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Are the European Union stock markets vulnerable to the Russia–Ukraine war?

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ABSTRACT

This study examines the market reaction to the 2022 Russian invasion of Ukraine on the leading European Union stock market indices employing the event study method, cross-sectional and network analysis We find adverse event day impact on the stock market indices. Further, Poland, Denmark, and Portugal exhibit positive cumulative abnormal returns post-event. A few developed nations are insignificant to the war event. The findings are attributable to the geographic proximity to the war zone and the market efficiency. While the developed markets and NATO nations exhibit positive returns, the economic sanctions and the fear of reduced exports negatively drive abnormal returns during the post-event windows. Contrary to previous studies, stronger past returns negatively drive the returns during the post-event windows. Additional analysis on the mapping of financial networks provides relevant insights into systemic integration between EU stock markets, especially during the war.

1. Introduction

Given the recent pandemic shocks to the developed markets[1] and the geographical proximity to the war zone, the Russia–Ukraine crisis seems to be more turbulent for the European Union (EU) stock markets. Although there have been anticipations for the initiation of the war, the world leaders tried to resolve the issue through diplomatic persuasion and trade concerning threats. Although the stock markets are already responding to the war event,[2] which the World Bank calls a catastrophe, severe impacts of the war on global trade are yet to be evidenced in the long run due to the geographical and political coalitions calling for several economic and financial sanctions affecting the energy, commodities, and transportation industry. These impacts will have spillover effects on other sectors of the economies worldwide.

While the conflict between Russia and Ukraine is not new, the Russian invasion of Ukraine shocked the world on 24 February 2022. The war has led to the fastest-growing refugee crisis since the second world war.[3] As of 30 March 2022, the number of refugees fleeing from Ukraine since the initiation of the war tolled 4,059,105.[4] Furthermore, this rapid displacement of people is also a humanitarian crisis, as millions of civilians in Ukraine have to flee their homes with no end in sight. Economies worldwide will suffer from the rising cause of concern for the energy and commodity markets, the economic sanctions against Russia, and the economic responses to the war. The economic impacts of the war are numerous and extensive, and the effects are already felt far beyond Ukraine. The effects are evident in the stock markets because investors are becoming increasingly risk-averse due to political and economic instability worldwide. Investors have become increasingly cautious as the uncertainty surrounding the conflict persists.

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1 The impacts of the COVID-19 pandemic on developed markets have notably been evidenced during the last two years (Akhtaruzzaman et al., 2020, 2021; Ashraf, 2020; Ashraf and Goodell, 2021; Batten et al., 2022; Corbet et al., 2021; Goodell and Huynh, 2020; Hassan et al., 2022a,b; Kinateder et al., 2021; Li et al., 2021; Ozkan, 2021; Pandey and Kumari, 2021a,b; Rehman et al., 2021; Salisu et al., 2021).

2 (Boubaker et al., 2022; Yousaf et al., 2022) show that the Russia–Ukraine war had an adverse effect on global and G20+ stock markets, respectively. Further, Abbassi et al. (2022), Chortane and Pandey (2022), and Umar et al. (2022) provide insights into the initial impacts of the war.

3 https://www.theguardian.com/world/2022/mar/06/ukraine-fastest-growing-refugee-crisis-since-second-world-war.

4 https://data2.unhcr.org/en/situations/ukraine.

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War events and their consequences are an important but understudied cause for concern. A considerable amount of literature examines the impacts of unexpected natural and human-borne disasters and emergency events on the stock markets (Antoniuk and Leirvik, 2021; Boubaker et al., 2015, 2016; Corbet et al., 2019; Gu et al., 2021; Heyden and Heyden, 2021; Ho et al., 2013; Liu et al., 2021; Miyajima and Yafeh, 2007; Ragin and Halek, 2016; Rai and Kumari, 2022). So far, very few studies have examined the impacts of war and conflict events on the financial markets (Bandara, 1997; Bradford and David Robison, 1997; Danisman et al., 2021; Guyot, 2011; Hudson and Urquhart, 2015; Kumari et al., 2022; Leigh et al., 2003; Schneider and Troeger, 2006). Recent studies conclude that bad news for someone is good news for another (Zaremba et al., 2022). Ragin and Halek (2016) examine the impact of insured-loss catastrophes to evidence positive impacts on the broker's returns. Along the same lines, Guidolin and La Ferrara (2010) examine the impact of internal and inter-state conflicts from 1974 to 2004 to evidence positive response of the stock market returns. Conversely, Hudson and Urquhart (2015) evidence the adverse effects of the second world war on the British stock market. Bradford and David Robison (1997), too, provide evidence of the negative impacts of the Iraqi invasion of Kuwait. The stock market is a complex network, and the price fluctuations among various markets have complicated relationships. Numerous studies have investigated the networks of financial markets, especially in times of crisis (Aswani, 2017; Zhang et al., 2020a,b; Wu, 2020; Tabak et al., 2022). By looking at international economic relationships and stock market developments, these studies have provided insight into the interplay of different factors that cause market volatility. The networks of financial markets tend to change during crises because investors tend to be more risk-averse and make decisions based on different levels of uncertainty. Hence, it becomes important to study how the networks of financial markets evolve during a crisis to understand how market volatility may be better managed.

Studies undertaken so far provide conflicting evidence concerning the impacts of war events on stock market returns. Concomitantly, Boubaker et al. (2022), Boungou and Yatié (2022), Pandey and Kumar (2022a), Sun and Zhang (2022), and Yousaf et al. (2022) evidence similar heterogeneous effects of the Russian invasion on the stock markets. While Boubaker et al. (2022), Boungou and Yatié (2022), and Sun and Zhang (2022) examine a sample of global indices, Yousaf et al. (2022) examine a sample of G20+ stock markets, and Pandey and Kumar (2022a) examine a sample of global tourism firms. We find only (Ahmed et al., 2022) to have conducted an event study on the European firms to confirm the negative impact of the war. However, they fail to provide for cross-sectional analysis to find which country-specific variables stimulate the negative impacts of the war. A more comprehensive cross-sectional analysis needs to be conducted to properly investigate the effects of the war and its individual country-specific impacts. Hence, this study contributes to the scant literature by providing insights into how war events impact a set of closely related markets in terms of the proximity of the war or the preliminary cause of the war being hyped. This study provides evidence of country-specific variables having a significant impact on the changes in the major indices of the European Union. Moreover, it would be insightful to conduct a network analysis and compare the pre-and post-war periods in terms of the financial networks of European nations. Hence, this study contributes to the literature on how financial networks change in form and intensity because of global shocks like war. While the US President calls it a 'war of aggression', the Russian President claims it reasonable, given its territorial threats due to the expansion of NATO. It is interesting to examine how the EU stock markets react to this violent war because they are close to the war zone or members of NATO. Further, until now, most of these countries have introduced several rounds of sanctions, both economic and financial, against Russia. We control the results using a dummy variable for these sanctions. Further, while responding to the Western sanctions, Russia has decided to settle the financial obligations to "unfriendly countries"[5] only in rubles.[6] As such, the Western sanctions against Russia and the adoption of rubles to settle financial obligations abroad have brought a substantial sense of uneasiness in the European financial markets, leading to a noticeable decrease in returns. Hence, through this event study, while evidencing how the war's progression impacts the health of the EU financial markets, we show that given the efficiency of developed markets and economic stimulus dues to military preparedness, the fear of reduced exports owing to the economic sanctions is negatively associated with the event-induced returns.

The results evidence the adverse event day impact of the Russia–Ukraine war on the EU stock markets. The cumulative abnormal returns (CARs) are significantly negative from day t − 3 onwards. While a positive impact is evident in seven countries, stock markets in seven countries did not react to the war event. Further, in the post-event period, Poland, Denmark, and Portugal exhibited positive CARs, Poland being the nearest nation to the war region. The positive post-event results in these nations indicate that the market sentiments became positive once the investors regained confidence that NATO would not opt for armed conflict on this issue. Although sharing direct borders with Ukraine and indirectly with Russia, Poland is a developed and efficient market; its stock market recovered the next day, given the reduced risk of the war. Our findings are robust to two-fold robustness checks. We present similar results with different estimation windows and a non-parametric test. The network analysis results show that the war (exogenous shock) has changed the connectedness across EU stock markets. The results further show that clusters with a higher degree of connectivity are formed as per the stock market's geographic locations. The study also lists the least and most connected markets in the pre-war and during-war periods. These results provide vital insights to guide portfolio construction and managing risk.

The remaining part of the paper is as follows. The second section describes the data and methods. The third section discusses the findings, and the last section, while concluding, provides for policy and research implications.

2. Data and methods

Initially, our sample consisted of 27 EU members. However, due to the unavailability of data, Latvia and Slovakia do not form part of our analysis. The final sample includes 25 countries. We use the daily price data of the leading stock exchange index of the sample nations from 17 March 2021 to 11 April 2022.[7] We use the Morgan Stanley Capital Investment Europe Index (MSCI EUROPE) as the benchmark for regressing the individual country's index returns during the estimation window. We employ the Brown and Warner (1985) event study method[8] with the market model

5 The Russian government put all EU member states on the enemy list for supporting the sanctions.

6 https://www.oe24.at/welt/ukraine-krieg/russland-setzt-oesterreich-auf-liste-der-unfreundlichen-staaten/512910266.

