

Article

Energy Supply Shock on European Stock Markets: Evidence from the Russia–Ukraine War

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Abstract: This study empirically investigates the impacts of the Russia–Ukraine war on the performance of brown and green stocks in Europe. Analyzing stocks listed on exchanges in 25 European countries, we find that, prior to this war, stocks of more energy-dependent firms (brown stocks) yielded higher returns compared to those of less energy-dependent firms (green stocks). However, after the unexpected Russian invasion, brown stocks underperformed relative to green stocks. As the conflict reached a stalemate and energy supplies were restored, brown stocks regained their advantage over green stocks. Additionally, brown stocks exhibited greater volatility following the invasion. Utilizing various factor models, we identify a pronounced negative energy risk premium during the initial Russia–Ukraine war outbreak period. This study highlights the dynamic stock market responses to energy supply and regulatory changes in Europe, reflecting the market’s evolving perception of energy supply risks and regulatory risks linked to the transition towards a net-zero economy.

Keywords: Russia–Ukraine war; stock markets; energy supply; carbon risk transition; event study

JEL Classification: G11; G12; G18; E52; E58



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1. Introduction

On 24 February 2022, Russia initiated a “special military operation” in Ukraine. The outbreak of the Russia–Ukraine military conflict had a severe impact on the financial markets, with nearly all stock markets worldwide being negatively impacted. Among them, European equity markets have been most affected, given Russia’s critical role as Europe’s leading energy supplier—in 2021, Russia was the world’s largest exporter of natural gas and the second-largest exporter of crude oil¹. The conflict has disrupted energy supplies in Europe, leading to surging energy prices. To reduce reliance on Russian supplies, major European nations, such as Germany and France, are considering extending and reopening coal-fired power plants.² The unexpected war and the ensuing energy shortage has complicated the transition path to a net-zero emission economy in the short term. However, in the long term, the war amplifies calls for an accelerated energy transition for improved energy efficiency and adopting alternatives to fossil fuels. Investors incorporate these net-zero transition innovations into their investment decision calculus.

According to the survey by [Krueger et al. \(2020\)](#), institutional investors believe climate-related regulatory risks have already begun to materialize. Investors have channeled trillions of dollars to portfolios consisting of sustainable (green) assets from unsustainable (brown) assets in recent years.³ A major driving force is the EU's ambition for an economy with net-zero greenhouse gas emissions by 2050, which is the objective of the European Green Deal and in line with the Paris Agreement.⁴ The energy supply disruption caused by the Russia–Ukraine war may adversely affect market confidence in the EU's commitment to a net-zero transition, thus slowing down sustainable investment.

This study empirically investigates the impacts of the Russia–Ukraine war on the performance of brown and green stocks in Europe. By analyzing the cross-sectional stock performance during the first half of 2022, we find that brown stocks are associated with higher risk-adjusted returns before the war. However, brown stocks underperformed compared to green ones following the unexpected Russian invasion. As war becomes the new norm and energy supplies are restored, companies in traditional energy sectors (brown stocks) begin to outperform their environmentally friendly (green) counterparts once again. Perhaps not surprisingly, we also find brown stocks experienced a higher level of volatility after the Russian invasion.

In addition, we study the evolving energy risk premium in EU stock markets as the Russia–Ukraine war unfolds. We sort firms by energy consumption and construct a brown (high-energy consumption) minus green (low-energy consumption), or BMG, portfolio. This portfolio can be interpreted as a zero-cost investment strategy of long brown stocks and short green stocks. We derive risk-adjusted returns based on various factor models and find consistent evidence that the brown portfolio underperforms compared to the green portfolio during a short period after the war outbreak. These returns cannot be fully explained by well-known Fama–French risk factors, such as market size, book-to-market ratio, operating profitability, and investment. Our results suggest the existence of a negative energy risk premium, ranging from 1.278% to 1.996% depending on the factor models, reflecting a market preference for energy-efficient stocks when market participants have concerns over the adverse impact of energy supply disruption on energy-dependent firms.

Our study makes three contributions to the existing literature. First, it provides empirical evidence of the relationship between a firm's environmental performance and its stock returns. Existing literature yields conflicting findings. [Hsu et al. \(2023\)](#) reveal that high-polluting firms are more exposed to environmental regulation risks, with their stocks delivering substantially higher average returns that cannot be explained by common systematic risk factors. By contrast, [In et al. \(2017\)](#) consider a different sample period and find that portfolios consisting of long positions in carbon-efficient stocks and short positions in carbon-inefficient stocks generate positive alphas. [Garvey et al. \(2018\)](#) document that reduced carbon ratios are associated with positive stock returns in a global universe of stocks. Our empirical evidence is unique inasmuch as it illustrates how an unfolding energy supply shock affects the relationship.

Second, we contribute to the study of the financial/equity market implications of the Russia–Ukraine war. This study reveals the dynamic responses of stock markets to the evolving disruption of energy supply. As European countries phase out new policies and actions in order to mitigate the energy supply shock, stock markets incorporate them and reevaluate stocks accordingly.

Third, our study provides empirical evidence of the relationship between the stages of conflict (pre-war, outbreak, stalemate) and market risk premiums. Although events such as wars are arguably infrequent, their potential for causing significant damage prompts investors to demand higher returns on equities in order to compensate for the risk of such rare disasters. Brown stocks are associated with higher risk-adjusted returns during

pre-war and stalemate periods, which provides empirical evidence of how investors view tail risks. Using several models, we build a brown-minus-green (BMG) portfolio based on firms' energy consumption and we find a negative energy risk premium during the outbreak stage. This finding, moreover, indicates that when those extreme events occur, investors rapidly react and sell stocks of energy-dependent firms.

The remainder of the paper proceeds as follows. Section 2 describes the literature review and hypotheses development. Section 3 describes data and methodology. Section 4 presents the estimation results. Specifically, we discuss the relationship between firms' stock performance and energy consumption. We also quantify the energy risk premium using factor models in Section 4. In Section 5, we present our conclusions.

2. Literature Review and Hypotheses Development

This study is related to several strands of the literature. Firstly, it aligns with the literature on rare events in financial markets and how investors price tail risk. Despite their infrequency, these events—such as natural disasters, wars, terrorist attacks, COVID-19-pandemic-type events, and the Global Financial Crisis—can cause significant damage (Pagnotoni et al., 2022; Hudson & Urquhart, 2015; Brounen & Derwall, 2010; Drakos, 2010; Akhtaruzzaman et al., 2021; Bekaert et al., 2014).

