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Applying event analysis to selected markets' reaction to the Russian invasion on Ukraine

Abstract

The aim of the study was to analyse the rate of return of selected stock exchange indices, currency pairs, raw materials and food in the event window determined by the start date of the Russian-Ukrainian war in 2022. The analysis used an approach based on the observation of the development of rates of return and their changes over time caused by Russia's invasion on Ukraine on February 24, 2022, applying the commonly used Average of Cumulative Abnormal Returns (ACAR) measure. The research showed many similarities as well as some differences in terms of the strength of the impact and the direction of changes in the prices of instruments on individual markets as a result of the outbreak of an armed conflict. The analysis comprehensively takes into account the impact of armed conflict on the development of short- and medium-term rates of return on various markets, the global scope of which has a significant influence on the economic development of individual countries. Not being limited to one market makes it possible to identify universal patterns of stock market behaviour in response to unforeseen events with a global impact on the world economy.

Keywords: event analysis, Russian-Ukrainian conflict, stock indices, ACAR, rate of return
JEL Classification: G14, G15, F51

Introduction

Before the war between Russia and Ukraine broke out, the global economy had been grappling with numerous challenges including external demand and supply shocks associated with the prevailing COVID-19 pandemic, climate change, energy issues, rising inflation or the appreciation of the US dollar [Obi, Waweru, Nyangu, 2023, p. 1]. The Russian invasion on Ukraine that began on 24 February, 2022, has caused additional perturbations, which include Europe's largest refugee crisis since the Second World War,[1] the escalation of political tensions between the two countries initiated in 2014 following the declaration of independence by pro-Russian separatists in Donbass (the eastern region of Ukraine), rising food prices largely due to the disruption of Ukraine's grain exports, and a surge in oil prices as a result of both limited supply and relatively high prices owing to the increased demand following the COVID-19 pandemic. All the factors made the conflict between Russia and Ukraine one of the most important geopolitical events of 2022. In addition, a strong reliance of the European countries on Russia's energy resources and Russia and Ukraine being among the largest grain producers in the world commodities has had a significant impact on global trade volumes [Liu, Pei, Wei, 2022, p. 398].

This paper aims to analyse evolution of returns of selected stock indices, currency pairs, commodities and food in the event window defined by the date of the start of the Russian-Ukrainian war in 2022. The selection of such diversified investment assets was determined by conducting a holistic analysis of the effects of the Russian invasion on Ukraine and obtaining answers as to which of them are characterized by the greatest sensitivity in the global economy during the period of hostilities. Adopting such a broad spectrum allows for comparison of individual markets from the strategic point of view for the economy and also fills the research gap in the literature describing the economic effects caused by warfare. Moreover, the analysis of selected markets, represented by selected financial assets, was aimed at obtaining explanations regarding the variability of their quotations in both the short and long term and the durability of these changes. The research hypotheses were based on previous economic reactions to unexpected events and concerned predictions of disruptions to the international supply chain leading to energy supply shocks and changes in trade, which translates into increases in energy, raw materials, and food prices directly related to the Ukrainian market.

The analysis uses an approach based on the magnitude and dynamics of changes in returns over time caused by the start of Russia's invasion on Ukraine on 24 February 2022, including the use of the commonly employed Cumulative Abnormal Returns (CAR) measure. For the quotations of selected investment assets, the behaviour of returns as a reaction to the information

[1] According to the UN Refugee Agency, more than 1.5 million people have crossed the borders of neighbouring countries since Russia's invasion on Ukraine. Retrieved from: www.theguardian.com/world/2022/mar/06/ukraine-fastest-growing-refugee-crisis-since-second-world-war [accessed: 05.08.2023].

about the war was considered from trading day -t to trading day +t for t = 1, 2, …, 25. By adopting such time horizons, it is possible to verify the direct impact of war news on stock prices. The estimation of the linear regression parameters for the quotations was based on the reliance of the stock return over the period from the early 2021 to the trading day preceding the first day of the analyzed period. Accordingly, the estimation window varies from t = –263 days (for ±25 days in the event window) to t = –287 days (for ±1 day in the event window). Closing prices of quotations from the given trading sessions were used for the calculations.

The analysis revealed a number of similarities, as well as some differences in the strength of the impact and orientation of changes in the price formation of instruments in individual markets following the outbreak of the armed conflict in Ukraine. Intra-market similarity can be observed on the food market, where the returns for corn and wheat followed the direction of change, although they differed in amplitudes. The stock market, with the S&P index being the only one among indices under study to show a positive return rate at day t = 0 (the day the Russian-Ukrainian war broke out), showed intra-market dissimilarity for the same period. Even more results are provided from the analysis of the CAR index, which allows inferences to be made about the magnitude of the perturbations in the immediate environment of the event under study and the time required for returns to stabilize.

The pertinent study takes a comprehensive view of the impact of the armed conflict on how short- and medium-term returns evolved in a variety of markets. The fact that the markets are present globally has a significant impact on the economic development of individual countries. Much as there are many works on selected areas (e.g., banking, finance, currency, etc.) and in-depth analyses related to the escalation of the Russian-Ukrainian conflict, still analyses that holistically approach the short- and medium-term impact of the February events on all the aspects of economic nature are absent in the literature. Not being confined to a single market offers an opportunity to identify universal patterns of stock price behaviour in response to unpredicted events having a global impact on the world economy. Such a broad approach to formulating the problem is the main added value of this work.

This article falls into six parts. Following the introduction, a literature review is presented that covers existing analyses and conclusions on the impact of the Russian-Ukrainian conflict on various areas of the economy. The next section discusses the data used in the study. Section four describes the research methods, including the definition of the CAR measure, and section five provides the findings of the study for different event window lengths for each of the contemplated investment assets including: stock indices, currencies, commodities, and food. The paper ends with a summary highlighting the strengths and weaknesses of the proposed analytical approach and a proposal for further research in this area.

Literature review

Event study, which examines the impact of a variety of events on the price formation of listed financial instruments, has been the subject of numerous academic publications. How prevalent the method is can be evidenced by a wide range of thematic works examining events affecting stock returns, including: cloud cover [Saunders, 1993], sunshine [Hirshleifer, Shumway, 2003], plane crashes [Kaplanski, Levy, 2010], earthquakes [Shan, Gong, 2012], or tsunamis [Ramiah, 2013].

Event study is commonly employed to investigate the market reaction of stock prices of listed companies to specific events, which include share splits, public disclosure of dividend payments, publication of financial results, and primary or secondary offering. It estimates extraordinary (abnormal, above-normal, not normal, excess) rates of return on stock of such companies. The rates of return under study a company realizes over a given period are compared to the expected rates of return estimated with a model, i.e. the rates of return that a given company could have obtained if a certain event had not occurred (normal, theoretical, expected rate of return).

Dolley's 1933 study comes among the earliest works in event study. Based on a sample of 95 stock splits on the US market from 1921 to 1931, Dolley analyzed the motives of companies and their impact on stock prices. The outcome showed that in 26 cases stock splits drove down the stock price, while in 57 cases the securities' price went up [Dolley, 1933a, 1933b; Gurgul, 2012].

A landmark work in the field of event study includes the research by Ball and Brown [1968] and Fama et al. [1969], who developed the contemporary abnormal returns methodology to assess investors' reactions to stock market news that resulted in a change in stock prices. Investor behaviour was assessed on the basis of the additional rate of return as a difference between the actual return over the observation period and the expected return on the stock. Ball and Brown analyzed the market's reaction to companies' earnings, the level of which differed from what investors had expected, and provided the reasons for the gains size. Fama, Fisher, Jensen, and Roll probed into 940 stock splits on the New York Stock Exchange (NYSE) from 1927 to 1959. The study findings showed that stock returns increase significantly after a stock split is announced.

