price data of five major equity indices, namely, the Dow Jones Industrial Average (DJIA), National Association of Securities Dealers Automated Quotations (Nasdaq), S&P 500 (United States), SMLLCAP, PFTS (Ukraine), and Moscow Exchange (MOEX; Russia). Besides some studies consider daily opening and closing prices of equity indices from different regions in such a way to deal the effect of nonsynchronous trading [27–29], our study follows other researches that also consider daily prices at different regions [30–33] and do not eliminate the non-synchronous effect as is done by rolling average returns [14].

Given the turbulent nature of the COVID-19 pandemic and the Russian–Ukrainian war during the study period, we divided the sample into four distinct periods, which enables the examination of the dynamics and interconnectedness of the equity indices in different contexts. The four periods include before COVID-19 (from June 7, 2010, to December 31, 2019), during COVID-19 (from January 2, 2020, to May 24, 2023), before the Russian–Ukrainian war (from June 7, 2010, to February 19, 2014), and during the

Russian–Ukrainian war (from February 20, 2014, to May 24, 2023).[1] By considering these specific time frames, we explore the variations in market dynamics and spillover effects under different circumstances. Following previous studies, the returns of the indices are calculated as follows: $\ln(P_t) - \ln(P_{t-1})$, where P is the price, and ln denotes the natural logarithm. Table 1 and Fig. 1 present the descriptive statistics of all equity indices log-returns series and their plots, respectively.

Table 1 presents the descriptive statistics for the log-return series of the indices included in the study. For the DJIA, the mean log-return is 0.00042 with a maximum value of 0.113 and a minimum value of −0.129. The standard deviation is 0.010, which indicates the volatility of the returns. Skewness is −0.531, which suggests a slightly leftward skewness, while kurtosis is 21.49, which points to a heavy-tailed distribution. The Nasdaq index exhibits a slightly positive average log-return of 0.00061, which suggests a small overall positive return on average. The maximum log-return of 0.093 represents the largest increase in the logarithm of the index, whereas the minimum log-return of −0.123 represents the largest decrease. The standard deviation of 0.012 implies a relatively moderate volatility in the Nasdaq returns. Skewness of −0.429 indicates a slightly left-skewed distribution, which pertains to a slightly higher likelihood of extreme negative returns compared with extreme positive returns. The S&P 500 index displayed a mean log-return of 0.00047, which translates into a small positive average return. The maximum log-return of 0.093 represents the largest increase in the logarithm of the index, whereas the minimum log-return of −0.119 represents the largest decrease. A standard deviation of 0.011 suggests moderate volatility in the S&P 500 returns. A skewness of −0.490 indicates a slightly left-skewed distribution and indicates a slightly higher likelihood of extreme negative returns compared with extreme positive returns. The Small Cap 100 index presents a mean log-return of 0.00041, which could be understood as a small positive average return. A maximum log-return of 0.093 represents the largest increase in the logarithm of the index, whereas a minimum log-return of −0.142 represents the largest decrease. A standard deviation of 0.014 suggests a relatively higher volatility in the Small Cap 100 returns compared with those of the other indices. Moreover, a skewness of −0.5741 indicates a moderately left-skewed distribution, which suggests a relatively higher likelihood of extreme negative returns compared with extreme positive returns. The PFTS displays a mean log-return of 0.00004, which indicates a very small positive average return. A maximum log-return of 0.276 represents the largest increase in the logarithm of the index, whereas a minimum log-return of −0.107 represents the largest decrease. A standard deviation of 0.012 suggests a relatively moderate volatility in the PFTS returns, and a skewness of 3.4877 points to a highly right-skewed distribution, which implies a higher likelihood of extreme positive returns compared with extreme negative returns. The MOEX index produces a mean log-return of 0.00032, which suggests a small positive average return. A maximum log-return of 0.200 represents the largest increase in the logarithm of the index, whereas a minimum log-return of −0.332 refers to the largest decrease. A standard deviation of 0.014 indicates a relatively higher volatility in the MOEX returns compared with those of the other indices. A skewness of −3.2995 indicates a highly left-skewed distribution, which implies a significantly higher likelihood of extreme negative returns compared with extreme positive returns. The results of the augmented Dickey–Fuller test indicate that no stationarity issues exist for all indices.

2.1.2. Econometric model framework

introduced a framework for assessing interconnectedness among financial assets or markets using a generalized VAR approach and forecast error variance decomposition. Although scholars widely use this approach, it has its limitations related to outliers and the arbitrary selection of a rolling window size. To address these issues, the current study adopted the TVP-VAR methodology proposed by Ref. [34], which incorporates the dynamic connectedness approach of [24,25] and utilizes the technique developed by Ref. [35]. Scholars in the field have successfully applied this approach to various market analyses, including equities, commodities, cryptocurrencies, and uncertainty indices, because it offers advantages such as robustness to outliers, independence from the choice of the rolling window size, and no loss of observations [36–38].

Thus, the current study employed the TVP-VAR as guided by the Bayesian information criterion to investigate the dynamic connectedness among the US, Russia, and Ukraine equity indices. Analysis begins by examining the impact of shocks in one index on another index and uses the generalized forecast error variance decomposition (GFEVD) to assess spillovers based on time frequency. Expression (1) represents the GFEVD to assess spillovers,

$$\tilde{\psi}^{g}_{ij,t}(J) = \frac{\sum_{t=1}^{J-1} \Psi^{2,g}_{ij,t}}{\sum_{j=1}^{N} \sum_{t=1}^{J-1} \Psi^{2,g}_{ij,t}} \tag{1}$$

Where,

$\sum_{j=1}^{N} \tilde{\psi}^{g}_{ij,t}(J) = 1$

$\sum_{i,j=1}^{N} \tilde{\psi}^{g}_{ij,t}(J) = \mathrm{m}$

$\sum_{t=1}^{J-1} \Psi^{2,g}_{ij,t}$: cumulative effect of "*i*" shock

$\sum_{j=1}^{N} \sum_{t=1}^{J-1} \Psi^{2,g}_{ij,t}$: aggregate cumulative effect of all shocks

Subsequently, the study constructs a set of connectedness indices is constructed using the GFEVD approach. The first index measures the influence of a shock in variable *i* on other indices *j*, which is referred to as the total directional connectedness to others. It can be represented by expression (2) as follows:

[1] The beginning of the "during Covid-19" time frame is based on the date when the World Health Organization activated its Incident Management Support Team.

Table 1
Descriptive statistics of equity indices log-returns.

