

Impact of Russian-Ukraine war on clean energy, conventional energy, and metal markets: evidence from event study approach

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Abstract

This article explores the impact of the Russian-Ukraine war on metals, conventional energy, and renewable energy markets using an event research technique. The data demonstrate a significant increase in the anomalous returns of the renewable energy industry. Apart from the gas oil index, none of the conventional energy or metals markets exhibit large abnormal returns on the event day. Europe was one of the first clean energy markets to react to war. The impact was likewise highest on the $t+1$ day, which was not the case in other markets. War had a significant influence on gold, platinum, palladium, and nickel, among other metals.

JEL Classification: G11, G14, G41, Q40, N40,

Keywords: Energy markets, Metals markets, Event study, Russia-Ukraine War

1 Introduction

The Russian-Ukraine war has been raging since February 2014, when a dispute over the official status of Crimea and Donbas erupted. According to Johannesson and Clowes (2022), Ukraine represents a potential direct competitive threat to Russia's energy exports, and that is one of the key reasons for the dispute and Russian annexation of Crimea. Following a full-scale invasion by Russia on February 24, 2022, tensions skyrocketed. The Russian government is subject to severe economic sanctions imposed by a number of countries and corporations around the world (Funakoshi et al., 2022). In the energy markets, Russia is one of the top exporters of oil, gas, and coal. As a result, the war has had a significant impact on the energy sector. The war appears to have prompted a boom in stock values around the world, particularly in renewable energy sectors (Mathis and Wade, 2022). The influence of the Russia-Ukraine war on the clean energy, conventional energy, and metal markets is examined in this article.

The Russia-Ukraine war, which has had a severe impact on the financial markets, is without a doubt the most major war in Europe since the Second World War. Global stock markets exhibit negative cumulative abnormal returns with significant heterogeneous impacts (Boubaker et al., 2022). Bounboua and Yatié (2022) also indicate that 94 nations had negative stock returns throughout the conflict. Yousaf et al. (2022) substantiate their findings for G20 stock markets. Russia is one of the world's leading oil suppliers; Adekoya et al. (2022) contend that oil was the key transmitter of shocks during the conflict, and that there was a deeper interconnectedness between different assets in general. According to Deng et al. (2022), equities with low-carbon transition opportunities did better, and Europe's reliance on Russian oil and gas exacerbated this impact. Transition risk had also a significant impact on US markets. This study adds to the literature by investigating the impact of the Russian-Ukraine war on the clean and conventional energy, and metal markets.

According to the Efficient Market Hypothesis, in an efficient capital market, stock prices adjust to any unexpected event immediately and without overreaction (Fama, 1970). It claims that to make decisions, a rational person evaluates all kinds of opportunities and their outcomes based on all available information. It means that the stock prices must reflect all available information. Behavioral theories, on the other hand, contradict this hypothesis, claiming that investors may overreact to news about geopolitical risk and conflicts (Zarembka et al., 2022). Bordalo et al. (2012) suggested the salience hypothesis of risky decision-making. The salience of war distorts objective probabilities of outcomes and alters decision-making weights when there is a chance of conflict. Heuristics are yet another important concept in finance. (Tversky, and Kahneman, 1973). It illustrates that, rather than analysing all available information before making a decision, humans tend to assign more weight to recent or easily recallable events and information. In this research, we use the Russia-Ukraine conflict as a case study to test these arguments.

This paper adds to the body of knowledge in the following three ways. It begins by looking into the effects of the Russian-Ukrainian war on clean energy, conventional energy, and metal sectors. Because Russia is the world's largest exporter of oil and gas, the Russia-Ukraine conflict is vital to the energy and metal markets. One-third of Europe's gas and oil usage is imported from Russia. Sanctions against Russia might have disastrous consequences for the economy of not only European countries, but the entire world. Further, the sanctions on Russian conventional energy markets also increased the demand of its substitute, the clean energy markets. We use statistical test to measure the impact of the Russian-Ukrainian conflict on renewable energy, conventional energy, and metal markets. We add to the body of knowledge about the impact of wars on financial markets. Choudhry (2010) investigated US stock markets during WWII, Hudson and Urquhart (2015) investigated British stock markets during WWII, Rigobon & Sack (2005) investigated US stock markets during Iraq, and Schneider and Troeger (2006) investigated Israel and Palestinian conflicts, US-Iraq wars, and Ex-Yugoslavia wars on the stock markets of London, New York, and Paris. All studies have found that wars have a major impact on financial markets. We contribute to the existing literature by investigating the impact of the Russian-Ukrainian war on energy and metal markets. Second, rather than focusing on specific news about the Russian-Ukrainian conflict, we investigate the influence of overall unobservable tension in the financial markets during wartime. To do so, we define and describe an event window based on war days, and then conduct empirical analysis using traditional event-study techniques (MacKinlay, 1997). Third, we segregate the companies into clean energy and conventional energy stocks to investigate the impact of the Russian-Ukrainian war on the two asset classes individually. The analysis also includes the metals market, which has been impacted by the war. It will enable us to investigate the impact on the three markets holistically.

The impact of the Russia-Ukraine war on the clean energy, conventional energy, and metal markets is investigated using standard event study techniques. The data ranges from September 2, 2021, to March 25, 2022. We calculate the expected returns using the market model, then subtract the expected results from the actual returns to get the abnormal returns. We also calculate cumulative abnormal returns by adding the abnormal returns over the event window, as well as aggregate abnormal returns by averaging the abnormal returns across the event window. From $t-5$ to $t+21$ days and $t-125$ to $t-6$ days, we construct a 27-day event window and a 120-day estimation window.

The results show a large increase in the clean energy market's abnormal returns on the event day. However, none of the conventional energy or metals markets show significant abnormal returns on the event day except the gas oil index. We test for the influence of war on the aggregate level of all markets, then on the aggregate level of each market, and finally on the level of each index utilised in the study. At all-markets aggregate level, the aggregate abnormal returns (AARs) are significant on the event day and during post-

event period. The analysis at each-market level shows that AARs are significant at 5% on the event day for clean energy markets only. The cumulative aggregate abnormal returns (CAARs) of the clean energy market are also significant in the post-event period whereas for the conventional energy and metals market the CAARs turn significant after $t+3$ period. Each-index level analysis shows that European clean markets start facing the affects of market 5 days before the event. The effect was also greater (i.e., 13.849% CAARs) on the $t+1$ day for the European clean markets when compared with other markets. In conventional energy markets only, gasoline was hit in the pre-event period while in metal markets, gold platinum, palladium and Nickel faced the intensity in the pre-event period.