7 The start and end day of the sample period slightly differs for a few sample nations owing to different trading days and holidays in different nations. We present the historical price movement of sample indices for the sample period in Fig. A.1.

8 The event study methodology has been more significantly used in recent time and argued to be among the best methods to examine the impacts of extreme events (Bekiros et al., 2017; Boubaker et al., 2015; Hassan et al., 2022a,b; Pandey and Kumari, 2021a,b; Rai and Pandey, 2021; Zoungrana et al., 2021).

Table 1
Variable definitions.

Variable	Abbreviation	Description	Data Sources
Cumulative abnormal return	*CAR*	The cumulative abnormal return over the respective event window.	Calculated using Eq. (3)
Developed market	*DEV*	A dummy variable that takes one for developed market countries, and 0 otherwise.	https://www.msci.com/our-solutions/indexes/market-classification
NATO members	*NATO*	A dummy variable that takes one for NATO member countries, and 0 otherwise.	https://www.nato.int/cps/en/natohq/nato_countries.htm
Sanctions against Russia	*SANC*	A dummy variable that takes one for countries who introduced sanctions against Russia, and 0 otherwise.	https://www.piie.com/blogs/realtime-economic-issues-watch/russias-war-ukraine-sanctions-timeline
Past returns	*PAST*	Average log returns of the last 20 days before the event day.	Calculated as natural log of price on day t divided by price on day t−1
Imports from Russia	*LnIMP*	Natural log of total value of imports from Russia for the year ending 2020	https://tradingeconomics.com/russia/exports-by-country
Exports to Russia	*LnEXP*	Natural log of total value of exports to Russia for the year ending 2020	https://tradingeconomics.com/russia/imports-by-country

Notes: This table defines all variables used in the study.

for estimating the expected returns[9] with a 225-days estimation window [−230,−6][10] and a 36-days event window [−5,+30].[11] We calculate the daily abnormal returns as per Eq. (1).

$$AR_{it} = R_{it} - (\widehat{\alpha} + \hat{\beta}.R_{bmit}) \tag{1}$$

where, AR_{it} is the abnormal return for index *(i)* on day *(t)*; R_{it} is the actual log-return[12] for the index *(i)* on the day *(t)*; α and β are estimators of the ordinary least squares regression model, respectively, and R_{bmit} is the return of the benchmark index (bmi) on day (t).

We calculate the daily average abnormal return (AAR) to generalize the findings for our sample set using Eq. (2).

$$AAR_{st} = \frac{1}{N}\sum_{i=1}^{N} AR_{it} \tag{2}$$

where, AAR_{st} is the average abnormal returns for the sample set *'s'* on day *(t)*; *N* is the number of sample indices; and AR_{it} as in Eq. (1). Further, we compute the cumulative average abnormal returns (CAAR) for each sample set.

We calculate the country-wise cumulative abnormal returns (CAR) during different event windows to examine the impact of the war event on the individual indices of the sample nations, as in Eq. (3).

$$CAR_{i,T1-T2} = \sum_{t=T1}^{T2} AR_{it} \tag{3}$$

where, $CAR_{i,T1-T2}$ is the CAR for each sample index (i) for the event window (T1–T2). For example, CAR for window [−5,−1] equals the sum of daily ARs from t − 5 to t − 1. We use CAR for different windows [−5,−1], [−3,−1], [0,0], [+1,+3], [+1,+5], [+1,+7], [+1,+10], [+1,+15], [+1,+20], [+1,+25], and [+1,+30] following Gogolin et al. (2018), Heyden and Heyden (2021), Jin et al. (2022), Nerger et al. (2021) and Rai et al. (2022).

Further, following Boubaker et al. (2022), we apply cross-sectional regressions to find if some country-specific characteristics drive abnormal returns. We control the CARs with a few independent variables such as past returns (PAST) as in Pandey and Kumar (2022b), and Boubaker et al. (2022), imports from Russia (LnIMP), and exports to Russia (LnEXP). We use LnIMP and LnEXP because the sanctions introduced by the EU will certainly impact the trade between the sample nations and Russia. The markets with more dependence on Russia are expected to be affected more.

Chaturvedula et al. (2015), Pandey and Kumar (2022b), and Boubaker et al. (2022) evidence that past returns are capable of predicting cumulative abnormal returns. Hence, we use past returns (PAST) as a control variable. Further, we apply the dummy variables for developed markets, NATO members, and countries that introduced sanctions against Russia to assess the heterogeneity across nations' results. Our model is

$$CAR_{i\prod} = \alpha_{i\prod} + \beta_1 NATO_{i\prod} + \beta_2 DEV_{i\prod} + \beta_3 SANC_{i\prod} + \beta_4 PAST_{i\prod} + \beta_5 LnIMP_{i\prod} + \beta_6 LnEXP_{i\prod} + \varepsilon_{i\prod} \tag{4}$$

where, $CARi\prod$ is the CAR of the country '*I*' for the event window $\prod$. We define the variables in Table 1. Our model is robust to heteroskedasticity issues due to robust standard errors (Shehadeh et al., 2021; Austmann and Vigne, 2021).

In order to visualize the connectedness among European stock markets, we first make use of the Minimum Spanning Tree (MST) as a graphical representation. This graph presents the systemic connections of the stock markets. MST further helps to identify the locations with the most stable market and least susceptible to external shocks and those with the highest risk reception from or highest risk passing to third parties. Second, a dendrogram is a drawing that shows the hierarchical relationship between stock markets. A dendrogram's primary use is to find the best way to allocate objects to clusters.

We follow Mantegna (1999) to build the MST. This method considers each market index as a node and edge as a representative of the linking effect in the network. As an initial step, nodes are first sorted based on the weight of the edges, *i.e.,* the distance between the nodes. This weight is an indication of the degree of connectivity between the indices. The distance is calculated as:

$$e_{ij} = \sqrt{2\left(1 - C\left(i, j\right)\right)} \tag{5}$$

where, *C(i, j)* is the correlation between the two stock markets. All nodes in the graph are connected with the minimum possible edge weight and without any loops.

3. Empirical results

3.1. Summary statistics

We present the summary statistics in Table 2. The pre-event [−5,−1] CAR has a mean of −2.07 and a standard deviation of

[9] Expected returns are the returns the index would have yielded if the war event had not occurred.

[10] A longer estimation window is selected to avoid seasonal biases (Mackinlay, 1997)

[11] We extend the event window to examine the presence of war effects in the longer event windows

[12] Log returns are calculated as $LN(P_t/P_{t-1})$*100, where P_t is the index price on day t and P_{t-1} is the index price on day t − 1.

Table 2
Summary statistics of cumulative abnormal returns.

CAR	Observations	Mean	Std. Deviation	Min	Max
[−5,−1]	25	−2.07	2.13	−7.23	0.96
[−3,−1]	25	−1.64	1.71	−5.66	0.67
[0,0]	25	−1.18	3.30	−8.57	4.26
[+1,+3]	25	−1.22	3.52	−10.74	5.92
[+1,+5]	25	−0.94	3.62	−6.36	8.69
[+1,+7]	25	−2.62	5.57	−12.49	10.81
[+1,+10]	25	−1.42	4.11	−7.74	8.31
[+1,+15]	25	−0.37	4.09	−5.31	10.92
[+1,+20]	25	−0.19	4.21	−6.73	12.11
[+1,+25]	25	0.01	4.54	−8.74	10.64
[+1,+30]	25	0.14	5.43	−10.24	11.47

Notes: This table presents the descriptive summary of the cumulative abnormal returns for the sample indices during different event windows.

2.13, with maximum and minimum values of 0.96 and −7.23, respectively. The pre-event [−3,−1] CAR has a mean of −1.64 and a standard deviation of 1.71, with maximum and minimum values of 0.67 and −5.66, respectively. The post-event CARs have a higher standard deviation, but lower mean with a bigger gap between the maximum and minimum values, indicating heavy variations in the impact across the sample nations. The minimum CAR in the event windows [0,0], [+1,+3], [+1,+5], [+1,+7], [+1,+10], [+1,+15], [+1,+20], [+1,+25], and [+1,+30] are of Hungary (−8.57), Hungary (−10.74), Estonia (−6.36), Romania (−12.49), Cyprus (−7.74), Greece (−5.31), Austria (−6.73), Ireland (−8.74), and Austria (−10.24). The event day minimum CAR belongs to Hungary (−8.57) followed by Poland (−7.86). The maximum CAR in the event windows [0,0], [+1,+3], [+1,+5], [+1,+7], [+1,+10], [+1,+15], [+1,+20], [+1,+25], and [+1,+30] are of Denmark (4.26), Denmark (5.91), Poland (8.69), Denmark (10.81), Poland (8.31), Poland (10.92), Poland (12.11), Poland (10.64), and Denmark (11.47). Denmark and Poland dominate the positive CARs.