The Russian-Ukrainian conflict has had an unprecedented impact on global trade and economic development. Examples include both the sharp rise, for the first time since 2014, in the price of Brent crude oil to 105 dollars a barrel, as well as in the price of gas in the UK and the Netherlands by around 40%–50%.[2] Undeniably, the Russian invasion has led to a significant increase in geopolitical risks in Europe, which has a negative impact on global stock

[2] Retrieved from: https://www.reuters.com/markets/europe/europe-war-six-charts-know-financial-markets-2022–02–26/#main-content [accessed: 07.08.2023].

markets [Antonakakis et al., 2017; Bouoiyour et al., 2019]. Geopolitical risks not only have a strong impact on the development of local stock markets and excess returns [Balcilar et al., 2018], but they also produce spillover reactions on international markets [Buigut, Kapar, 2020].

The war in Ukraine has an adverse effect on the stockholders of a majority of companies world-wide, which is due to the following [Sun, Song, Zhang, 2022]:

1) companies located in regions neighbouring Russia and Ukraine or in European Union countries have significant negative excess stock returns in various event windows as these regions are considerably affected by the war and carry a relatively high geopolitical risk;
2) the impact of the Russian invasion on the manufacturing, financial, and service industries varies from country to country, depending on whether they border the war-affected areas;
3) oil and gas companies in the regions away from the battlefield are receiving positive excess returns on their shares, likely due to the expected increase in their market share corresponding to Russia's declining share.

The economic impact of the Russian-Ukrainian war on the global economy in terms of the disruption of the international supply chain led to energy supply and trade shocks, which directly drove up the energy, commodities, and food prices, as well as inflation. This means that geopolitical conflicts tend to have economic effects on other countries not directly related to the hostilities [Balbaa, Eshov, Ismailova, 2022]. An analysis of the impact of Russia's invasion on Ukraine on equity markets in G7 countries and Africa showed that excess stock returns were negative during the initial period of the conflict in both regions, with losses being larger in G7 countries than in African countries. It was the same shortly before the war broke out, which, as the authors found, meant the outbreak date may have been predictable. In commodity markets, cumulative excess returns were positive for both regions both before and after the outbreak of the war [Obi, Waweru, Nyangu, 2023]. A study done to assess the impact of the Russian-Ukrainian war on stock markets from the G20 and other selected countries revealed that the announcement of a 'special military operation' on 24 February, 2022, had a negative impact on most markets, with the largest being on Russia. Aggregate coefficients in the form of average cumulative excess stock returns took on negative values on the day of the event and on the days to come. In contrast, an analysis of cumulative excess returns at the country level showed that the equity markets in Hungary, Poland, and Slovakia took negative values both on the days before and after the war broke out. The markets of some countries including Australia, France, Germany, India, Italy, Japan, Romania, South Africa, Spain, and Turkey reacted differently, with their stock markets seeing declines only in the days following the start of the conflict. Finally, at the regional level, it was shown that the average cumulative excess stock returns on European and Asian stock markets took negative values on the day the conflict broke out and for several days immediately after the event. In conclusion, the authors of the study noted that during the ongoing Russian-Ukrainian conflict investors should consider allocating capital to the regions of North America, Latin America, the Middle East, and Africa, as they have been least affected by the war [Yousaf, Patel, Yarovaya, 2022].

Data analysis

The main added value of this paper is the analysis covering a wide range of areas of the economy described by the formation of the value of selected stock market indices, and of the prices of currencies, commodities, and food. In the following section, the data used in the study will be characterized, and it will also include the basics of descriptive statistics which allow for determining the volatility of the quotations from the early 2021.

Research sample selection

The research used the data from the financial website stooq.pl covering selected markets: equity, currencies, commodities, and food. The analysis of the stock market followed the development of index values: S&P 500,[3] WIG,[4] DAX,[5] FTSE 250,[6] CAC 40,[7] OMX Riga,[8] and OMX Vilnius.[9] The selection of indices was aimed at analyzing the effects of the outbreak of the war in Ukraine in the world's (USA) and Europe's (Germany, UK, France) leading economies, in countries of relatively immature capital market (Latvia, Lithuania), and in Poland – Ukraine's immediate neighbour. For the FX market, currency pairs belonging to the most liquid instruments in this market were selected: USD/GBP, EUR/USD, CHF/EURO, USD/JPY. In addition, the USD/PLN and USD/RUB exchange rates were analyzed. Two types of financial instruments can be distinguished in the commodities market. The first is represented by precious metals futures including gold,[10] silver,[11] and platinum,[12] which are treated as stable and safe investment in times of armed conflicts and geopolitical uncertainty. The second type of financial instruments refers to strategic futures investment in energy commodities, which

[3] S&P 500 (*Standard and Poor's 500*) – a stock market index comprising 500, mainly American, highest capitalisation companies listed on the New York Stock Exchange and NASDAQ. Retrieved from: https://www.britannica.com/money/SandP-500 [accessed: 02.08.2023].

[4] WIG – (Warsaw Stock Exchange Index) includes all companies (more than 300) listed on the WSE Main Market that meet the underlying criteria for participation in the indices. Retrieved from: https://gpwbenchmark.pl/notowania [accessed: 02.08.2023].

[5] DAX (in German: *Deutscher Aktienindex*) – German stock market index of the 40 largest companies in terms of turnover and capitalisation on the Frankfurt (am Main) Stock Exchange. Retrieved from: https://en.wikipedia.org/wiki/DAX [accessed: 03.08.2023].

[6] FTSE 250 (the Financial Times Stock Exchange 250 Index) is an index of the 250 (101 to 350) largest companies listed on the London Stock Exchange. Retrieved from: https://en.Wikipedia.org/wiki/FTSE_250_Index [accessed: 03.08.2023].

[7] CAC 40 (in French: *Cotation Assistée en Continu* – continuous listing), a French equity index comprising the 40 largest companies among the 100 with the highest capitalisation on the Paris Stock Exchange. Retrieved from: https://en.wikipedia.org/wiki/ CAC_40 [accessed: 03.08.2023].

[8] OMX Riga – an index comprising 9 companies. Retrieved from: https://www.nasdaqomxnordic.com/index/index_info?Instrument=LV0007100017 [accessed: 03.09.2023].

[9] OMX Vilnius – an index comprising 21 companies. Retrieved from: https://www.nasdaqomxnordic.com/index/index_info?Instrument=LT0000999963 [accessed: 03.09.2023].

[10] Commodities Futures: GC.F.

[11] Commodities Futures: SI.F.

[12] Commodities Futures: PL.F

include coal,[13] natural gas,[14] and oil.[15] Access to these commodities is essential for energy security, which in turn is a key factor to ensure broadly understood economic security and it belongs to non-military categories of national security. The last group of the financial instruments under analysis includes food futures covering the price formation of wheat[16] and corn,[17] which are among the staple cereals exported globally by Ukraine and Russia.

Data characteristics

In order to analyse abnormal returns, it is necessary to know the actual quotations. Due to the variety of data used in the study, the discrepancies in quotation amounts as well as their volatility are obvious. However, the purpose of the study was to verify possible short- and medium-term changes in quotations as a result of the outbreak of war in Ukraine. Not every investment asset under study reacted in the same way. To prove this, selected descriptive statistics following the period from the early 2021 until the day before the Russian invasion of Ukraine, i.e. 23 February, 2022, can be presented and compared with similar statistics, albeit for a period more than a month longer (until the end of March 2022). The statistics were compiled in Table 1.