Previous studies have analyzed stock market reactions to the conflict between Ukraine and Russia, but most of them have analyzed commodities, geopolitical shocks, and other macroeconomic factors. For instance, Obi et al. (2023) find that abnormal losses in the initial period of the conflict were larger and more persistent in the G7 markets, contradicting the widely held notion that more developed equity markets are more efficient than the less developed markets, while Boungou and Yatié (2022) identify a significant negative effect of the armed conflict between Ukraine and Russia on global stock returns. Huang et al. (2022) reveal that sanctions against Russia result in an average loss of 2.39% in stock markets. Boubaker et al. (2022) discover that the Russian invasion generated negative abnormal returns for global stock market indices. Yousaf et al. (2022) demonstrate that European and Asian regions are significantly and adversely affected by the invasion. Das et al. (2023) also show that the Ukraine–Russia conflict negatively impacts stock returns in the EU. Other studies, such as Ahmed et al. (2023); Federle et al. (2025).

Specifically, existing findings suggest a directional impact: conflict has a negative effect on stock returns. Our study also contributes to the existing literature on this topic, but unlike previous studies, we also investigate other unexplored aspects. For example, this study uncovers the dynamic responses of stock markets to the evolution of energy supply disruption. As European countries phase out new policies and actions to mitigate the energy supply shock, stock markets incorporate them and reprice stocks accordingly. Our paper provides empirical evidence of the relationship between conflict phases (pre-war, outbreak, stalemate) and market risk premiums. Using different models, we construct a brown-minus-green (BMG) portfolio based on firms' energy consumption and find a negative energy risk premium during the outbreak phase. We also examine the pricing of climate risks. For instance, Cao et al. (2024) and Ni and Sun (2023) report that firms with poor environmental performance deliver higher returns. Similarly, Hsu et al. (2023) find that firms with high toxic emission intensity exhibit higher returns. Bolton and Kacperczyk (2021) utilize carbon dioxide emissions as an indicator of transition risk, discovering that firms with higher emissions tend to have stocks that yield higher returns. Overall, these studies argue that firms exposed to greater regulatory risk are expected to provide higher returns to compensate investors for the extra risk they bear.

Concerning the Russia–Ukraine war regarding the environmental factor, very few papers have studied this topic. Nerlinger and Utz (2022) investigate whether the Russia–

Ukraine conflict has affected investors' assessment concerning a green energy transition and find positive cumulative abnormal returns for energy firms, in particular, for North American firms as compared to European and Asian ones. Similarly, Umar et al. (2022) find a significant increase in the anomalous returns associated with the renewable energy industry at the onset of the Russia–Ukraine war. Das et al. (2023) find a more pronounced negative impact in the mining, construction, and manufacturing sectors, which are more likely to face greater challenges due to disruptions caused by the conflict. Singh et al. (2022) studied how the conflict influenced investor preferences and found that investor preference for energy and the aerospace and defense sectors has increased. Kick and Rottmann (2022) find that the abnormal returns of companies with high ecological scores are positively influenced in the pre- and post-war windows. However, the magnitude is of economic irrelevance. Deng et al. (2022) argue that stocks strongly exposed to the regulatory risks of the transition to a low-carbon economy outperform their counterparties.

After the initial chaos, the EU quickly managed to find alternative energy supplies and ensured sufficient energy supply.⁵ Since we believe that results can change according to the period, based on previous empirical studies, we build our first hypothesis as follows:

H1. *Stocks of energy-dependent firms experience lower risk-adjusted returns during the outbreak period.*

Military conflicts increase investors' uncertainty about a firm's future profitability, leading to greater fluctuations in stock prices. Previous studies have examined the relationship between conflict and market volatility. For instance, Izzeldin et al. (2023) and Bougias et al. (2022) find that the Russia–Ukraine war results in higher volatility in financial markets. Lo et al. (2022) claim that countries that are dependent on Russian commodities suffer from sinking stock returns and intensifying instability. However, several studies, examining returns and volatility, differentiate by periods around the event. Wu et al. (2023), differentiating by periods and countries, find that volatility reduces initially, before the conflict, and subsequently increases after the invasion. They also find significant differences between the equity-price volatility of NATO and non-NATO countries. Gheorghe and Panazan (2023) investigate some countries neighboring Ukraine (i.e., Hungary, Poland, Serbia, Bosnia and Herzegovina, and the Czech Republic) and find a preview of pre-conflict volatility. In particular, their results show a higher level of volatility before the conflict and a lower level in the days close to the conflict. Based on previous studies we formulate our second hypothesis:

H2. *Stocks of energy-dependent firms experience higher volatility during the outbreak period.*

3. Data and Methodology

The Russian invasion began on 24 February 2022, following an escalation of conflict and diplomatic efforts starting in early January of 2022. Figure 1, based on Google Trend data, shows that worldwide searches for “Ukraine”, “Russia invasion”, “Russia–Ukraine war” started to increase in January and peaked during the week of 24 February. The search activity quickly dropped in March and April and stabilized in May and June. Our study covers the period from January 2022 to June 2022, divided into three periods: pre-war (3 January–23 February), outbreak (24 February–31 March), and stalemate (1 April–30 June).

In this study, we focus on stocks listed in exchanges in European Union (EU) countries, European Economic Area countries (Iceland, Liechtenstein, Norway, and Switzerland), one candidate country (Turkey), and one former member country (United Kingdom, UK). We include the UK due to its past influential EU membership and numerous and extensive ongoing economic connections with EU countries post-Brexit. After cleaning some missing data, our final sample includes 1770 firms in 10 industries from 25 European countries.