3.2. Results of the event study analysis

We present the country-wise CARs for event windows of different lengths, namely, [−5,−1], [−3,−1], [+1,+3], [+1,+5], [+1,+7], [+1,+10], [+1,+15], [+1,+20], [+1,+25], [+1,+30], and that of the event day [0,0], in Table 3. The Russia–Ukraine war has impacted the sample nations differently. Most sample nations experience significant negative CAR on the event day, except significant positive for Belgium, Denmark, France, Netherlands, Portugal, Spain, and Sweden and insignificant for Estonia, Finland, Germany, Ireland, Italy, Luxemburg, and Malta. Further, Hungary evidences the highest significant negative abnormal return of −8.57 percent on the event day, followed by Poland (−7.86 percent). While Hungary shares its borders with Ukraine, Poland shares its borders with Ukraine and Russia, and being a NATO member; the stock market must have anticipated more adverse impact if the NATO nations take forward to Russia. We evidence significant negative CAR in the event windows of all lengths for Austria, indicating that the uncertainty triggered by the war adversely impacts the stock market indices of Austria. Furthermore, Belgium, Luxemburg, Netherlands, Spain, and Sweden have no significant negative CAR during any event windows, except Sweden in the [−5,−1] window. With significant negative CAR in [−3,−1] and [0,0], Poland experienced significant positive CAR in all the event windows. Denmark and Portugal have experienced significant positive CAR during all the event windows since the event day. The results indicate that while the event has significantly impacted the Austrian stock market, those of Denmark, Portugal, Poland, Belgium, and Luxemburg have been positively impacted. Netherlands, Spain, and Sweden are insignificant after the positive event day impact. The positive results may be attributable to their military preparedness (Boubaker et al., 2022). Concomitantly, they are farthest from the war zone, and most are among the developed markets. Ahmed et al. (2022) provide different evidence on firm-level data, which may be attributed to the firm-specific characteristics that significantly affect the war's impacts on the firm's stock price.

The stock markets of Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Romania, and Slovenia exhibit significant negative CAR during a few post-event windows. The possible reason for this would be: first, the geographic proximity (Ichev and Marinč, 2018), since they are geographically closest to Ukraine, and second, the lack of experienced and matured stock markets affecting the market efficiency (Risso, 2009; Wang and Wang, 2021), except for those in Czech Republic Finland, France, Germany, and Ireland. Moreover, institutional investors in emerging markets are more sensitive to new information than individual investors (Zhang and Mao, 2022), and emerging markets react quickly to exogenous shocks (Peltomäki et al., 2018), thus, attributing to the market crash.

Owing to different market reactions in different nations, we distribute the sample based on the market classification and NATO membership. We present the AARs and CAARs for different sample sets in Table 4. While the event day reaction of all the sample sets is the same (except for a significant positive event day impact on developed markets), the market response differs on other days in the event window. The EU stock markets ($N = 25$) evidence five (two) significant negative (positive) AARs during the shorter window (+1 to +7), and three (seven) significant negative (positive) AARs during the extended event window (+8 to +30). However, the CAARs are significant and negative from $t - 3$ to $t + 30$. Fig. 1 is the graphical presentation of the generalized impact of the event on the EU stock markets.

The developed markets evidence only one significant negative and positive AAR during the shorter event window and five (six) significant negative (positive) AAR during the extended window. The cumulative impact is significant and negative from $t - 4$ to $t + 10$ and on $t + 24$ and $t + 25$. Contrastingly, the other markets evidence five (two) significant negative (positive) AARs during the shorter event window and eight significant positive AARs during the extended window. The cumulative impact is significant and negative from $t - 3$ to $t + 30$. The results indicate that although the markets other than developed are more impacted in the shorter window, during the extended period, they are positively impacted; however, the cumulative impact is more adverse during the entire event window. Furthermore, the effect of the Russia–Ukraine war is more significant on markets other than developed markets in the post-event period (see Fig. 2), supporting that emerging markets are more sensitive than developed markets (Zhang et al., 2020a,b).

Moving ahead, the NATO nations evidence three (two) significant negative (positive) AARs during the shorter event window and two (eight) significant negative (positive) AARs during the extended window. The cumulative impact is significant and negative from $t - 3$ to $t + 30$, with a declining trend since $t + 12$. Contrary to this, the non-NATO nations experienced three (one) significant negative (positive) AARs during the shorter event window and four (three) significant negative (positive) AARs during the extended window. In a rising trend, the cumulative impact is significant and negative from $t - 3$ to $t + 30$. The results indicate that the war event adversely impacts the stock markets of the non-NATO nations as compared to those of the NATO nations (see Fig. 2).

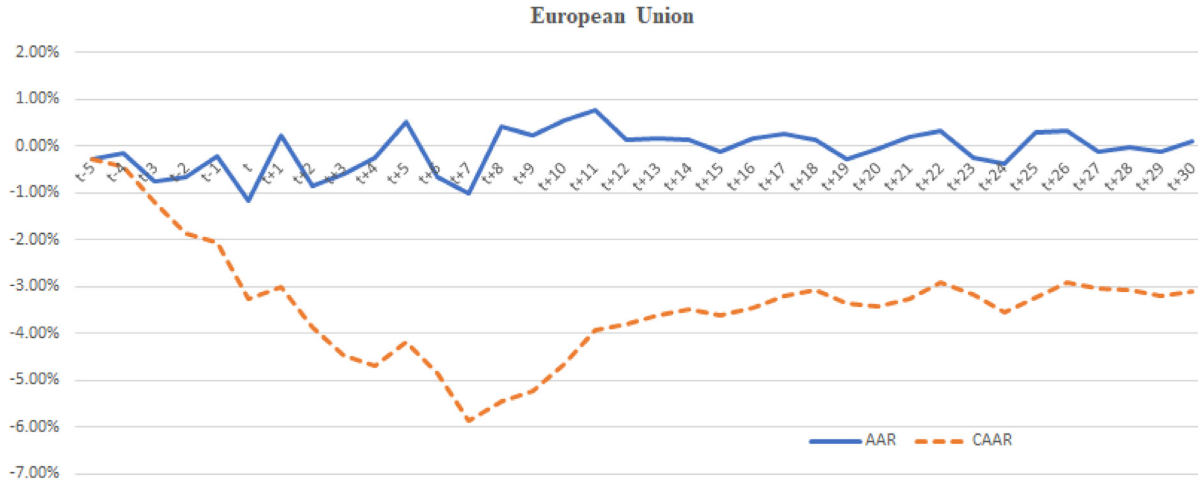

Fig. 1. AAR and CAAR-line during the *36*-days event window period.

Table 3
Country-wise cumulative abnormal returns during different event windows.

Country	Cumulative abnormal returns in different event windows										
	[−5,−1]	[−3,−1]	[0,0]	[+1,+3]	[+1,+5]	[+1,+7]	[+1,+10]	[+1,+15]	[+1,+20]	[+1,+25]	[+1,+30]
Austria	−5.92***	−3.78***	−3.06***	−7.89***	−6.23***	−8.58***	−5.20**	−4.22	−6.73**	−6.79**	−10.24***
Belgium	−1.06	−0.69	1.76***	0.26	−0.07	−0.66	1.16	3.52**	3.78*	3.68*	5.19**
Bulgaria	−2.67	−2.79**	−1.33**	−0.94	−3.42**	−8.20***	−3.41	−0.86	0.16	3.40	1.81
Croatia	−0.89	0.20	−5.46***	−0.50	0.01	−2.52**	−0.73	1.45	1.82	3.27	4.20
Cyprus	−1.34	−1.75	−3.74***	−2.97*	−2.36	−7.78***	−7.74**	−4.96	−0.95	−2.61	−2.38
Czech Republic	−2.51*	−1.86*	−3.18***	0.15	1.62	−6.73***	−4.04**	−4.44*	−2.25	−2.09	−3.43
Denmark	−2.05	−0.75	4.26***	5.91***	6.19***	10.81***	7.44**	7.40**	5.15	6.19	11.47**
Estonia	−3.34	−4.45**	1.74	−1.89	−6.36**	−8.06**	−3.56	−3.28	−3.32	−4.27	−2.20
Finland	−2.41**	−1.47*	0.79	−3.02***	−2.89***	−2.54*	−0.29	1.49	−0.09	−0.93	0.35
France	0.11	−0.81	0.88**	−3.01***	−1.65*	−2.21*	−1.97	−1.42	−2.19	−2.33	−3.64
Germany	−1.91*	−1.27*	0.72	−1.95**	−1.73*	−2.38**	−0.99	0.41	−0.03	−0.45	−0.87
Greece	0.36	0.20	−3.32***	−3.28**	−3.55**	−7.11***	−5.39**	−5.31*	−5.09	−3.00	0.51
Hungary	−7.23***	−4.68***	−8.57***	−10.74***	−3.43	−5.73**	−1.87	0.86	1.00	2.47	−5.09
Ireland	−2.20	−1.54	0.02	−2.21*	−3.64**	−5.27***	−6.22***	−3.66	−6.49**	−8.74**	−9.83***
Italy	−0.92	−0.73	0.73	−2.94***	−3.00**	−4.83***	−4.94***	−5.21**	−4.05	−3.21	−4.20
Lithuania	−1.45	−2.05*	−3.31***	1.33	−2.79**	−6.44***	−4.10**	−3.95*	−2.31	−0.64	2.06
Luxembourg	0.96	0.67	−0.15	2.89*	3.67*	2.53	1.31	3.03	3.55	3.05	2.27
Malta	0.83	0.25	−0.15	−2.63**	−0.38	−0.87	−0.91	−2.37	−3.24	−3.23	−4.03
Netherlands	−1.39	−0.94	1.89***	−0.26	0.21	0.55	−2.25	−2.47	−0.39	−1.43	−0.75
Poland	−5.42***	−3.55***	−7.86***	5.92***	8.69***	8.84***	8.31***	10.92***	12.11***	10.64***	9.62**
Portugal	−2.10	−2.63**	2.11***	1.92*	2.59*	5.66***	5.41***	3.95*	5.89**	8.48***	10.17***
Romania	−0.18	0.43	−2.48***	−2.02	−5.15***	−12.49***	−5.57**	−3.40	−3.75	−2.77	−3.16
Slovenia	−5.92***	−5.66***	−5.20***	−0.95	2.34*	−2.82*	−3.31*	0.83	2.06	3.84	3.24
Spain	−0.69	−0.38	1.48**	−0.95	−1.56	−0.84	1.59	0.76	−0.19	0.18	2.24
Sweden	−2.38**	−1.01	1.93***	−0.62	−0.59	2.14	1.67	1.73	0.93	−2.41	0.22