Table 1. Summary descriptive statistics for investment assets quotations from 04.01.2021 to 23.02.2022 and from 04.01.2021 to 31.03.2022

Investment assets	from 04.01.2021 to 23.02.2022						from 04.01.2021 to 31.03.2022		
	Mini-mum	Average	Median	Maximum	Standard deviation	Coefficient of variation	Maximum	Standard deviation	Coefficient of variation
Stock indices (pts.)									
S&P 500	3700.65	4296.08	4357.73	4793.54	280.60	6.5%	4793.54	272.20	6.3%
WIG	56448.66	65688.11	67128.80	74813.24	5383.39	8.2%	74813.24	5309.30	8.1%
DAX	13432.87	15231.40	15450.72	16271.75	672.11	4.4%	16271.75	737.76	4.9%
FTSE 250	20228.58	22443.41	22577.34	24250.83	959.93	4.3%	24250.83	1070.85	4.8%
CAC 40	5399.21	6489.86	6570.19	7376.37	470.97	7.3%	7376.37	454.69	7.0%
OMX RIGA	1108.54	1220.22	1237.38	1305.79	62.81	5.1%	1305.79	65.57	5.4%
OMX VILNIUS	829.92	927.32	938.33	1028.74	48.33	5.2%	1028.74	49.26	5.3%
Currency pairs									
USD_GBP	0.70	0.73	0.73	0.76	0.01	1.7%	0.77	0.01	2.0%
EUR_USD	1.11	1.18	1.18	1.23	0.03	2.6%	1.23	0.04	3.1%
CHF_EURO	0.90	0.93	0.92	0.97	0.02	2.0%	1.00	0.02	2.4%

[13] Ice Rotterdam coal – Commodities Futures: LU.F.
[14] UK natural gas – Commodities Futures: NF.F.
[15] Crude oil Brent – Commodities Futures: CB.F.
[16] Wheat – Commodities Futures: ZW.F.
[17] Corn (Commodities Futures: ZC.F.

cont. Table 1

Investment assets	from 04.01.2021 to 23.02.2022						from 04.01.2021 to 31.03.2022		
	Mini-mum	Average	Median	Maximum	Standard deviation	Coefficient of variation	Maximum	Standard deviation	Coefficient of variation
USD_JPY	102.72	110.42	109.96	116.14	3.26	3.0%	123.89	3.94	3.6%
USD_PLN	3.65	3.88	3.88	4.19	0.13	3.4%	4.59	0.17	4.4%
USD_RUB	69.60	74.09	73.90	80.83	1.73	2.3%	152.14	10.37	13.5%
Commodities (USD)									
GOLD	1686.00	1802.64	1798.80	1954.40	48.65	2.7%	2043.30	62.28	3.4%
SILVER	2148.50	2490.11	2494.40	2941.80	180.83	7.3%	2941.80	173.96	7.0%
PLATINUM	894.20	1079.26	1067.60	1293.10	99.08	9.2%	1293.10	96.01	8.9%
COAL	62.30	117.45	118.40	274.50	43.24	36.8%	459.80	71.42	53.3%
NATURAL GAS	38.79	133.69	106.95	452.35	85.20	63.7%	539.53	98.28	66.1%
OIL	51.09	72.86	72.52	96.48	9.61	13.2%	127.98	14.20	18.7%
Food (USD)									
CORN	483.75	577.66	559.25	732.25	52.14	9.0%	758.00	67.76	11.5%
WHEAT	601.75	711.83	710.75	876.00	60.12	8.4%	1294.00	123.41	16.6%

Note: the grey background is for investment assets for which the coefficient of variation increased by at least 25%.
Source: own analysis.

The quotations of many of the investment assets examined reacted only marginally or did not react at all to the Russian military invasion on Ukraine. This can be inferred from the absence of differences in the maximum values of the quotations or the small differences in standard deviations or coefficients of variation. For example, stock indices appear to be insensitive to the event under investigation. The grey background in Table 1 is for investment assets for which the coefficient of variation increased by at least 25%. In line with economic predictions, it was food (corn, wheat), key energy commodities (oil, coal), investments in precious metals (gold), exchange rates of currency pairs including the currency of the country involved in the conflict (the Russian rouble) and of Poland, as a country neighbouring the battlefield (the Polish zloty), whose reactions in the form of changes in quotations were the most dramatic.[18]

However, the statistics in Table 1 only demonstrate there are differences in changes in quotations for certain investment assets. These changes should be considered over a medium-term time horizon (changes from 24 February to 31 March). Still, this does not show the presence or absence of short-term changes, nor the quotations stabilizing over time. For this purpose, a more sophisticated event study is required, the primary tool of which is a measure based on abnormal rates of return described in more detail in the next chapter.

[18] Similar results with respect to currencies, crude oil, corn, and wheat were achieved by the authors in the article: *An Event Study on the Reaction of Equity and Commodity Markets to the Onset of the Russia–Ukraine Conflict* [Obi, Waweru, Nyangu, 2023].

Methodology

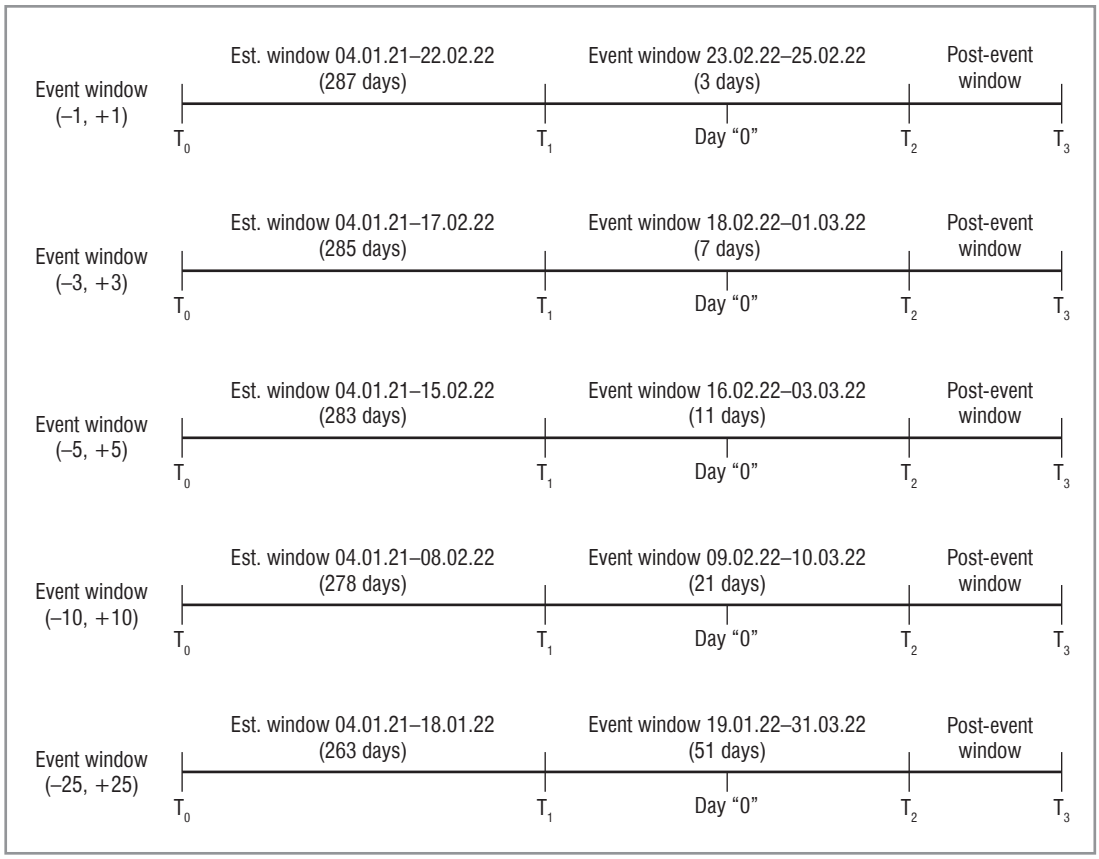
Definition and structure of event study

In order to assess the impact of the outbreak of war in Ukraine, event study was taken as a standard financial tool to examine the effects of events on the price formation of broadly defined investment assets. An event study requires that various stages of the study be identified, and they include [Campbell et al., 1997]: definition of the event, identification of the event windows, criteria for selecting the investment assets to be analysed and determination of the expected rate of return.