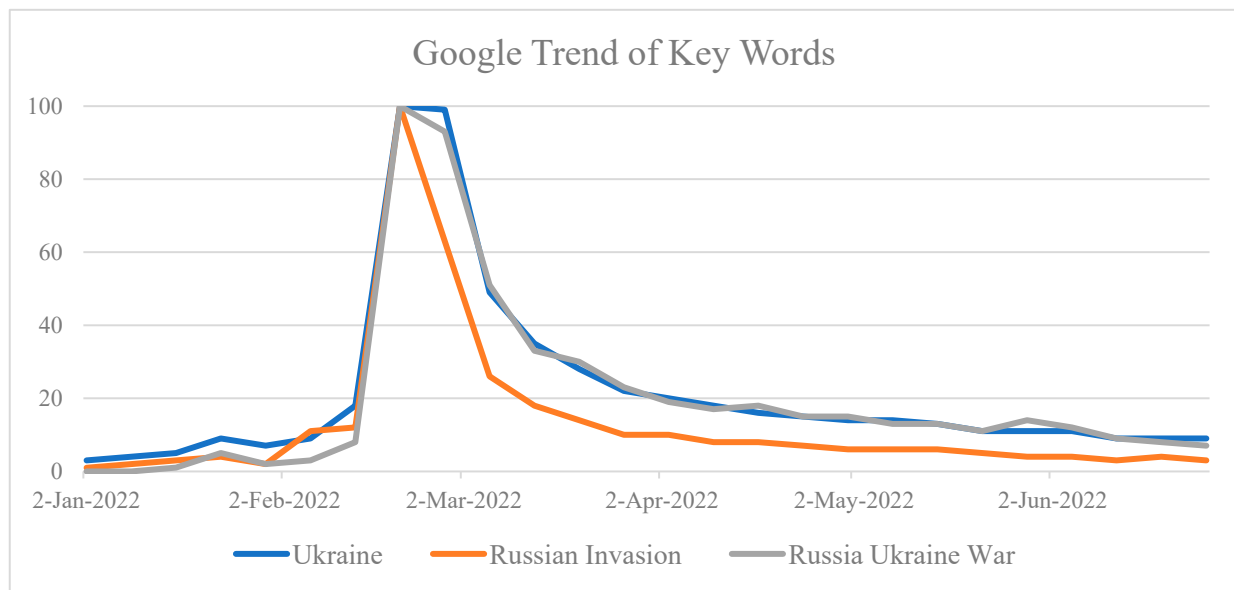


Figure 1. Google trend of Russia–Ukraine-war-related keywords. The figure above illustrates the popularity of search terms “Ukraine”, “Russian Invasion”, and “Russia–Ukraine War” on Google Trends⁶ from 2 January 2022 to 30 June 2022. The index is scaled with a maximum value of 100.

The most important variables, firms’ carbon emissions and energy consumption, are collected from the Refinitive ESG database. Stock and financial data are from the Reuters Worldscope database. It should be noted that, except for the stock prices, stock return returns, and dividends, which are reported daily, other accounting data are on an annual basis.

Descriptive statistics for the variables used in our analysis are provided in Panel A of Table 1. The average daily stock return is negative, at -0.15% , indicating a declining stock market during the sample period. The average market capitalization is USD 6437.88 million. We use the logarithm of two key variables, carbon emissions and energy consumption, due to the variability in their original values. The ratios of carbon emissions and energy consumption to market capitalization show large standard deviations. Investment, defined as the firm’s capital expenditures divided by the book value of its assets, has a mean of 0.04. Sales per share have a mean value of 0.91.

We also report the descriptive statistics for green stocks and brown stocks in Panels B and C, respectively. Not surprisingly, brown stocks exhibit higher energy consumption and carbon emissions, along with lower energy efficiency, as measured by energy/market cap. In terms of financial performance, brown firms tend to have larger market capitalizations, higher book-to-market ratios, greater investments, higher sales, and lower returns on equity.

We then examine the carbon emissions and energy consumption in each industry. As shown in Panel D of Table 1, carbon emission and energy consumption are disproportionately distributed across industries⁷. The basic materials industry has the most carbon emissions and energy consumption per firm, followed by the utilities and energy industries. The healthcare and technology firms on average are the most energy efficient.

To examine the first hypothesis (H1), we examine the relationship between energy consumption and stock returns. We use the cumulative abnormal returns, $CAR_{i,t}$, of individual stock i for period t , including pre-war (3 January–23 February), outbreak (24 February–31 March), and stalemate (1 April–30 June). Our expectation is that firms with higher energy consumption are more vulnerable to energy shortage and price volatility. The sudden Russian invasion disrupted the energy supply in the EU and caused market concerns over the EU’s dependence on Russian energy during the outbreak period.

Table 1. Summary Statistics. This table reports the statistics for the variables in our analysis. Our sample consists of 1770 firms in 10 industries from 25 European countries. Panel A reports firm-level variables from Refinitive ESG and Reuters Worldscope databases. Market Cap is the market capitalization (stock price times shares outstanding), Book-to-Market Ratio is the book-to-market ratio, Investment represents the firm’s capital expenditures divided by the book value of its assets, Sales is the sales per share, and ROE is the return on equity. We also report the same set of variables for green stocks and brown stocks in Panels B and C, respectively. Panel D reports the carbon emissions and energy consumption in each industry.

Panel A: Statistics of variables, all stocks					
Variables	Mean	Standard Deviation	25th percentile	Median	75th percentile
Stock Ret	−0.15	2.54	−1.51	0.00	1.19
Log(Energy Consumption)	9.37	2.96	7.18	9.21	11.45
Log(Carbon Emission)	12.86	2.82	10.89	12.81	14.84
Energy/Market Cap	100.07	275.39	1.04	5.29	38.93
Carbon/Market Cap	1858.07	4911.81	25.61	132.02	798.11
Market Cap (in USD million)	6437.88	12,496.64	536.78	1606.44	5386.47
Book-to-Market Ratio	1.45	2.28	0.26	0.59	1.29
Invest	0.04	0.06	0.00	0.02	0.05
Sales	0.91	1.03	0.20	0.53	1.23
ROE	0.13	0.24	0.04	0.13	0.23
Panel B: Statistics of variables, green stocks					
Variables	Mean	Standard Deviation	25th percentile	Median	75th percentile
Stock Ret	−0.17	2.53	−1.53	0.00	1.16
Log(Energy Consumption)	7.23	1.75	5.95	7.49	8.32
Log(Carbon Emission)	9.76	1.38	8.74	10.12	10.9
Energy/Market Cap	11.55	47.5	0.32	1.42	4.5
Carbon/Market Cap	55.30	114.65	4.82	18.18	49.38
Market Cap (in USD million)	2682.89	5808.04	400.79	996.17	2747.47
Book-to-Market Ratio	1.09	1.86	0.18	0.43	0.99
Invest	0.02	0.05	0.002	0.008	0.023
Sales	0.66	0.74	0.18	0.39	0.85
ROE	0.15	0.23	0.006	0.13	0.26
Panel C: Statistics of variables, brown stocks					
Variables	Mean	Standard Deviation	25th percentile	Median	75th percentile
Stock Ret	−0.08	2.46	−1.42	0.00	1.27
Log(Energy Consumption)	13.14	1.64	12.13	12.94	14.39
Log(Carbon Emission)	16.00	1.42	14.84	15.66	17.02
Energy/Market Cap	321.92	449.35	18.55	103.13	417.33
Carbon/Market Cap	5208.96	7523.93	345.56	1519.77	6564.48
Market Cap (in USD million)	15,336.45	19,359.49	1918.32	6075.25	19,878.41
Book-to-Market Ratio	1.61	2.59	0.31	0.57	1.32
Invest	0.08	0.07	0.03	0.06	0.11
Sales	1.32	1.17	0.45	0.95	1.78
ROE	0.12	0.26	0.08	0.15	0.27
Panel D: Carbon emission and energy consumption across industries					
Industry	# of Obs.	Average Carbon Emission		Average Energy Consumption	
Basic Materials	128	1093.40		11,508.36	
Consumer Cyclicals	276	55.74		3044.16	
Consumer Non-Cyclicals	110	162.39		2298.13	
Energy	65	444.87		6846.69	
Financials	284	47.58		684.40	
Healthcare	144	9.46		228.78	
Industrials	353	170.25		2144.17	
Real Estate	106	18.30		354.17	
Technology	259	15.79		150.16	
Utilities	45	543.93		8453.90	