Notes: The daily closing prices for the leading stock indices are collected from www.investing.com for all the countries except Estonia & Lithuania (www.finance.yahoo.com) and Luxembourg (Refinitiv).*, **, and *** indicate significant values at 10%, 5%, and 1%, respectively. CARs are presented in terms of percentage.

3.3. Cross-sectional analysis

During the event study analysis, we find variations in the impacts of the war event across nations. Hence, we move forward with the cross-sectional approach. We present the coefficients of the dummy and the explanatory variables in Table 5. While the coefficient of DEV is significantly positive during all the event windows, that of NATO is significantly positive during the post-event windows, indicating that the developed markets and NATO nations experience positive impacts. The results are consistent with Boubaker et al. (2022). Further, SANC is negatively associated with the CARs in the post-event windows, especially the longer windows ([+1,+20], [+1,+25], and [+1,+30]), indicating that investors anticipate that the sanctions will impact trade between the nations which will ultimately affect the value of the firms in that country. Further, while the past returns positively drive the CARs during the pre-event ([−5,−1], [−3,−1]) and event window [0,0], they are negatively associated with the CARs in the post-event windows, except in [+1,+3] and [+1,+5]. These results are contrary to those in Chaturvedula et al. (2015), Pandey and Kumar (2022b), and Boubaker et al. (2022).

Furthermore, contrary to our expectations, the import values do not significantly impact the CARs during the event windows. However, the results also exhibit that the war event adversely impacts the countries with higher exports to Russia. An explanation for these results could be that the economic sanctions might downsize the overall export figures, thus, impacting the export-oriented nations. The fear of reduced exports adversely affects the abnormal returns during the post-event windows.

3.4. Network analysis

The study uses MST diagrams to identify the country-level indices that play a central role in the stock market networks.

Table 4
Daily average and cumulative average abnormal returns during the [−5,+30] event window period.

Days	AAR_{all}	$CAAR_{all}$	AAR_{dev}	$CAAR_{dev}$	AAR_{ndev}	$CAAR_{ndev}$	AAR_{nato}	$CAAR_{nato}$	AAR_{nnato}	$CAAR_{nnato}$
t−5	−0.281	−0.281	−0.478***	−0.478	−0.067	−0.067	−0.257	−0.257	−0.356	−0.356
t−4	−0.146	−0.427	−0.198	−0.677*	−0.090	−0.157	−0.088	−0.345	−0.330	−0.687
t−3	−0.764***	−1.191***	−0.838***	−1.514***	−0.685***	−0.842*	−0.921***	−1.266***	−0.268	−0.955*
t−2	−0.671***	−1.862***	−0.234	−1.748***	−1.145***	−1.986***	−0.734***	−2.000***	−0.473	−1.427***
t−1	−0.207	−2.070***	−0.433**	−2.181***	0.037	−1.949***	−0.017	−2.016***	−0.811***	−2.238***
t	−1.181***	−3.250***	0.434***	−1.747***	−2.930***	−4.879***	−1.332***	−3.348***	−0.702**	−2.940***
t+1	0.235*	−3.015***	−0.071	−1.818***	0.567**	−4.312***	0.299*	−3.049***	0.032	−2.908***
t+2	−0.853***	−3.869***	−0.076	−1.894***	−1.696***	−6.008***	−0.677***	−3.726***	−1.412***	−4.320***
t+3	−0.597***	−4.466***	−0.533***	−2.427***	−0.667***	−6.675***	−0.203	−3.929***	−1.846***	−6.166***
t+4	−0.239*	−4.705***	0.450***	−1.977***	−0.985***	−7.660***	−0.203	−4.133***	−0.350	−6.516***
t+5	0.515***	−4.190***	−0.053	−2.030***	1.131***	−6.529***	0.396**	−3.737***	0.893***	−5.623***
t+6	−0.657***	−4.846***	0.112	−1.918***	−1.490***	−8.019***	−0.848***	−4.585***	−0.051	−5.674***
t+7	−1.025***	−5.872***	0.223	−1.694***	−2.378***	−10.397***	−1.007***	−5.592***	−1.083***	−6.758***
t+8	0.408***	−5.463***	0.380**	−1.315***	0.439*	−9.958***	0.404**	−5.188***	0.423	−6.334***
t+9	0.232	−5.232***	−0.255	−1.569***	0.759***	−9.199***	0.395**	−4.793***	−0.286	−6.620***
t+10	0.557***	−4.674***	0.108	−1.462***	1.045***	−8.154***	0.555***	−4.238***	0.565*	−6.055***
t+11	0.751***	−3.923***	0.996***	−0.466	0.487**	−7.667***	0.587***	−3.651***	1.272***	−4.784***
t+12	0.125	−3.797***	0.030	−0.436	0.228	−7.439***	0.046	−3.604***	0.375	−4.409***
t+13	0.172	−3.625***	0.003	−0.433	0.355	−7.084***	0.238	−3.367***	−0.036	−4.445***
t+14	0.142	−3.484***	0.399**	−0.034	−0.136	−7.220***	0.143	−3.223***	0.137	−4.307***
t+15	−0.134	−3.618***	−0.696***	−0.730	0.475**	−6.746***	0.023	−3.201***	−0.631**	−4.939***
t+16	0.172	−3.446***	0.155	−0.576	0.190	−6.556***	0.106	−3.095***	0.379	−4.559***
t+17	0.254*	−3.192***	−0.237	−0.813	0.786***	−5.770***	0.362**	−2.733***	−0.087	−4.647***
t+18	0.117	−3.075***	0.301*	−0.511	−0.082	−5.852***	0.245	−2.488***	−0.288	−4.934***
t+19	−0.290**	−3.365***	−0.228	−0.740	−0.357	−6.209***	−0.304*	−2.792***	−0.244	−5.178***
t+20	−0.071	−3.436***	−0.415**	−1.155	0.302	−5.906***	0.073	−2.720***	−0.525*	−5.703***
t+21	0.180	−3.255***	−0.093	−1.248	0.476**	−5.430***	0.507***	−2.213***	−0.854***	−6.557***
t+22	0.328**	−2.927***	0.567***	−0.681	0.069	−5.361***	0.236	−1.977***	0.620**	−5.937***
t+23	−0.238*	−3.165***	−0.296*	−0.977	−0.174	−5.535***	−0.309*	−2.285***	−0.013	−5.950***
t+24	−0.376***	−3.541***	−0.625***	−1.602*	−0.106	−5.641***	−0.073	−2.358***	−1.335***	−7.285***
t+25	0.302**	−3.239***	0.076	−1.526*	0.547**	−5.094***	0.326*	−2.032**	0.226	−7.060***
t+26	0.309**	−2.930***	0.751***	−0.776	−0.170	−5.264***	0.280*	−1.752**	0.401	−6.659***
t+27	−0.117	−3.047***	0.004	−0.772	−0.248	−5.512***	−0.170	−1.922**	0.052	−6.608***
t+28	−0.028	−3.075***	0.103	−0.668	−0.170	−5.682***	0.098	−1.824**	−0.428	−7.036***
t+29	−0.128	−3.203***	−0.412**	−1.080	0.179	−5.503***	−0.075	−1.899**	−0.297	−7.333***
t+30	0.094	−3.109***	0.082	−0.998	0.107	−5.396***	0.100	−1.799**	0.075	−7.258***

Notes: AAR_{all}, AAR_{dev}, AAR_{ndev}, AAR_{nato} and AAR_{nnato} represent average abnormal returns of the sample, developed markets, other than developed markets, NATO members, and non-NATO members, respectively. $CAAR_{all}$, $CAAR_{dev}$, $CAAR_{ndev}$, $CAAR_{nato}$ and $CAAR_{nnato}$ represent cumulative average abnormal returns of the sample, developed markets, other than developed markets, NATO members, and non-NATO members, respectively. *, **, and *** indicate significant values at 10%, 5%, and 1%, respectively. AARs and CARs are presented in terms of percentage.

