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Joshua Aizenman
Robert Lindahl
David Stenvall
Gazi Salah Uddin

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Geopolitical Shocks And Commodity Market Dynamics: New Evidence From The Russian-Ukraine Conflict
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ABSTRACT

We investigate the event-based geopolitical shocks from the Russian invasion of Ukraine on selected agricultural and energy commodities using daily event-based structural vector autoregression (SVAR). We find that the geopolitical shock affects the markets of wheat (3%) and European natural gas (12%). However, substantial heterogeneity is observed among the food and energy markets. Geopolitical risk affects the European natural gas market more strongly than the US and Asian markets. The regional segment of natural gas markets could explain this. Finally, the dynamics of the impacts of geopolitical news are analyzed in the stock, currency, and bond markets.

Joshua Aizenman
Economics and SIR
University of Southern California
University Park
Los Angeles, CA 90089-0043
and NBER
aizenman@usc.edu

Robert Lindahl
Department of Management
and Engineering
Linköping University
SE-581 83
Linköping, Swed
Sweden
robert.lindahl@liu.se

David Stenvall
Linköping University
SE-581 83
Linköping
Sweden
david.stenvall@liu.se

Gazi Salah Uddin
Department of Management and Engineering
Linköping University
Linköping 58183
Sweden
gazi.salah.uddin@liu.se

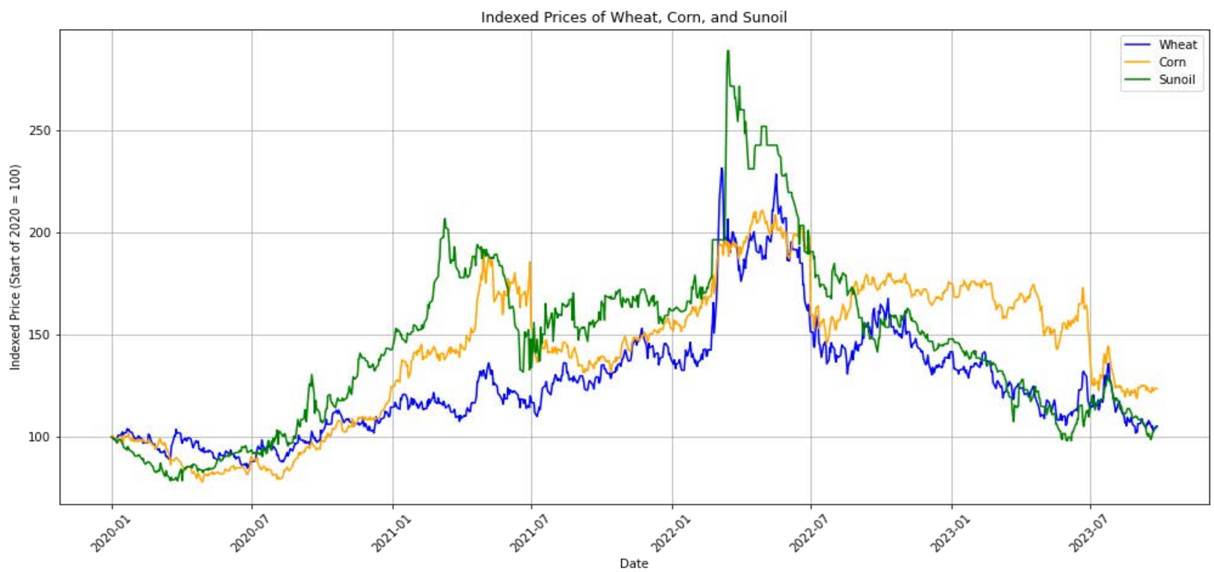
1. Introduction

Global supply chains have seen significant disturbances in recent times. In early 2020, the world started grappling with the significant repercussions of the COVID-19 pandemic, which redefined global trade and commodity flows. However, soon before the world was able to stabilize, another major geopolitical event shook the world – the Russian invasion of Ukraine in February 2022. This invasion did not remain a regional conflict but rapidly created a significant disruption for the global economy.