	Mean	Max	Min	Std	Skew	Kurt	J-B	ADF	Obs
DJIA	0.00042	0.113	−0.129	0.010	−0.531	21.49	46,704.7***	−18.9***	3265
NASDAQ	0.00061	0.093	−0.123	0.012	−0.429	10.24	7232.33***	−19.4***	3265
S&P 500	0.00047	0.093	−0.119	0.011	−0.4900	15.60	21,749.5***	−19.2***	3265
SMLLCAP	0.00041	0.093	−0.142	0.014	−0.5741	11.55	10,137.3***	−39.1***	3265
PFTS	0.00004	0.276	−0.107	0.012	3.4877	86.95	965,439***	−44.1***	3265
MOEX	0.00032	0.200	−0.332	0.014	−3.2995	95.24	116,347***	−60.1***	3265

Note: This table provides the descriptive statistics for the log-return of all indices under study. Min, Max, SD, Skew, Kurt, J-B, Obs, and ADF indicate maximum, minimum, standard deviation, skewness, kurtosis, Jarque–Bera test of normality, observations, and the augmented Dickey–Fuller test of stationarity, respectively.
***Significance at the 1 % level.

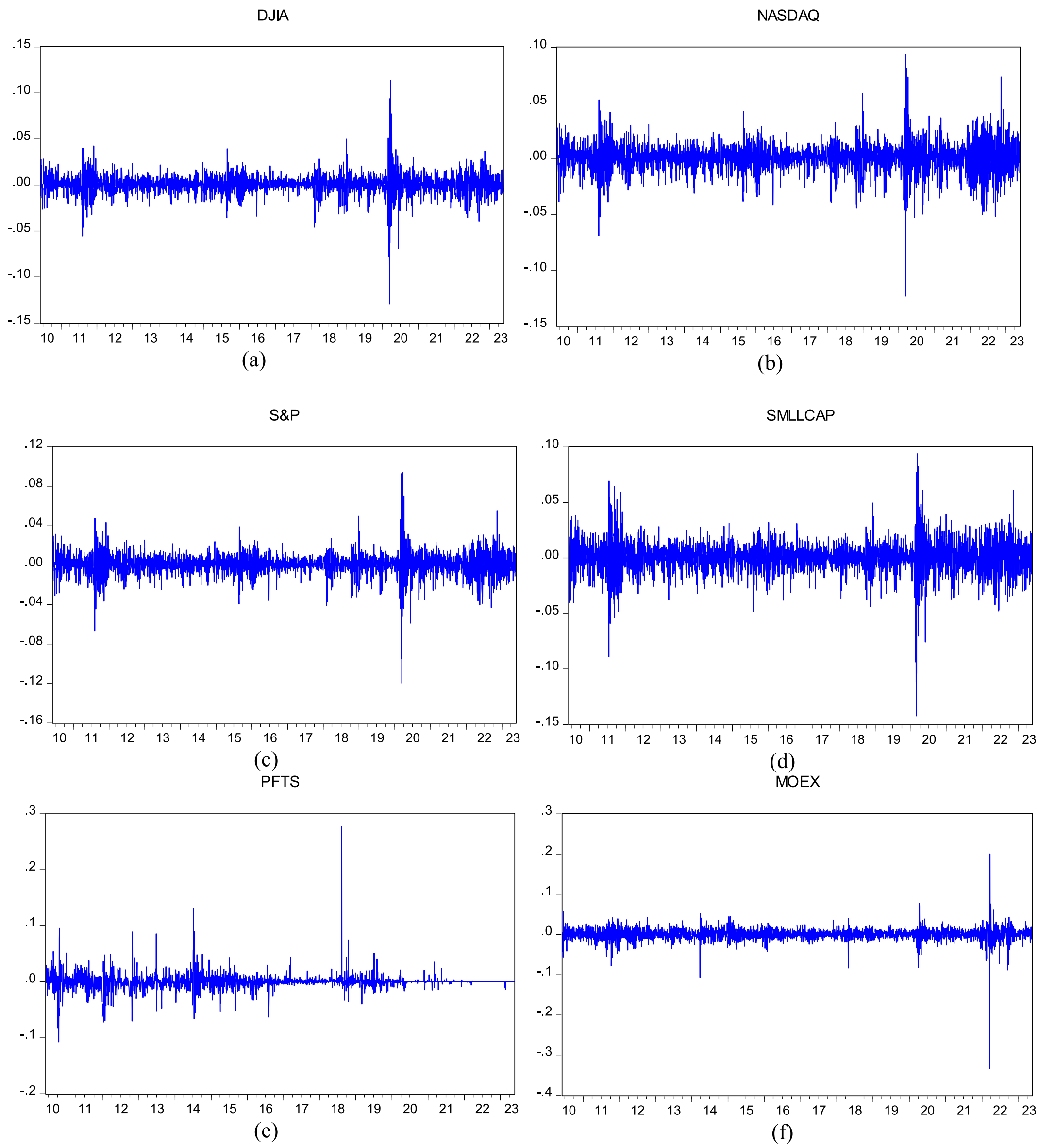

Fig. 1. Log-returns series of equity indices.

$$TO:_{\mathbb{C}^g_{i\rightarrow j,t}}(K) = \frac{\sum_{j=1,i\neq 1}^{m} \widetilde{\psi}^g_{ji,t}(K)}{\sum_{j=1}^{m} \widetilde{\psi}^g_{ji,t}(K)} \tag{2}$$

Similarly, in the third equation, we estimate the influence that variable *i* receives from shocks in other indices, which is referred to as the total directional connectedness from others following expression (3) as:

$$FROM:_{\mathbb{C}^g_{i\leftarrow j,t}}(K) = \frac{\sum_{j=1,i\neq 1}^{m} \widetilde{\psi}^g_{ij,t}(K)}{\sum_{i=1}^{m} \widetilde{\psi}^g_{ij,t}(K)} \tag{3}$$

Next, we demonstrate the net total directional connectedness by calculating the difference between the total directional connectedness to others and the total directional connectedness from others. The positive values of the net total directional connectedness indicate that the index acts as a net transmitter to other indices. In other words, it exerts a greater impact on other indices compared with that it receives from them. Conversely, the negative values of the net total directional connectedness indicate that the index serves as a net receiver, because it is influenced by other indices more than it influences them. In essence, the net total directional connectedness examines the influence of one variable on the spillover network under analysis. This measure is represented by expression (4) as:

$$\mathbb{C}^g_{i,t} = \frac{\sum_{j=1,i\neq 1}^{m} \widetilde{\psi}^g_{ji,t}(K)}{\sum_{j=1}^{m} \widetilde{\psi}^g_{ji,t}(K)} - \frac{\sum_{j=1,i\neq 1}^{m} \widetilde{\psi}^g_{ij,t}(K)}{\sum_{i=1}^{m} \widetilde{\psi}^g_{ij,t}(K)} \tag{4}$$

Lastly, we compute the spillover index by calculating the total connectedness index (TCI), which quantifies the average influence of a single variable on all other variables. A high value of the connectedness index indicates a greater extent of volatility shock spillovers, whereas a low value suggests that the majority of indices exhibit a relatively independent relationship with one another [24,39]. The spillover index can be derived as shown in expression (5):

$$\mathbb{C}^g_t(K) = \frac{\sum_{i,j=1,i\neq j}^{m} \widetilde{\psi}^g_{ij,t}(K)}{m} \tag{5}$$

