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The Russo-Ukrainian War and Its Influence on Coal Markets: Event Study and Interconnectedness Analysis

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Abstract

In this paper, we analyse the immediate market response of the coal industry to the onset of Russia's full-scale invasion of Ukraine. We apply the event study methodology to identify the impact of the war on the coal firms' share prices. Subsequently, we use a Time-Varying Parameter Vector Auto Regressive (TVP-VAR) approach to analyse changes in market interconnectedness. The results reveal significant cumulative average abnormal returns (CAARs) for the Titans sub-sample, indicating that coal-related firms headquartered in the United States, the UK, Canada, and Australia outperformed the stock market on a cumulative basis after the outbreak of the war. Our findings also show that the onset of the Russo-Ukrainian war resulted in an approximately 11% increase in average interconnectedness among the defined groups and led to shifts in their roles as transmitters and receivers. Specifically, while Europe and the Titans transitioned from net transmitters to net receivers, East Asia became a major net transmitter of shock.

Keywords: Russo-Ukrainian war, Event study, Coal Markets

1. Introduction

While the world was still recovering from the consequences of the COVID-19 pandemic, Russian troops initiated the full-scale invasion of Ukraine on

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February 24, 2022. The invasion not only caused the fastest-growing refugee crisis since World War II (United Nations High Commissioner for Refugees, 2023) but also heavily impacted geopolitics, perturbed the global economy and food and energy markets, and put at risk the global environmental agenda.

Among numerous devastating consequences, the outbreak of the war has also exacerbated the energy crisis that had been evolving since the second half of 2021 due to the rapid post-COVID economic rebound and reduced supplies of Russian gas to the European Union (EU)[1].

The EU energy market is one of the most affected by the war, given its dependence on Russian fossil fuels. Indeed, in 2021, the EU imported from Russia more than 40% of its gas consumption, 7% of oil, and 46% of coal consumption (European Commission, 2022). With the beginning of the full-scale invasion, the EU committed to reducing its energy dependency on Russia, with a major focus on natural gas, and imposed sanctions on the Russian energy sector. The supply-side constraints forced governments to reshape supply chains and to look for readily available substitutes, such as coal. Consequently, in 2022, global coal consumption reached a new all-time high, rising by 4% year-on-year to 8.42 billion tonnes, resulting in a 1.6% increase in coal-related emissions for the same year (International Energy Agency (IEA), 2022).

Although the long-term consequences of such a relapse to coal are still unclear, the financial gains for coal producers are already tangible. In 2022, the Swiss giant Glencore achieved a record $17.9 billion profit from its coal mining operations, triggering an unprecedented $7.1 billion distribution to shareholders, while Australian coal export revenue attributable to the Russian invasion is estimated to be between $21 and $39 billion.

The ongoing global energy crisis has affected the political economy of the coal sector not only by reshuffling the resources available to pro-coal actors due to the windfall profits but also by bolstering the pro-coal narrative (Yanguas-Parra et al., 2023). Notably, several countries intensified their coal mining operations, while others delayed their coal phase-out commitments (Beyond Fossil Fuels, 2023). The Global Energy Monitor reported that, as of January 2024, 76% (1,626 GW) of global coal capacity lacked a commitment

[1] Pipeline deliveries from Russia to the EU declined by 25% year-on-year in Q4 2021 (European Commission, 2021).

for closure. To align with the Paris Climate Goals, OECD countries must phase out coal by 2030, with global coal phase-out needed by 2040. Although global coal demand is set to decline by 2026 (IEA, 2023), as evidenced by Yanguas-Parra et al. (2023), even a short-term relapse to coal could lead to a vicious cycle and undermine the global just transition process.

In light of the above-mentioned considerations, the present study aims to expand the existing literature by investigating the impact of the invasion on the global coal market. By applying the event study approach to a sample of 213 firms drawn from the Global Coal Exit List (GCEL, 2022), we analyse abnormal returns for a 14-day event window. We expect that Russia's full-scale invasion of Ukraine is associated with positive abnormal returns for the coal mining sector and that the magnitude of the impact varies among defined groups of interest. To our knowledge, this is the first study to specifically examine the impact of the Russian-Ukrainian war on the coal markets. Furthermore, we contribute to the literature on the impact of exogenous shocks on markets and their contagion effects by employing an econometric methodology for connectedness analysis, specifically utilising a Time-Varying Parameter Vector Auto Regressive (TVP-VAR) model.

The rest of the paper is organised as follows: Section 2 provides a literature review, Section 3 explains the data and methodology, and Section 4 presents and discusses our findings.

2. Literature review

The Russo-Ukrainian war stands as one of the most impactful black swan events in recent history, profoundly disrupting global equity markets and elevating geopolitical risk to one of the highest levels in the last decades. The analysis of the financial impact of the black swan events has been gaining more interest recently with the outbreak of the COVID-19 pandemic, while the literature focusing on military conflicts is still relatively limited.

Notably, World War II (WWII) serves as a foundational case in literature for understanding the financial consequences of wars. For instance, Frey and Kucher (1999) analysed the value of the government bonds of countries affected by WWII and found that some events connected with the war were reflected in government bond prices in Germany and Austria. In a similar vein, Frey and Daniel (2004) studied sovereign debt prices traded on the Zurich and Stockholm stock exchanges and observed significant, though not entirely symmetric, price reactions in both markets to key turning points in the war, highlighting an efficient operation of markets. Choudhry (2010) analysed the US market and demonstrated that most wartime events led to structural breaks in both price movement and stock returns volatility. In contrast, Hudson and Urquhart (2015) investigated the impact of WWII on the British stock markets and found limited evidence of strong links between war events and market returns.

Beyond WWII, other military conflicts have also demonstrated profound financial consequences. For instance, Chen and Siems (2004) analysed the response of the global markets to Iraq's invasion of Kuwait in 1990 and found a significant negative reaction in the Dow Jones Industrial Average. Wolfers and Zitzewitz (2009) conducted an ex-ante analysis applied to the Iraq war, finding that a 10% rise in the likelihood of war was linked to a $1 increase in spot oil prices. Schneider and Troeger (2006) examined the impact of developments in three different war regions on stock market indices from 1990 to 2000, specifically the CAC, FTSE, and Dow Jones, revealing adverse and asymmetric market reactions. Similarly, Guidolin and Ferrara (2005) used event study methodology to examine more than 100 conflicts and found that a significant number of these events notably affected stock market indices, exchange rates, and oil and commodity prices. Additionally, the analysis revealed that national stock markets tend to show positive reactions rather than negative ones at the start of a conflict.