The first step of the analysis is to define the event. As already mentioned in the introduction, the event is marked by the start of the Russian-Ukrainian war on 24 February, 2022, and therefore this day is the event day (day 0).

Time structure of the event window analysis is shown in the figure below.

Figure 1. Time structure of the event window analysis



Source: own analysis.

The length of an event window does not have one clear definition in the literature. However, for a majority of the studies, an event window covers three days, that is the day before the event, the day of the event and the day after the event (–1,+1) [MacKinlay, 1997]. Depending on the events' particular features, their windows can be of any length. Examples are the event windows in the works of Kansas (–3,+3) [2005], Miyajima and Yafeh (–5,+5) [2007] or of Cox and Peterson (+4,+20) [1994]. Likewise, the number of days for an estimation window is not explicitly specified, either. Depending on the event type, various researchers have analysed diversified periods prior to a given event, for instance: 200 days [Carrow, Kane, 2002], 250 days [MacKinlay, 1997], 500 days [Litvak, 2007]. It is assumed that the estimation window should last on average 250 days (the number of working days in a calendar year), but not less than 126 days [Benninga, 2008]. In the present study, given the particular character of an event such as the outbreak of the Russian-Ukrainian war, five event windows pertaining to the following periods were analysed:

1. Event window (–1, +1), from 23.02.2022 to 25.02.2022 (3 days), estimation window 04.01.2021–22.02.2022 (287 days),
2. Event window (–3, +3), from 18.02.2022 to 01.03.2022 (7 days), estimation window 04.01.2021–17.02.2022 (285 days),
3. Event window (–5, +5), from 06.02.2022 to 03.03.2022 (11 days), estimation window 04.01.2021–15.02.2022 (283 days),
4. Event window (–10, +10), from 09.02.2022 to 10.03.2022 (21 days), estimation window 04.01.2021–08.02.2022 (278 days),
5. Event window (–25, +25), from 19.01.2022 to 31.03.2022 (51 days), estimation window 04.01.2021–18.01.2022 (263 days).

Selection criteria for the investment assets under analysis were presented earlier on in the paper (selection of the research sample including the stock, currency, commodity, and food markets).

The expected rate of return on individual investment assets was computed with a linear regression model described later on in this paper.

AR and CAR measurement

This paper resorts to the methodology of determining abnormal returns to assess how strong the impact of the Russian invasion on Ukraine was on selected investment asset quotations. The Cumulative Abnormal Returns (CAR), which is commonly used in event study [Campbell et al., 1997], was employed as a measure here.

By abnormal return we mean the difference between the actual return and the expected return had the event not occurred.

$$AR_{it} = R_{it} - E(R_{it})$$

where:
AR_{it} – abnormal return of stock instrument i on day t,
R_{it} – actual return rate of investment asset i generated on day t in case there is access to war news,
$E(R_{it})$ – expected return on investment asset i on day t in the absence of Russian invasion on Ukraine,
for $i = 1,2, ..., N$, where N is the number of investment assets under analysis.

All returns in the study contemplated in this article were computed on the basis of closing quotations.

The measure of abnormal return used in the study is the cumulative abnormal return, determined as the total of daily abnormal returns from consecutive trading days over the period T under analysis:

$$CAR_{iT} = \sum_{t=1}^{T} AR_{it}$$

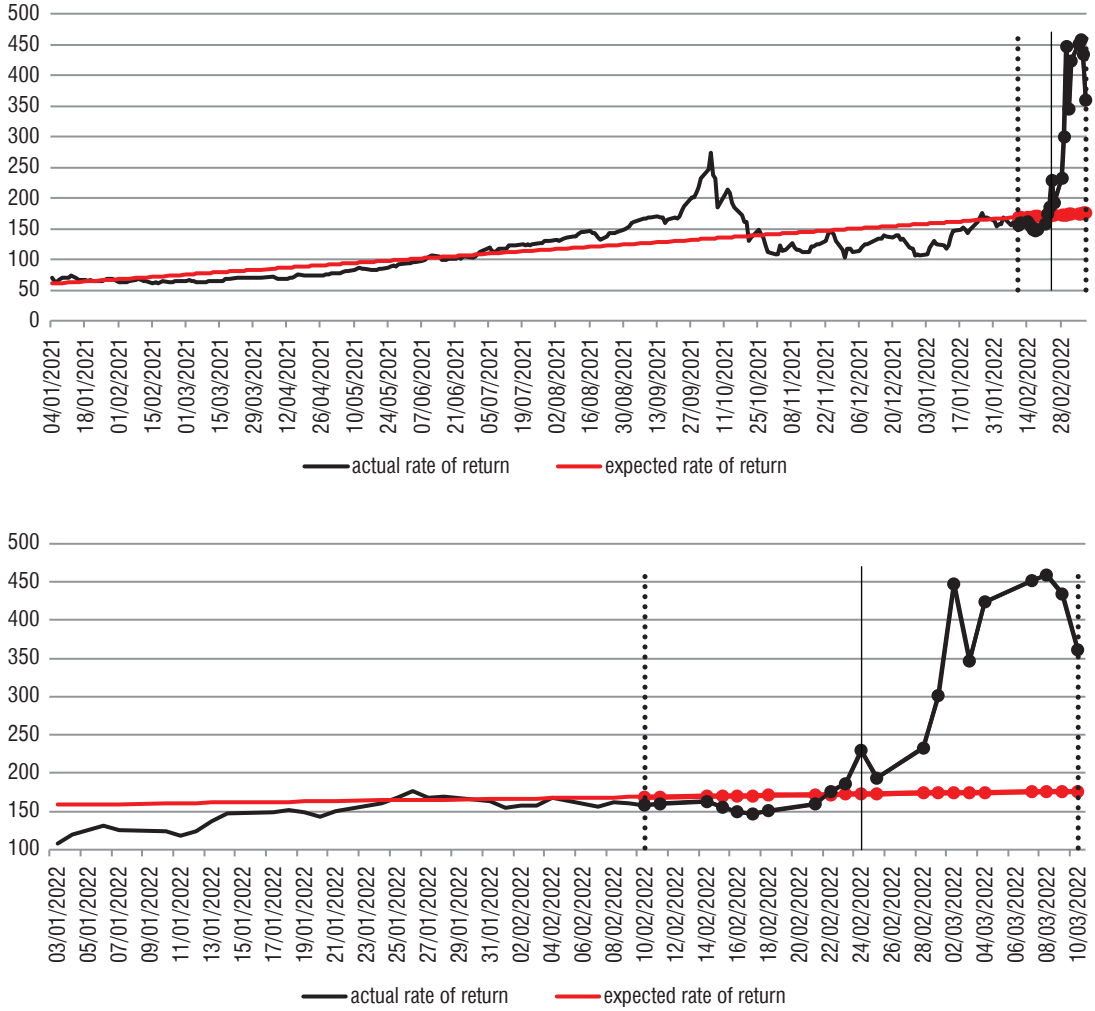
where:
CAR_{it} – cumulated abnormal return on investment asset i on day t,
T – time of analysis measured in trading days,
AR_{it} – abnormal return on investment asset i on day t.

A key factor in the analysis is to specify how the expected return on the stock instrument i is determined. Following the methodology introduced by MacKinlay [1997], predictions based on a linear regression model, whose parameters were estimated independently for each stock instrument using the procedure referred to in the following section, were taken as the reference level of returns.