3. Results and discussion

We present the results in three distinct sections. First, the study explores the dynamic spillovers and connectedness among the equity indices among the United States, Russia, and Ukraine across the period of analysis. Doing so provides insights into the interdependencies and interactions between these markets across a comprehensive timeframe. Second, the study considers the impact of the COVID-19 pandemic on the equity indices of the United States, Russia, and Ukraine. By examining the dynamic spillovers and connectedness during this extraordinary period, analysis elucidates the influence of the pandemic on the relationships among these markets and their interconnections. Lastly, the study considers the ongoing Russian–Ukrainian war and its influence on the equity indices of the United States, Russia, and Ukraine. By examining the dynamic spillovers and connectedness in the context of this geopolitical conflict, analysis reveals the extent to which these markets are influenced and interconnected amidst the tension and uncertainty emerging from the war.

3.1. Dynamic spillovers connectedness among the US, Russia, and Ukraine equity indices across the period of analysis

Table 2 presents the TCI for the US, Russia, and Ukraine equity indices, which provides insights into the degree of interconnectedness among these markets throughout the study period. TCI values serve as indicators of the strength of connections among the indices in which high values indicate strong interdependencies and low values reflect weak connections. The study observes that the TCI reaches a value of 45 %, which suggests a relatively high level of interdependence among the equity indices of the United States, Russia, and Ukraine. This finding indicates that movements in one market are likely to exert significant effects on the movements of the other markets, which reflects the interconnected nature of these economies. Furthermore, after examining the diagonal elements of the table, we find that they generally produce higher values compared to those of the off-diagonal elements. This pattern suggests that the

Table 2
Total connectedness index over the whole period of analysis.

	DJIA	Nasdaq	S&P 500	Small Cap 100	PFTS	MOEX	FROM
DJIA	36.29	24.92	32.09	3.36	2.06	1.28	63.71
NASDAQ	25.2	37.02	32.26	1.57	2.47	1.48	62.98
S&P 500	30.67	30.32	34.16	2.07	1.66	1.13	65.84
Small Cap 100	3.94	1.99	2.16	86.58	3.35	1.98	13.42
PFTS	1.46	1.56	0.64	2.7	91.1	2.54	8.9
MOEX	1.52	1.76	0.99	2.01	3.83	89.89	10.11
TO	62.79	60.55	68.15	11.71	13.37	8.41	224.98
Inc. Own	99.08	97.57	102.3	98.28	104.46	98.3	**TCI**
NET	−0.92	−2.43	2.3	−1.72	4.46	−1.7	45.00

spillovers within each individual market, which are known as own index stock market spillovers, exert the greatest influence in explaining forecast error variance. In other words, the respective domestic factors and dynamics within each market play a significant role in driving the fluctuation and movement of each equity index.

We can further analyze the *FROM* and *TO* columns to gain an in-depth understanding of the spillovers and interconnectedness among the US, Russia, and Ukraine equity indices. The *FROM* column represents the share of shocks received from other indices in the total variance of the forecast error for each index. Moreover, it quantifies the extent to which shocks that originate from other indices influence the variability of the forecast error of each index. The percentages in this column range from 8.9 % for the PFTS index to 65.84 % for the S&P 500 index. These figures indicate that the S&P 500 index is most susceptible to receiving shocks from other indices, because it contributes the highest share of shocks to the total variance of its forecast error. This result is followed by the DJIA with a contribution of 63.71 %, Nasdaq with 62.98 %, Small Cap 100 with 13.42 %, and MOEX with 10.11 %. This result suggests that shocks that originate from other indices significantly impact the variability of the forecast errors of these indices, which indicates a substantial degree of interconnectedness. Alternatively, the *TO* row provides insights into the shocks transmitted from a specific index to the variance of the forecast error for each index. It represents the influence exerted by an index on the forecast error variance of other indices. The percentages in this row range from 8.41 % for MOEX to 68.15 % for the S&P 500. These results indicate that the S&P 500 index is the most influential one in transmitting shocks to other indices and contributes the highest share of shocks to the forecast error variance of other indices. This result is followed by the DJIA with 62.79 %, and Nasdaq with 60.55 %. This finding highlights the importance of the S&P 500 index in transmitting shocks and influencing the movement and performance of the other indices.

Further analysis reveals additional insights by examining *NET* values, which are calculated by subtracting the *total directional connectedness from others* from the *total directional connectedness to others*. Table 2 reports the NET values, which are observed at the last row of the table, provide information on whether each index is a net receiver or transmitter of spillovers. Negative *NET* values indicate that the index receives more spillovers than those it transmits, whereas positive values indicate the opposite. In this case, we find that DJIA, Nasdaq, Small Cap 100, and MOEX are net receivers of spillovers, because their *NET* values are −0.92 %, −2.43 %, −1.72 %, and −1.7 %, respectively. This result implies that these indices receive large shares of spillovers from other indices compared with those they transmit. Shocks that originate from other indices tend to influence these indices, which renders them more responsive to external factors. Conversely, all the other indices in the table are net transmitters of spillovers. In other words, they transmit more shocks to other indices than those they receive. The S&P 500 index stands out as a significant net transmitter along with the PFTS index. These indices play a crucial role in transmitting shocks and influencing the movement and behavior of the other indices.

Fig. 2 provides a comprehensive visual representation of the spillovers among the equity market indices under study. Arrows indicate the direction of spillovers, while the thickness of the arrows represents the strength of the spillovers. Additionally, the size of each circle corresponds to the total contribution of spillovers to all other markets. We observe that the S&P 500 and PFTS indices emerge as significant net transmitters of spillovers. These indices play a crucial role in transmitting shocks to other markets and exerting influence on the movement and behavior of the connected indices. Their prominent positions in the figure highlight their importance in driving the interconnectedness and interdependency among the examined equity markets. Alternatively, the DJIA, Nasdaq, Small Cap 100, and MOEX indices are net receivers of spillovers, that is, they receive larger shares of spillovers from other indices compared to those they transmit. These indices tend to be more responsive to external factors, because shocks that originate from other markets influence them. The figure illustrates their relatively smaller sizes compared with those of the net transmitter indices, which indicates their role as receivers instead of transmitters of spillovers.