The geopolitical ramifications of the invasion were immediate and widespread. Many nations responded by imposing stringent tariffs on Russia to exert economic pressure and signal opposition to the invasion. A direct consequence of these sanctions was observed in the energy markets. Europe, closely tied to Russian natural gas, witnessed a sharp increase in energy prices, adding another layer of complexity to the already stressed global economic situation. However, the conflict has directed attention not only to energy markets but also to other commodities.

Ukraine has consistently been a pivotal part of the global agricultural supply chain. In 2021, Ukraine was responsible for 46% of sunflower oil exports, 12% of corn exports, and 9% of wheat exports (World Economic Forum, 2022). The conflict has significantly hampered Ukraine's ability to export. Figure 1 shows the rapid price development and high volatility among high-export commodities.

Figure 1. Price development of wheat, corn, and sunflower oil.



Since the start of the Russia-Ukraine war, academic literature has begun quantifying the financial and economic consequences. Recent studies estimate the effect of the war on green financial assets (Zhang et al., 2023), equity markets (Lo et al., 2022), precious metals (Shahzad et al., 2023) and on various financial markets (e.g., Umar et al., 2022; Tong 2024). While the available literature offers a broad view of the initial impact of the war on multiple assets, there is still room for improvements. First, many studies use a short sample period spanning approximately the initial year or less, and thus only capture the early effects of the war. Secondly, the literature currently lacks studies that comprehensively explore the impact on agricultural markets. Despite that Ukraine is an important exporter of some agricultural commodities, we argue that there are reasons to explore commodities beyond those directly exposed through disruptions in trade. Although the literature is still quite scare and the effects remains unclear, some recent evidence indicates that geopolitical risk may influence different agricultural commodities (e.g., Bossman et al., 2023), and that it can affect spillovers across commodities (Gong and Xu, 2022). Furthermore, there is extensive literature that has documented spillover and dependence among energy commodities, especially crude oil, and agricultural commodities (e.g., Nazlioglu et al., 2013; Shahzad et al., 2018; Ji et al., 2018; Dahl et al., 2020; Tiwari et al., 2022). Hence, soaring energy prices due to the war might spread to agricultural commodities. Against this background, this study aims to quantify the impact of the Russia-Ukraine war on the prices of agricultural commodities and a selected number of energy commodities. Furthermore, we extend the analysis to agrarian companies, creating our stock market index with companies particularly exposed to agricultural commodities[1][1]. Specifically, we aim to select significant war-related events from February 24, 2022, until September 25, 2023, discerning the tangible effects. To achieve this, we use the methodology developed by Rigobon (2003) and subsequently expanded upon by Wright (2012). This approach utilizes a structural vector autoregression (SVAR) and allows us to measure shocks by identifying heteroskedasticity between non-event and event days. This method has recently been used to study the effect of other geopolitical events on financial markets (e.g., Boer et al., 2022; Miescu & Rossi, 2021).

We contribute to the literature in several ways. While some previous papers examine the volatility spillover and price shocks on agricultural markets (e.g., Hamadi et al., 2017; Nazlioglu et al., 2013; Umar et al., 2021; Yang et al., 2003), no study to our knowledge has investigated the effect of Russia-Ukraine war and focused in such a detailed manner on agricultural markets. Additionally, we analyze the impact on agricultural stock market companies and not only the prices of agricultural commodities. Lastly, we contribute to the current literature by providing more knowledge on the contrasting effects on the European and American natural gas markets, assessing the impact on the European equity market, and examining the war-related effects on specific currencies and bond markets.

Our study is primarily related to Tong (2024), who extensively investigated the economic effects of the Russia-Ukraine conflict on various financial markets using a similar methodological approach. However, our study differs from Tong (2024) in certain vital aspects. Regarding methodology, we identify the events based on a narrative approach in which the events are chosen based on news readings. This approach differs from Tong (2024), who uses more of a quantitative approach based on selecting the events from a war-related news index. Using our method, we ensure the inclusion of specific events, such as bombings of ports, that we believe might impact the agricultural infrastructure. This allows us to include events with agricultural significance but might need more headline coverage. Hence, our narrative approach is the most appropriate method for capturing the full extent of the war on agricultural markets. In terms of the data, our study differs from Tong (2024) as we focus on a selected number of energy commodities and agricultural

[1] The purpose of this specialized equity index is to investigate whether or not these firms respond to the war shock in a similar manner as the broader stock market or if there are mechanisms that impact the effect. Note that the companies we include in this stock market index do not have business in Ukraine.

markets instead of financial markets. Thus, we include a more extensive set of agricultural commodities and the self-created stock price index for Western agricultural-related companies. Unlike Tong (2024), who chose to start the sample period a year before the Russian invasion (i.e., January 2021), our sample period is more directly related to the actual war period (starting in early 2022). Additionally, our sample extends much further into the conflict[2][2], allowing us to investigate the longer-term effects of the war.