To capture the relationship between energy consumption and cumulative abnormal returns, we use the following empirical specification:

$$CAR_{i,t} = \alpha + \beta \times \log(\text{EnergyConsumption}_i) + X_i + e_{i,t}. \quad (1)$$

The dependent variable, $CAR_{i,t}$, is the cumulative abnormal return for each period—pre-war, outbreak, and stalemate. We calculate the cumulative abnormal returns (CARs) using the capital asset pricing model (CAPM). First, we estimate the alpha ($\hat{\alpha}_i$) and beta ($\hat{\beta}_i$) for each stock using daily stock returns ($R_{i,t}$), market index returns ($M_{i,t}$), and risk-free rates (r_t) from the year 2021. Using these estimated parameters, we then compute the daily abnormal returns for each stock, $AR_{i,t} = R_{i,t} - [\hat{\alpha}_i + \hat{\beta}_i(M_{i,t} - r_t)]$, during the specified periods in 2022. The cumulative abnormal return for each stock is then obtained by compounding the daily abnormal returns over the corresponding periods, $CAR_i(t_1, t_2) = \prod_{t_1}^{t_2} (1 + AR_{i,t}) - 1$. The independent variable is the logarithm of the firm's energy consumption. The control variables, X_i , are defined as follows: Log(Market Cap) is the logarithm of market capitalization (stock price times shares outstanding), Book-to-Market Ratio is the book-to-market ratio, Investment represents the firm's capital expenditures divided by the book value of its assets, Sales is the sales per share, and ROE is the return on equity. The independent and control variables are as of 2022. As noted in Panel D of Table 1, these effects could be driven by differences among industries. To address this concern, we incorporated industry-fixed effects. Additionally, we included country-fixed effects to account for time-invariant country-specific factors.

To examine the second hypothesis (H2) regarding how the Russia–Ukraine war affects the stock price volatility of firms having different energy dependence and efficiency, we use the following formula:

$$Vol_{i,t} = \alpha + \beta \times \log(\text{EnergyConsumption}_i) + X_i + e_{i,t}. \quad (2)$$

The dependent variable, $Vol_{i,t}$, is the standard deviation of daily stock returns for each period (pre-war, outbreak, and stalemate). The independent and control variables are the same as described for Equation (1).

Evolving Energy Risk Premium

Different from previous studies, this study also investigates the evolving energy risk premium in EU stock markets as the Russia–Ukraine war unfolds. To address this task, we build portfolios by energy consumption and then calculate the value-weighted portfolio returns for the corresponding high energy consumption (brown) minus low energy consumption (green). We derive risk-adjusted returns based on various factor models and find consistent evidence that the brown portfolio underperforms compared to the green portfolio during the outbreak period, which cannot be explained by well-known, i.e., conventional, risk factors and thus is suggestive of the existence of a negative energy risk premium.

We first categorize the stocks by their previous year's energy consumption volume and take the top 33% as brown stocks, the middle 34% as neutral stocks, and the bottom 33% as green stocks and then build each category (brown, neutral, and green) portfolio by their respective market capitalizations.

As shown in Figure 2, the brown portfolio outperforms the green portfolio in the pre-war and stalemate periods but underperforms compared to the green portfolio in the outbreak period. The cumulative abnormal returns of brown and green portfolios are 8.26% versus −5.23% in the pre-war period, respectively. Their performance reverses to −2.37% versus 2.33% in the outbreak period. As the war enters the stalemate period, the

brown portfolio regains its advantage over the green portfolio, -0.90% versus -1.86% . We also categorize the stocks by their carbon emission and energy consumption scaled by firms' market capitalization and carbon emission scaled by firms' market capitalization, respectively. Similar estimation results are found and are available upon request.