The analysis pertained to event windows from trading day -t to trading day +t for t = 1, 2,…, 25. Window length for a given t is $2 * t+1$. For example, for t = 10, the event window contains 10 quotations from before 24 February, 2022, a quotation on the day Russia's invasion on Ukraine began, and 10 quotations after 24 February, 2022 – a total of 21 quotations. For fixed t, the estimation of the linear regression parameters was based on the dependence of the return on investment assets over the period from the early 2021 to the day before the first day of the event window. Accordingly, the estimation window varies from t = –263 days (for ±25 days in the event window) to t = –287 days (for ±1 day in the event window). Figure 2 shows a diagram for measuring expected returns and abnormal returns based on coal quotations, and an event window of ±10 days in close proximity to the day of the Russian invasion on Ukraine (marked with the vertical continuous line on the graphs). The event window between the two dashed lines, therefore, pertains to quotations from 9 February, 2022 (10 days before the analysed event) to 10 March, 2022 (10 days after the analysed event). The estimation window, on the other hand, includes returns measured from quotations from the early 2021 to 8 February, 2022, the day before the start of the event window. Using the 278 quotations from the estimation window, returns were computed (the solid black line), and then the parameters of the linear regression model were estimated (the solid red line). The expected returns were assumed to be derived from the linear regression model (in red). The actual rates

of return rise significantly, immediately after the event under study occurs (the black dots in the interval bounded by the blue dashed vertical lines which also mark the event window). Abnormal returns are the difference between expected and actual returns within the event window under study. In the first half of the event window, i.e. up to the very day of Russia's starting the invasion on Ukraine, the abnormal returns were not high, but the escalation of the conflict triggered a clear disparity between expected and actual returns. A summary of the actual, expected, and abnormal returns for this case is shown in Table 2. An average of the ten abnormal returns before the event under analysis (–10.12) is significantly lower than an average of the ten abnormal returns after the start of Russia's invasion on Ukraine (190.52).

Figure 2. Diagram for measuring actual and expected returns based on coal quotations and an event window of ±10 trading days in close proximity to the day of the Russian invasion of Ukraine



Note: the upper part of the chart shows the period from the early 2021 to 10.03.2022, and the lower part is from the early 2022 to 10.03.2022.

Source: own analysis.

Table 2. Summary of actual, expected, and abnormal returns for coal quotations and an event window of ±10 trading days in close proximity to the day of the Russian invasion on Ukraine

No.	Date	Actual rate of return	Expected rate of return	Abnormal rate of return	Average abnormal rate of return
1	10.02.2022	157.60	168.83	–11.23	**–10.12**
2	11.02.2022	160.00	169.10	–9.10	
3	14.02.2022	163.20	169.90	–6.70	
4	15.02.2022	156.00	170.17	–14.17	
5	16.02.2022	149.05	170.44	–21.39	
6	17.02.2022	147.20	170.71	–23.51	
7	18.02.2022	150.30	170.98	–20.68	
8	21.02.2022	159.55	171.78	–12.23	
9	22.02.2022	176.00	172.05	3.95	
10	23.02.2022	186.20	172.32	13.88	
11	**24.02.2022**	**229.75**	**172.59**	**57.16**	
12	25.02.2022	193.80	172.86	20.94	**190.52**
13	28.02.2022	233.05	173.66	59.39	
14	01.03.2022	300.85	173.93	126.92	
15	02.03.2022	447.50	174.20	273.30	
16	03.03.2022	347.00	174.47	172.53	
17	04.03.2022	423.75	174.74	249.01	
18	07.03.2022	451.20	175.54	275.66	
19	08.03.2022	459.80	175.81	283.99	
20	09.03.2022	434.85	176.08	258.77	
21	10.03.2022	361.00	176.35	184.65	

Note: the day of the Russian invasion on Ukraine against the grey background.

Source: own analysis.

For each instrument and for various sizes of the event window, a similar analysis was made, followed by a comparison of the results and conclusions on the strength of the impact of Russia's invasion on Ukraine and the time span for quotations to stabilize.

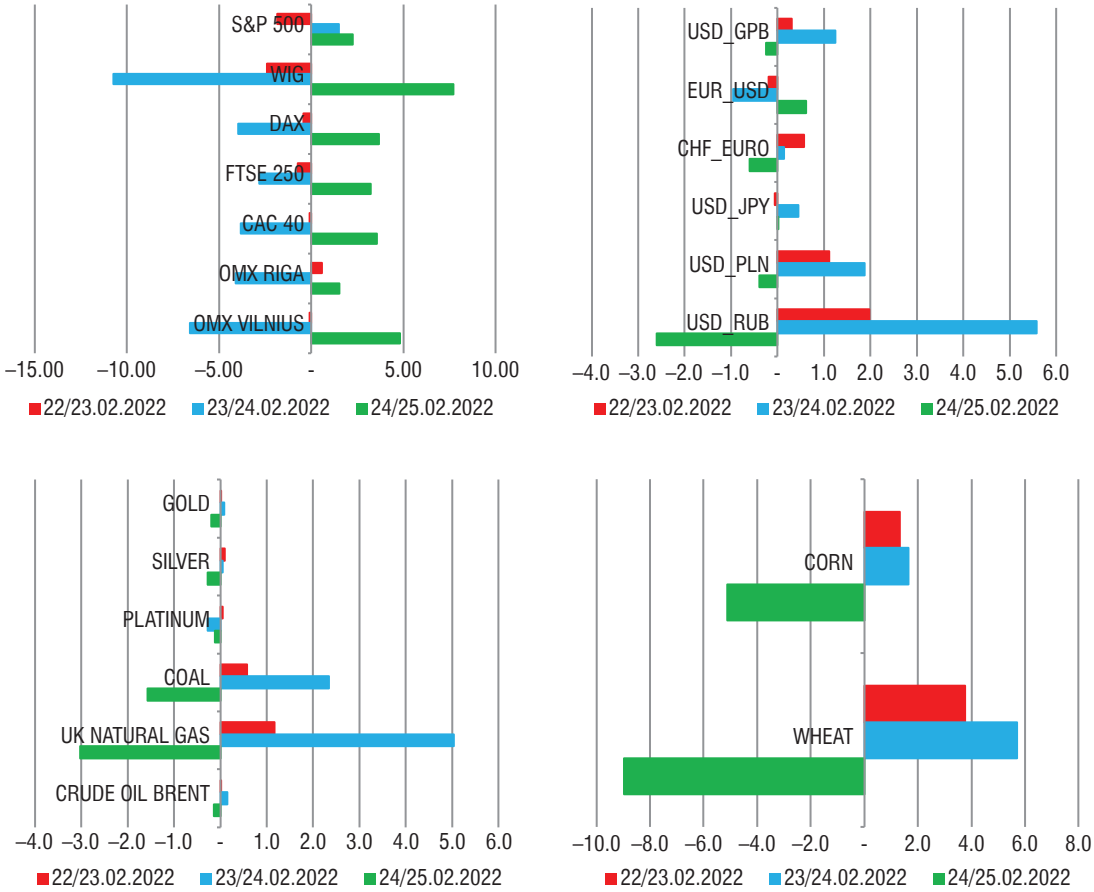
Results

Returns for individual investment assets

The analysis in question falls into two stages: at stage one, the size of returns for individual investment assets was assessed immediately before, on the day of and in the quotation immediately after the analysed event. The observations made from the orientations of change were the basis for a further, more detailed analysis, which employed a commonly used approach

with additional returns immediately after the start of Russia's invasion on Ukraine (24.02.2022) and the observation of their changes over time. At both stages of analysis, comparisons were made within and between the groups considered (stock indices, currency pairs, commodities, and food) in an attempt to identify certain patterns and regularities noted by researchers analysing other historical events.