Our paper is also related, although to a lesser extent, to two other articles that investigate the effect of the Russia-Ukraine war on commodities, i.e., Saâdaoui et al. (2022) and Wang et al. (2022). These papers differ from our paper in three different ways. First, they include a more limited number of agricultural commodities[3][3]. Secondly, the authors use different methodologies, focusing on causality testing (Saâdaoui et al., 2022) or connectedness (Wang et al., 2022). Lastly, their sample periods end in April 2022, thus covering only the initial period after the Russian invasion.

Our results show heterogeneous responses of various agricultural commodities, with a positive response on wheat prices but insignificant effects on corn and sunflower oil. European natural gas has a significant response (12%), while other natural gas markets seem primarily unaffected. Our propriety equity index does not exhibit the same negative response as general European equity.

From this point onward, the paper will be structured as follows. The next section presents the data used to study the war's effect on the selected markets and the heteroskedasticity-based SVAR methodology. Following that, we present our results from the various SVAR models and evaluate them. Finally, we summarize our findings to present a more general picture of which selected markets have been most affected.

The paper proceeds as follows. Section 2 discusses the data sample and methods. Section 4 presents the empirical results. Section 5 concludes and discusses policy implications.

[2] The sample period of Tong (2024) ends in late November 2022.

[3] As relates to the agricultural market, Saâdaoui et al. (2022) include rice, corn, and wheat, while Wang et al. (2022) include Wheat, Corn, Oats, Sugar, and Soybeans.

2. Data and methodology

2.1. Data and event days

We use daily data from Refintiv Datastream from January 3, 2022, to September 25, 2023. The Russian invasion of Ukraine began on February 24, 2022, meaning we were captured a couple of weeks prior to the war. The time window is limited to minimize the risk of structural breaks and avoid significant events unrelated to the war in our data. Table 1 shows the selection of commodity and financial variables. Incorporating macroeconomic controls into our analysis, we include the following variables: the German 10-year yield, the Euronext equity index, the VSTOXX 50, and the USD-EUR exchange rate. All variables are entered into the model as log levels, except for interest rate, which is entered as first-difference, as the yield exhibits a clear upward trend. Table 2 shows the descriptive statistics of all variables.

Table 1.

	Description	Symbol
Wheat future	Chicago Board of Trade Wheat Composite Futures	CWFCS00
Corn future	Chicago Board of Trade Corn Composite Futures	CCFCS00
Soybean future	Chicago Board of Trade Soybean Composite Futures	CSYC.01
Rough rice future	Chicago Board of Trade Rough Rice Composite Futures	CRRCS00
Rapeseed future	MATIF Euro Rapeseed TRC1	PROC.01
Cocoa future	CSCE – Cocoa Continuous Index	NCCCS04
Coffee future	CSCE – Coffee Continuous Index	NKCCS04
Sugar future	CSCE – Sugar #11 Continuous Index	NSBC04
Sunflower oil future	1 Month US futures	SUNFXT1
Crude oil future	NYMEX – Light Crude Oil Continuous	NCLCS00
Natural gas future (US)	NYMEX – Natural Gas Continuous	NNGCS00
Natural gas future (EU)	RFV Natural Gas TTF Netherlands	TRNLTTM
Natural gas future (India)	MCX – Natural Gas TRc1	MNGC.01
Natural gas spot (Japan)	Clean Tanker Middle East Gulf-Japan 75KT TC1	CFMEJPL
Agricultural Index	S&P 600 Agricultural and Farming Machinery Index	SP6SAG4

In constructing our proprietary equity index of milling companies, we initially categorized publicly traded firms in North America and Europe's milling, corn, wheat, and sunflower oil sectors. Subsequently, we obtained daily market capitalization data for each of these firms. The weight assigned to each firm's daily market capitalization in the index was determined based on size. For a comprehensive list of all included firms, see the appendix.