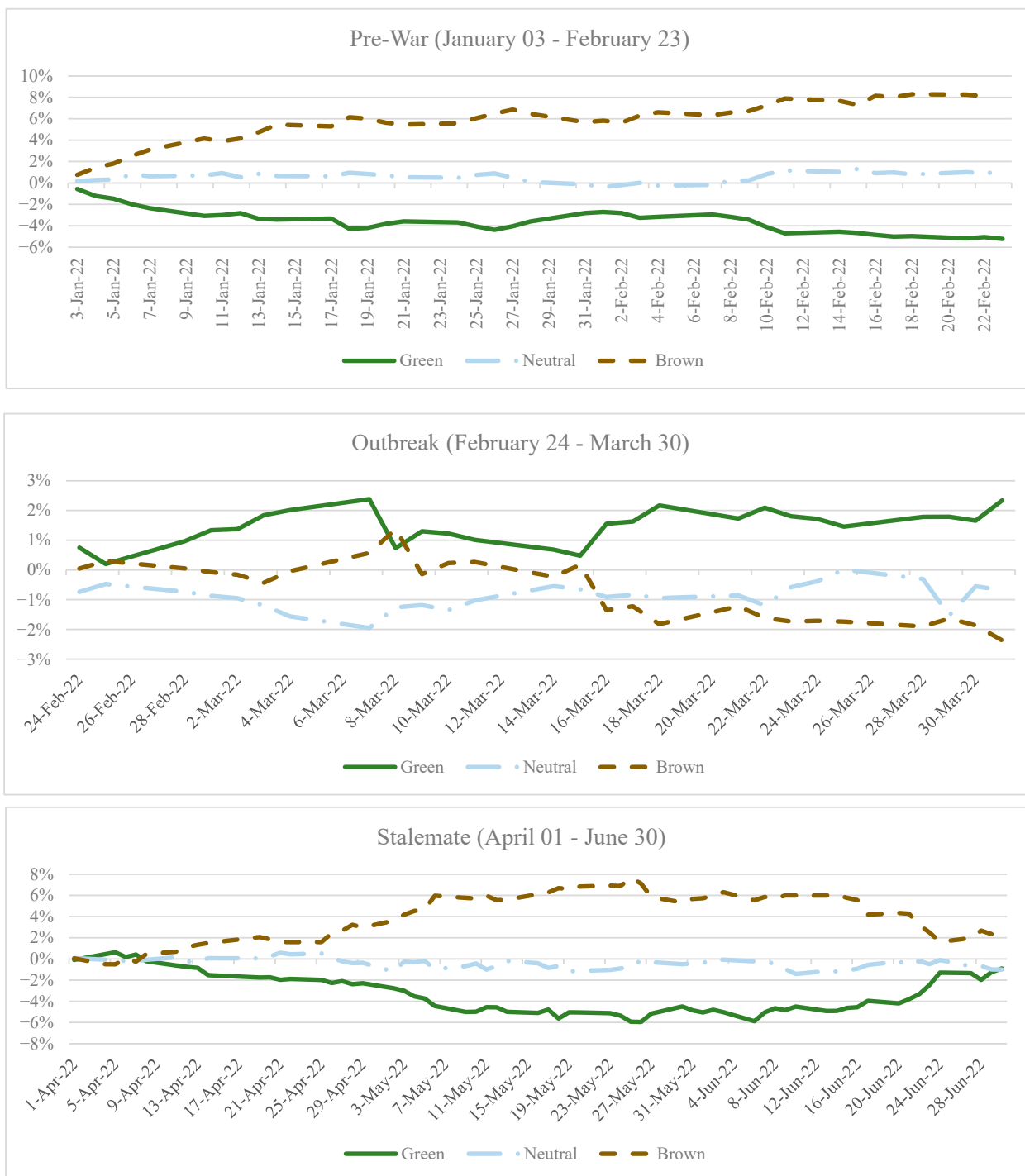


Figure 2. Cumulative abnormal returns of brown, neutral, and green portfolios. This figure presents the cumulative abnormal returns of brown, neutral, and green portfolios in three war phrases: pre-war (3 January–23 February), outbreak (24 February–31 March), and stalemate (1 April–30 June). The stocks are categorized based on their energy consumption levels, with the top 33% categorized as brown stocks, the middle 34% as neutral stocks, and the bottom 33% as green stocks. Each portfolio, namely the brown, neutral, and green portfolios, consists of stocks from their respective category weighted by their market capitalizations.

4. Empirical Results

The first three columns of Table 2 present the energy consumption data. Our analysis shows that stocks of companies with higher energy consumption experience higher risk-adjusted returns during the pre-war and stalemate periods but lower returns during the outbreak period. These findings are both statistically and economically significant. Specifically, a one standard deviation (2.96) increase in Log(energy consumption) is associated with 4.23 percentage point and 3.06 percentage point higher stock returns during the pre-war and stalemate periods, respectively. Conversely, the same increase leads to 3.37 percentage point lower stock returns during the outbreak period.

Table 2. Cross-sectional regression of cumulative abnormal returns on energy consumption. This table represents the results of cross-sectional regressions of stock cumulative abnormal returns on energy consumption. The dependent variable is the cumulative abnormal returns for each of the pre-war, outbreak, and stalemate periods. The independent variable is the logarithm of a firm's energy consumption for columns (1–3) and energy consumption scaled by market capitalization for columns (4–6). Control variables are as described in Table 1. *p* values, calculated using the robust standard errors, are in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Dependent Variable: Cumulative Abnormal Return						
Period	Pre-War	Outbreak	Stalemate	Pre-War	Outbreak	Stalemate
Log(Energy Consumption)	1.429 *** (0.262)	−1.137 *** (0.296)	1.033 *** (0.317)			
Energy Consumption/Market Cap				0.154 (0.275)	−0.803 *** (0.307)	0.156 (0.378)
Log(Market Cap)	−0.861 ** (0.406)	0.642 (0.460)	−0.604 (0.491)	0.387 (0.345)	−0.171 (0.385)	0.284 (0.412)
Book-to-Market Ratio	−0.002 (0.002)	−0.005 *** (0.002)	−0.001 (0.002)	−0.002 (0.002)	−0.005 *** (0.002)	−0.001 (0.002)
Investment	1.284 (2.802)	2.037 (3.172)	−5.222 (3.378)	4.194 (2.794)	−0.012 (3.123)	−3.187 (3.332)
Sales	0.411 (0.380)	−0.358 (0.430)	−0.898 * (0.459)	1.008 *** (0.371)	−0.745 * (0.414)	−0.481 (0.443)
ROE	0.000 (0.002)	0.001 (0.002)	−0.001 (0.002)	0.001 (0.002)	0.001 (0.002)	−0.001 (0.002)
Constant	5.198 (11.924)	−7.721 (13.491)	2.682 (14.371)	−5.503 (12.016)	−2.973 (13.427)	−4.774 (14.324)
Country and Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1770	1770	1770	1770	1770	1770
R-squared	0.205	0.145	0.150	0.177	0.137	0.140

Stocks of more energy-dependent firms underperformed during the outbreak period, reflecting the lack of market confidence in sufficient energy supply. On March 8, the European Commission unveils REPowerEU, a plan to reduce dependence on Russian natural gas by two-thirds by the end of the year. On March 25, EU leaders agree to phase out the EU's dependence on Russian fossil fuels as soon as possible. Meanwhile, the EU imposes multiple sanctions against Russia, banning transactions with major Russian enterprises. Clearly, the outbreak of the Ukraine–Russia war disrupts the EU's energy supply. Energy-dependent firms suffer more shocks than their energy-efficient peers. Their operations are compromised, and outlooks are diminishing. Investors sold their stocks to avoid uncertainty. The war also disrupts the EU's transition to a green economy, and investors question the EU's commitment to clean energy. As the EU's economy leaders, Germany and France, plan to reopen coal-fired power plants, the market predicts relaxed regulations on traditional energy and carbon emissions. As interpreted regulation risk diminishes, investors require a lower compensation risk premium. In the stalemate

period, brown stocks regained their advantage as the EU introduced policies to ensure energy supply, including diversifying energy supply sources and routes, accelerating the deployment of renewables, improving energy efficiency, and so forth.⁸ The EU managed to largely shift its energy import from Russia to other partners and import more energy products in the first half of 2022 as compared to 2021.⁹ Adequate energy supply ensures the smooth operation and profitability of energy-dependent firms, benefiting their stock performance and hence shareholders and employees.

The level of energy consumption serves as an indicator of a firm's dependence on energy. However, larger companies might consume more energy than smaller ones, even if they are more environmentally friendly. To account for the size effect, we scale a firm's energy consumption by its market capitalization, using this ratio as a measure of energy efficiency. We then perform a cross-sectional regression with the energy efficiency measure as the independent variable. The results are presented in columns (4) to (6) of Table 2. We find that energy-efficient firms significantly outperformed during the outbreak period, while no significant results were found for the pre-war and stalemate periods. These results indicate that investors are more aware of environmental sustainability during the crisis periods.