When it comes to the full-scale Russo-Ukrainian war, the existing literature has explored its effects on different markets and following different methodologies. Focusing on the global markets, Boungou and Yatié (2022) revealed that the stock market indices of nations in close geographical proximity to the conflict and of those who condemned the invasion experienced the greatest impact from the war. A number of studies have been conducted to analyse the reactions of markets at the regional or country level. For instance, using the event study approach, Martins et al. (2023b) found a negative and statistically significant European banks' stock market reaction to the invasion of Ukraine. Following a similar methodology, Kamal et al. (2023) revealed a negative response from the Australian stock market. The analysis of the Indian stock market by Pandey et al. (2023) evidenced negative abnormal returns during the pre-invasion period, followed by positive abnormal returns in the initial days after the invasion.

Bentley et al. (2010), Martin and Minot (2022), Abay et al. (2023), and Poursina et al. (2024) studied the implications for food security, while Martins et al. (2023a) focused on the implications for tourism and hospitality industry.

Several studies have examined the implications of the war through the lens of interconnectedness. For instance, Yousaf et al. (2023) found that uncertainty stemming from the war significantly increased the interdependence among global financial market volatilities, particularly in the short term. Similarly, Khoury et al. (2023), focusing on FinTech, ESG, and MSCI indexes, noted an escalation in spillover intensity during the conflict.

Finally, a number of studies place their primary emphasis on energy markets. In particular, Ferriani and Gazzani (2023) studied the impact of the shock to energy prices induced by the Russian invasion on the financial performance of the STOXX Euro 600 index. Umar et al. (2022), in their event study analysis applied to the energy and metal markets, demonstrated a significant increase in abnormal returns related to the renewable energy sector. Similarly, Mohammed et al. (2022) investigated the response of the renewable energy market by combining event study and connectedness analysis. Their findings indicate that renewable energy markets experienced significant and positive cumulative abnormalities, whereas traditional energy markets were substantially impacted in the post-war period. Additionally, the study reveals increased pairwise return connectedness after the announcement event. The research by Adekoya et al. (2022) revealed how the connectedness between oil and financial assets intensified following the full-scale invasion, with oil shifting from being a net receiver to a net transmitter of spillovers. Ohikhuare (2023) showed an increased interconnectedness between the exchange and oil markets. Rubbaniy et al. (2024) investigated the interconnections among hydrogen economy, renewable energy, equity, and commodity markets during both the COVID-19 pandemic and the Russo-Ukrainian war. They observed that total connectedness peaked in the early days of the COVID-19 pandemic, declined with the onset of Russia's full-scale invasion of Ukraine, and rose again right after. Similarly, Jiang et al. (2023) found that the interconnectedness between traditional energy, green finance, and ESG rose by approximately 10% with the oil market shifting to the role of a net risk receiver.

Overall, the majority of the studies focus on renewable energy, oil and gas markets, while there is still a gap related to the coal sector.

3. Data and methodology

3.1. Data

We retrieve our sample of firms from the Global Coal Exit List as of 2022. The list, provided by the German NGO Urgewald, encompasses nearly 3000 companies and their subsidiaries, collectively accounting for over 90% of the global thermal coal value chain, spanning from coal extraction and mining to coal power production. To eliminate any possible source of bias and confounding, we obtain the final sample through the following steps. First, we removed all non-public firms, reducing the sample to 375 firms. As the next step, observations characterised by thin trading or incomplete stock mark data were eliminated. Finally, the firms with the announcement date of dividend payments as of February 24, 2022, were also removed. The final sample comprises 213 firms from 23 countries (see Appendix, Table A.1 for the detailed list of companies along with their respective countries).

We define Russia's full-scale invasion of Ukraine as the *event* and, thus, February 24, 2022, as the *event day* (t=0). The event window consists of 14 days, from t-3 (February 21, 2022) to t+10 (March 10, 2022), while the estimation window spans 120 days, from t-125 (September 2, 2021) to t-5 (February 17, 2022).

Such a short window allows for the estimation of the immediate reaction of the market to the invasion itself, isolating its impact from subsequent developments, such as the announcements of sanctions and bans on Russian fossil fuels or broader economic shifts. A longer event window would introduce confounding effects from other major developments, complicating the attribution of abnormal returns specifically to the invasion. These subsequent developments, including policy responses, should be considered distinct events rather than part of the same window.

Only trading days are taken into consideration. We calculate trade-to-trade and lumped returns to handle the discrepancies in trading days among the considered markets. The trade-to-trade method excludes missing days from the calculation, while the lumped method treats missing returns as zero. No significant changes were observed when comparing results obtained using these two adjustment techniques. For brevity, we report results based solely on the lumped returns.

While we use a relatively short event window to examine the immediate market reactions in the event study, our connectedness analysis employs a broader timeframe, from September 2, 2021, to May 31, 2022. This extended period allows us to capture the dynamics of interconnectedness following the reshuffling of supply chains and various countries' adoption of sanctions on Russian fossil fuels.

We use daily closing prices of the stocks, subsequently adjusted for dividend payments. Both share prices and dividend payments are retrieved from Refinitiv. Furthermore, we download the daily closing prices of three regional market indexes to be used as benchmarks in the calculation of Abnormal Returns (ARs): STOXX Europe 600, Dow Jones Global Titans 50, and S&P EM 100. Based on the country of the firms' headquarters and according to the reference benchmark index, we create four sub-samples for the calculation of Average Abnormal Returns (AARs) (see Appendix, Table A.1 for the detailed list of companies along with their respective sub-sample groupings) and estimation of connectedness at the aggregated level:

- *Europe*: Czech Republic, Finland, Germany, Italy, Poland, Turkey;
- *Titans*: Australia, Canada, UK, US;
- *Emerging Markets*: Brazil, Chile, India, Indonesia, Malaysia, Morocco, Pakistan, South Africa, Thailand, Vietnam;
- *East Asia*: China, South Korea, Taiwan.

Table 1 provides the distribution of firms across sub-samples. Please refer to Table B.2 in the Appendix for a more detailed breakdown.