Table 2. Descriptive statistics

	Mean	Std. dev	Skewness	Kurtosis	ADF	PP
Wheat	6.67	0.82	0.53	2.55	0.46	0.47
Corn	6.46	0.57	-0.66	3.12	0.45	0.45
Sunflower oil	7.19	1.08	0.41	2.38	0.35	0.35
Soybean	7.32	0.31	0.19	2.19	0.57	0.58
Rough rice	7.42	0.32	-0.49	2.63	0.76	0.72
Rapeseed	6.39	1.03	0.34	2.23	0.18	0.20
Cocoa	4.67	0.57	0.89	2.68	0.94	0.94
Coffee	3.44	0.55	-0.25	1.77	0.31	0.35
Sugar	4.92	0.64	0.64	1.83	0.98	0.98
Milling Companies	10.55	0.30	-0.06	2.33	0.61	0.63
S&P Agricultural	5.21	0.43	-0.06	1.72	0.57	0.50
Crude oil	4.45	0.62	0.51	2.38	0.71	0.73
US Natural gas	1.46	1.57	-0.01	1.47	0.40	0.44
EU Natural gas	4.33	2.59	0.03	1.89	0.46	0.43
India Natural gas	5.85	0.48	0.03	1.47	0.50	0.53
Japan Natural gas	5.02	0.25	-0.67	3.93	0.67	0.66
VSTOXX 50	3.11	1.33	0.28	2.45	0.56	0.59
Euronext	7.15	0.24	-0.53	2.17	0.60	0.57
German 10-year yield	0.01	0.52	-0.67	4.17	0.00	0.00
Euro/USD FX	0.06	0.18	-0.56	2.73	0.12	0.13

Notes: Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are presented with 5 lags, in line with our specification for the VAR-model.

Regarding the events, we used Refinitiv Eikon to attain significant days of the Russian invasion of Ukraine. In order to filter the initial list, we used a keyword search syntax (e.g. ("Ukraine" OR "Russia) AND ("Agriculture" OR "Attack" OR "Port")), and the selection of relevant events was made based on the search. Table 3 shows the dates and description of the selection. All events in Table 3 are included in our baseline model. If the news of the event occurs on the day the market is closed, the subsequent trading day is selected. As a robustness test, we run our model with fewer " Restricted " events and **"**Attacks." These results can be found in the appendix. The baseline model consists of 35 dates starting from February 24, 2022, and the last event on August 23, 2023**.** We chose to adopt a narrative approach when selecting event days to ensure that the selection did not accidentally include events that were not relevant to the purpose of the paper. Other studies (e.g., Tong, 2024) select a more quantitative approach using a war-related news index. However, we would argue that the approach opens up the possibility of including events that do not necessarily affect the agricultural markets or are unrelated to the 2022 invasion. The selection of events does not solely encompass general war-related news, but we include specific events, such as bombings of ports, that should impact the agricultural infrastructure in Ukraine.

Table 3. Selection of event days

Date	Description	Events: Baseline	Restricted	Attacks
2022-02-24	Russian invasion begins	X	X	X
2022-02-25	First attacks on Kyiv	X	X	X
2022-03-01	Siege of Mariupol and attacks on Kharkiv	X	X	X
2022-03-04	Seizure of Zaporizhzhia nuclear power plant	X		X
2022-03-09	Mauripol hospital attack	X		X
2022-03-16	Mauripol theater bombing	X		X
2022-03-23	Mykolaiv port attack	X		X
2022-03-29	Attack on Mykolaiv regional state administration building	X	X	X
2022-04-02	Russia retreats from Kyiv	X		X
2022-04-08	Attack on Kramatorsk railway station	X	X	X
2022-05-09	Biden signed act to lend defensive support to Ukraine	X	X	
2022-06-27	Attack on Kremenchuk	X	X	X
2022-07-01	Attack on Serhiivka, Odesa	X	X	X
2022-07-22	Black Sea Agreement begins	X	X	
2022-07-24	Attack on Odesa port	X		X
2022-09-21	Russia extends mobilization and draft	X		
2022-10-08	Crimean bridge attack	X		X
2022-10-10	Attack on Kyiv, blackout in city	X	X	X
2022-10-29	Russia leaves Black Sea Agreement	X		
2022-11-02	Russia re-enters Black Sea Agreement	X		
2022-11-19	Black Sea Agreement extended to 18th of March	X		
2022-12-12	Odesa port attacked	X	X	X
2023-01-25	Germany ships military equipment	X		
2023-03-18	Black Sea Agreement extended another 60 days	X		
2023-05-02	Poland, and others, ban Ukrainian grain imports	X		
2023-05-17	Black Sea Agreement extended another 60 days	X		
2023-05-29	Attack on Odesa port	X		X
2023-07-17	Russia leaves Black Sea Agreement	X	X	
2023-07-18	Attack on Odesa port	X	X	X
2023-07-19	Attack on Chornomorsk port and Poland extends import ban	X	X	X
2023-07-24	Attack on Danube port	X		X
2023-07-27	Attack on Odesa port	X		X
2023-08-16	Attack on Reni port	X		X
2023-08-23	Attack on Danube port	X		X
Total		**35**	**14**	**23**