Table 5
Results of the cross-sectional analysis.

Variables	Cumulative abnormal returns										
	[−5,−1]	[−3,−1]	[0,0]	[+1,+3]	[+1,+5]	[+1,+7]	[+1,+10]	[+1,+15]	[+1,+20]	[+1,+25]	[+1,+30]
DEV	0.0151*** (0.0045)	0.0130* (0.0073)	0.0544*** (0.0122)	0.0548** (0.0241)	0.0478** (0.0240)	0.1180*** (0.0246)	0.0761*** (0.0160)	0.0610*** (0.0171)	0.0565*** (0.0145)	0.0517*** (0.0134)	0.0914*** (0.0222)
NATO	−0.0013 (0.0086)	−0.0037 (0.0081)	−0.0040 (0.0173)	0.0531** (0.0203)	0.0628*** (0.0196)	0.0904*** (0.0249)	0.0726*** (0.0189)	0.0709*** (0.0184)	0.0887*** (0.0182)	0.1117*** (0.0153)	0.1299*** (0.0248)
SANC	0.0180** (0.0062)	0.0090 (0.0055)	0.0019 (0.0121)	−0.0333** (0.0143)	−0.0206 (0.0158)	−0.0206 (0.0206)	−0.0223 (0.0195)	−0.0282 (0.0176)	−0.0261* (0.0136)	−0.0241* (0.0131)	−0.0375* (0.0200)
PAST	11.7913*** (1.9635)	8.0796** (2.8466)	15.2597*** (4.8646)	4.0951 (9.1274)	−12.1443 (7.3710)	−18.1781*** (5.7007)	−13.8191** (5.2094)	−18.5231*** (5.1077)	−21.0307*** (6.1525)	−22.1796*** (5.1220)	−14.4333 (8.4662)
LnIMP	0.0022 (0.0022)	0.0016 (0.0026)	0.0013 (0.0028)	−0.0027 (0.0034)	−0.0064 (0.0045)	−0.0078 (0.0068)	−0.0044 (0.0055)	−0.0073 (0.0051)	−0.0062 (0.0043)	−0.0058 (0.0036)	−0.0023 (0.0045)
LnEXP	−0.0038 (0.0025)	−0.0015 (0.0028)	−0.0005 (0.0049)	−0.0077 (0.0061)	−0.0135 (0.0094)	−0.0280** (0.0108)	−0.0178* (0.0082)	−0.0149** (0.0058)	−0.0201*** (0.0056)	−0.0230*** (0.0047)	−0.0309*** (0.0062)
R-squared	72.46%	45.56%	62.38%	44.87%	49.89%	70.35%	64.16%	67.80%	72.55%	80.59%	71.81%
F-stat.	21.57***	6.61***	14.21***	2.89**	2.35*	5.41***	6.53***	4.95***	6.78***	14.26***	12.53***
Obs.	25	25	25	25	25	25	25	25	25	25	25

Notes: *, **, and *** indicate significant values at 10%, 5%, and 1%, respectively. Robust standard errors are reported in parenthesis below the coefficients. All variables are defined in Table 1.

MST also helps identify the peripheral indices with limited power to influence the network. Additionally, the study tries to classify the European markets into clusters through hierarchical analysis using dendrograms. The analysis is divided into two sub-sections to study the impact of war. A pre-war analysis is focused on the network of Europe's stock markets thirty days prior to the start of

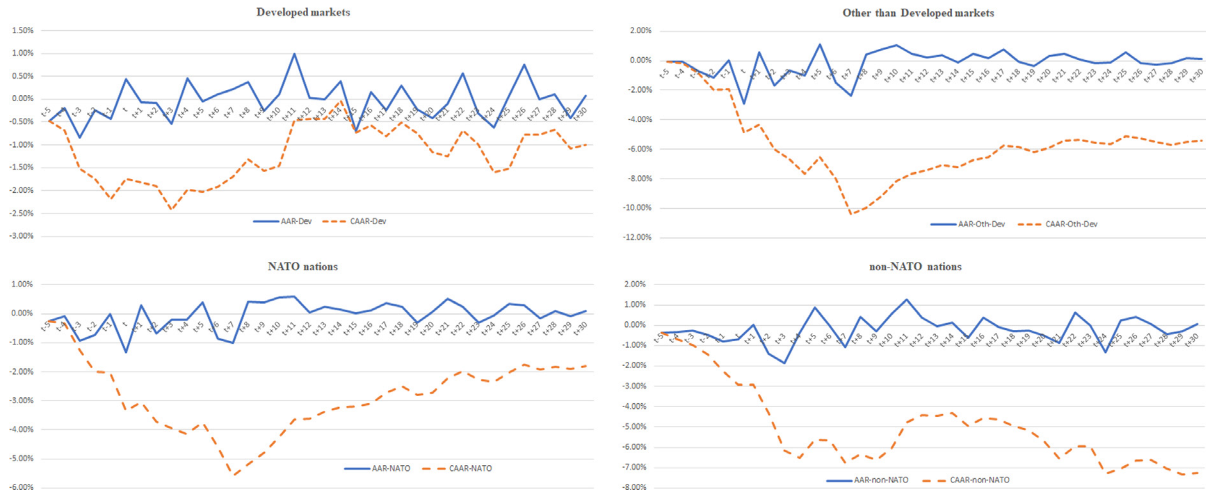

Fig. 2. Movement of AARs and CAARs during the 36-days event window period for different sample sets.

the war. The later part is focused on during-war analysis, i.e., till thirty days after the start of the war.

3.4.1. Pre-war analysis

Jittery markets and fears of supply disruption on oil markets from the war mark this period. Fig. 3 displays the MST of the 25 European stock markets before the war. It is observed that Germany is the most central market, with more connections than any other stock market. Also, it acts as a connector between Sweden's and Italy's stock markets. The markets with a node degree higher than two are considered central. It is surprising to note that the French stock market does not appear central. Around Germany, as a core, two groups of stock markets took shape, namely, Italy and Sweden, while four others are linked but isolated. This model, centralized in Germany, can be explained by the fact that Germany is the largest economy in the EU, a net contributor in the EU, and has the highest number of neighbors. The other central stock markets are Austria, Spain, Italy, and Sweden. The study also observes grouping, which reflects the regional variations, albeit to a lower degree. For example, the two groups based on geographical proximity seem to include Sweden, Denmark, Finland, and the Netherlands in the first group and Austria, Slovenia, Czech Republic, and Croatia in the second group. The least connected markets with degree one are the ones at peripheral positions. These markets are Bulgaria, Greece, Romania, Ireland, Denmark, Netherlands, Hungry, Belgium, Portugal, France, Poland, Cyprus, Luxemburg, Estonia, and Malta.

Fig. 4 shows the dendrogram containing the closest elements grouping before the war. Observing the dendrogram, it can be inferred that if grouping into two heterogeneous clusters is chosen, group one would contain 15 markets, and group two would contain ten markets. The short distance between the first clusters indicates the existence of little heterogeneity between the groups.

3.4.2. During war analysis

This period is marked by deteriorated consumer outlook and the underperformance of eurozone equities because of growth fears, geographical proximity to the crisis, reliance on Russian energy imports, and higher inflation. The surge in oil and gas prices threatens a sharp rise in costs for European industries.

Fig. 5 displays the differentiated network of European stock markets during the war. Interestingly the network shows pronounced deviations from the network presented in Fig. 3. Nodes, and their relative position changes significantly during war times. For instance, Spain was one of the central nodes before the war. However, its degree reduces from 5 to 2 during the war. It is seen that the geographical factor plays a role in determining the connections in the network, although with some exceptions. Austria, one of the central European markets, is surrounded by other central European markets of Czechia, Romania, Croatia, and Slovenia. Similarly, another central node, France, is surrounded by nearby markets of Belgium, Germany, Spain, Portugal, and the Netherlands. This indicates that there is a sign of co-movement between the regions. It is observed that the war also leads to changing the group formation and composition.

The network presented in Figs. 3 and 5 also has some similarities. Bulgaria, Malta, Croatia, Romania, Portugal, Luxembourg, and Slovenia's markets lie at the periphery of both the network diagrams. These markets are said to be weekly connected and less exposed to spillover during both periods. Some key European markets like Sweden, Germany, Italy, Austria, and Spain tend to position themselves centrally for both periods. It is interesting to note that France was not a key node during the pre-war time, and it turned out to be the key node during the war. There appears to be some synchronization in the pair dynamics between some markets. For example, the link between Germany and France; and Germany and Italy show stable behavior. The degree of German markets is six before the war, and the degree of the French markets is four during the war. This further indicates Germany and France's political and economic weight in the European Union. These markets have been instrumental in the network during both periods.