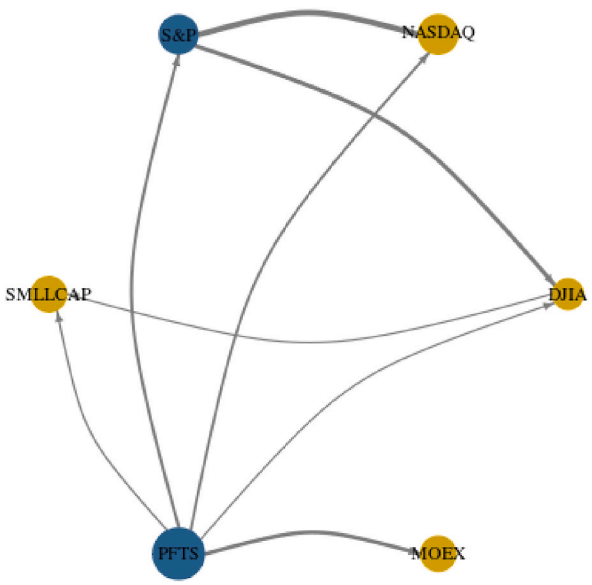

Fig. 2. Network plot of spillovers among the US, Russia, and Ukraine equity indices across the study period.

3.2. Assessing the interconnectedness of equity indices during the COVID-19 pandemic

To gain in-depth insight into the interconnectedness of equity indices by considering the COVID-19 pandemic, the study conducted a comprehensive analysis by categorizing the results into two distinct periods, namely, before and during the pandemic. This division enables a comparative examination of the dynamics and changes in the interconnectedness of the US, Russia, and Ukraine equity indices during this unprecedented global crisis. Table 3 presents the findings of the TCI before the COVID-19 pandemic, which provides a quantitative measure of the overall interconnectedness among these indices. A TCI of 41.19 % highlights a notable level of interdependence among the equity indices of the three countries, which implies that changes and fluctuations in one market can exert a considerable influence on the others and underscores the interconnectedness and interdependency among these economies. The findings reveal that Nasdaq, Small Cap 100, PFTS, and MOEX demonstrate a reception of net spillovers, which is reflected in NET values of −0.41 %, −1.55 %, −1.75 %, and −2.29 %, respectively. In other words, these indices receive a larger share of spillover effects from other indices compared with those they transmit. Fig. 3 shows that the S&P 500 index along with the DJIA, emerges as a significant net transmitter in this context.

Table 4 presents the results of the TCI analysis conducted during the COVID-19 pandemic. A TCI value of 56.57 % indicates a significant level of interdependence among these indices. This finding underscores the extent to which fluctuations in one index can influence and transmit spillover effects to the others. Notably, the TCI during the COVID-19 pandemic is higher compared with those of previous periods. This finding suggests that the pandemic has intensified the interconnectedness among the US, Russian, and Ukrainian equity indices. The higher TCI value during this period indicates a heightened sensitivity to market development and a stronger transmission of shocks among these markets. These findings indicate that the DJIA, Nasdaq, S&P 500, Small Cap 100, and MOEX indices exhibit net spillover reception, as evident from their *NET* values of −6.72 %, −4.52 %, −3.36 %, −2.88 %, and −1.83 %, respectively. This result suggests that these indices receive larger proportions of spillover effects from other indices compared with those they transmit. Fig. 4, which depicts the network spillovers among the indices during COVID-19 pandemic, shows a notable finding that PFTS index stands out as a significant net transmitter. Before the COVID-19 pandemic, the PFTS index demonstrated a net spillover reception, which indicates its role as a receiver of spillover effects. However, the pandemic has exerted a significant impact on the interconnectedness among these indices.

3.3. Assessing the interconnectedness of equity indices in the face of the Russian–Ukrainian war

Given the ongoing war, Table 5 presents the TCI values observed prior to the escalation of the conflict. The findings indicate that the TCI was recorded at 42.36 %, which emphasizes a significant level of interdependence among the equity indices of the three countries. This finding suggests that changes and fluctuations occurring in one market can exert a substantial influence on the other markets, which highlights the interconnectedness and interdependency among these economies. Notably, the TCI value prior to the Russian–Ukrainian war is close to the TCI value recorded prior to the COVID-19 pandemic, which was 41.19 %. This similarity in TCI values suggests that the level of interconnectedness among these indices was significant before the war, which is comparable to the period preceding the global health crisis due to COVID-19.

The analysis reveals that the Nasdaq, Small Cap 100, PFTS, and MOEX indices demonstrate net spillover reception, as indicated by their *NET* values of −1.18 %, −0.84 %, −2.5 %, and −2.13 %, respectively. This finding indicates that these indices receive larger shares of spillover effects from other indices compared with those they transmit. This result highlights their sensitivity to external market factors and their role as recipients of spillover effects. Furthermore, a notable aspect is that the DJIA and S&P 500 indices emerge as significant net transmitters (Fig. 5), which implies that they transmit larger proportions of spillover effects to other indices that potentially influence market trends and developments. This finding suggests their influence as key drivers of interconnectedness in the analyzed equity markets. Importantly, these results align with those of the analysis we conducted prior to the COVID-19 pandemic. The consistent nature of these results indicates a persistence in the patterns of spillover reception and transmission even in the face of significant events such as COVID-19.

Table 6 displays the outcomes of the TCI analysis performed amid the Russian–Ukrainian war. The calculated TCI value of 44.15 % reveals a substantial degree of interconnectedness among the examined indices. This observation emphasizes the potential impact of the fluctuations in one index on transmitting spillover effects to the others. Notably, the TCI during the COVID-19 pandemic exhibits a higher value compared to that observed during the Russian–Ukrainian war, which implies that the level of interconnectedness among

Table 3
Total connectedness index before the COVID-19 pandemic.

	DJIA	Nasdaq	S&P 500	Small Cap 100	PFTS	MOEX	FROM
DJIA	36.81	28.15	33.77	0.48	0.36	0.43	63.19
Nasdaq	28.4	37.23	33.23	0.4	0.37	0.38	62.77
S&P 500	32.2	31.41	35.21	0.42	0.38	0.38	64.79
Small Cap 100	1.17	0.95	0.91	95.11	0.85	1	4.89
PFTS	0.98	0.8	0.93	0.94	95.27	1.09	4.73
MOEX	1.15	1.06	1.25	1.1	1.02	94.43	5.57
TO	63.9	62.35	70.08	3.34	2.98	3.28	205.94
Inc. Own	100.71	99.59	105.3	98.45	98.25	97.71	**TCI**
NET	0.71	−0.41	5.3	−1.55	−1.75	−2.29	41.19

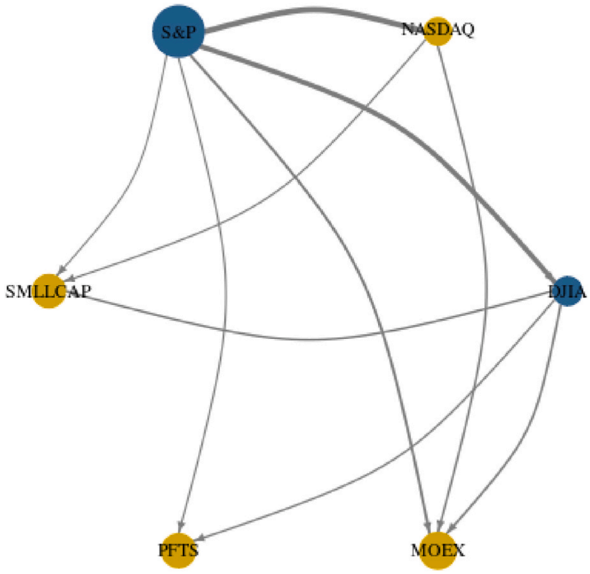

Fig. 3. Network plots of spillovers among the US, Russia, and Ukraine equity indices before the COVID-19 pandemic.