Figure 3. Increase in returns for stock indices (top left chart), exchange rates (top right chart), commodities (bottom left chart), and food (bottom right chart) immediately before (22/23.02.2022), on the day of (23/24.02.2022) and immediately after (24/25.02.2022) Russia's invasion of Ukraine (in percentage points)



Source: own analysis.

Figure 3 illustrates the behaviour of returns for individual investment asset groups immediately before (22/23.02.2022), on (23/24.02.2022) and immediately after (24/25.02.2022) Russia's invasion on Ukraine. Within each group, most of the return behaviour is fairly consistent. All the stock indices yielded higher returns on 24/25.02.2022 although most of them had seen negative returns the day before (all except the S&P 500). For exchange rates, the behaviour seems to be different as most currency pairs declined on the day after the start of the Russian

invasion. Only for EUR/USD and USD/JPY no negative returns were observed. Returns for commodities and food emulated the pattern of most currency pairs exchange rates. However, it is worth noting the scale; by far the highest negative returns on 24/25.02.2022 were observed for the following investment assets: USD/RUB, coal, natural gas, corn, and wheat. These results largely overlap with the observations for the quotations discussed in the data characteristics section.

Short- and medium-term abnormal returns

Observations of actual returns and their rise or decline immediately after the event under analysis do not provide information on short- and medium-term behaviour, the occurrence of patterns and their stability, which are much better measured by abnormal returns. CAR values for selected event window sizes are given in Table 3. The numerical results confirm there is variation in values among the financial instruments under study and, at the same time, there is a general pattern of CAR increment stabilizing as of a certain size of the event window, which can be interpreted as the stabilization of quotations. For various assets, however, the threshold sizes for the stabilization window vary. It is because it will suffice to inspect the size of CAR increments between the given event window lengths. In general terms, the greatest dynamics of change are observed in the immediate vicinity of the event under analysis (1–3 trading days). However, certain patterns and exceptions to them are evident. One of the most prominent exceptions is certainly the USD/RUB currency pair exchange rate for which the CAR measure shows a rising trend even after 10 quotations from the start of Russia's invasion on Ukraine. The CAR is seen as rising also for the runner-up, USD/PLN pair, albeit to an incomparably lesser extent than the USD/RUB counterpart. From the perspective of abnormal returns, the behaviour of the other currencies remains fairly stable over time.

Similar patterns can also be identified for commodities. Abnormal returns for virtually all commodities rose immediately after the escalation of the Russia-Ukraine conflict (in contrast to stock indices which recorded negative increments). However, the increase was not the same everywhere. Coal, natural gas, and oil stand out clearly, with the increase in the CAR measures far exceeding (especially in the first 1–8 days of trading) changes for the other commodities. Both in the short and medium term, the abnormal returns for commodities but also for food take positive values. For many of the instruments, the CAR measures finally stabilize, but the values in many cases do not approximate 0, but attain another, a higher, level. This means that quotations, as a result of the sudden event of the Russian invasion and the related consequences, have not reverted to pre-conflict numbers, but have found a new level that reflects the changed geopolitical and economic situation.

Inter-group differences and similarities are even more evident in the basic descriptive statistics summarized in Table 4. The coefficient of variation of the CAR measure for the individual groups appears to stabilize between days 3 and 5 of trading (the length of the event window), but in the case of food, it continues to trend upwards (even after five quotations).

Table 3. CAR size for selected event window lengths

Group	Size recorded	from –1 up to +1 day	from –3 up to +3 day	from –5 up to +5 day	from –10 up to +10 day
Stock market index	S&P 500	3.6%	–1.4%	–3.1%	–8.6%
	WIG	–3.1%	–5.2%	–8.1%	–13.0%
	DAX	–0.3%	–5.8%	–10.9%	–14.2%
	FTSE 250	0.4%	–2.9%	–7.2%	–10.9%
	CAC 40	–0.4%	–6.1%	–9.0%	–14.2%
	OMX RIGA	–2.7%	–7.2%	–14.1%	–8.9%
	OMX VILNIUS	–1.8%	–4.0%	–7.4%	–12.2%
Exchange rate	USD_GBP	1.0%	2.0%	1.9%	3.4%
	EUR_USD	–0.3%	–1.5%	–2.3%	–3.3%
	CHF_EUR	–0.5%	1.3%	2.8%	3.1%
	USD_JPY	0.4%	0.0%	0.1%	–0.5%
	USD_PLN	1.4%	5.8%	8.6%	9.5%
	USD_RUB	3.0%	25.5%	37.7%	65.4%
Commodities	GOLD	–1.2%	2.3%	3.5%	8.7%
	SILVER	–2.1%	7.0%	7.6%	13.8%
	PLATINUM	–3.7%	–1.6%	2.7%	7.9%
	COAL	7.4%	72.0%	105.6%	104.9%
	NATURAL GAS	19.6%	67.9%	96.5%	79.8%
	OIL	–0.1%	11.8%	16.8%	17.9%
Food	CORN	–3.5%	10.7%	14.8%	15.9%
	WHEAT	–3.4%	22.0%	38.6%	34.3%

Source: own analysis.

Table 4. Basic descriptive statistics for selected event window lengths

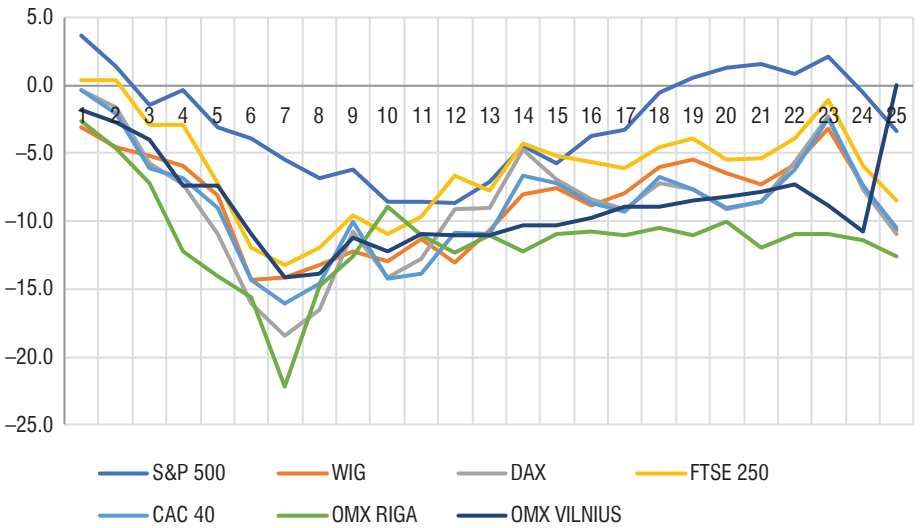
Event window: from –1 to +1 trading day						
Group	Minimum	Maximum	Average	Median	Standard deviation	Coefficient of variation
Stock market index	–3.11%	3.64%	–0.62%	–0.38%	2.28%	–369.13%
Exchange rate	–0.49%	2.98%	0.84%	0.70%	1.28%	152.11%
Commodities	–3.71%	19.64%	3.33%	–0.62%	8.88%	266.89%
Food	–3.49%	–3.36%	–3.43%	–3.43%	0.09%	–2.67%
Event window: from –3 to +3 trading day						
Group	Minimum	Maximum	Average	Median	Standard deviation	Coefficient of variation
Stock market index	–7.15%	–1.43%	–4.66%	–5.23%	1.99%	–42.78%
Exchange rate	–1.50%	25.46%	5.50%	1.65%	10.07%	183.11%
Commodities	–1.55%	71.96%	26.57%	9.41%	33.90%	127.56%
Food	10.67%	22.00%	16.33%	16.33%	8.01%	49.06%

Event window: from –5 to +5 trading day						
Group	Minimum	Maximum	Average	Median	Standard deviation	Coefficient of variation
Stock market index	–14.08%	–3.12%	–8.55%	–8.14%	3.40%	–39.77%
Exchange rate	–2.33%	37.69%	8.13%	2.33%	14.93%	183.65%
Commodities	2.74%	105.57%	38.77%	12.17%	48.58%	125.32%
Food	14.78%	38.61%	26.70%	26.70%	16.85%	63.11%

Source: own analysis.