Fig. 6 shows the dendrogram containing the closest elements grouping during the war. Observing the dendrogram, it can be inferred that if grouping into two heterogeneous clusters is chosen, group one would contain ten markets, and group two would contain 15 markets. The difference in height between the first two clusters has increased compared to the previous dendrogram (Fig. 4). This indicates that heterogeneity between the groups increased during the war.

Table 6 presents the degree of each node in the two time periods. The analysis of this table shows that the node counter has increased for some markets, indicating their susceptibility to external risk. The degree of France, Hungry, Croatia, Estonia, Cyprus, Greece, Belgium, Ireland, and Netherlands increased during wartime. However, it appears that some markets like Finland, Germany, Spain, Italy, Lithuania, and Slovenia can potentiate the impact of war by reducing the number of nodes.

The network analysis of European stock markets' results also corroborates the event study methodology findings with some differences. Like the event study, the network analysis finds evidence regarding the heterogeneous market responses based on

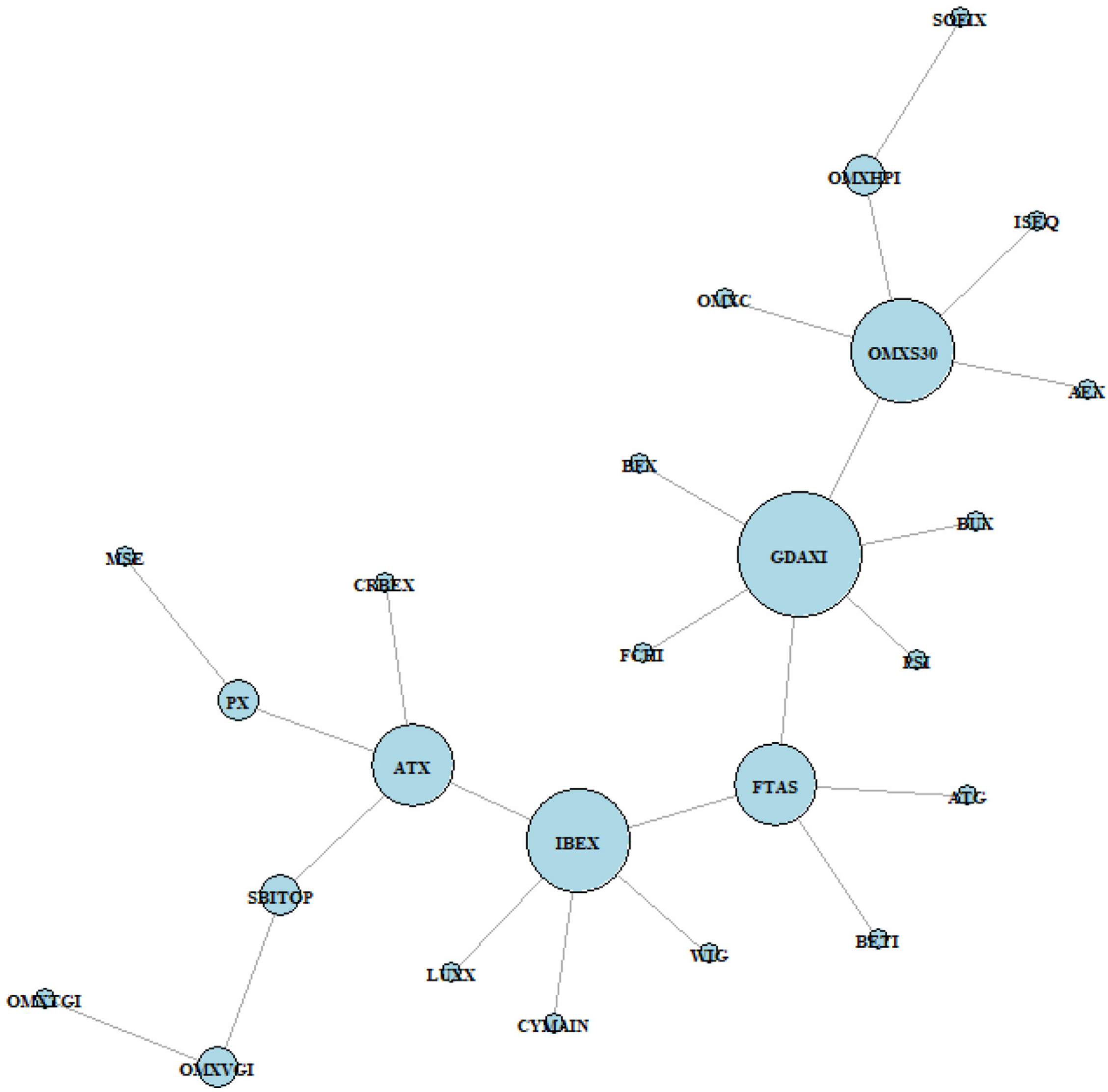

Fig. 3. MST of daily pre-war returns. Notes: MST diagram obtained using the correlations of the pre-war logarithmic returns of indexes. The size of the node is indicative of the relative importance of the node.

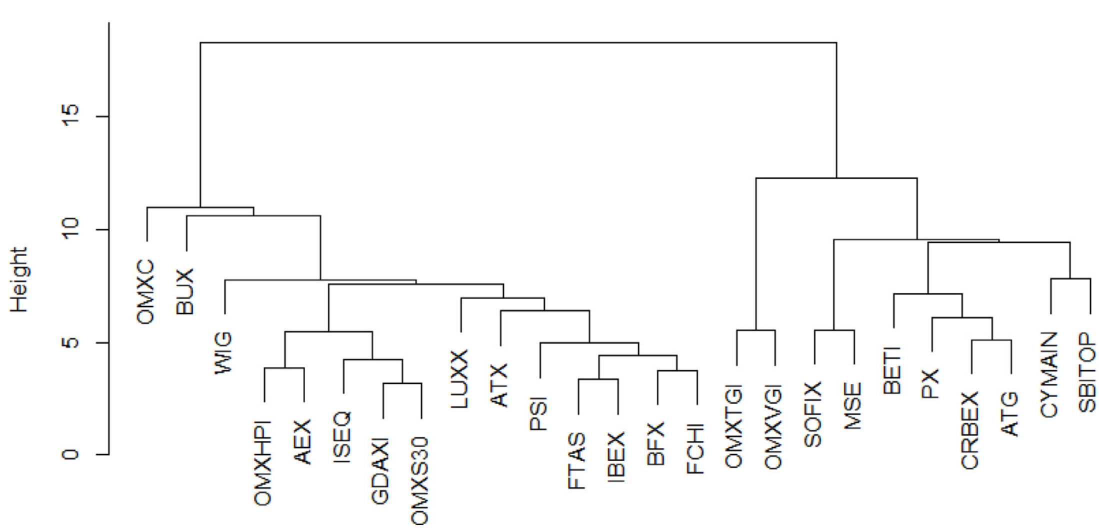

Fig. 4. Pre-war dendrogram.