Table 1: Distribution of companies across sub-samples

Sub-sample	**Number of Firms**	**% of Full sample**
Titans	40	18.8
Europe	18	8.4
Emerging Markets	56	26.3
East Asia	99	46.5
TOTAL	**213**	

Source: Authors' elaboration.

We use the STOXX Europe 600 index for the *Europe* sub-sample, Dow Jones Global Titans 50 for *Titans* and S&P EM 100 for both *Emerging Markets* and *East Asia* groups.

3.2. Methodology

3.2.1. Event study

The event study techniques are based on the assumption of the efficiency of the financial markets, implying that all available information about firms is reflected in their stock prices. Central to the event study is the calculation of the abnormal returns (ARs), potentially induced by specific events, defined as follows:

$$\mathrm{AR}_{it} = R_{it} - \mathbb{E}(R_{it}), \tag{1}$$

where AR_{it} is the abnormal return at time t for the firm i, R_{it} represents the actual return at time t, and $\mathbb{E}(R_{it})$ is the expected return at time t for the same firm.

The actual returns are defined as follows:

$$R_{it} = \ln\left(\frac{P_{it}}{P_{it-1}}\right), \tag{2}$$

where P_{it} is the dividend and split-adjusted firm's share price at time t, and P_{it-1} is the price at time $t-1$.

To estimate the expected returns, we employ the Market Model, which considers the firm's past performance and its sensitivity to the general market by using stock market indexes as benchmarks. The model is estimated using the following equation:

$$\mathbb{E}(R_{it}) = \alpha_i + \beta_i R_{mt}, \tag{3}$$

where α_i and β_i are the Ordinary Least Squares (OLS) estimators of the model's parameters, and R_{mt} is the market return of the benchmark index m at time t. As previously mentioned, we use three benchmark indexes, namely STOXX Europe 600, DJ Global Titans 50, and S&P EM100.

The next step is the calculation of the AARs, which measure the daily average of ARs at an aggregated level using the equation:

$$\mathrm{AAR}_t = \frac{1}{N}\sum_{i=1}^{N} AR_i, \tag{4}$$

where N is the total number of firms in the sub-sample.

Finally, we calculate the CAARs defined as follows:

$$\mathrm{CAAR}_{(t_1,t_2)} = \sum_{t_1}^{t_2} AR_{it} \tag{5}$$

To assess the statistical significance of AARs, we use both parametric and non-parametric tests. We use the adjusted standardised cross-sectional test (Adjusted StdCSect Z) for parametric testing, which builds upon the Patell Z test by considering event-induced volatility and cross-serial correlation. As for the non-parametric tests, (Campbell et al., 2010) found that the generalised sign and rank tests are the most powerful. However, the former must be applied to not cumulative buy-and-hold returns for correct specification. Thus, we only report the generalised rank test (Generalised Rank T).

3.2.2. TVP-VAR connectedness approach

In the second step, we rely on the dynamic connectedness approach proposed by Antonakakis et al. (2020). The methodology, based on the TVP-VAR model, extends the original framework by Diebold and Yilmaz (2012) by allowing the variance-covariance matrix of the forecast errors to vary and so to capture possible changes in the underlying structure of data without constraints imposed by an arbitrarily selected rolling window size. Moreover, the model is not sensitive to the outliers, and there is no loss of observations.

The TVP-VAR(p) model is defined as follows:

$$\begin{aligned} \mathbf{y_t} &= \mathbf{A_t}\mathbf{y_{t-1}} + \epsilon_\mathbf{t}, & \epsilon_\mathbf{t} \mid \Omega_{t-1} &\sim N(\mathbf{0}, \Sigma_t) \\ vec(\mathbf{A_t}) &= vec(\mathbf{A_{t-1}}) + \xi_\mathbf{t}, & \xi_\mathbf{t} \mid \Omega_{t-1} &\sim N(\mathbf{0}, \Xi_t), \end{aligned} \tag{6}$$

where y_t and y_{t-1} are $n \times 1$ and $np \times 1$ vectors, respectively, A_t and A_{t-1} represent $n \times np$ and $n \times n$ dimensional matrices, respectively. ϵ_t is an $n \times 1$ vector and ξ_t is an $n^2p \times 1$ dimensional vector. Σ_t and Ξ_t are $n \times n$ and $n^2p \times n^2p$ time-varying variance-covariance matrices. Ω_{t-1} denotes all information available at time $t-1$.

Subsequently, using the Wold Representation Theorem, the TVP-VAR model is transformed into its Time-Varying Parameter Vector Moving Average (TVP-VMA) representation through the following equation:

$$y_t = \sum_{i=1}^{p} A_{it} y_{t-1} + \epsilon_t = \sum_{j=0}^{\infty} B_{jt}\epsilon_{t-j}, \tag{7}$$

where $B_{jt}\epsilon_{t-j}$ is a $n \times n$ matrix of TVP-VMA parameters.This step enables the computation of the Generalized forecast error variance decompositions (GFEVD) and Generalized impulse response function (GIRF), which form the basis for the connectedness approach. The latter estimates the response of all variables to the shock in variable i, while the former allows the quantification of the impact of variable j on variable i through its contribution to the forecast error variance in the directional connectedness and can be defined as follows:

$$\widetilde{\phi}_{ij,t}(K) = \frac{\sum_{t=1}^{K-1} \Psi_{ij,t}^2}{\sum_{j=1}^{n} \sum_{t=1}^{K-1} \Psi_{ij,t}^2}, \tag{8}$$

where $\Psi_{ij,t}$ is the $GIRF_{it}$ at time t.