The rest of the paper is organized in the following way: section 2 is a literature review, section 3 is a discussion of the data and methods used to analyse the models, section 4 displays the study's findings, and section 5 concludes the study with significant global implications.

2 Data and research methodology

2.1 Data description

To perform the event study, we need to define the event, the event day, the event window. The declaration of the Russia-Ukraine war is the *event* for the study. Russia and Ukraine are both key trading partners for European nations. Both are the leading suppliers of energy to European nations, and the conflict between these countries has caused widespread hardship not just in Europe but across the world (Qureshi et al., 2022). Energy and metal prices have plummeted. The war was declared on 24th February 2022, which is taken as an *event day*. The *event window* consists of 27 days from $t-5$ to $t+21$ days. The estimation window is of 120 days from $t-125$ to $t-6$ days. We only consider trading days in our analysis. We use the daily data of clean energy stock indices (S&P Global Clean Energy Index-SPGCE, European Renewable Energy-ERIX, iShares Global Clean Energy ETF-ICLN, VanEck Vectors Low Carbon Energy ETF-SMOG, Invesco WilderHill Clean Energy ETF-PBW, Invesco Global Clean Energy ETF-PBD, Invesco Solar ETF-TAN, First Trust Global Wind Energy ETF-FAN), conventional energy indices (Brent crude oil, WTI crude oil, Gas Oil, Gasoline, Heating Oil, Natural Gas), and metal markets (Gold, Silver, Platinum, Palladium, Copper, Aluminium, Zinc, Lead, Nickel, Tin) indices The research period runs from September 2, 2021 through March 25, 2022. This is a post-covid era that includes the Russian-Ukraine war. It allows us to focus on the Russian-Ukraine conflict era, specifically and explore it in depth. Table 1 displays the summary statistics for each market.

2.2 Methodology

Utilizing data from the estimation window—a period of time before the event window—we calculate the expected returns. Our method is the Ordinary Least Square (OLS) Market Model. According to Dyckman et al. (1984), the OLS market model yields superior outcomes for event study analysis. $E(R_{it})$, the expected return for the index i at time t , is estimated as follows:

$$E(R_{it}) = \alpha_i + \beta_i R_{mt} \quad (1)$$

Where, R_{mt} is the market return on day t , or in our case, it is the return of the benchmark Dow Jones Global index. We compute the actual returns for each asset using the price change log formula, which is as follows.

$$R_{it} = \ln \left[\frac{P_{it} - P_{it-1}}{P_{it-1}} \right] \times 100 \quad (2)$$

In this equation, P_{it} represents the current price level of the index i at time t , whereas P_{it-1} displays the index's lag price at time t .

2.2.1 Abnormal Returns (AR) and Cumulative abnormal returns (CAR)

We compute the abnormal returns for each index by subtracting the daily expected returns determined by equation (1) from the actual returns obtained from equation (2). We can write this mathematically:

$$AR_{it} = R_{it} - E(R_{it}) \quad (3)$$

Where, AR_{it} represents the abnormal returns at time t for index i , R_{it} displays index's actual log-return at time t , and $E(R_{it})$ displays the expected return at time t . Over the event window, we estimated the cumulative abnormal return (CARs) as follows:

$$CAR_i(p, q) = \sum_{t=p}^q AR_{it} \quad (4)$$

Where, CAR_i represents the cumulative abnormal returns of index i over day p to day q , and AR_{it} is the abnormal return estimated in equation (3).

The equations (3) and (4) allows us to study the impact of Russian-Ukraine war for each index. It will be evident that the particular index or asset has been impacted by the war if we discover any sizable AR or CAR at the index level.

2.2.2 Aggregate of Abnormal Returns (AAR) and Cumulative Aggregate of Abnormal Returns (CAAR)

To study the impact of the Russian-Ukraine war at each-market aggregate level, we sum up all indices's daily abnormal returns and determine the response of each market to the event. The equation below is used to assess average abnormal returns at market level:

$$AAR_t = \frac{1}{N} \sum_{i=1}^N AR_{it} \quad (5)$$

Where, AAR_t represents the daily average of abnormal returns over all the indices in a specific market. N is the total number of indices in the market. Then, using AAR_t , the cumulative average abnormal returns (CAARs) for the event window are calculated for each market.

We employ equations (4) and (5) to calculate the impact of war at each-market level, aggregating abnormal returns from all indices for each market. To examine the consequences of war at all-markets aggregate level, we additionally estimate the aggregate AARs and CAARs of all the indices of all markets. We present our findings in the next section.

3 Results

The Russian invasion of Ukraine has caused substantial losses in the financial markets around the world, but the renewable energy companies have been gaining as investors consider the need for substitute energy sources. We specifically test for the reaction of energy and metal markets in response to Russia-Ukraine war. Figure 1 shows average changes in prices of various clean energy, conventional energy, and metal markets on the event day. The share prices of all the clean energy markets soared swiftly during the event day; However, ERIX, the European renewable energy index, show the highest price change on the event day followed by TAN, i.e., a solar ETF. Overall, the clean energy market has shown the greatest price change followed by conventional energy and the metals markets, respectively. As the Russian economy faced the sanctions from the western economies, the Russia is one of the world's largest energy exporters, and the dependence of world on the Russian exports caused worldwide economic disruption. The investors started to look for alternative energy resources. The conventional energy markets also experienced a sudden increase in prices due to supply shocks except the natural gas (that shows a decrease in prices). Further, the war has spurred uncertainty in the market and the governments have started working on the alternate sources of materials. The investors smell such moves in advance and move wealth in the safe heaven metals like gold and silver. Russia is a major producer of nickel, aluminium, and palladium and these markets reacted to war. The reaction of metals markets to the war seems less pronounced as compared to energy markets.