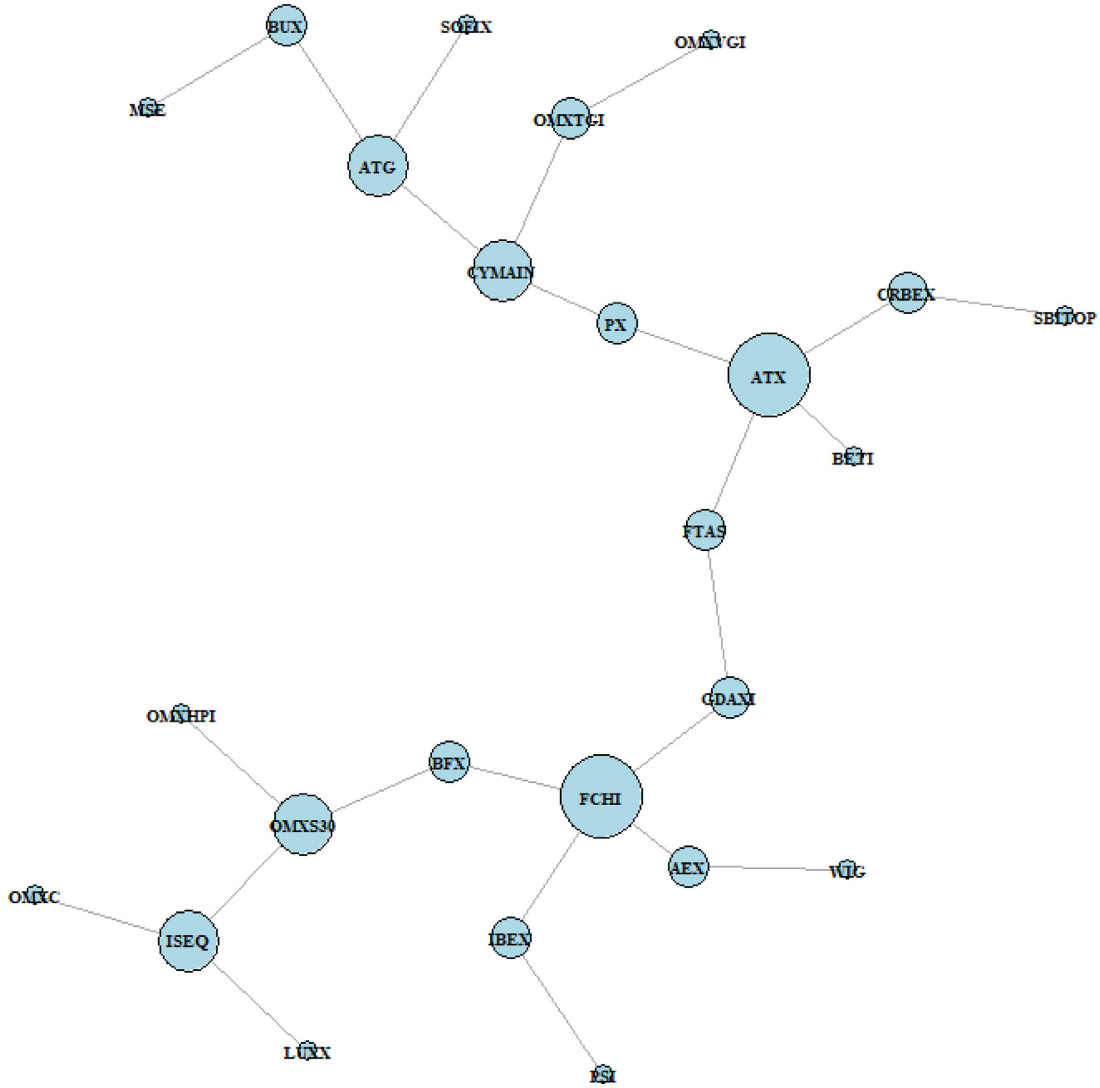

Fig. 5. MST of daily during-war returns. Notes: MST diagram obtained using the correlations of the during-war logarithmic returns of indexes. The size of the node is indicative of the relative importance of the node.

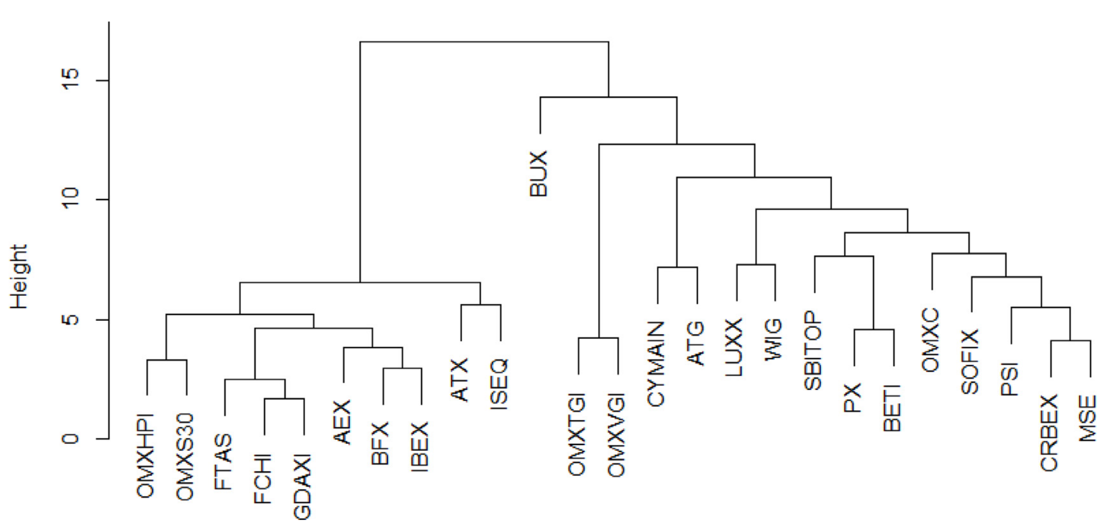

Fig. 6. During war dendrogram.

Table 6
Degree of nodes during pre-war and war period.

Index	Pre war	During war	Index	Pre war	During war
ATX	4	4	ATG	1	3
BFX	1	2	BUX	1	2
SOFIX	1	1	ISEQ	1	3
CRBEX	1	2	FTAS	4	2
CYMAIN	1	3	OMXVGI	2	1
PX	2	2	LUXX	1	1
OMXC	1	1	MSE	1	1
OMXTGI	1	2	AEX	1	2
OMXHPI	2	1	WIG	1	1
FCHI	1	4	PSI	1	1
GDAXI	6	2	BETI	1	1
IBEX	5	2	SBITOP	2	1
OMXS30	5	3			

Notes: This table presents the nodes indicating the number of connections with other markets. These connections change during the post-war period.

the geographies. As per the analysis, relatively insulated markets are Luxembourg, Malta, and Portugal. The most affected markets per the analyses are Austria, Croatia, Cyprus, Estonia, France, Greece, Hungary, and Ireland. Surprisingly, Austria, an industrialized state in the very center of Europe, is highly connected in the network during both periods. This means that uncertainty triggered by the war is adversely impacting its market indices. This is further supported by the fact that Austrian markets show negative CAR in event windows of all lengths. The graph density, mean degree, and diameter before the war are found to be .08, 1.92, and 3.410, respectively. The graph density, mean degree, and diameter during the war is found to be 0.08, 1.92, and 4.8, respectively. This shows that most of these matrices remain unchanged during both periods. Before the war, an increased Russian force mobilization caused elevated concern for the European markets. The overall network before the war reflects all available information, and no new adverse information like the war getting spilled over to other nations has struck the markets.

3.5. Robustness check

We conduct a two-fold robustness check for our results. First, we check the results of the market model with a shorter 135-day estimation window. Second, although the parametric test provides stable results irrespective of the data being normal or abnormal (Brown and Warner, 1985; Dyckman et al., 1984), we conduct the Corrado (1989) test as modified by Ataullah et al. (2011), which is a non-parametric test of significance of the abnormal returns. We present the results of the parametric and non-parametric tests in Table 7 for comparison indicating the robustness of the findings.

4. Conclusions and implications

Using the event study methodology with a sample of 25 EU stock market indices, we examine how the Russia–Ukraine conflict impacts these markets. We evidence heterogeneous market responses based on the geographic proximity to the war zone and the efficiency of the stock markets. Further, while Austria, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Romania, and Slovenia are the most affected markets, Belgium, Luxembourg, Malta, Netherlands, Portugal, Spain, and Sweden, are the least unaffected markets. We find that the markets geographically closer to the war zone and those with less efficient markets are significantly more affected by the conflict.

Furthermore, while the developed markets and NATO nations experience positive impacts, the negative association of sanctions indicates that investors anticipate that the sanctions will impact trade between the nations, ultimately affecting the value of the firms in that country. We find contrasting results for past returns. While the import values do not significantly impact the CARs during the event windows, we find that the war event adversely impacts the countries with higher exports to Russia, owing to the expectations about economic sanctions downsizing the overall export figures and ultimately impacting the export-oriented nations. Hence, the fear of reduced exports negatively drives abnormal returns during the post-event windows. This result can be attributed to the disruption of trade that occurs when countries implement economic sanctions against each other, thereby significantly reducing the expected returns for those countries involved in trading with the affected nation. These findings have important implications because they suggest that investors should be aware of the expected impact to make appropriate decisions while investing in emerging markets, as these markets are susceptible to geopolitical events such as economic sanctions.

The correlation of financial market returns plays a crucial role in several branches of modern finance, such as investment theory, capital allocation, and risk management. The dendrogram and the network diagram generated in the study exposed the European stock market hierarchy and the correlation between the markets. The study visualizes the complex network of European markets before and during the war through these diagrams. The study lists the markets most significant in the network, viz. Sweden, Germany, Italy, Austria, France, and Spain. The markets of Bulgaria, Malta, Croatia, Romania, Portugal, Luxembourg, and Slovenia are found to be least connected with the other European markets. The network appears to be clustered in the regions with geographic proximity. These correlations can be the key input parameters to the portfolio optimization problem. Additionally, the network diagram shows that few markets have many connections represented by the power law degree distribution. Stocks with higher degrees may be considered market movers. The study reports that Sweden, Germany, Italy, Austria, and Spain's stock markets possess a higher degree in pre- and during-analysis periods. This suggests that stock markets with a higher degree of connectivity may be necessary when allocating assets in a portfolio, though more prone to extreme movements. These findings have important implications for investors looking to diversify their investments across different markets. Indeed, while investors may be attracted to the large returns that a well-connected stock market can yield, they should consider the inherent risks associated with such investments. As such, investors should consider diversifying their portfolios to protect against extreme market movements.