Based on the GFEVD, we can calculate the Total Connectedness Index (TCI) using the following equation:

$$TCI_t(K) = \frac{\sum_{i,j=1,i\neq j}^{n} \widetilde{\phi}_{ij,t}(K)}{n} \times 100 \tag{9}$$

Several additional measures can be computed following the original approach by Diebold and Yilmaz (2012). To evaluate the directional connectedness from the variable i to others:

$$TO_{i\to j,t}(K) = \left(\frac{\sum_{j=1,i\neq j}^{n} \widetilde{\phi}_{ji,t}(K)}{\sum_{j=1}^{n} \widetilde{\phi}_{ji,t}(K)} \right) \times 100 \tag{10}$$

The connectedness of all other variables j to the variable i can be defined as follows:

$$\text{FROM}_{i\leftarrow j,t}(K) = \left(\frac{\sum_{j=1,i\neq j}^{n} \widetilde{\phi}_{ij,t}(K)}{\sum_{i=1}^{n} \widetilde{\phi}_{ij,t}(K)} \right) \times 100 \tag{11}$$

By utilising the two previously mentioned measures, we can define the net total directional connectedness (NET), which quantifies the impact of variable i on all other variables:

$$\text{NET}_{i,t} = \text{TO}_{i\to j,t}(K) - \text{FROM}_{i\leftarrow j,t}(K) \tag{12}$$

A positive value of $NET_{i,t}$ indicates that variable i at time t acts as a net transmitter of shock, meaning its influence on other variables is greater than the influence it receives from them.

The empirical findings from the event study and connectedness analysis are discussed in the following section.

4. Empirical results

4.1. Event Study

The full-scale Russian invasion of Ukraine has undermined global energy security, emphasising the imperative to transition away from fossil fuels. The outbreak of the war boosted investments in clean energy, potentially accelerating the green transition. However, it has also triggered the gas-to-coal shift, bringing windfall profits to the companies operating within the coal sector.

Table 2 presents the AARs over the 14-day event window, analysed at the sub-sample level. The table also includes the AARs' significance levels as determined by the parametric adjusted standardised cross-sectional test (Adjusted StdCSect Z-test). Table C.3 in the Appendix provides the significance levels based on the non-parametric generalised rank test (Generalised Rank T-test).

Considering the pre-event period, we observe a negative and statistically significant Europe's stock price reaction on day -3, corresponding to February 21, 2022, when Russia's president announced that he would have recognised the occupied territories of Donetsk and Luhansk regions as independent. The missing values for that day have been imputed using the lumped returns approach to account for the closure of the US and Canadian stock exchanges on national holidays. Consequently, the potential impact of this announcement on the *Titans* sub-sample may be underestimated in our results. The other two groups have not registered any significant change. On the event day, *Europe* is the only group to react, showing 1% significant AARs of -4,1%.

The first day after the invasion brought a significant and positive increase in the share price of 1.8% and 2.2% in the *Titans* and *Europe* sub-samples, respectively. Additionally, we observe a significant and positive increase in AARs for *Europe* on the 8th post-event day, which coincides with the EU Commission's call for a rapid phase-out of Russia's fossil fuels. Three consecutive days of positive AARs can be observed for *Titans* starting from the 4th day post-event. *Emerging Markets* sub-sample registers a 2% increase in share prices two days after the invasion, confirmed by both tests. This is mainly due to companies headquartered in India, which represent 43% of the sample. Turning our attention to the *East Asia* sub-group, we can note that firms in the sample were almost unaffected, except for a 3.4% decrease registered on the 8th day.

Table 2: Average abnormal returns at sub-sample level

Day	**Titans**	**Europe**	**Emerging**	**East Asia**
-3	0.002	-0.031^{***}	-0.011	0.010
-2	-0.008	0.014	-0.004	-0.002
-1	0.009	-0.005	0.013	0.005
0	-0.021	-0.041^{*}	-0.200	-0.003
1	0.018^{**}	0.022^{*}	0.023	0.009
2	0.001	0.035	0.020^{*}	0.017
3	0.010	-0.000	0.070	0.010
4	0.024^{**}	0.038	0.010	$+0.007$
5	0.021^{***}	0.001	0.007	0.022
6	0.016^{**}	0.010	0.038	0.001
7	0.016	0.008	0.001	0.001
8	-0.007	0.019^{*}	-0.002	-0.034^{*}
9	-0.015^{**}	-0.006	0.008	0.000
10	0.013	0.011	0.006	0.016

Notes: *, **, *** indicate 10, 5, and 1 percent significance levels according to the Adjusted StdCSect Z test.

Table 3 reports the CAARs for the considered event window. The analysis applied to the defined 14-day event window shows positive CAARs across all examined sub-sampled, albeit achieving statistical significance exclusively for *Titans*. Thus, the coal-related firms headquartered in the USA, the UK, Canada, and Australia outperformed the stock market on a cumulative basis following the outbreak of the war.

Table 3: Cumulative average abnormal returns at sub-sample level

	CAAR	**Adj.Std. Csect. T**	**Gen. Rank T**
Titans	0.078	3.122^{***}	2.713^{***}
Europe	-0.074	0.425	0.593
Emerging	0.064	0.799	1.133
East Asia	0.059	0.977	1.174

Notes: *, **, *** indicate 10, 5, and 1 percent significance levels.

To enhance the robustness of our findings, we conducted a comprehensive analysis, exploring various sub-sample configurations and employing diverse benchmark indexes for abnormal return calculations. No contradictory outcomes were observed.

Table 4 provides summary statistics of CAARs. Based on the provided table, except for the *Europe* sub-sample, the return distributions are slightly left-skewed, indicating more frequent small positive abnormal returns. Moreover, the distributions are platykurtic for all groups, implying that returns are more evenly distributed around the mean. The Jarque and Bera (JB) test suggests the non-normality of the return distributions for *Europe* and *East Asia* at the 1% significance level.

Table 4: CAAR's summary statistics

	Mean	**Skewness**	**Kurtosis**	**JB**	**ADF**	**LB(Q)**	**LB(Q^2)**
Titans	0.0009	−0.13	−0.22	0.82	−7.65***	15.57	18.74**
Europe	0.0011	0.24	1.79	29.34***	−9.77***	8.84	22.28***
Emerging	0.0004	−0.06	0.50	2.46	−9.36***	8.21	13.26
East Asia	0.0005	−0.54	1.71	35.47***	−6.07***	7.68	15.50*

Notes: *, **, *** indicate 10, 5, and 1 percent significance levels.

4.2. TVP-VAR

This subsection presents the findings from the dynamic connectedness analysis conducted on the abnormal returns derived from the event study, using the methodology presented in Subsection 3.2.2. Table 5 presents the average Total Connectedness Index (TCI) calculated through the TVP-VAR approach with a lag order of one day, selected based on the Bayesian Information Criterion (BIC). The timeframe is segmented into two intervals to facilitate the analysis of how the outbreak of the war has affected average connectedness.