The energy, and metals markets has reacted to the Russia-Ukraine war; however, the magnitude of the effect is different for each market. We estimate both the size and statistical significance of the impact of war on the energy and metal markets and present the results in Table 2. In Table 2, Panel A presents the tests for the clean energy market, Panel B demonstrates the results for the conventional energy market, and Panel C presents the tests for the precious and industrial metals. Panel A shows that the abnormal returns for the clean energy stocks are all positive and statistically significant at 1% level. The highest abnormal

returns are for TAN index (i.e., 10.198%) followed by PBW (9.868%), ERIX (9.852%) and ICLN (8.806%) with very little difference. The lowest abnormal returns are shown by the SMOG index with abnormal return of 5.321% on the event day. The effect of war on the conventional energy markets is insignificant except for the Gas Oil index. The Gas Oil index show 7.495% abnormal return during the event day. In case of metals, the effect is significant for platinum and aluminium but at 10% level of significance. Platinum has shown a negative abnormal return of -2.829% whereas aluminium shows 3.077% of the abnormal returns. It shows effects of the war are more pronounced in the clean energy markets as compared to conventional energy and metal markets. Costola and Lorusso (2022) show that The strongest spillovers of crude oil to other Russian sectors come from the Oil & Gas and Metals & Mining industries. For the global, industry, and commodity-specific samples used in this study, we investigate the impact of the event at the all-markets aggregate, each-market aggregate, and each-index levels. The results are presented below.

3.1 All-markets Aggregate

3.2 This section presents the results for the abnormal returns at all-markets aggregate level. It gives us an overarching overview of the effect of the event on the financial markets. Table 3 presents the estimated AARs and CAARs at an aggregate level of all markets during a 27-day event window. The results show 3 positive and 2 negative AAR before event, but all are insignificant. On the event day, AAR is 3.465% and significant at 1% level. The AAR remains positive for 11 days and negative for 10 days following the event. The 12 post-event AARs are significant while 9 remain insignificant at 5% level of significance. In the pre-event period, none of the CAAR is significant; however, in the post-event period, all the estimated CAARs are significant at 5% level. The CAAR on the event day is 8.754% significant at 1% level. On and after the event day, more significant CAARs suggest that the information regarding war and the economic sanctions have severely influenced the financial market and has been leading the prices for a longer time. The war between Russia and Ukraine has had a profound impact on the global financial system. We also find that the war event has a significant influence on the markets studied, as proposed by Boubaker et al., (2022) and Boungou and Yatié (2022) for stock markets, Wang et al. (2022) for metals, Costola & Lorusso (2022) for energy commodities and stocks, Lyócsa and Plhal (2022) for foreign exchange markets, and Just and Echaust (2022) for agricultural markets.

Each-Market Aggregate

We also study AARs and CAARS separately at each-market aggregate level. In this way, we are able to study the aggregate effect of war on each market. Clean energy market abnormal returns are presented in Table 4. It shows that none of the AARs are significant in the clean energy markets before the event.

However, out of 5 pre-event AARs, 3 are positive and 2 are negative. On the event day, AAR is positive and significant at 1% level with a coefficient of 7.965%. It shows the significance and intensity of the event. After the event, 12 AARs are negative and 9 AARs are positive. 6 AARs are significant at 5% level in the post event period and others are insignificant. CAAR estimations are also presented in Table 4. CAAR remain insignificant (significant) before (after) event. CAAR is significant at 1% level on the event day with a magnitude of 9.105%. The CAAR has also been significant after the event.

Conventional energy market also reacted to the Russia-Ukraine war. Table 5 presents the estimated AARs and CAARs for aggregate conventional energy markets for an event window of 27 days. In the conventional energy markets, we find significant AAR at 5% level on only the 3rd day before the event, i.e., 3.392%. Overall, we find 2 negatives and 3 positive AARS before event. AAR on the event day in conventional energy markets is positive but insignificant in contrast to clean energy markets. The post event AARs were significant in the conventional energy markets with some exceptional days. We find 9 negative AARs and 12 positive AARs following the event. In the post event period, 12 AARs are significant at 5% level while it remains insignificant on other days. We also estimate CAAR and present in the Table 5. The CAAR is insignificant in pre-event period. It is significant on the event day with a magnitude of 5.060% at 1% level of significance. It is insignificant on day 1-3 following the event; however, turns significant afterwards. It is insignificant on day 14 and 15 only.

The metal market is another important market that was severely hit by the Russian-Ukrainian conflict. For a 27-day event window, Table 6 shows the estimated AARs and CAARs for aggregate metal markets. We discover considerably large AAR 5 days before the event significant at 5% that disappears afterwards. All the estimated AARs before event are positive. The metal markets also show insignificant AAR on the event day like traditional energy stocks with a positive coefficient of 0.445%. After event, 11 AARs are negative while 10 are positive. 12 AARs are significant at 5% level while 9 are insignificant. We also estimate and report CAAR for the 27 days window. The CAAR for only one day before the event is significant while four days are insignificant. On the event day, the CAAR is 4.741% significant at 1% level. The CAAR turns significant at 5% level after 2 days in the post-event period.

To summarize, the clean energy market is the only market that has shown significant AAR on the event day whereas the AARs on conventional energy market and metals market remain insignificant. All the markets have significant CAARs on the event day. After event day, the CAARs remain significant during the whole window for the clean energy stocks; however, for the conventional energy stocks and the metals market, CAARs turn significant after the third day of the event. The clean energy market has shown a longer time significant effect of the event as compared to other two markets. The results at the market aggregate level signifies the findings of Mohamad (2022). He claims that assets exhibit asymmetric time-varying herding behaviour, in particular, cryptocurrencies and energy commodities. He also identifies signs

of a flight from the Ruble to other safe haven assets. Brent and bitcoin dominated price discovery at the start of the era of financial crisis precipitated by Russia's invasion of Ukraine.

3.3 Each-Index Aggregate

We also estimate cumulative abnormal return (CAR) at indices and ETF level to investigate the influence of Russia-Ukraine war on various subsections of the markets. Table 7 presents the estimates of CARs for each index of the clean energy markets. It shows no significant CAR on any index before event except ERIX at 10% level of significance. It shows that European clean energy markets started facing the brunt even before the event. When compared with the global SPGCE index, it does not show any response to the war in the pre-event period. The CARs turn significant in the post-event period for most of the indices. Differently, the SMOG index shows insignificant CARs even after the event except at $t+9$. Most of the CARs are positive except few exceptions (where the effect is insignificant). It signifies the war's consequences on the renewable energy markets in Europe, as well as internationally.