Table 4
Total connectedness index during the COVID-19 pandemic.

	DJIA	NASDAQ	S&P 500	Small Cap 100	PFTS	MOEX	FROM
DJIA	35.74	16.24	26.69	11.18	6.4	3.74	64.26
Nasdaq	15.45	36.95	29.52	4.59	8.42	5.07	63.05
S&P 500	24.86	27.56	32.2	6.12	5.6	3.65	67.8
Small Cap 100	12.03	5.09	5.52	61.4	10.41	5.54	38.6
PFTS	2.73	4.86	1.05	7.82	77.12	6.42	22.88
MOEX	2.48	4.78	1.65	6.01	11.34	73.74	26.26
TO	57.54	58.53	64.44	35.72	42.18	24.43	282.85
Inc. Own	93.28	95.48	96.64	97.12	119.3	98.17	**TCI**
NET	−6.72	−4.52	−3.36	−2.88	19.3	−1.83	56.57

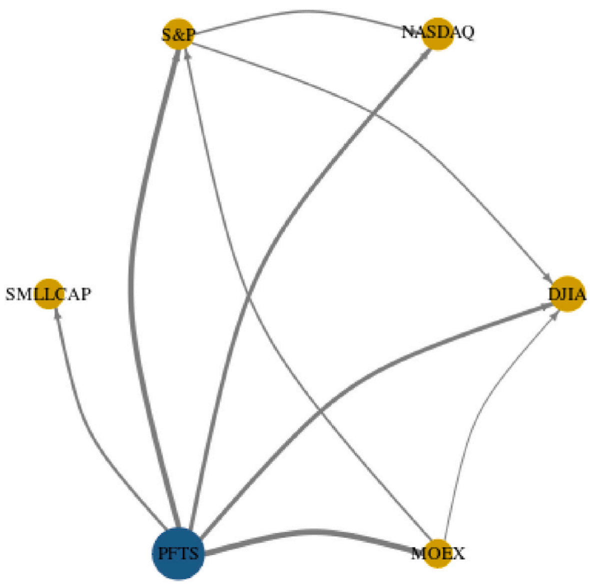

Fig. 4. Network plots of spillovers among the US, Russia, and Ukraine equity indices during the COVID-19 pandemic.

Table 5
Total connectedness index before the Russian–Ukrainian war.

	DJIA	Nasdaq	S&P 500	Small Cap 100	PFTS	MOEX	FROM
DJIA	36.74	27.29	34.29	0.45	0.57	0.66	63.26
Nasdaq	27.65	37.01	32.8	0.84	0.75	0.96	62.99
S&P 500	32.57	30.79	34.93	0.41	0.63	0.67	65.07
Small Cap 100	1.07	1.04	1.03	93.81	1.51	1.53	6.19
PFTS	1.06	1.13	1.05	1.85	93.29	1.62	6.71
MOEX	1.8	1.56	1.66	1.79	0.75	92.44	7.56
TO	64.15	61.82	70.83	5.34	4.21	5.43	211.78
Inc. Own	100.89	98.82	105.76	99.16	97.5	97.87	TCI
NET	0.89	−1.18	5.76	−0.84	−2.5	−2.13	42.36

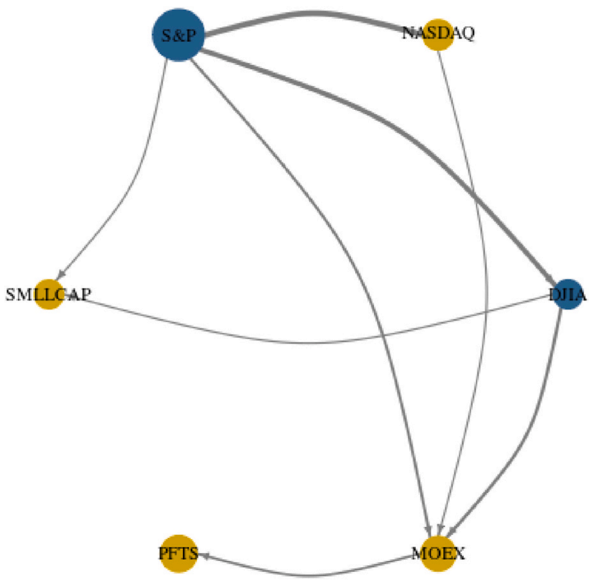

Fig. 5. Network plots of spillovers among the US, Russia, and Ukraine equity indices before the Russian–Ukrainian war.

Table 6
Total connectedness index during the Russian–Ukrainian war.

	DJIA	Nasdaq	S&P 500	Small Cap 100	PFTS	MOEX	FROM
DJIA	36.17	25.34	32.9	4.25	0.71	0.63	63.83
Nasdaq	25.61	36.68	32.43	4.12	0.62	0.54	63.32
S&P 500	30.85	30.07	33.89	4.19	0.46	0.54	66.11
Small Cap 100	4.99	5.02	5.2	83.1	0.93	0.75	16.9
PFTS	0.65	0.65	0.49	0.69	96.08	1.43	3.92
MOEX	1.07	1.19	1.08	0.84	2.51	93.31	6.69
TO	63.17	62.27	72.1	14.09	5.23	3.9	220.77
Inc. Own	99.35	98.95	105.99	97.19	101.31	97.21	**TCI**
NET	−0.65	−1.05	5.99	−2.81	1.31	−2.79	44.15

the indices was more pronounced during the pandemic instead of the war. The heightened TCI value during the COVID-19 pandemic signifies a stronger interdependence, which indicates that market developments and shocks exerted more significant cross-market impacts during this period.

Analysis reveals that the DJIA, Nasdaq, Small Cap 100, and MOEX indices demonstrate net spillover reception as indicated by their *NET* values of −0.65 %, −1.05 %, −2.81 %, and −2.79 %, respectively. This result indicates that these indices receive larger shares of spillover effects from other indices compared with those they transmit and suggest that external factors exert a large influence on these markets, which are receivers of spillover effects from other markets. Interestingly, the S&P 500 and PFTS indices stand out as significant net transmitters with recorded values of 5.99 % and 1.31 %, respectively. This finding indicates that these indices transmit larger proportions of spillover effects to other indices. The S&P 500 plays a prominent role in transmitting spillover effects across the three equity markets. Fig. 6 provides further insights by illustrating that the PFTS (Russia) index primarily transmits spillover effects to the MOEX (Ukraine) index. This result suggests a specific directional transmission of spillover effects between the two markets and indicates notable interconnectedness and interdependence between Russia and Ukraine.