Based on the findings presented in the table, the average level of connectedness, as indicated by the TCI, appears relatively moderate both before and after the onset of the war. However, there has been an increased connectedness of approximately 11% attributable to the war. The disruptions in supply chains and sanctions imposed on Russian fossil fuels have heightened interdependence among the specified groups. These findings align with other studies that have documented intensified linkages between assets in response to the war (Khoury et al., 2023; Rubbaniy et al., 2024).

The TCI during the war period stands at approximately 30%, indicating that almost 30% of the forecast error variance within this network is

Table 5: Averaged dynamic connectedness based on TVP-VAR (1)

	Titans	*Europe*	*Emerging*	*East Asia*	FROM
Pre-war period (02.09.2021 – 18.02.2022)					
Titans	78.03	13.22	2.10	6.64	21.97
Europe	5.49	89.49	2.62	2.40	10.51
Emerging	15.61	9.29	73.64	1.46	26.36
East Asia	4.23	5.91	3.53	86.34	13.66
TO	25.33	21.84	19.37	5.96	
NET	3.36	11.32	−6.99	−7.7	18.13 (TCI)
	Titans	*Europe*	*Emerging*	*East Asia*	FROM
War period (21.02.2022– 31.05.2022)					
Titans	61.56	10.01	9.66	18.76	38.44
Europe	11.95	75.48	9.31	3.26	24.52
Emerging	16.47	10.71	64.33	8.48	35.67
East Asia	13.78	0.59	6.39	79.34	20.76
TO	42.20	21.32	25.36	30.51	
NET	3.76	−3.20	−10.31	9.75	29.85 (TCI)

Notes: predictive horizon of 10 days.

attributable to internal network interactions. The remaining 70% of the variance is explained by factors specific to each group, captured by their idiosyncratic components. Furthermore, while *Titans* and *Emerging Markets* retained their positions as shock transmitter and receiver, respectively, *Europe* transitioned from being a transmitter to becoming a shock receiver. This shift can be attributed to the region's significant reliance on Russian fossil fuels. Concurrently, *East Asia* emerged as the primary transmitter of shocks.

For the remainder of the analysis, we focus on a condensed timeframe starting from December 2021, when Russia first signalled the possibility of a military invasion, to capture better the developments in the weeks preceding the outbreak of the war.

Figure 1 provides a visual representation of the dynamic TCI. The index varies considerably throughout the observed timeframe, ranging from 11%

to 20%. The lowest value is observed during the last week of February 2022, coinciding with the lead-up to the invasion, followed by a sharp increase in early March. During March and April 2022, the TCI remains high and volatile, reflecting increased market uncertainty and interconnectedness in response to the invasion. Finally, starting in mid-April 2022, the TCI starts to decline, suggesting a period of adjustment where the market starts to stabilise, though still experiencing significant volatility.

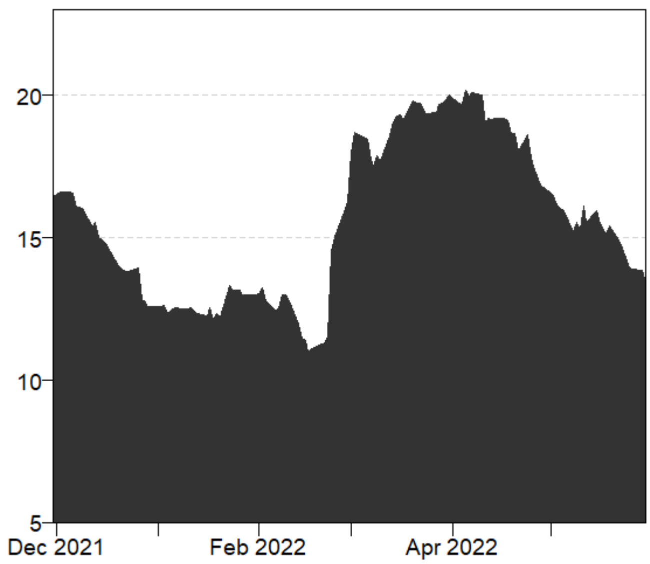
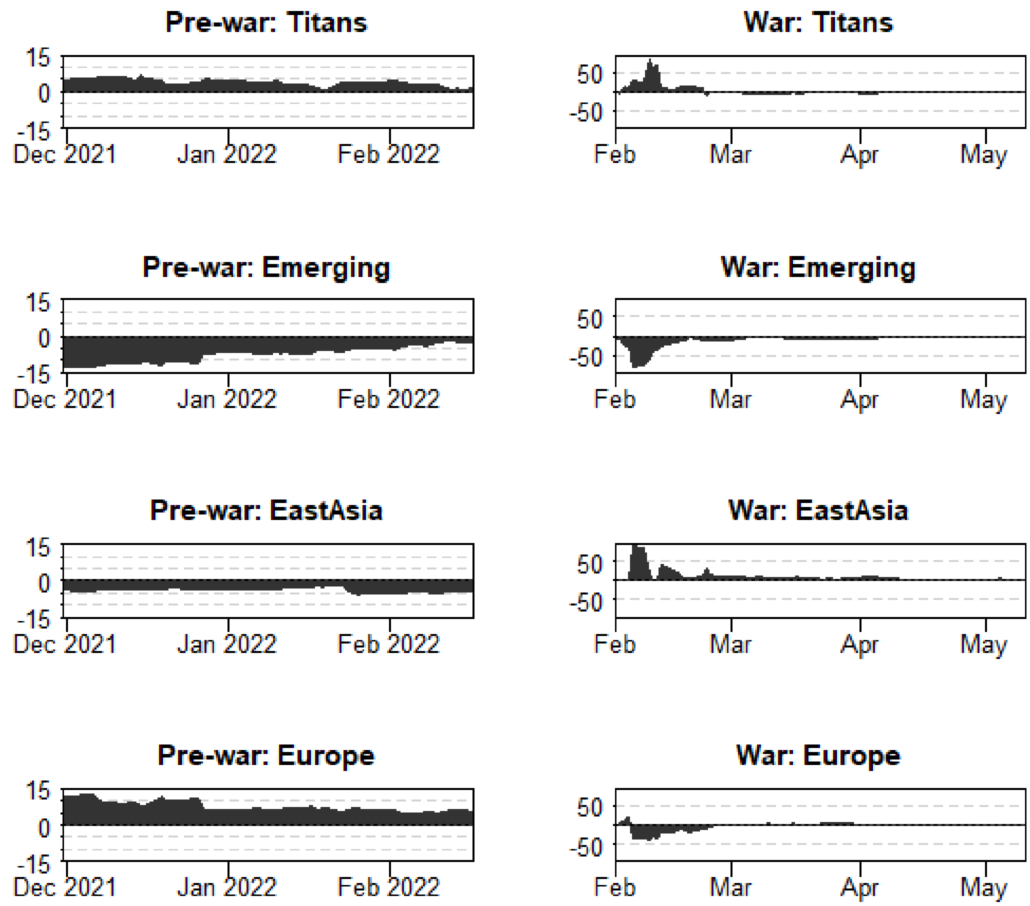