The conventional energy market CARs estimates are presented in Table 8. The CARs on the conventional energy markets are insignificant except for gasoline index. Gasoline shows a significant CAR before the event at $t-3$ time. The CARs are significant in the post-event period after $t+3$. Brent, WTI, Gas oil, Gasoline, Heating Oil and Natural gas all show 8, 7, 10, 10, and 9 significant CARs in the post-event period. Natural gas seems an only exception in this case and do not show any significant CAR in pre- and post-event period. The results are quite different when compared with clean energy. The clean energy markets show a spontaneous reaction to the war; however, the conventional energy markets show a 3-days lag in the effect. Overall, both markets do not show any response to the war in pre-event period.

Table 9 presents the CAR estimates for the precious and industrial metals. Gold, Silver, Platinum, and Palladium show significant CARs during pre-event period especially one day before the event. Nickel also follows the suite and has 2 significant CARs before the event on day $t-3$ and $t-5$. The pre-event CARs on silver, platinum, palladium, and nickel are significant at 5% level. The CARs on all metals have been positive during pre-and post-event periods with few exceptions in palladium and Lead that too after $t+11$. CARs are significant for all metals on $t+7$ with positive returns at 5% level and 10% level (for the lead only). The CARs on Nickel have been highest in percentage terms in the post-event period. Russia is one of the largest exporters of metals in the world. Therefore, fears of short supply led to enormous increase in prices during the war. Nickel led the brigade with a huge price increase topping the all-time high, i.e., \$100,000 per ton on London Metal Exchange (LME). LME halted the trading of nickel contracts on the exchange.

To summarize, The European clean markets are among the first one to be hit by the war implications. According to Santorsola et al. (2022), the European and UK financial markets which were being affected

by the crisis, followed by gold and bitcoin. CARs on clean energy have been insignificant in the pre-event period except for the European markets. The CARs on the European markets as well as global markets have been significant in the post-event period. The only exception is the SMOG index. The results are in line with the literature. For instance, Umar et al. (2022) finds that European stocks and Russian bonds were leading the transmitters of volatility shocks. As a result, the crisis's spillover effects from Russian and European markets to safe-haven assets like gold. Geopolitical risk has a significant influence on the financial markets globally (Zaremba et al., 2022). When compared with conventional energy markets, the clean energy markets have a simultaneous effect of the war that was lagged by 3 days in the conventional energy markets. Gasoline has been an exception in conventional energy markets. Oil was one of the biggest oil transmitters in the post-war era; however, it was a net receiver of shocks in the pre-war period (Adekoya et al., 2022). Among the metal markets, Gold, Silver, Platinum, Palladium, and Nickel have significant CARs during the pre-event period. The most severe effects of conflict have been felt by the Nickel. It has the greater number of significant CARs. Wang et al. (2022) observe an overall rise in systemic risk, beyond the pandemic threshold, particularly in the metals market. During the wartime, aluminium, copper, gold, platinum, and silver all prove to be significant shock transmitters.

4 Conclusion

Using an event research technique, this paper investigates the impact of the Russian-Ukrainian war on the clean energy, conventional energy, and metal sectors. The Russian invasion of Ukraine has resulted in significant losses in global financial markets, but renewable energy firms have benefited as investors anticipate the need for alternative energy sources. We especially look at how energy and metal markets react to the Russian-Ukrainian conflict. We use data from September 2, 2021, through March 25, 2022. We use the market model to calculate expected returns, abnormal returns, aggregate abnormal returns, cumulative abnormal returns, and cumulative aggregate abnormal returns. We use a 27-day event window from $t-5$ to $t+21$ days for the study.

The abnormal returns on clean energy stocks have increased dramatically, according to the findings. The results are significant for the all-markets aggregate, each-market aggregate, and each-index levels for global, and industry-specific samples, we use in this study. When we look at the AARs for the full market sample, AARs are positively significant on the day of the event and afterwards. During the pre-event phase, AARs are usually insignificant. In all the markets, CAARs are high in the post-event period only. To study the impact of war on each index independently, we generate cumulative abnormal returns (CARs) for each index used as a market proxy. The results are significant for all-markets aggregate, each-market aggregate and each-index levels used in this study.

We find the investors overreacted to the news about geopolitical risk and conflict related to Russian-Ukraine war (Zaremba et al., 2022). The investor put more weight on the probability of outcomes related to clean energy sector due to war (the most salient feature) and distort the objective probability of outcomes. Shares with salient upsides attract investors due to the salience-induced biases in attention allocation. Shares with salient downsides, on the other hand, become undervalued and generate larger subsequent returns, as in our case. The lesson for investors is to have the ability to disregard recent developments to avoid falling victim to the irrational behaviour as suggested by salience theory (Cosemans & Frehen, 2021). This becomes utmost important during times of strong market sentiment, as happened during the Russian-Ukrainian War. The markets studied in this paper do not seem to be efficient and they did not incorporate all the information available in the market. The Russian-Ukraine war period was led by the behavioural biases of investors.

This research has implications for the consumers, government, investors, energy and manufacturing sector managers, policy makers, and regulators. The Russian-Ukrainian conflict is one of the world's most serious geopolitical crises, and its implications have already begun to reverberate across global financial markets. Several western nations have imposed sanctions on Russia and ceased trade with it. It has had a direct impact on energy and metal prices, which has directly affected consumers and governments. This affect will be felt by consumers not only in Europe but throughout the world. Prices are already skyrocketing. To prevent more collateral damage, governments must coordinate and assist in bringing this war to an end. This research shows a significant impact of the Russian-Ukraine war on the energy and metal markets.

The investors also need to be vigilant about the progression of the geopolitical situation before making any decision. The investors have clearly shown their preference for the renewable clean energy as shown by the price surge of the clean stocks. The managers of energy and manufacturing sector should look for the alternate source of energy or metals to save themselves from such ramifications in the future. Policy makers and regulators need to make policy and regulations to help the industry in transitioning to sustainable energy sources.