Some descriptive statistics for whole groups can be misleading as they do not allow for the identification of outliers, such as the USD/RUB exchange rate versus other currency pairs. Intra-group differences can be inferred from, for instance, standard deviations. A longer time horizon (presented in the graphical summary for event window lengths from 3 days (t = ±1) to 51 days (t = ±1, ±2,…, ±25) in Figures 4–7) enables a comparative analysis of the evolution of abnormal returns for individual financial assets within a given group.

Figure 4. CAR for stock indices, for event window lengths from 3 days (t = ±1) to 51 days (t = ±1, ±2, …, ±25) (in %)

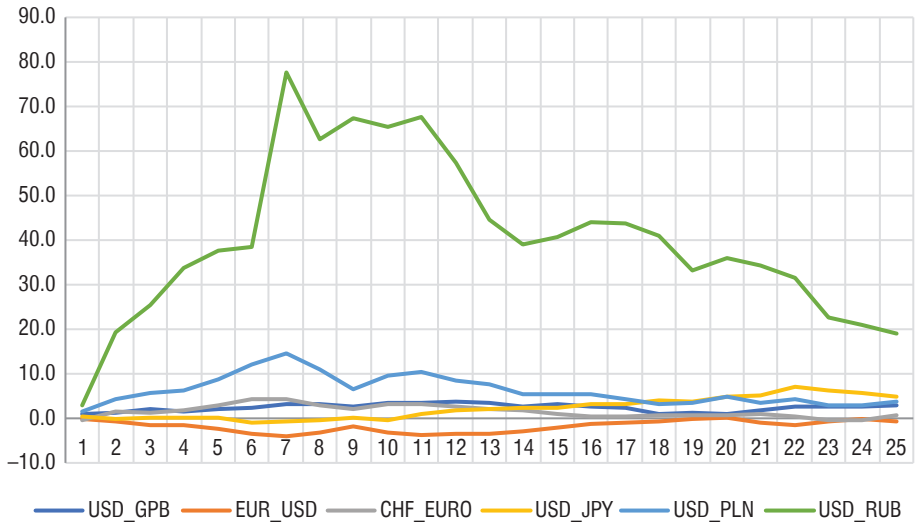


Source: own analysis.

The CAR charts for all stock indices follow the same pattern. A clear downward trend is evident at the onset with a breakout around the 7th–11th day of trading, followed by a slow increase stabilizing rather below zero. By far the largest decline in terms of abnormal returns was recorded for the OMX Riga index, with the CAR stabilizing after 25 trading days at approx. –12%. On the other hand, the S&P 500 index was the least affected of all the stock indices under study. Although it was relatively the last to start recovering from its losses in terms of

abnormal returns, it was also the only index that managed to break through the expected return limit (in the period of 18–24 trading days) with actual returns.

Figure 5. CAR for exchange rates, for event window lengths from 3 days (t = ±1) to 51 days (t = ±1, ±2, …, ±25) (in %)



Source: own analysis.

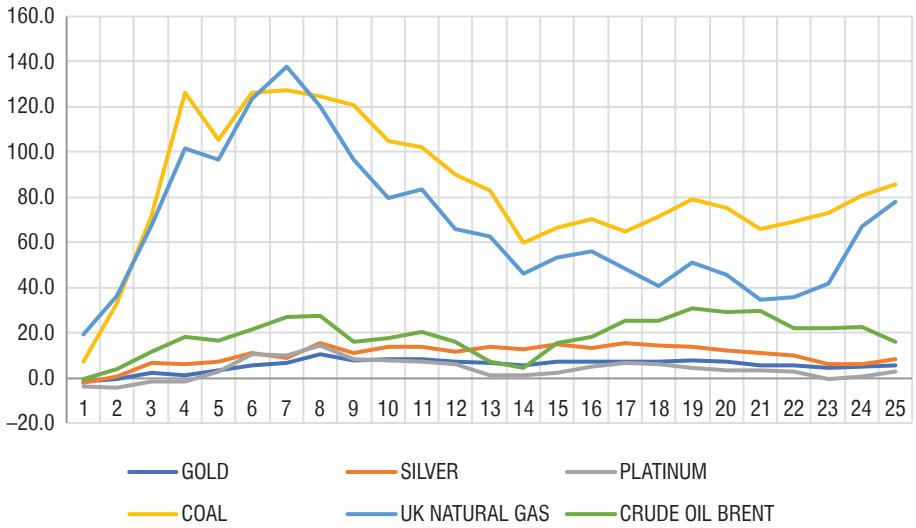
The CAR charts for all the exchange rates have one evident outlier observation in the USD/RUB pair. It is the only currency pair to have such a large disparity between expected and actual returns (CAR of 20%–80%). The other currency pairs were not so much affected by Russia's invasion on Ukraine; here, the signs from the CAR are worth noting. Only for the EUR/USD pair does CAR take negative values throughout the period under analysis. In some periods, negative values are observed for the CHF/EUR and USD/JPY pairs. For the remaining pairs, the values are positive, sometimes exceeding 10% only for the USD/RUB and USD/PLN pair.

Apart from certain event window lengths for platinum and initial readings for gold, silver, and oil, all the CAR sizes for commodities are positive. In comparison with coal and natural gas, the values of the other commodities should be viewed as stable. The CARs for oil demonstrate a somewhat different behaviour. After an initial increase, from around day 7 onwards, the indices tend to decline and stabilize, whereas from around day 13 onwards, there is a clear increase in the divergence between actual and expected returns.

In terms of the CAR values, food demonstrates a behaviour completely different from the other groups of stock instruments considered. First of all, both corn and wheat record an unprecedented increase in their CAR values up to the length of the event window marked by, approximately, the 7th trading day after Russia's invasion on Ukraine. The CAR values for corn have shown a steady upward trend since then, while wheat has tended to see a decline in its CAR values as the length of the event window rises. Both the stock instruments appear to be converging to a similar point (CAR ≈ 22.6%), which can be considered an equilibrium

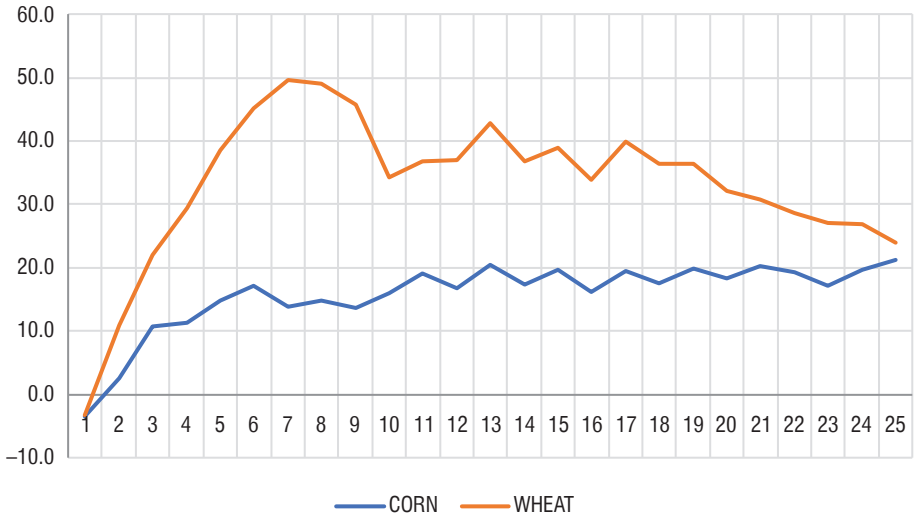
point. Therefore, in comparison to other groups, the stabilization of commodity-related stock instruments appears to be a unique example of stabilization not meaning a return to the state prior to the escalation of the Russian-Ukrainian conflict (understood as the CAR oscillating around point 0), but as finding a new equilibrium point.