To the best of our knowledge, this study is the first to analyze the interaction among the US, Russian, and Ukrainian equity indices on the basis of the TVP-VAR connectedness approach with emphases on current events such as the COVID-19 pandemic and the Russian–Ukrainian war. However, other studies also considered the relationship between the US and the BRIC stock markets (i.e., Brazil, Russia, India, China, and South Africa). In this respect [30], analyzed the potential contagion from Russia to 18 global markets given the 2014 international sanctions. Using under the DCC-GARCH model, the authors concluded that the Russian stock market has separated from the majority of international stock markets. The specific results indicated that the Central and Eastern European markets are less sensitive than the Western European markets due to the contagion effects. However, the study found that global stock markets have become more vulnerable when associated with the Ukrainian crisis. Furthermore, the dynamic correlations between Russia and the United States largely decreased during the 2014 crisis period, which turned from positive to negative. In a similar study [27], reported that spillovers effects from the United States US to the BRIC markets were significant in a window frame from 1998 to 2012. Alternatively, under the multivariate DECO-GJR-GARCH (Dynamic EquiCorrelation GJR-GARCH) model [40], demonstrated that the Russian market is a net receiver from US spillovers given a sample period from 1998 to 2016. The authors suggested that diversification possibilities could be reduced based on the contagion effects found from the US to Russia, which is in contrast to the findings of [30].

Although the reference studies consider different sample periods, which is in contrast to that of the current study, the results also illustrate that Russia is a net receiver of spillovers from US equity indices as a whole in the new sample period, which covers the periods before, during, and after crisis. Nevertheless, breaking down the connectedness across the subperiods enabled the current study to identify that spillover effects among equity markets will never run in the same directions given specific events. As an example, we found that during the 2022 Russian–Ukrainian war, the Russian equity market was a net receiver of US equity spillovers, which is in contrast to the result of [30], who found that the Russian and US markets largely decreased during the 2014 crisis period. Thus, the results of spillover effects, which could be analyzed under the same or similar (geopolitical) events, may differ according to a retransformation in the topology of international financial markets with practical implications for portfolio investment purposes.

4. Conclusion

Analysis of the TCI for the equity indices of the United States, Russia, and Ukraine reveals a significant level of interconnectedness and interdependency among these markets. The TCI values indicate high degrees of interdependence in which movements in one market are likely to exert substantial effects on other markets. The analysis also highlights the role of domestic factors and dynamics within each market in driving the fluctuation and movement of each equity index. The results indicate that the S&P 500 index is most susceptible to receiving shocks from other indices, which contributes the highest share of shocks to the total variance of forecast error. It is also a significant net transmitter and exerts a strong influence on the movements of other indices. The DJIA, Nasdaq, Small Cap 100, and MOEX indices demonstrate net spillover reception, which indicates higher levels of sensitivity to external factors and their role as recipients of spillover effects. Conversely, the PFTS index stands out as a significant net transmitter during the COVID-19 pandemic and before the Russian–Ukrainian war, which indicates its role in transmitting shocks and influencing other indices. Further analysis of the results across periods, including before and during the COVID-19 pandemic and before the Russian–Ukrainian war, provided valuable insights into the impact of significant events on the interconnectedness of these equity markets. The findings indicate that the COVID-19 pandemic intensified the interconnectedness among these indices with higher TCI values observed during compared with before the COVID-19 pandemic and the periods allocated for the war. The results also suggest a persistence in the patterns of spillover reception and transmission, which points to the consistent role of certain indices as net receivers or transmitters. Our findings are similar to those of [41], who applied the ST-HAR approach to measure the reactions of stock markets and business sectors of the G7 economies during the Covid-19 pandemic, where they discovered that markets reacted immediately to the health crisis. However, our findings and those of [41] differ from those of [42], who applied a Markov-switching HAR approach to model the response of global stock and commodity markets during the Russian–Ukrainian war and Covid-19 pandemic, where they discovered that global stock markets reacted instantaneously and with more intensity to the Russian–Ukrainian war than to a lagged response during the Covid-19 pandemic. Furthermore, our findings coincide with [43], who, by applying the TVP-VAR approach, argue that the Russian–Ukrainian war has changed the relationship among financial markets, but slightly differ since they argue that Russia is only a transmitter of shocks, whereas our findings suggest that Russia was a transmitter and receiver during the war.

The theoretical implications of the results highlight the interconnectedness and interdependency among the equity markets of the United States, Russia, and Ukraine. Moreover, the findings support the notion that financial markets across countries are closely linked and can influence the movement of one another. This result underscores the importance of considering global factors and cross-market dynamics in understanding the behavior of equity indices. In addition, the analysis provides empirical evidence that changes and fluctuations in one market can exert significant effects on other markets, which reflects the interconnected nature of these economies. This notion further implies that investors and policymakers need to consider potential spillover effects and transmission of shocks across markets when making investment decisions or formulating policies. The analysis also emphasizes the role of key indices, such as the S&P 500, DJIA, and PFTS, in transmitting and receiving spillover effects. These indices serve as significant drivers of interconnectedness, which exert influence on other indices and reflect their importance in global financial markets. This finding poses theoretical implications for comprehending the dynamics of interconnected markets and the transmission of shocks through influential market participants. Lastly, it suggests that these key indices can serve as barometers for the assessment of overall market conditions and potential contagion risks.

The empirical findings provide the quantitative measures of interconnectedness among the examined equity indices and offers

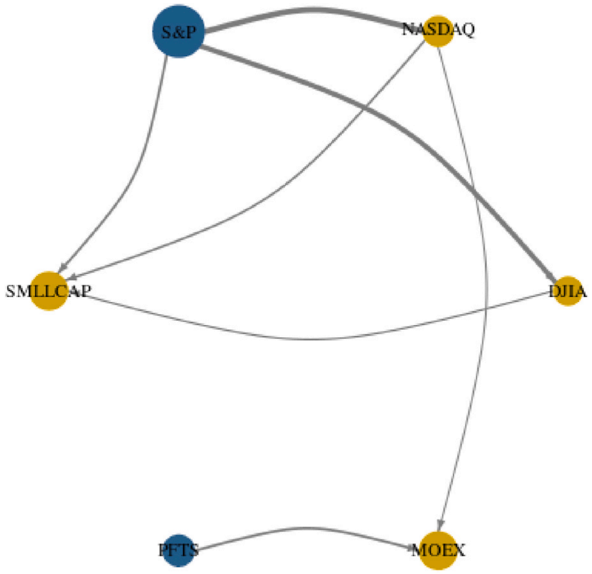

Fig. 6. Network plots of spillovers among the US, Russia, and Ukraine Equity indices during the Russian–Ukrainian war.

insights into the degree of interdependence. The TCI serves as a useful tool for the assessment and monitoring of cross-market linkages and systemic risks. Furthermore, the analysis across periods, including before and during the pandemic and the war periods, yields empirical evidence of the impact of significant events on the interconnectedness of equity markets. The identification of net receivers and transmitters of spillover effects among the indices presents practical implications for investors and portfolio managers. In other words, understanding which indices are more susceptible to receiving shocks and exert a greater influence in transmitting shocks can help in constructing diversified portfolios and risk management strategies. Investors can use this information to make informed decisions in terms of asset allocation and corresponding strategies for risk management. Similarly, policymakers can utilize these empirical findings to better understand the potential transmission channels of shocks and develop appropriate policies for mitigating systemic risks and promoting financial stability.