Events in the world of geopolitics have always had an impact on the economy. In Germany, for example, inflation expectations rose by 0.75 percent following the war (Dräger et al., 2022). It has immediate consequences for monetary policy recommendations. Experts also warn against the European Central Bank taking prompt monetary policy action to combat inflation, which is being driven by a supply-side shock. Further research is warranted in this domain. Furthermore, corporate sector has also faced severe consequences, although no research has yet examined the impact of the Russian-Ukraine war on it. Tosun and Eshraghi (2022) is one of the studies on the topic.

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Table 1. Summary Statistics

	Mean	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability
SPGCE	-0.066	7.696	-3.955	1.916	0.978	4.908	45.403	0.000
ERIX	-0.082	10.550	-7.399	2.455	0.883	6.133	78.658	0.000
ICLN	-0.063	7.627	-4.664	2.057	0.976	4.931	45.843	0.000
SMOG	-0.091	6.036	-4.175	1.996	0.430	3.197	4.738	0.094
PBW	-0.126	9.373	-6.838	2.979	0.457	3.546	6.899	0.032
PBD	-0.119	7.500	-4.335	2.173	0.650	3.895	15.156	0.001
TAN	-0.056	9.316	-6.695	2.919	0.606	3.912	13.998	0.001
FAN	-0.101	5.852	-3.175	1.524	0.860	4.748	36.584	0.000
BRENT	0.381	8.794	-13.158	2.686	-1.075	9.674	299.101	0.000
WTI	0.374	8.354	-12.126	2.808	-0.843	7.841	159.838	0.000
GAS_OIL	0.559	15.026	-33.530	4.374	-2.787	28.504	4145.796	0.000
GASOLINE	0.362	10.429	-11.612	2.768	-0.418	7.645	135.505	0.000
HEATING_OIL	0.499	13.153	-21.928	3.396	-1.443	17.987	1417.117	0.000
NATURAL_GAS	0.254	15.786	-12.086	5.096	0.015	3.338	0.700	0.705
GOLD	0.055	2.375	-2.697	0.939	-0.239	3.420	2.462	0.292
SILVER	0.062	4.822	-4.747	1.765	-0.081	3.468	1.494	0.474
PLATINUM	0.026	5.287	-6.167	1.915	-0.011	3.921	5.162	0.076
PALLADIUM	0.040	10.369	-15.593	3.394	-0.468	6.136	65.164	0.000
COPPER	0.075	3.706	-4.182	1.599	-0.041	2.787	0.317	0.853
ALUMINIUM	0.219	4.237	-6.471	1.958	-0.525	3.756	10.178	0.006
ZINC	0.228	7.539	-5.099	1.745	0.543	5.461	44.028	0.000
LEAD	0.006	4.483	-3.664	1.230	0.287	4.338	12.903	0.002
NICKEL	0.761	68.583	-40.719	9.170	4.650	41.937	9749.089	0.000
TIN	0.182	4.098	-9.137	1.716	-1.424	8.728	248.969	0.000

Figure 1. The average change in prices of various clean energy, conventional energy, and metal markets on the event day

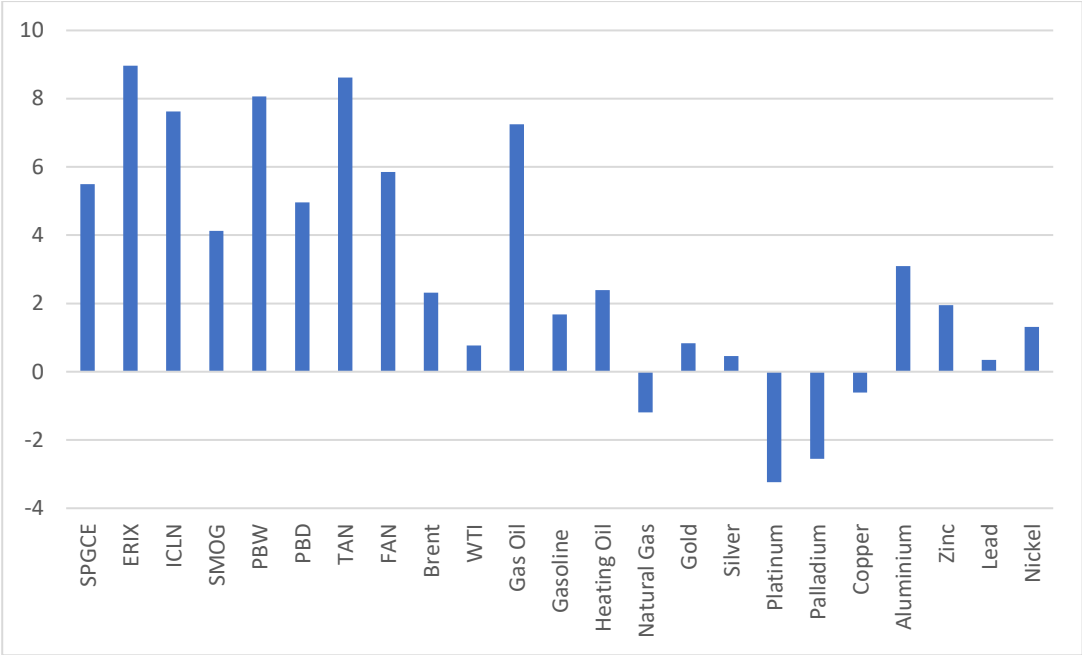


Table 2. Abnormal returns on event day

Markets	Abnormal Returns (AR)	<i>t stat</i>_{AR}
<i>Panel A: Clean energy markets</i>		
SPGCE	6.622 ^a	5.518
ERIX	9.852 ^a	5.322
ICLN	8.806 ^a	6.670
SMOG	5.321 ^a	4.429
PBW	9.868 ^a	5.031
PBD	6.376 ^a	5.028
TAN	10.198 ^a	4.977
FAN	6.676 ^a	6.545
<i>Panel B: Conventional energy markets</i>		
Brent	2.654	1.456
WTI	1.135	0.565
Gas Oil	7.495 ^a	3.540
Gasoline	2.054	1.086
Heating Oil	2.589	1.431
Natural Gas	-0.926	-0.173
<i>Panel C. Precious and industrial metals</i>		
Gold	0.834	0.997
Silver	0.714	0.442
Platinum	-2.829 ^c	-1.774
Palladium	-2.043	-0.786
Copper	-0.114	-0.081
Aluminium	3.077 ^c	1.809
Zinc	2.125	1.305
Lead	0.480	0.424
Nickel	1.616	0.915
Tin	0.590	0.397

Notes: ^a, ^b, ^c indicate the 1, 5, and 10 percent level of significance.