Another legitimate concern is that some firms use more clean energy. The level of energy consumption may not accurately reflect a firm's reliance on traditional fossil fuels, whose supply is/has been compromised by the Russia–Ukraine war. To address this issue, we use carbon emissions as the independent variable and repeat our analysis. The results, shown in the first three columns of Table 3, are consistent with those in Table 2. We find significantly higher cumulative abnormal stock returns for companies with higher carbon emission levels during the pre-war and stalemate periods but lower stock returns during the outbreak period. A standard deviation (2.82) increase in Log(Carbon Emission) is associated with 5.36 percentage point and 2.94 percentage point increases in stock cumulative abnormal returns during the pre-war and stalemate periods, respectively. Conversely, the same increase results in a 3.49 percentage point *decrease* in stock returns during the outbreak period.

The findings of the higher returns of energy-dependent and inefficient stocks during the pre-war and stalemate periods are consistent with previous literature. [Cao et al. \(2024\)](#) and [Ni and Sun \(2023\)](#) report that firms with poor environmental performance deliver higher returns. Similarly, [Hsu et al. \(2023\)](#) find that firms with high toxic emission intensity exhibit higher returns. These studies argue that firms exposed to greater regulatory risk are expected to provide higher returns to compensate investors for the extra risk they bear. As the war enters the stalemate period, the EU shifts away from its dependence on Russian energy and clarifies its long-term commitment to clean and renewal energy, and environmental regulation risk is reincorporated with asset prices by capital markets.

Similarly, we also adopt the ratio of carbon emissions to market capitalization as the key independent variable (columns (4) to (6) of Table 3) to remove the size impact and find that firms with higher carbon emissions relative to their size underperformed during the outbreak period. Meanwhile, we find no significant evidence suggesting they outperformed during the pre-war and stalemate periods. This is mainly due to the European regulators suspending Russian energy imports, the risk becomes a reality, and brown stocks underperform on the market. Our findings provide empirical evidence and supplement current literature by showing how EU stock markets respond when the sword of Damocles drops.

Table 3. Cross-sectional regression of cumulative abnormal returns on carbon emission. This table represents the results of cross-sectional regressions of stock cumulative abnormal returns on carbon emission. The dependent variable is the cumulative abnormal return for each of the pre-war, outbreak, and stalemate periods. The independent variable is the logarithm of a firm’s carbon emission for columns (1–3) and carbon emission scaled by market capitalization for columns (4–6). Control variables are as described in Table 1. *p* values, calculated using the robust standard errors, are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Dependent Variable: Cumulative Abnormal Return						
Period	Pre-War	Outbreak	Stalemate	Pre-War	Outbreak	Stalemate
Log(Carbon Emission)	1.902 *** (0.242)	−1.239 *** (0.242)	1.043 *** (0.311)			
Carbon Emission/Market Cap				3.196 (3.002)	−11.666 *** (2.942)	−1.259 (3.935)
Log(Market Cap)	−1.848 *** (0.357)	0.820 ** (0.357)	−0.748 (0.457)	−0.259 (0.302)	0.003 (0.296)	0.189 (0.378)
Book-to-Market Ratio	−0.001 (0.002)	−0.005 *** (0.002)	−0.001 (0.002)	−0.001 (0.002)	−0.006 *** (0.002)	−0.001 (0.002)
Investment	0.445 (2.856)	2.858 (2.855)	−4.932 (3.644)	4.944 * (2.861)	0.199 (2.806)	−2.440 (3.585)
Sales	0.291 (0.352)	−0.344 (0.351)	−1.007 ** (0.457)	1.102 *** (0.345)	−0.731 ** (0.338)	−0.511 (0.440)
ROE	0.000 (0.002)	0.002 (0.002)	−0.002 (0.002)	0.001 (0.002)	0.001 (0.002)	−0.001 (0.002)
Constant	−1.848 *** (0.357)	0.820 ** (0.357)	−0.748 (0.457)	8.538 (12.024)	−6.687 (11.785)	−2.947 (15.043)
Country and Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1770	1770	1770	1770	1770	1770
R-squared	0.210	0.138	0.104	0.173	0.131	0.096

If higher returns are primarily due to higher risk, one would expect that brown stocks exhibit greater stock return volatility as compared to their counterparts. In Table 4, we turn to examining the relationship between energy consumption and stock return volatility. The first three columns of Table 4 indicate that companies with high energy consumption had lower stock volatility during the pre-war and stalemate periods but higher stock volatility during the war outbreak period. We find that a one standard deviation (2.96) increase in Log(energy consumption) is associated with 1.74 percentage point and 1.36 percentage point decreases in annual volatility during the pre-war and stalemate periods, respectively. Conversely, the same increase leads to a 4.89 percentage point increase in stock volatility during the outbreak period. When using the ratio of energy consumption to market capitalization, which measures energy efficiency as the independent variable (columns (4) to (6) of Table 4), we find that energy-inefficient firms experience greater stock price volatility during the outbreak period.

When focusing upon the carbon emissions variable (ratio of carbon emissions to market capitalization), we find that stocks of firms with more carbon emissions tend to have more volatile performance during the outbreak. According to column (2) of Table 5, a one standard deviation (2.82) increase in Log(Carbon Emission) is associated with a 3.76 percentage point increase in stock volatility during the outbreak period. Table 5 column (5) suggests a similar result based on the carbon efficiency measure—carbon emission per unit of market capitalization. This result indicates that in Europe brown stocks are subject to more volatility caused by the war than green stocks.