Stock markets exhibit different risks and opportunities to investors during crises, and diversification is the best tool for rational investors. The modified relationship between markets in shock-like situations warrants changes in portfolio diversification strategies. The systematic risk mapping made in the study using network diagrams can help formulate risk diversification strategies between different European markets. Moreover, high returns do not always compensate for the high risk associated with emerging markets (Bekiros et al., 2017). Our findings are robust to two-fold robustness checks. The known limitation of this study is that although the shorter event window [−5,+7] is robust, the impacts in the extended event window [+8,+30] may also be attributable to several events[13] that occurred during the latter period. Future research may also target examining the connection between stock markets and other financial assets during war events in line with Corbet et al. (2020), Lucey et al. (2022),

13 For example, several sanctions by the EU on 10, 11, 13, 15, and 23 March 2022; and Russian Central Bank announced that rubble will be linked to gold.

Table 7
Results of the parametric (t-value) and non-parametric tests (c-value).

Days	EU		Dev		nDev		NATO		non-NATO	
	c-value	t-value	c-value	t-value	c-value	t-value	c-value	t-value	c-value	t-value
t−5	−2.37**	−1.97**	−2.60***	−2.83***	−0.72	−1.97**	−1.96**	−1.57	−1.36	−1.23
t−4	−0.83	−1.02	−0.84	−1.17	−0.32	−1.02	−0.17	−0.54	−1.39	−1.14
t−3	−4.28***	−5.35***	−4.17***	−4.95***	−1.84*	−5.35***	−4.41***	−5.61***	−0.89	−0.92
t−2	−3.07***	−4.70***	−1.40	−1.38	−2.98***	−4.70***	−2.77***	−4.47***	−1.35	−1.63
t−1	−1.02	−1.45	−2.25***	−2.56**	0.86	−1.45	0.35	−0.10	−2.71***	−2.80***
t	−0.11	−8.26***	3.72***	2.57***	−4.03***	−8.26***	−0.10	−8.11***	−0.05	−2.42**
t+1	0.50	1.65*	−2.08**	−0.42	2.88***	1.65*	0.95	1.82*	−0.68	0.11
t+2	−2.62***	−5.97***	−0.47	−0.45	−3.30***	−5.97***	−1.79***	−4.12***	−2.16**	−4.87***
t+3	−0.89	−4.18***	−1.16	−3.15***	−0.08	−4.18***	0.43	−1.24	−2.58***	−6.37***
t+4	0.13	−1.67*	2.48**	2.66***	−2.39**	−1.67*	0.47	−1.24	−0.56	−1.21
t+5	0.70	3.60***	−1.34	−0.31	2.40**	3.60***	0.41	2.41**	0.69	3.08***
t+6	−2.28**	−4.60***	0.03	0.66	−3.32***	−4.60***	−2.52**	−5.16***	−0.18	−0.18
t+7	−1.78*	−7.17***	1.09	1.32	−3.71***	−7.17***	−1.56	−6.13***	−0.87	−3.74***
t+8	2.14**	2.86***	1.56	2.24**	1.47	2.86***	1.77*	2.46**	1.23	1.46
t+9	0.60	1.62	−0.03	−1.50	0.89	1.62	0.79	2.41**	−0.18	−0.98
t+10	2.01**	3.90***	0.48	0.64	2.40**	3.90***	1.65*	3.38***	1.17	1.95*
t+11	4.39***	5.26***	4.49***	5.89***	1.67*	5.26***	3.45***	3.58***	2.83***	4.39***
t+12	1.49	0.88	1.14	0.18	0.96	0.88	1.31	0.28	0.72	1.29
t+13	0.72	1.20	0.38	0.02	0.64	1.20	1.11	1.45	−0.49	−0.12
t+14	1.90*	0.99	2.76***	2.36**	−0.12	0.99	1.50	0.87	1.21	0.47
t+15	−1.31	−0.94	−3.31***	−4.12***	1.55	−0.94	−0.54	0.14	−1.72*	−2.18**
t+16	1.41	1.20	0.86	0.91	1.13	1.20	0.69	0.65	1.65*	1.31
t+17	0.54	1.78*	−1.59	−1.40	2.43**	1.78**	0.86	2.20**	−0.44	−0.30
t+18	1.48	0.82	1.96**	1.78*	0.10	0.82	2.51**	1.49	−1.44	−0.99
t+19	−2.03**	−2.03**	−1.43	−1.35	−1.44	−2.03**	−1.72*	−1.85*	−1.08	−0.84
t+20	−0.83	−0.50	−1.69*	−2.45**	0.56	−0.50	0.13	0.44	−1.92*	−1.81*
t+21	1.35	1.26	0.29	−0.55	1.64	1.26	2.57***	3.09***	−1.83*	−2.95***
t+22	3.17***	2.30**	3.43***	3.35***	1.00	2.30**	2.21**	1.44	2.54**	2.14**
t+23	−0.85	−1.66*	−1.02	−1.75*	−0.17	−1.66*	−1.02	−1.88*	0.07	−0.04
t+24	−2.47**	−2.63***	−2.50**	−3.69***	−0.97	−2.63***	−1.04	−0.44	−3.19***	−4.60***
t+25	2.06**	2.11**	0.12	0.45	2.84***	2.11**	1.79*	1.99**	1.01	0.78
t+26	2.96***	2.16**	4.16***	4.44***	−0.05	2.16**	2.60***	1.70*	1.41	1.38
t+27	0.45	−0.82	0.18	0.02	0.46	−0.82	0.39	−1.04	0.24	0.18
t+28	0.01	−0.20	−0.06	0.61	0.08	−0.20	0.51	0.60	−0.89	−1.48
t+29	−1.09	−0.90	−2.29**	−2.44**	0.80	−0.90	−1.08	−0.46	−0.30	−1.02
t+30	−0.01	0.66	−0.21	0.49	0.21	0.66	−0.18	0.61	0.31	0.26

Note: *, **, and *** indicate significant values at 10%, 5%, and 1%, respectively.

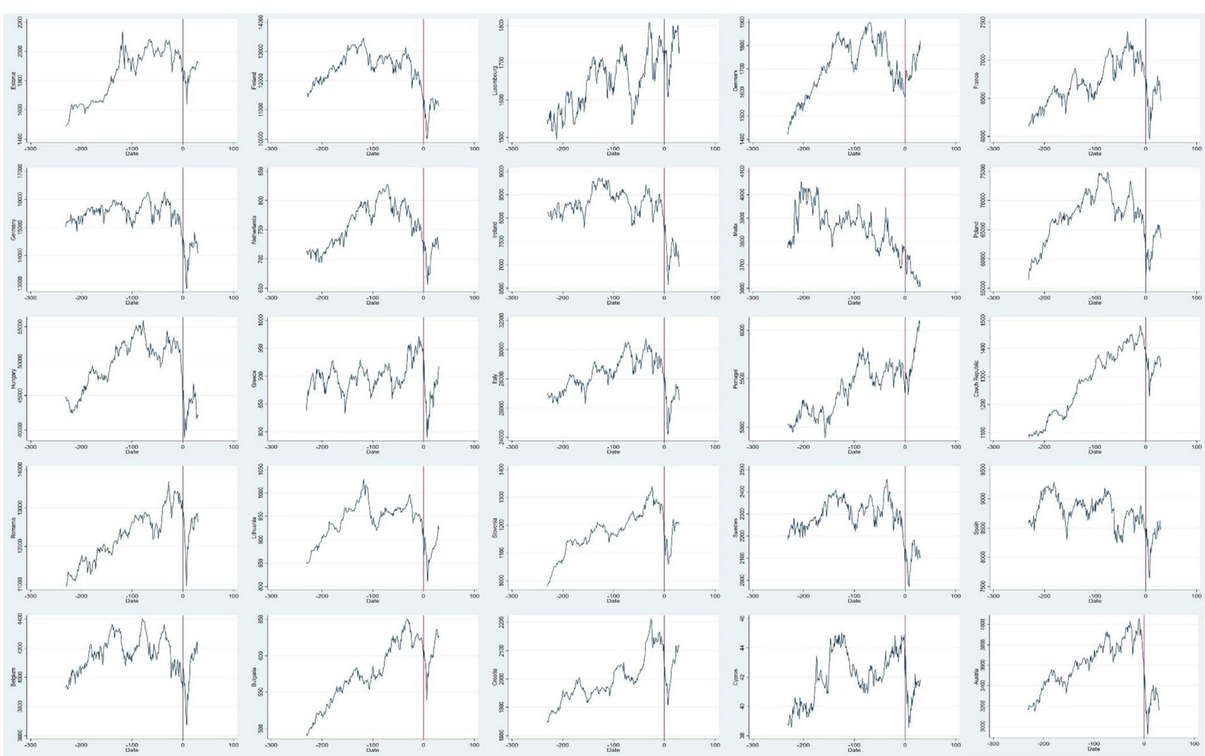

Fig. A.1. Historical price movement of sample indices. Note: The vertical line indicates the event day.

and Salisu et al. (2021). Concomitantly, Deng et al. (2022) argue that while the investors are concerned with regulatory climate risks, the Russia–Ukraine war has instigated the energy security issues. Future studies should also focus on these aspects of the war. Apart from war, potential drivers of network change can be a fruitful area of research.

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.

Appendix

See Fig. A.1.

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