Table 3. Aggregate AARs and CAARs of all sample markets

Days	AAR	<i>t stat</i>_{AAR}	CAAR	<i>t stat</i>_{CAAR}
-5	0.702	0.979	0.702	0.979
-4	-0.096	-0.134	0.606	0.598
-3	1.140	1.590	1.746	1.406
-2	-0.108	-0.150	1.638	1.143
-1	1.172	1.634	2.810	1.753 ^c
0	3.465	4.834 ^a	6.275	8.754 ^a
1	-2.478	-3.456 ^a	3.798	2.002 ^b
2	3.235	4.513 ^a	7.033	3.469 ^a
3	3.513	4.900 ^a	10.546	4.904 ^a
4	0.938	1.309	11.484	5.066 ^a
5	0.241	0.336	11.725	4.931 ^a
6	4.642	6.475 ^a	16.367	6.591 ^a
7	6.610	9.220 ^a	22.978	8.889 ^a
8	8.127	11.336 ^a	31.104	11.596 ^a
9	-8.383	-11.694 ^a	22.721	8.183 ^a
10	-1.029	-1.435	21.692	7.565 ^a
11	-0.292	-0.407	21.400	7.240 ^a
12	-3.412	-4.760 ^a	17.988	5.914 ^a
13	-2.131	-2.973 ^a	15.856	5.074 ^a
14	-1.455	-2.029 ^b	14.402	4.492 ^a
15	1.593	2.222 ^b	15.995	4.869 ^a
16	-1.048	-1.461	14.947	4.445 ^a
17	0.966	1.347	15.913	4.628 ^a
18	-1.010	-1.409	14.903	4.243 ^a
19	2.513	3.505 ^a	17.416	4.859 ^a
20	0.128	0.179	17.544	4.799 ^a
21	-1.167	-1.628	16.377	4.396 ^a

Notes: ^{a, b, c} indicate the 1, 5, and 10 percent level of significance.

Table 4. Aggregate clean energy market's AARs and CAARs

Days	AAR	<i>t stat</i>_{AAR}	CAAR	<i>t stat</i>_{CAAR}
-5	0.906	0.730	0.906	0.730
-4	-0.669	-0.539	0.237	0.135
-3	0.348	0.280	0.585	0.272
-2	-0.594	-0.478	-0.009	-0.004
-1	1.149	0.926	1.140	0.411
0	7.965	6.416 ^a	9.105	7.334 ^a
1	-1.070	-0.862	8.035	2.446 ^b
2	6.447	5.193 ^a	14.481	4.124 ^a
3	0.785	0.632	15.266	4.099 ^a
4	-2.694	-2.170 ^b	12.572	3.202 ^a
5	-2.046	-1.648 ^c	10.526	2.556 ^b
6	1.769	1.425	12.295	2.859 ^a
7	6.946	5.595 ^a	19.241	4.298 ^a
8	8.320	6.701 ^a	27.561	5.933 ^a
9	-3.273	-2.636 ^a	24.288	5.051 ^a
10	-1.476	-1.189	22.812	4.594 ^a
11	0.734	0.591	23.545	4.600 ^a
12	-2.879	-2.319 ^a	20.666	3.924 ^a
13	0.162	0.131	20.828	3.849 ^a
14	-0.446	-0.359	20.382	3.671 ^a
15	-1.262	-1.016	19.121	3.361 ^a
16	-0.293	-0.236	18.828	3.233 ^a
17	-0.747	-0.602	18.081	3.037 ^a
18	0.061	0.049	18.141	2.983 ^a
19	-0.404	-0.326	17.737	2.857 ^a
20	0.003	0.002	17.740	2.802 ^a
21	-1.505	-1.212	16.235	2.517 ^b

Notes: ^a, ^b, ^c indicate the 1, 2, and 3 percent level of significance.

Table 5. Aggregate conventional energy market's AARs and CAARs

Days	AAR	<i>t stat</i> _{AAR}	CAAR	<i>t stat</i> _{CAAR}
-5	-1.671	-0.975	-1.671	-0.975
-4	0.349	0.204	-1.322	-0.546
-3	3.392	1.980 ^b	2.070	0.697
-2	-0.714	-0.417	1.356	0.396
-1	1.204	0.703	2.560	0.668
0	2.500	1.459	5.060	2.953
1	-4.600	-2.684 ^a	0.460	0.102
2	3.056	1.784	3.517	0.726
3	7.499	4.377 ^a	11.016	2.143
4	6.559	3.828 ^a	17.575	3.244 ^a
5	0.054	0.031	17.629	3.102 ^a
6	8.553	4.992 ^a	26.182	4.411 ^a
7	5.038	2.940 ^a	31.220	5.054 ^a
8	5.916	3.453 ^a	37.136	5.793 ^a
9	-11.831	-6.905 ^a	25.305	3.813 ^a
10	-1.944	-1.134	23.361	3.409 ^a
11	-2.130	-1.243	21.231	3.005 ^a
12	-3.906	-2.279 ^b	17.326	2.383 ^b
13	-6.657	-3.885 ^a	10.669	1.429
14	-1.850	-1.080	8.819	1.151
15	7.879	4.598 ^a	16.698	2.127 ^b
16	-0.183	-0.107	16.515	2.055 ^b
17	5.419	3.163 ^a	21.934	2.669 ^a
18	0.083	0.048	22.017	2.623 ^a
19	4.369	2.550 ^b	26.385	3.080 ^a
20	-1.179	-0.688	25.206	2.885 ^a
21	0.352	0.205	25.558	2.871 ^a

Notes: ^a, ^b, ^c indicate the 1, 2, and 3 percent level of significance.