Table 4. Cross-sectional regression of stock return volatility on energy consumption. This table represents the results of cross-sectional regressions of stock return volatility and energy consumption. The dependent variable is the standard deviation of stock returns for the pre-war, outbreak, and stalemate periods. The independent variable is the logarithm of a firm’s energy consumption for columns (1–3) and energy consumption scaled by market capitalization for columns (4–6). Control variables are as described in Table 1. *p* values, calculated using the robust standard errors, are in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Dependent Variable: Stock Return Volatility						
Period	Pre-War	Outbreak	Stalemate	Pre-War	Outbreak	Stalemate
Log(Energy Consumption)	−0.037 ** (0.015)	0.104 ** (0.039)	−0.029 ** (0.015)			
Energy Consumption/Market Cap				0.021 (0.014)	0.175 *** (0.041)	−0.017 (0.017)
Log(Market Cap)	−0.054 ** (0.023)	−0.088 (0.063)	−0.034 (0.023)	−0.093 *** (0.019)	−0.044 (0.052)	−0.056 *** (0.018)
Book-to-Market Ratio	0.000 ** (0.000)	0.001 *** (0.000)	0.000 (0.000)	0.000 ** (0.000)	0.001 *** (0.000)	0.000 (0.000)
Investment	−0.215 (0.157)	0.001 (0.432)	0.044 (0.160)	−0.300 * (0.154)	0.148 (0.423)	−0.010 (0.157)
Sales	0.032 (0.021)	0.004 (0.059)	0.012 (0.022)	0.015 (0.020)	0.026 (0.056)	0.003 (0.021)
ROE	0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)	0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)
Constant	3.822 *** (0.668)	3.798 ** (1.837)	3.092 *** (0.681)	4.223 *** (0.664)	3.958 ** (1.808)	3.257 *** (0.675)
Country and Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1770	1770	1770	1770	1770	1770
R-squared	0.180	0.064	0.137	0.177	0.077	0.137

Table 5. Cross-sectional regression of stock return volatility on carbon emissions. This table represents the results of cross-sectional regressions of stock returns volatility and carbon emissions. The dependent variable is the standard deviation of stock returns for the pre-war, outbreak, and stalemate periods. The independent variable is the logarithm of a firm’s carbon emission for columns (1–3) and carbon emission scaled by market capitalization for columns (4–6). Control variables are as described in Table 1. *p* values, calculated using the robust standard errors, are in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Dependent Variable: Stock Return Volatility						
Period	Pre-War	Outbreak	Stalemate	Pre-War	Outbreak	Stalemate
Log(Carbon Emission)	−0.015 (0.014)	0.084 *** (0.032)	−0.013 (0.016)			
Carbon Emission/Market Cap				0.273 (0.169)	1.406 *** (0.384)	0.136 (0.195)
Log(Market Cap)	−0.077 *** (0.021)	−0.099 ** (0.047)	−0.0625 *** (0.023)	−0.094 *** (0.017)	−0.057 (0.039)	−0.080 *** (0.019)
Book-to-Market Ratio	0.000 * (0.000)	0.001 *** (0.000)	0.000 (0.000)	0.000 * (0.000)	0.001 *** (0.000)	0.000 (0.000)
Investment	−0.309 * (0.165)	−0.115 (0.375)	−0.118 (0.183)	−0.352 ** (0.160)	0.044 (0.366)	−0.169 (0.178)
Sales	−0.007 (0.024)	0.011 (0.048)	−0.008 (0.023)	−0.017 (0.019)	0.028 (0.044)	−0.018 (0.022)
ROE	0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)	0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)
Constant	3.851 *** (0.687)	4.382 *** (1.560)	3.406 *** (0.757)	4.136 *** (0.678)	4.278 *** (1.538)	3.651 *** (0.749)
Country and Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1770	1770	1770	1770	1770	1770
R-squared	0.250	0.057	0.186	0.251	0.062	0.189

Tables 4 and 5 are generally consistent with the theory that investors require higher returns from stocks with more carbon-emission-related risks, including energy supply risk and regulatory risk (Monasterolo & de Angelis, 2020; Bolton & Kacperczyk, 2021; Ilhan et al., 2021).

Next, we want to study whether the extra returns of the brown stocks are alpha or simply constitute the compensation for bearing higher risk. If the brown portfolio did outperform the green portfolio, one can form a brown-minus-green (BMG) portfolio, by longing the high energy consumption portfolio and shorting the low energy consumption portfolio¹⁰, and gain some abnormal returns.

To demonstrate this, we divide firms in each industry into three groups based on the previous year’s energy consumption volume. It should be noted that we use the previous year’s energy consumption data in portfolio formation to mitigate the look-forward bias. Once again, the high energy consumption and low energy consumption portfolios consist of firms with the top and bottom 33% energy consumption volume, respectively, and both portfolios are value-weighted based on market capitalization.

We calculate the risk-adjusted returns of BMG portfolios, using the following five well-known factor models: CAPM, Fama–French three-factor model (Fama & French, 1993), Fama–French three-factor model with momentum, Fama–French five-factor model (Fama & French, 2015), and Fama–French five-factor model with momentum. More specifically, we run cross-sectional regressions for each of the specifications below:

$$R_{i,t} - r_{f,t} = \alpha + \beta_1(r_{M,t} - r_{f,t}) + e_{i,t}, \tag{3}$$

$$R_{i,t} - r_{f,t} = \alpha + \beta_1(r_{M,t} - r_{f,t}) + \beta_2SMB_t + \beta_3HML_t + e_{i,t}, \tag{4}$$

$$R_{i,t} - r_{f,t} = \alpha + \beta_1(r_{M,t} - r_{f,t}) + \beta_2SMB_t + \beta_3HML_t + \beta_4MOM_t + e_{i,t}, \tag{5}$$

$$R_{i,t} - r_{f,t} = \alpha + \beta_1(r_{M,t} - r_{f,t}) + \beta_2SMB_t + \beta_3HML_t + \beta_4RMW_t + \beta_5CMA_t + e_{i,t}, \tag{6}$$

$$R_{i,t} - r_{f,t} = \alpha + \beta_1(r_{M,t} - r_{f,t}) + \beta_2SMB_t + \beta_3HML_t + \beta_4RMW_t + \beta_5CMA_t + \beta_6MOM_t + e_{i,t}, \tag{7}$$

where $R_{i,t}$ is the return of the BMG portfolio, $r_{f,t}$ is the risk-free return, $(r_{M,t} - r_{f,t})$ is the monthly value-weighted market risk premium. SMB_t , HML_t , RMW_t , CMA_t , and MOM_t are Fama–French risk factors that capture size, book-to-market ratio, operating profitability, investment, and momentum, respectively. Moreover, the term α is the risk-adjusted return of the portfolio; it represents the abnormal return from ESG investment in excess of what can be explained by widely accepted Fama–French factors.

Table 6 reports alphas for the BMG portfolio using factor models. Overall, the BMG portfolio has larger negative alphas during the outbreak period when compared to pre-war and stalemate periods.