Figure 1: Dynamic Total Connectedness

The net directional TCI (NET) for both the pre-war and war periods is reported in Figure 2. During the pre-war period, companies from the *Titans* and *Europe* groups predominantly transmit shocks, while the other two groups primarily receive them. Following the outbreak of war, the dynamics undergo significant changes across all groups. Initially major transmitters during the early weeks of the invasion, companies in the *Titans* group swiftly transitioned to becoming net receivers after that. Similarly, *Europe* changes its status in the proximity of the event and remains a net receiver at least until mid-March. Such a rapid transformation highlights the region's dependence on Russian fossil fuels. The *Emerging Markets* group maintains its status as a net receiver, albeit with lower values. Lastly, East Asian companies shift to becoming net transmitters with heightened shock transmission intensity immediately after the invasion.



Notes: The pre-war period spans from December 1, 2021, to February 18, 2022, whereas the war period extends from February 21, 2022, to May 31, 2022.

Figure 2: Dynamic Net Total Directional Connectedness

Overall, our findings indicate that the onset of the Russo-Ukrainian war resulted in higher interconnectedness among the defined groups, a shift in their roles, and an intensification of shock transmission.

5. Conclusions and policy implications

This paper analyses the impact of the Russo-Ukrainian war on the global coal markets by combining event-study and connectedness analysis approaches. We examine a sample of companies operating in the coal sector, obtained from the Global Coal Exit List of 2022 and categorised into four groups based on their headquarters' countries. For the event study analysis, we employ a market model to identify the impact of the war on abnormal returns. Subsequently, we apply the TVP-VAR model to measure the group connectedness.

The event study results reveal positive Cumulative Average Abnormal Returns (CAARs) across all defined groups, with statistical significance observed exclusively within the *Titans*. This suggests that coal-related firms headquartered in the USA, the UK, Canada, and Australia outperformed the stock market on a cumulative basis during the first 14 days after the invasion.

At the daily level, the results show that on the invasion day, only coal companies from Europe registered a significant share price change. Furthermore, this group experienced a significant decrease also on February 21, 2022, in response to Russia's president's announcements regarding the independence of Donetsk and Luhansk regions. *Titans* saw three consecutive days of a significant increase in share prices starting from the 4th-day post-event. *Emerging Markets* sub-sample shows a 2% rise in share prices two days after the invasion, mainly attributable to companies headquartered in India. Finally, no significant reactions of the East Asia market have been detected within the defined event window. The post-event window applied within the event study is relatively brief, reflecting the immediate market response, and does not include the impact of supply chain reshuffling and other processes that followed the EU's decision to ban coal imports from Russia.

Regarding the connectedness analysis, the results from the TVP-VAR model with a lag order of one day lead to several conclusions. Firstly, the outbreak of the Russo-Ukrainian war led to an approximate 11% increase in average interconnectedness among the defined groups, driven by heightened market uncertainty and the urgent search for readily available substitutes for Russian fossil fuels. Furthermore, dynamic total connectedness analysis indicates a temporary reduction in values around the event, followed by a sharp rebound that persisted until mid-April, when the market began stabilising.

Finally, when considering the condensed timeline from December 2021 to May 2022, the war brought about notable changes in the roles of net transmitters or receivers among the groups. Specifically, *Europe* and *Titans* transitioned from being net transmitters to net receivers, though with varying timelines and intensities. *East Asia*, on the other hand, became a net transmitter immediately after the invasion and maintained this role until mid-April.

Although limited to the defined sample and timeline, our findings have important implications for investors, regulators, and policymakers. First, the abnormal profits garnered by coal companies in the aftermath of the Russian invasion may create a misleading optimistic outlook regarding the sector's future. While providing short-term benefits to these companies, intensified coal mining and export operations will have consequences for the coal-intensive regions and contribute to an increase in stranded assets over the long term. When considering financial support for coal, investors should carefully assess the mid- and long-term consequences of such decisions, especially given the global trend toward a coal phase-out, which is anticipated to reduce demand significantly.

Our analysis highlights how regional dependence on fossil fuels can jeopardise other regions by fostering investments in carbon-intensive industries, undermining global decarbonisation goals and climate commitments. In response, national governments should play a crucial role in dismantling pro-coal narratives by reducing coal subsidies and implementing stricter taxation policies. It is imperative to establish clear coal phase-out commitments alongside comprehensive strategies and regulatory frameworks aligned with the Paris Agreement's climate objectives. Lastly, all decarbonisation measures must prioritise a just transition framework that addresses regional inequalities and vulnerabilities. This approach ensures fairness and inclusivity in the transition to a low-carbon future.