Future studies in the field of interconnectedness and spillover effects among equity markets should consider extending the analysis to include more countries, exploring diverse time periods and events to assess their impact on market linkages, incorporating additional factors that influence spillover effects, utilizing advanced modeling techniques, such as machine learning and network analysis, and investigating nonlinear dynamics in market interconnectedness. These recommendations are intended to provide a comprehensive understanding of global financial integration, to identify the drivers of spillover effects, and to enhance the accuracy of predictions and risk management strategies for policymakers, investors, and risk managers.

Data statement

Data will be made available on request.

CRediT authorship contribution statement

Bashar Yaser Almansour: Writing - original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sabri Elkrghli:** Writing - original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Jesus Cuauhtemoc Tellez Gaytan:** Writing - review & editing, Validation, Methodology, Investigation, Conceptualization. **Rajesh Mohnot:** Writing - review & editing, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We acknowledge Tecnologico de Monterrey for providing financial support for the article proof reading and Ajman University for providing financial support for the article processing charges (APC).

References

[1] L. Charfeddine, H. Al Refai, Political tensions, stock market dependence and volatility spillover: evidence from the recent intra-GCC crises, North Am J Econ Fin 50 (2019), https://doi.org/10.1016/j.najef.2019.101032.

[2] W. Mensi, S. Hammoudeh, I.M.W. Al-Jarrah, K.H. Al-Yahyaee, S.H. Kang, Risk spillovers and hedging effectiveness between major commodities, and Islamic and conventional GCC banks, J Int Financ Markets Inst Money 60 (2019) 68–88, https://doi.org/10.1016/j.intfin.2018.12.011.

[3] T. Wen, G.-J. Wang, Volatility connectedness in global foreign exchange markets, J Multinat Financ Manag 54 (2020), https://doi.org/10.1016/j.mulfin.2020.100617.

[4] H.K. Chow, Connectedness of Asia Pacific forex markets: China's growing influence, Int J Fin Econ 26 (3) (2021) 3807–3818, https://doi.org/10.1002/ijfe.1988.

[5] N.T. Hung, Financial connectedness of GCC emerging stock markets, Eurasian Econ Rev 11 (4) (2021) 753–773, https://doi.org/10.1007/s40822-021-00185-2.

[6] B. Awartani, A.I. Maghyereh, Dynamic spillovers between oil and stock markets in the Gulf cooperation Council countries, Energy Econ. 36 (2013) 28–42, https://doi.org/10.1016/j.eneco.2012.11.024.

[7] S. Neaime, Financial crises and contagion vulnerability of MENA stock markets, Emerg Markets Rev 27 (2016) 14–35, https://doi.org/10.1016/j.ememar.2016.03.002.

[8] C. Hommes, A. Kopányi-Peuker, J. Sonnemans, Bubbles, crashes and information contagion in large-group asset market experiments, Exp. Econ. 24 (2) (2021) 414–433, https://doi.org/10.1007/s10683-020-09664-w.

[9] A.A. Khalifa, A.A. Alsarhan, P. Bertuccelli, Causes and consequences of energy price shocks on petroleum-based stock market using the spillover asymmetric multiplicative error model, Res Int Bus Fin 39 (2017) 307–314, https://doi.org/10.1016/j.ribaf.2016.08.003.

[10] S. Griffith-Jones, The Slow Progress of International Financial Reform. *Globalisation, Poverty And Conflict: A "Critical Development" Reader*, 2005. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84892303112&doi=10.1007%2F1-4020-2858-X_6&partnerID=40&md5=d093b8b96a55e448665133be514d3ad9.

[11] D. Ashraf, M.S. Rizwan, D.H. Adiwibowo, R.I. Yusan, Loan portfolio composition of Islamic and conventional banks pre- and post-Covid-19 pandemic? case of Indonesia, J Islamic Monet Econ Fin 8 (3) (2022) 407–428, https://doi.org/10.21098/jimf.v8i3.1561.

[12] H.R. Izadi, Investigating the role of financial sanctions in utility function and their impact on household behavior, DLSU Bus Econ Rev 31 (1) (2021) 132–141.

[13] D. Zhang, M. Shi, X. Shi, Oil indexation, market fundamentals, and natural gas prices: an investigation of the Asian premium in natural gas trade, Energy Econ. 69 (2018) 33–41, https://doi.org/10.1016/j.eneco.2017.11.001.

[14] R. Karkowska, S. Urjasz, How does the Russian-Ukrainian war change connectedness and hedging opportunities? Comparison between dirty and clean energy markets versus global stock indices, J Int Financ Markets Inst Money 85 (2023), 101768, https://doi.org/10.1016/j.intfin.2023.101768.

[15] A. Samitas, E. Kampouris, Z. Umar, Financial contagion in real economy: the key role of policy uncertainty, Int J Fin Econ 27 (2) (2022) 1633–1682, https://doi.org/10.1002/ijfe.2235.

[16] T.P.T.D. Le, H.L.M. Tran, The contagion effect from u.s. stock market to the Vietnamese and the Philippine stock markets: the evidence of DCC – GARCH model, J Asian Fin Econ Bus 8 (2) (2021) 759–770, https://doi.org/10.13106/jafeb.2021.vol8.no2.0759.

[17] M.F. Keating, Asia catches cold, Russia sneezes the political economy of emerging market crises in 1997–98, in: V. Fouskas (Ed.), The Politics of International Political Economy, Routledge, 2014, pp. 95–118. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84956771629&doi=10.4324%2F9780203145975-12&partnerID=40&md5=12a1554c7386623dd130bfbaabe7c4b3.

[18] B. Abuzayed, N. Al-Fayoumi, Risk spillover from crude oil prices to GCC stock market returns: new evidence during the COVID-19 outbreak, North Am J Econ Fin 58 (2021), https://doi.org/10.1016/j.najef.2021.101476.