As one can find in Table 6, the CAMP model suggests that the BGM portfolio exhibits statistically significant negative alphas of -1.278% and the results are similar across other models. The Fama–French three-factor model delivers a significant alpha with a value of 1.653% , suggesting the existence of a negative energy risk premium for the outbreak period only. Adding a momentum factor to the Fama–French three-factor model barely changes the results. In fact, the risk premium magnitude slightly increases to -1.811% . The Fama–French five-factor model suggests the existence of a negative energy risk premium in all periods, but the premium size increases in the outbreak period with a value of -1.996% . Adding a momentum factor to the Fama–French five-factor model lowers the premium magnitude to 1.746% , but the trend holds. It is worth noting that our application of factor models is constrained by a limited time period. This consistent underperformance of

brown firms relative to green firms confirms our previous findings that energy-efficient companies held a decisive advantage during acute disruptions. We expect differences between the CAPM model and the Fama–French models, since the single-factor model is limited in explaining the risk premium. Although the CAPM is a robust theoretical model, over the years it has been exposed to numerous empirical criticisms that have empirically demonstrated its poor explanatory capacity. However, in our case, with the exception of the pre-war and stalemate periods, during the outbreak period it produces the same results as the other models. We also believe that these differences, evidently related to the period, do not represent an inconsistency, since the Fama–French models also generate different results when we compare the pre-war and stalemate periods with the outbreak period. Recently, [Kolari et al. \(2022\)](#), using data from the US market during the period 1928–2020, found that ZCAPM outperforms the CAPM as well as the Fama and French three-factor model and Carhart four-factor model. They also found that the CAPM tends to overestimate the risk premium, performs worse than multifactor models, and has a coefficient of determination close to zero, with virtually no explanatory capacity in measuring the relationship between risk and return.

Table 6. Energy risk premium by sorted portfolio. This table reports the energy risk premium, alpha, based on BMG portfolios sorted by energy consumption volume under various factor models, including CAPM, Fama–French three-factor model, Fama–French three-factor model with momentum, Fama–French five-factor model, and Fama–French five-factor model with momentum. We categorize firms in each industry into three categories using the previous year’s energy consumption volume. The high energy consumption (low energy consumption) portfolio consists of firms with the top (bottom) 33% energy consumption volume, both portfolios are value-weighted based on market capitalization. BMG portfolio = high energy consumption portfolio—low energy consumption portfolio. The sample periods consist of pre-war (3 January–23 February), outbreak (24 February–31 March), and stalemate (1 April–30 June). *p* values, calculated using the robust standard errors, are in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

	Alpha of BMG Portfolio		
	Pre-War	Outbreak	Stalemate
CAPM	1.470 *** (0.337)	−1.278 ** (0.559)	0.076 (0.289)
Fama–French 3 factor	−0.739 (0.671)	−1.653 ** (0.752)	−0.291 (0.316)
Fama–French 3 factor + momentum	0.383 (0.780)	−1.811 ** (0.846)	−0.422 (0.326)
Fama–French 5 factor	−1.234 * (0.710)	−1.996 * (1.168)	−0.659 * (0.345)
Fama–French 5 factor + momentum	−0.066 (1.715)	−1.746 ** (0.791)	−0.683 * (0.350)

We shall focus on the qualitative rather than quantitative implications of the empirical results. Consistent with our findings in Section 3, we find an evolving energy risk premium in EU stock markets as the Russia–Ukraine war unfolds. Before the war started, there was no clear sign showing the existence of an energy risk premium. The surprise Russian invasion caused stock market participants’ concern over the EU energy supply and brown firms’ operation. Soon after the outbreak EU regulators suspended Russian energy imports, and the concern became a reality as brown stocks significantly underperformed their green peers. As the EU managed to find an alternative to Russian energy, market participants regained their confidence in brown stocks and, as a result, the negative energy risk premium largely disappeared in the stalemate period.

5. Conclusions

This study investigates the impacts of the Russia–Ukraine war on the performance of stocks with different energy dependence in Europe. By analyzing the cross-sectional stock performance, we find that brown stocks are associated with higher risk-adjusted returns before the war. However, brown stocks underperform compared to green ones after the unexpected Russian invasion. As the war enters a stalemate period and Europe manages to replace the Russian energy supply with that from other partners, brown stocks outperform again. We also find brown stocks experienced a higher level of volatility after the Russian invasion. Using various factor models, we show a heightened negative energy risk premium during the outbreak period. Such a risk premium is not clearly present before the war starts and as the war enters a stalemate stage. Our study reveals the evolving stock market responses to the energy supply and regulations in Europe, reflecting the evolving market interpretation of energy supply risk and the regulatory risk associated with a transition to a net-zero economy. Our results have practical implications. On the one hand, they show how the stock market does not react in the same way to a war and, on the other hand, how investors might react in their portfolio choices. Future research could examine the long-term abnormal return to determine whether the trend persists over time, perhaps using the buy-and-hold abnormal returns (BHAR) model. It could also be interesting to explore other factors that act as determinants of the energy risk premium. The same topic could be studied from the perspective of investors to understand what trading strategy they use and how they balance between “brown” and “green” stocks in their portfolios.

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Notes

¹ <https://www.eia.gov/todayinenergy/detail.php?id=55021> (accessed in 17 April 2025).

² <https://apnews.com/article/europe-business-france-climate-and-environment-government-politics-1d16e1c1cb53fef03a2a77a437f8410e> (accessed in 17 April 2025). and <https://www.forbes.com/sites/juliecoleman/2022/07/08/germany-reopens-coal-plants-because-of-reduced-russian-energy/> (accessed in 17 April 2025).

³ <https://www.refinitiv.com/perspectives/market-insights/the-rise-and-rise-of-sustainable-investment/> (accessed in 17 April 2025) and <https://www.bloomberg.com/professional/blog/esg-assets-may-hit-53-trillion-by-2025-a-third-of-global-aum/> (accessed in 17 April 2025).

⁴ https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en (accessed in 17 April 2025).

⁵ EU gas market report—first quarter 2022, https://circabc.europa.eu/ui/group/3ef9355f-1ffe-4c82-ba19-f60a3ed2f652/library/295bae48-18a2-4901-afbe-edc7dcd40dee?p=1&n=10&sort=modified_DESC (accessed in 17 April 2025).

⁶ Google Trends: <https://trends.google.com/trends/> (accessed in 17 April 2025).

⁷ https://www.refinitiv.com/content/dam/marketing/en_us/documents/quick-reference-guides/trbc-business-classification-quick-guide.pdf (accessed in 17 April 2025).

⁸ <https://www.consilium.europa.eu/en/policies/eu-response-ukraine-invasion/impact-of-russia-s-invasion-of-ukraine-on-the-markets-eu-response/> (accessed in 17 April 2025).

- ⁹ https://ec.europa.eu/eurostat/statistics-explained/index.php?title=EU_imports_of_energy_products_-_latest_developments#Main_suppliers_of_natural_gas_and_petroleum_oils_to_the_EU (accessed in 17 April 2025).
- ¹⁰ BMG = High-Energy-Consumption portfolio—Low-Energy-Consumption portfolio.

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