Appendix A. Full list of companies

Table A.1: Full list of companies

Company Name	Country	Sub-sample
Aluminum Corporation of China Ltd	China	EastAsia
Anhui Hengyuan Coal Industry and Electricity Power Co Ltd	China	EastAsia
Anshan Heavy Duty Mining Machinery Co Ltd	China	EastAsia
Guangxi Guiguan Electric Power	China	EastAsia
China Longyuan Power Group Co Ltd	China	EastAsia
Ningxia Younglight Chemicals Co Ltd	China	EastAsia
China Coal Energy Co Ltd	China	EastAsia
Shanghai Datun Energy Resources Co Ltd	China	EastAsia
Pingdingshan Tianan Coal Mining Co Ltd	China	EastAsia
China Resources Power Holdings Co Ltd	China	EastAsia
Daqin Railway Co Ltd	China	EastAsia
Fujian Funeng Co Ltd	China	EastAsia
Guangdong Investment Ltd	China	EastAsia
Guanghui Energy Co Ltd	China	EastAsia
Guangzhou Development Group Co Ltd (GDG)	China	EastAsia
Guangzhou Hengyun Enterprises Holding Ltd	China	EastAsia
Guizhou Panjiang Refined Coal Co Ltd	China	EastAsia
Huaibei Mining Holdings Co Ltd	China	EastAsia
Hubei Yihua Chemical Industry Co Ltd	China	EastAsia
Jinneng Holding Shanxi Coal Industry Co Ltd	China	EastAsia
Kailuan Energy Chemical Co Ltd	China	EastAsia
Luenmei Quantum Co Ltd	China	EastAsia
Sany Heavy Equipment International Holdings Co Ltd	China	EastAsia
Shaanxi Coal Industry Co Ltd	China	EastAsia
SDIC Power Holding Co Ltd	China	EastAsia
Shanxi Coal International Energy Group Co Ltd	China	EastAsia
Shenergy Co Ltd	China	EastAsia
Shenzhen Energy Group Co Ltd	China	EastAsia
Anyuan Coal Industry Group Co	China	EastAsia
Baotailong New Materials CO LTD	China	EastAsia
Beijing Jingneng Power Co Ltd	China	EastAsia
Tiandi Science & Technology Co Ltd	China	EastAsia
China Coal Xinji Energy Co Ltd	China	EastAsia
GD Power Development Co Ltd	China	EastAsia
Guangdong Electric Power Development Co Ltd	China	EastAsia
Harbin Hatou Investment Co Ltd	China	EastAsia
Jointo Energy Investment Co Ltd Hebei	China	EastAsia
HuBei Energy Group Co Ltd	China	EastAsia
Inner Mongolia Yitai Coal Co Ltd	China	EastAsia
Jinneng Holding Shanxi Electric Power Co	China	EastAsia
Jizhong Energy Resources Co Ltd	China	EastAsia
Linzhou Heavy Machinery Group Co Ltd	China	EastAsia
Ningbo Energy Group Co Ltd	China	EastAsia
Ningbo Marine Co Ltd	China	EastAsia
Shenyang Huitian Thermal Power Co Ltd	China	EastAsia
Shenyang Jinshan Energy Co Ltd	China	EastAsia
Wintime Energy Co Ltd	China	EastAsia
Yangmei Chemical Co Ltd	China	EastAsia
Henan Dayou Energy Co Ltd	China	EastAsia
Zhejiang Zheneng Electric Power Co Ltd	China	EastAsia

(continued)

Company Name	**Country**	**Sub-sample**
Zhengzhou Coal Industry & Electric Power Co Ltd	China	EastAsia
Zhejiang Hugeleaf Co Ltd	China	EastAsia
Guangxi Guidong Electric Power Co Ltd	China	EastAsia
Dalian Thermal Power Co Ltd	China	EastAsia
Huaihe Energy (Group) Co Ltd	China	EastAsia
Gansu Jingyuan Coal Industry and Electricity Power Co Ltd	China	EastAsia
Huaneng Power International INC	China	EastAsia
Jiangxi Ganneng Co Ltd	China	EastAsia
Huadian Energy Co Ltd	China	EastAsia
Datang Environment Industry Group Co Ltd	China	EastAsia
Xinjiang Tianfu Energy Co Ltd	China	EastAsia
Henan Shenhuo Coal & Power Co Ltd	China	EastAsia
China XLX Fertiliser Ltd	China	EastAsia
CITIC Ltd	China	EastAsia
Datang International Power Generation Co Ltd	China	EastAsia
Dongguang Chemical Ltd	China	EastAsia
E-Commodities Holdings Ltd	China	EastAsia
Elion Clean Energy Co Ltd	China	EastAsia
Feishang Anthracite Resources Ltd	China	EastAsia
First Pacific Co Ltd	China	EastAsia
Guangdong Baolihua New Energy Stock Co	China	EastAsia
HK Electric Investments	China	EastAsia
Power Assets Holdings Ltd	China	EastAsia
China Power International Development Ltd	China	EastAsia
Doosan Enerbility Co Ltd	South Korea	EastAsia
Korea Electric Power Corp (KEPCO)	South Korea	EastAsia
LX International Corp	South Korea	EastAsia
Posco Holdings Inc	South Korea	EastAsia
Formosa Plastics Corp	Taiwan	EastAsia
Formosa Petrochemical Corp (FPCC)	Taiwan	EastAsia
Eneva SA	Brasil	Emerging
Adani Enterprises Ltd	India	Emerging
Adani Power Ltd	India	Emerging
Bodal Chemicals Ltd	India	Emerging
CESC Ltd	India	Emerging
Coal India Ltd	India	Emerging
GOCL Corp Ltd	India	Emerging
Gujarat Industries Power Co Ltd	India	Emerging
Gujarat Mineral Development Corp Ltd	India	Emerging
Hindalco Industries Ltd	India	Emerging
Jindal Steel & Power Ltd	India	Emerging
JSW Energy Ltd	India	Emerging
Maheshwari Logistics Ltd	India	Emerging
National Aluminium Co Ltd	India	Emerging
Nava Bharat Ventures Ltd	India	Emerging
NTPC Ltd	India	Emerging
REC Ltd	India	Emerging
Refex Industries Ltd	India	Emerging
Reliance Infrastructure Ltd	India	Emerging
Sarda Energy & Minerals Ltd	India	Emerging
Sunflag Iron & Steel Co Ltd	India	Emerging
Bharat Heavy Electricals Ltd	India	Emerging
Prakash Industries Ltd	India	Emerging
SJVN Ltd	India	Emerging

(continued)