Figure 6. CAR for commodities, for event window lengths from 3 days (t = ±1) to 51 days (t = ±1, ±2, …, ±25) (in %)



Source: own analysis.

Figure 7. CAR for food, for event window lengths from 3 days (t = ±1) to 51 days (t = ±1, ±2, …, ±25) (in %)



Source: own analysis.

Summary

The outbreak of the war in Ukraine caused by Russia, ranked among the most important geopolitical events in the world in 2022, has had a negative impact on both global trade and economic development, expressed in changes in the prices of investment assets in various markets including equities, currencies, commodities, and food. The economic impact of the armed conflict in Ukraine on the global economy in terms of the disruption of the international supply chain has led to energy supply shock and changes in trade, which directly translated into rising energy, commodities, and food prices, as well as inflation. It means that geopolitical conflicts tend to have economic effects on other countries not directly engaged in the hostilities.

The first stage of the analysis which focused on assessing the development of the actual size of returns for individual investment assets immediately before, on the day of, and in the quotation immediately following the analysed event showed the following correlations:

- on the day the armed conflict broke out, negative returns were observed in the group of stock investment assets for the majority of stock indices. The S&P 500 index came as an exception as it recorded an increase in returns, which may imply that the date of conflict outbreak may have been predictable. On the day the war began, all stock market indices had positive returns, with the values of the positive returns being comparable to the negative returns (symmetry),
- the currency market reacted differently than the stock market. On the day of the Russian invasion, most currency pairs apart from EUR/USD produced positive returns. The USD/RUB currency pair had the highest return, which was due to the risk of the Russian currency and the denomination of assets into a safe-haven currency in times of armed conflict. In contrast, the post-outbreak day saw declines for the currency pairs under study, with the exception of EUR/USD and USD/JPY,
- on the commodities market on day '0', futures for coal and natural gas, treated as strategic energy commodities, produced the highest positive values of returns. Investments in precious metals (gold, silver) and crude oil (Brent) demonstrated relatively modest growth. Only platinum yielded a negative return. On the post-outbreak day, investments in all commodities took negative values, with natural gas and coal taking the biggest hits,
- on the date the war in Ukraine began, returns on food futures for corn and wheat were positive, with the yield on wheat contracts being approximately three times higher (6%). On the day after the Russian invasion, investments took negative values at higher levels: wheat (–9%), corn (–5%).

All in all, the negative impact of the Russian-Ukrainian war on the development of investment asset values varied across groups. All of the stock indices under analysis (except the S&P 500) reacted on the same day (the day of the outbreak of war in Ukraine on 24 February, 2022) by demonstrating negative return values. The commodity and food markets reacted with negative returns on the day after the war broke out, with the following instruments taking the highest

negative values: coal, natural gas, corn, and wheat futures. On the FX market, relatively small negative returns were observed on the day after the Russian invasion for most of the currency pairs under study (following a significant increment recorded on day '0').

The second stage of the analysis was aimed at assessing how the value of abnormal returns on selected investment assets evolved in the short and medium term for event windows from 3 days (t=±1) to 51 days (t = ±1, ±2,…, ±25). The pertinent study allowed for the following conclusions:

- abnormal returns, understood as the difference between expected and actual returns, of most of the indices under analysis (except for S&P 500) demonstrated significant negative values in different event windows which are characteristic for investments in regions neighbouring Russia and Ukraine or in European Union countries, as these regions are significantly affected by the war and carry a relatively high geopolitical risk;
- in the FX market, the USD/RUB currency pair produced a clear increase in positive abnormal returns (CAR of 20%–80%). The USD/PLN pair also had significantly positive values in all the event windows. The appreciation of the US dollar versus the Russian rouble and the Polish zloty may have been caused by investors' concerns and uncertainty about local currencies in favour of a safe-haven currency which is present internationally;
- the commodities market showed significant positive abnormal growth rates for gas and coal (strategic energy commodities), whose price increase is mainly due to geopolitical risks associated with the outbreak of the war in Ukraine and a period of uncertainty for importers of these commodities. Among precious metals, positive growth rates in all event windows were evident for silver and gold, with silver enjoying greater confidence among investors as it took relatively higher return values,
- in the food market, abnormal returns were negative in the event window (–1,+1), for corn and wheat futures taking values of respectively: – 3.5% and –3.4%. In the other event windows under study, abnormal rates of return were positive and they reached a much higher equilibrium level than before the war broke out, at ca. 22%. The increase in food prices is related to the negative economic impact of the Russian-Ukrainian war on the entire world economy through, inter alia, disrupting the international supply chain which caused an imbalance in energy supply and disruptions in trade patterns immediately affecting the growth of, i.a., food.

All in all, CAR measures were computed for each of the assets considered for various window lengths. The quotations of most of the investment assets under study stabilized between 3 and 10 days after Russia had invaded Ukraine. It is noteworthy, however, that in the period immediately following the moment of the crisis under study, some investment assets demonstrated a deviation of the CAR measure *in plus* and some *in minus*. The magnitude of the deviation and the length of time, however, are case specific. The observed differences among and within groups confirm there are exceptions to the discussed patterns of behaviour.

The analyses have limitations, primarily in the subjective selection of selected markets. However, it seems that this choice allows us to draw certain universal regularities in market

behaviour. The second limitation is the lack of guarantee of repeatability of these behaviours. Each unforeseen event (disasters, wars, crises, etc.) is unique. Nevertheless, based on the literature research, one can find confirmation of the high repeatability of the behaviour of the entire economy. Differences occur in the times when the economic situation returns to equilibrium. Depending on the strength of the connection between a specific investment asset and the threat created by the event being investigated for the stability of mining, production or the supply chain, the stabilization time may be counted in days, weeks or even months. Moreover, it does not necessarily mean a return to the previous equilibrium point, but an entirely new value may be determined around which new economic dependencies will be built. Typically, prices of raw materials, e.g. those at risk due to war, increase. The presented analyses confirm this pattern of behaviour. On the other hand, it is difficult to predict the behaviour and the process of shaping new relations and prices a priori.

One of the limitations of every study is the quality of the results. In this analysis, the results obtained rely mainly on the validity of the CAR measures used. Even though they are generally accepted methods in event analysis for measuring abnormal rates of return, due to their simplified structure assuming linearity of relationships over time, they may not sufficiently reflect the high volatility of quotations over a more extended period. One of the variables that should be taken into account in this matter is the estimated window length itself, and even the issue of the symmetry of the event window. However, the adopted analysis values do not differ from the parameters commonly used in this type of analyses.

The pertinent study, which employed an event study to assess the reaction of selected markets (equities, currencies, commodities, and food) to the Russian invasion of Ukraine in 2022, has allowed to determine changes in the returns of selected investment assets over the short to medium term. Despite its limitations, this is the first study that addresses in such a broad way the issue of the impact of the outbreak of war on the prices of various investment assets. The added value of this article cannot be overestimated from the point of view of consolidating the validity of the event window analysis approach to examining short and medium-term changes. Moreover, the presented analyses constitute an essential argument for the applicability of multidimensional event analysis. Particularly in the case of examining economic dependencies, connections between individual investment assets should not be treated independently and discussing them in isolation from other values may contribute to too narrow a perception of the examined issues. Nevertheless, due primarily to the inflow of new information from war zones, as well as the multidimensional character of the analyses, the researched topic cannot be considered as complete. Further research in this area will pertain to both new financial instruments and longer-term analysis.

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