[19] M.S. Gassouma, M. Ghroubi, Discriminating between Islamic and Conventional banks in term of cost efficiency with combination of credit risk and interest rate margin in the GCC countries: does Arab Spring revolution matter? ACRN J Fin Risk Perspect 10 (2021) 280–295, https://doi.org/10.35944/jofrp.2021.10.1.013.

[20] K. Istiak, M.R. Alam, US economic policy uncertainty spillover on the stock markets of the GCC countries, J. Econ. Stud. 47 (1) (2020) 36–50, https://doi.org/10.1108/JES-11-2018-0388.

[21] S. Baek, K.Y. Lee, The risk transmission of Covid-19 in the US stock market, Appl. Econ. 53 (17) (2021) 1976–1990, https://doi.org/10.1080/00036846.2020.1854668.

[22] N.S. Al-Nassar, A.A. Albahouth, Inflation spillovers among advanced and emerging economies: evidence from the G20 group, Economies, https://www.scopus.com/inward/record.uri?eid=2-s2.0-85153725914&doi=10.3390%2Feconomies11040126&partnerID=40&md5=44e1ce5210fc3dc864c090c748a0a7bc, 2023, 11(4).

[23] M. Babar, H. Ahmad, I. Yousaf, Returns and volatility spillover between agricultural commodities and emerging stock markets: new evidence from Covid-19 and Russian-Ukrainian war, Int. J. Emerg. Markets (2023) (ahead-of-print).

[24] F.X. Diebold, K. Yilmaz, Better to give than to receive: predictive directional measurement of volatility spillovers, Int J Forecasting 28 (1) (2012) 57–66, https://doi.org/10.1016/j.ijforecast.2011.02.006.

[25] F.X. Diebold, K. Yilmaz, Trans-Atlantic equity volatility connectedness: U.S. and European financial institutions, 2004–2014, J. Financ. Econ. 14 (1) (2015) 81–127, https://doi.org/10.1093/jjfinec/nbv021.

[26] B.Y. Almansour, M.M. Uddin, S. Elkrghli, A.Y. Almansour, The dynamic connectedness between cryptocurrencies and foreign exchange rates: evidence by TVP-VAR approach, Industrial Engineering & Management Systems 22 (3) (2023) 349–362, https://doi.org/10.7232/iems.2023.22.3.349.

[27] R. Bhuyan, M.G. Robbani, B. Talukdar, A. Jain, Information transmission and dynamics of stock price movements: an empirical analysis of BRICS and US stock markets, Int Rev Econ Fin 46 (2016) 180–195, https://doi.org/10.1016/j.iref.2016.09.004.

[28] M. Balcilar, H. Ozdemir, B. Agan, Effects of COIVD-19 on cryptocurrency and emerging market connectedness: empirical evidence from quantile, frequency, and lasso networks, Phys A 604 (2022), 127885, https://doi.org/10.1016/j.physa.2022.127885.

[29] Z. Ouyang, X. Zhou, Y. Lai, Global stock markets risk contagion: evidence from multilayer connectedness networks in the frequency domain, N. Am. J. Econ. Finance 68 (2023), 101973, https://doi.org/10.1016/j.najef.2023.101973.

[30] G. Castagneto-Gissey, E. Nivorozhkin, No contagion from Russia toward global equity markets after the 2014 international sanctions, Econ Anal Policy 52 (2016) 79–98, https://doi.org/10.1016/j.eap.2016.08.006.

[31] M.A. Naeem, F. Hamouda, S. Karim, S.A. Vigne, Return and volatility spillovers among global assets: comparing health crisis with geopolitical crisis, Int Rev Econ Fin 87 (2023) 557–575, https://doi.org/10.1016/j.iref.2023.06.008.

[32] M.A. Naeem, S. Farid, M. Arif, A. Paltrinieri, M. Alharthi, COVID-19 and connectedness between Sustainable and Islamic equity markets, Borsa Istanb Rev 23 (1) (2023) 1–21, https://doi.org/10.1016/j.bir.2022.06.001.

[33] I. Yousaf, Y. Riaz, J.W. Goodell, Energy cryptocurrencies: assessing connectedness with other asset classes, Fin Res Lett 52 (2023), 103389, https://doi.org/10.1016/j.frl.2022.103389.

[34] N. Antonakakis, D. Gabauer, Refined Measures of Dynamic Connectedness Based on TVP-VAR, University Library of Munich, Germany, 2017. *MPRA* Paper 78282, https://mpra.ub.uni-muenchen.de/78282/.

[35] G. Koop, D. Korobilis, A new index of financial conditions, Eur. Econ. Rev. 71 (2014) 101–116, https://doi.org/10.1016/j.euroecorev.2014.07.002.

[36] J.A. Batten, C. Ciner, B.M. Lucey, Which precious metals spill over on which, when and why? Some evidence, Appl. Econ. Lett. 22 (6) (2015) 466–473, https://doi.org/10.1080/13504851.2014.950789.

[37] M. Hasan, M.A. Naeem, M. Arif, S.J.H. Shahzad, X.V. Vo, Liquidity connectedness in cryptocurrency market, Financ Innov 8 (1) (2022) 3, https://doi.org/10.1186/s40854-021-00308-3.

[38] L. Yarovaya, J. Brzeszczyński, C.K.M. Lau, Intra- and inter-regional return and volatility spillovers across emerging and developed markets: evidence from stock indices and stock index futures, Int. Rev. Financ. Anal. 43 (2016) 96–114, https://doi.org/10.1016/j.irfa.2015.09.004.

[39] A.H. Elsayed, L. Yarovaya, Financial stress dynamics in the MENA region: evidence from the arab spring, J Int Financ Markets Inst Money 62 (2019) 20–34, https://doi.org/10.1016/j.intfin.2019.05.004.
[40] R.P. McIver, S.H. Kang, Financial crises and the dynamics of the spillovers between the U.S. and BRICS stock markets, Res Int Bus Fin 54 (2020), 101276, https://doi.org/10.1016/j.ribaf.2020.101276.
[41] M. Izzeldin, Y. Gulnur, V. Pappas, S. Sivaprasad, The impact of Covid-19 on G7 stock markets volatility: evidence froma a ST-HAR model, Int. Rev. Financ. Anal. 74 (2021), 101671, https://doi.org/10.1016/j.irfa.2021.101671.
[42] M. Izzeldin, Y. Gulnur, V. Pappas, A. Petropoulou, S. Sivaprasad, The impact of the Russian-Ukrainian war on global financial markets, Int. Rev. Financ. Anal. 87 (2023), 102598, https://doi.org/10.1016/j.irfa.2023.102598.
[43] Z. Umar, O. Polat, S. Choi, T. Teplova, The impact of the Russia-Ukraine conflict on the connectedness of financial markets, Fin Res Lett 48 (2022), 102976, https://doi.org/10.1016/j.frl.2022.102976.