Table 6. Aggregate metal market's AARs and CAARs

Days	AAR	<i>t stat</i> _{AAR}	CAAR	<i>t stat</i> _{CAAR}
-5	1.962	1.985 ^b	1.962	1.985 ^b
-4	0.096	0.098	2.058	1.472
-3	0.422	0.427	2.481	1.449
-2	0.645	0.653	3.126	1.581
-1	1.170	1.184	4.296	1.944 ^b
0	0.445	0.450	4.741	4.797 ^a
1	-2.330	-2.358 ^b	2.411	0.922
2	0.774	0.783	3.185	1.139
3	3.304	3.343 ^a	6.489	2.188 ^b
4	0.471	0.476	6.960	2.227 ^b
5	2.183	2.209 ^b	9.143	2.789 ^a
6	4.594	4.648 ^a	13.736	4.012 ^a
7	7.285	7.370 ^a	21.021	5.899 ^a
8	9.299	9.408 ^a	30.320	8.199 ^a
9	-10.402	-10.525 ^a	19.917	5.203 ^a
10	-0.123	-0.124	19.795	5.007 ^a
11	-0.010	-0.010	19.785	4.855 ^a
12	-3.543	-3.584 ^a	16.242	3.873 ^a
13	-1.251	-1.266	14.991	3.480 ^a
14	-2.025	-2.049 ^b	12.966	2.934 ^a
15	0.106	0.107	13.072	2.886 ^a
16	-2.170	-2.195 ^b	10.902	2.352 ^b
17	-0.336	-0.340	10.566	2.229 ^b
18	-2.523	-2.552 ^b	8.044	1.661
19	3.733	3.777 ^a	11.777	2.383 ^b
20	1.013	1.025	12.789	2.538 ^b
21	-1.808	-1.829	10.981	2.138 ^b

Notes: ^a, ^b, ^c indicate the 1, 5, and 10 percent level of significance.

Table 7. Cumulative abnormal returns (CAR) of clean energy markets

	SPGCE	ERIX	ICLN	SMOG	PBW	PBD	TAN	FAN
t-5	1.571 (1.202)	2.577 ^c (1.672)	1.030 (0.738)	0.833 (0.602)	-0.659 (-0.326)	0.410 (0.276)	0.710 (0.361)	0.778 (0.718)
t-3	0.790 (0.349)	-0.216 (-0.081)	1.276 (0.528)	0.597 (0.249)	-0.277 (-0.079)	0.729 (0.283)	1.183 (0.347)	0.596 (0.318)
t-1	1.934 ^c (0.662)	3.628 (1.052)	1.648 (0.529)	-0.347 (-0.112)	-1.289 (-0.285)	0.830 (0.250)	1.430 (0.325)	1.287 (0.531)
t+1	8.826 ^b (2.552)	13.849 ^a (3.395)	9.621 ^b (2.607)	3.940 (1.076)	4.682 (0.875)	5.863 (1.490)	9.027 ^c (1.734)	8.473 ^a (2.956)
t+3	17.351 ^a (4.425)	21.111 ^a (4.565)	17.538 ^a (4.191)	7.819 ^c (1.883)	12.706 ^b (2.093)	12.677 ^a (2.842)	21.699 ^a (3.677)	11.229 ^a (3.455)
t+5	12.615 ^a (2.910)	14.725 ^a (2.880)	12.800 ^a (2.767)	3.610 (0.786)	8.981 (1.338)	9.095 (1.844)	15.153 ^b (2.323)	7.232 ^b (2.013)
t+7	21.289 ^a (4.517)	25.899 ^a (4.659)	21.704 ^a (4.316)	9.578 ^c (1.919)	18.762 ^a (2.572)	16.354 ^a (3.050)	27.479 ^a (3.874)	12.863 ^a (3.293)
t+9	25.795 ^a (5.095)	30.901 ^a (5.176)	26.328 ^a (4.874)	13.258 ^b (2.473)	24.963 ^a (3.186)	22.972 ^a (3.988)	33.563 ^a (4.405)	16.522 ^a (3.938)
t+11	25.911 ^a (4.808)	32.233 ^a (5.071)	25.601 ^a (4.452)	9.961 ^c (1.745)	23.379 ^a (2.803)	22.992 ^a (3.750)	32.311 ^a (3.984)	15.975 ^a (3.576)
t+13	22.499 ^a (3.949)	28.116 ^a (4.184)	23.617 ^a (3.885)	8.280 (1.372)	20.342 ^a (2.307)	19.862 ^a (3.064)	29.325 ^a (3.420)	14.586 ^a (3.089)
t+15	20.733 ^a (3.461)	26.558 ^a (3.759)	20.826 ^a (3.258)	7.189 (1.133)	20.393 ^a (2.200)	18.934 ^a (2.778)	25.346 ^a (2.812)	12.988 ^a (2.616)
t+17	19.647 ^a (3.134)	24.904 ^a (3.369)	19.500 ^a (2.915)	6.581 (0.991)	20.290 ^a (2.091)	17.741 ^b (2.487)	24.460 ^a (2.593)	11.520 ^b (2.217)
t+19	19.614 ^a (3.001)	22.245 ^a (2.886)	19.147 ^a (2.746)	7.714 (1.115)	20.524 ^b (2.029)	17.891 ^b (2.406)	24.915 ^b (2.533)	9.846 ^b (1.818)
t+21	18.421 ^a (2.712)	20.198 ^b (2.521)	18.468 ^b (2.548)	5.637 (0.784)	19.271 ^c (1.833)	16.428 ^b (2.126)	22.252 ^b (2.177)	9.206 (1.635)

Notes: ^a, ^b, ^c indicate the 1, 5, and 10 percent level of significance and t-value are in brackets.