Company Name	**Country**	**Sub-sample**
Indian Railway Finance Corp Ltd	India	Emerging
Malakoff Corp Bhd	Malaysia	Emerging
YTL Corp Bhd	Malaysia	Emerging
YTL Power International Bhd	Malaysia	Emerging
Toyo Ventures Holdings Bhd	Malaysia	Emerging
Hub Power Co Ltd	Pakistan	Emerging
RATCH Group Public Co Ltd	Thailand	Emerging
Pha Lai Thermal Power JSC	Vietnam	Emerging
Refrigeration Electrical Engineering Corp	Vietnam	Emerging
Deo Nai Coal JSC	Vietnam	Emerging
Ha Tu Coal JSC	Vietnam	Emerging
PetroVietnam Power Corp JSC	Vietnam	Emerging
PT Indo Tambangraya Megah Tbk	Indonesia	Emerging
PT United Tractors Tbk	Indonesia	Emerging
PT Adaro Energy Indonesia Tbk	Indonesia	Emerging
PT Astra International Tbk	Indonesia	Emerging
PT Bayan Resources Tbk	Indonesia	Emerging
PT Indika Energy Tbk	Indonesia	Emerging
PT Bukit Asam Tbk	Indonesia	Emerging
PT Petrosea Tbk	Indonesia	Emerging
PT Prima Andalan Mandiri Tbk	Indonesia	Emerging
PT Transcoal Pacific Tbk	Indonesia	Emerging
PT Mitrabara Adiperdana Tbk	Indonesia	Emerging
PT Baramulti Suksessarana Tbk	Indonesia	Emerging
PT ABM Investama Tbk	Indonesia	Emerging
PT Samindo Resources Tbk	Indonesia	Emerging
Engie Energia Chile SA	Chile	Emerging
AES Andes SA	Chile	Emerging
Exxaro Resources Ltd	South Africa	Emerging
Sasol Ltd	South Africa	Emerging
Thungela Resources Ltd	South Africa	Emerging
TAQA Morocco SA	Morocco	Emerging
CEZ AS	Czech Republic	Europe
HMS Bergbau AG	Germany	Europe
Mainova AG	Germany	Europe
RWE AG	Germany	Europe
Enea SA	Poland	Europe
Lubelski Wegiel Bogdanka SA	Poland	Europe
Enel SpA	Italy	Europe
Energa SA	Poland	Europe
Grupa Azoty SA	Poland	Europe
PGE SA (Polska Grupa Energetyczna SA)	Poland	Europe
ZEW Kogeneracja SA	Poland	Europe
PKP Cargo SA	Poland	Europe
ZE PAK SA Group	Poland	Europe
Elektrocieplownia Bedzin SA	Poland	Europe
TAURON Polska Energia SA	Poland	Europe
Park Elektrik Uretim Madencilik Sanayi ve Ticaret AS	Turkey	Europe
Odas Elektrik Uretim Sanayi Ticaret AS	Turkey	Europe
Fortum Oyj	Finland	Europe
AGL Energy Ltd	Australia	Titans
Aurizon Holdings Ltd	Australia	Titans
BHP Group Ltd	Australia	Titans
Washington H Soul Pattinson and Co Ltd	Australia	Titans

(continued)

Company Name	**Country**	**Sub-sample**
New Hope Corp Ltd	Australia	Titans
Stanmore Resources Ltd	Australia	Titans
TerraCom Ltd	Australia	Titans
Emera Inc	Canada	Titans
Silver Elephant Mining Corp	Canada	Titans
TransAlta Corp	Canada	Titans
Fortis Inc	Canada	Titans
Westshore Terminals Investment Corp	Canada	Titans
Bisichi PLC	UK	Titans
Air Products And Chemicals Inc	USA	Titans
ALLETE Inc	USA	Titans
Alliance Resource Partners LP	USA	Titans
Alliant Energy Corp	USA	Titans
Ameren Corp	USA	Titans
Black Hills Corp	USA	Titans
CenterPoint Energy Inc	USA	Titans
CMS Energy Corp	USA	Titans
CONSOL Energy Inc	USA	Titans
Dominion Energy Inc	USA	Titans
DTE Energy Co	USA	Titans
Duke Energy Corp	USA	Titans
FirstEnergy Corp	USA	Titans
Hallador Energy Co	USA	Titans
IDACORP Inc	USA	Titans
MGE Energy Inc	USA	Titans
Natural Resource Partners LP	USA	Titans
NiSource Inc	USA	Titans
NorthWestern Corp	USA	Titans
NRG Energy Inc	USA	Titans
Otter Tail Corp	USA	Titans
Peabody Energy Corp	USA	Titans
Pinnacle West Capital Corp	USA	Titans
Ramaco Resources Inc	USA	Titans
Vistra Corp	USA	Titans
WEC Energy Group Inc	USA	Titans
Glencore	Switzerland	Titans

Source: Authors' elaboration.

Appendix B. Breakdown by countries

Table B.2: Breakdown of Sub-samples by Countries

Country	**N of Firms**	**% of Sub-sample**
Titans		
Australia	7	17.5
Canada	5	12.5
United Kingdom	2	5.0
United States	26	65.0
Total	**40**	
Europe		
Czech Republic	1	5.6
Finland	1	5.6
Germany	3	16.7
Italy	1	5.6
Poland	10	55.6
Turkey	2	11.1
Total	**18**	
Emerging		
Brazil	1	1.8
Chile	2	3.6
India	24	42.9
Indonesia	14	25.0
Malaysia	4	7.1
Morocco	1	1.8
Pakistan	1	1.8
South Africa	3	5.4
Thailand	1	1.8
Vietnam	5	8.9
Total	**56**	
East Asia		
China	93	94.0
South Korea	4	4.0
Taiwan	2	2.0
Total	**99**	

Source: Authors' elaboration.

Appendix C. AARs at sub-sample level

Table C.3: Average abnormal returns at sub-sample level

Day	**Titans**	**Europe**	**Emerging**	**East Asia**
-3	0.002	0.031^{***}	-0.011	0.010
-2	-0.008	0.014	-0.004	-0.002
-1	0.009	-0.005	0.013	0.005
0	-0.021	-0.041^{*}	-0.200	-0.003
1	0.018^{**}	0.022^{*}	0.023^{*}	0.009
2	0.001	0.035	0.020^{**}	0.017
3	0.010	-0.000	0.070	0.010
4	0.024^{***}	0.038	0.010	0.007
5	0.021^{***}	0.001	0.007	0.022
6	0.016^{**}	0.010	0.038	0.001
7	0.016	0.008	0.001	0.001
8	-0.007	0.019^{*}	-0.002	-0.034
9	-0.015^{**}	-0.006	0.008	0.000
10	0.013	0.011	0.006	0.016

Notes: *, **, *** indicate 10, 5, and 1 percent significance levels according to the Generalized Rank T-test.

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