Table 8. Cumulative abnormal returns (CAR) of conventional energy markets

	Brent	WTI	Gas Oil	Gasoline	Heating Oil	Natural Gas
t-5	-0.879 (-0.587)	-0.879 (-0.539)	-2.443 (-1.464)	0.030 (0.02)	-1.745 (-1.199)	-4.110 (-1.069)
t-3	2.234 (0.861)	0.659 (0.233)	-0.433 (-0.15)	9.399 ^a (3.528)	-0.699 (-0.277)	1.260 (0.189)
t-1	5.119 (1.528)	1.536 (0.422)	1.655 (0.444)	5.408 (1.572)	0.979 (0.301)	0.663 (0.077)
t+1	4.147 (1.046)	-1.340 (-0.311)	0.703 (0.159)	3.469 (0.852)	-0.033 (-0.009)	-4.184 (-0.411)
t+3	11.889 ^a (2.645)	11.925 ^b (2.44)	15.702 ^a (3.137)	17.203 ^a (3.728)	10.676 ^c (2.446)	-1.297 (-0.112)
t+5	16.531 ^a (3.327)	15.390 ^a (2.849)	28.344 ^a (5.122)	22.916 ^a (4.492)	21.115 ^a (4.376)	1.480 (0.116)
t+7	31.275 ^a (5.79)	29.847 ^a (5.082)	49.082 ^a (8.159)	35.174 ^a (6.343)	35.311 ^a (6.731)	6.634 (0.478)
t+9	19.814 ^a (3.415)	18.935 ^a (3.001)	63.996 ^a (9.904)	25.621 ^a (4.301)	24.730 ^a (4.389)	-1.268 (-0.085)
t+11	21.829 ^a (3.534)	20.219 ^a (3.01)	30.872 ^a (4.488)	27.045 ^a (4.265)	23.881 ^a (3.981)	3.542 (0.223)
t+13	9.497 (1.454)	7.311 (1.03)	19.165 ^a (2.635)	16.738 ^b (2.497)	11.569 ^c (1.824)	-0.265 (-0.016)
t+15	11.802 ^c (1.719)	9.183 (1.23)	31.473 ^a (4.116)	19.552 ^a (2.774)	22.713 ^a (3.407)	5.463 (0.31)
t+17	18.892 ^a (2.629)	16.566 ^b (2.12)	39.728 ^a (4.965)	23.178 ^a (3.142)	30.432 ^a (4.361)	2.806 (0.152)
t+19	23.271 ^a (3.107)	18.193 ^b (2.234)	45.545 ^a (5.46)	24.488 ^a (3.184)	37.834 ^a (5.201)	8.982 (0.467)
t+21	21.196 ^a (2.723)	15.870 ^c (1.875)	40.974 ^a (4.726)	24.192 ^a (3.027)	36.687 ^a (4.853)	14.430 (0.722)

Notes: ^{a, b, c} indicate the 1, 5, and 10 percent level of significance and t-value are in brackets..

Table 9. Cumulative abnormal returns (CAR) of precious and industrial metals

	Gold	Silver	Plat	Pall	Copp	Alum	Zinc	Lead	Nickel	Tin
t-5	1.669 ^c (2.047)	1.719 (1.330)	4.631 ^a (3.495)	4.633 ^b (2.355)	0.906 (0.729)	0.536 (0.402)	1.226 (0.930)	0.670 (0.680)	2.948 ^b (2.058)	0.678 (0.556)
t-3	2.193 (1.552)	2.649 (1.184)	4.373 ^c (1.905)	6.823 ^b (2.002)	0.700 (0.325)	0.805 (0.348)	0.153 (0.067)	0.393 (0.230)	5.356 ^b (2.159)	1.361 (0.644)
t-1	2.146 (1.177)	5.793 ^b (2.005)	6.657 ^b (2.246)	12.053 ^a (2.740)	2.538 (0.914)	1.340 (0.449)	1.312 (0.445)	0.913 (0.414)	6.725 ^b (2.100)	3.484 (1.278)
t+1	0.824 (0.382)	2.689 (0.787)	1.794 (0.512)	6.071 (1.166)	0.758 (0.231)	2.569 (0.727)	1.395 (0.400)	1.856 (0.711)	4.902 (1.293)	1.249 (0.387)
t+3	3.788 (1.548)	9.479 ^b (2.446)	2.668 (0.671)	16.802 ^a (2.847)	4.257 (1.143)	6.103 (1.523)	5.160 (1.305)	3.832 (1.296)	8.564 ^b (1.993)	4.233 (1.157)
t+5	3.317 (1.226)	8.059 ^c (1.881)	4.370 (0.994)	22.405 ^a (3.433)	7.859 ^c (1.908)	12.432 ^a (2.807)	9.267 ^b (2.119)	3.688 (1.128)	15.017 ^a (3.161)	5.014 (1.240)
t+7	6.544 (2.226)	11.876 ^b (2.549)	12.149 ^b (2.543)	33.787 ^a (4.763)	10.650 ^b (2.379)	13.863 ^a (2.879)	16.164 ^a (3.400)	6.399 ^c (1.800)	91.713 ^a (17.757)	7.065 (1.607)
t+9	6.075 ^b (1.923)	11.655 ^b (2.329)	8.212 (1.600)	32.079 ^a (4.210)	5.534 (1.151)	2.112 (0.408)	10.639 ^b (2.083)	4.236 (1.109)	117.838 ^a (21.240)	0.795 (0.168)
t+11	5.917 ^b (1.760)	13.469 ^b (2.528)	8.273 (1.514)	28.535 ^a (3.518)	7.611 (1.486)	6.253 (1.136)	7.744 (1.425)	1.134 (0.279)	118.340 ^a (20.037)	0.574 (0.114)
t+13	3.043 (0.856)	9.524 ^c (1.691)	-2.151 (-0.372)	14.831 ^c (1.729)	4.867 (0.899)	-0.105 (-0.018)	6.843 (1.191)	-2.568 (-0.597)	117.835 ^a (18.872)	-2.207 (-0.415)
t+15	3.485 (0.933)	9.533 (1.610)	-1.132 (-0.186)	17.460 ^c (1.936)	4.926 (0.866)	1.753 (0.287)	4.752 (0.787)	-3.287 (-0.727)	101.020 ^a (15.389)	-7.789 (-1.394)
t+17	2.682 (0.686)	8.013 (1.293)	-0.680 (-0.107)	17.275 ^c (1.831)	4.254 (0.714)	5.242 (0.819)	6.945 (1.098)	-3.210 (-0.679)	73.609 ^a (10.715)	-8.465 (-1.448)
t+19	3.014 (0.739)	7.387 (1.144)	-2.777 (-0.419)	15.377 (1.563)	5.229 (0.842)	8.579 (1.285)	10.546 (1.600)	1.601 (0.325)	77.130 ^a (10.769)	-8.321 (-1.365)
t+21	3.789 (0.894)	8.722 (1.299)	-5.551 (-0.806)	7.136 (0.698)	2.657 (0.412)	6.692 (0.964)	8.894 (1.298)	-1.248 (-0.244)	86.325 ^a (11.598)	-7.600 (-1.200)

Notes: ^{a, b, c} indicate the 1, 5, and 10 percent level of significance and t-value are in brackets.