2.2. Methods

This paper applies the identification method through heteroskedasticity, first developed by Rigobon (2003) and later expanded upon by Wright (2012). We use a structural vector autoregression (SVAR) with five lags following Boer et al. (2022). Our model always includes four financial variables: the Euronext Index, VSTOXX implied volatility index, German 10-year yield, and USD-Euro foreign exchange rate. The fifth variable in each model is one of the commodities found in Table 1 and the index of milling companies. Relating to the signs of the results, similar to Boer et al. (2022) and Miescu & Rossi (2021), we look at a war shock such that it leads to an increase in market volatility[4], i.e., the VSTOXX index.

The reduced form VAR can be represented as:

$$A(L)Y_t = \mu + \varepsilon_t \tag{1}$$

Where Y_t is the p x 1 vector of variables, and ε_t is the reduced-form errors. Following Wright (2012) it can be further assumed that the relationship between the reduced-form errors and the structural shock can be described as:

$$\varepsilon_t = \sum_{i=1}^{p} R_i \eta_{i,j} \tag{2}$$

Where η represents the structural shocks and R is the vector of coefficients, the rest of the variables in equation (1) and (2) are assumed to be constant. The underlying assumption is that the structural shock on event days has the variance, σ_e^2, with a mean of zero, but another variance, σ_{ne}^2 on non-event days. This method assumes that $\sigma_e^2 \neq \sigma_{ne}^2$, but that all other shocks to the variables are identically distributed during the whole time period. Wright (2012) discusses that other shocks, unrelated to the purpose of our paper, can occur and differ from day to day, but it will not affect the measurement of our war-shock as long as they can be assumed to average out between event and non-event days.

Similar to Wright (2012), we denote the variance-covariance matrix of reduced-form errors on announcement days as Σ_e, and for non-event days, Σ_{ne}. We can now subtract the variance-covariance matrices, $\Sigma_e - \Sigma_{ne}$ and express them as:

$$\Sigma_e - \Sigma_{ne} = \mathrm{R}_1 R_1' \sigma_e^2 - \mathrm{R}_1 R_1' \sigma_{ne}^2 = \mathrm{R}_1 R_1' (\sigma_e^2 - \sigma_{ne}^2) \tag{3}$$

[4]Practically, this is implemented by imposing a restriction such that we force the parameter for VSTOXX to be positive.

And following Wright (2012), we can estimate the impact of the war shock, represented by R_1, through solving minimum distance problem:

$$\mathrm{R}_1 = \arg\min[vech(\hat{\Sigma}_e - \hat{\Sigma}_{ne}) - vech(\mathrm{R}_1 R_1')]'\left[\widehat{V_e} + \widehat{V_{ne}}\right]^{-1}[vech(\hat{\Sigma}_e - \hat{\Sigma}_{ne}) - vech(\mathrm{R}_1 R_1')] \quad (4)$$

Following Boer et al. (2022), we can obtain the first structural shocks by:

$$\varepsilon_{1t} = \frac{\mathrm{R}_1{}'\Sigma_e{}^{-1}\mathrm{u}_t}{\mathrm{R}_1{}'\Sigma_e{}^{-1}\mathrm{R}_1} \quad (5)$$

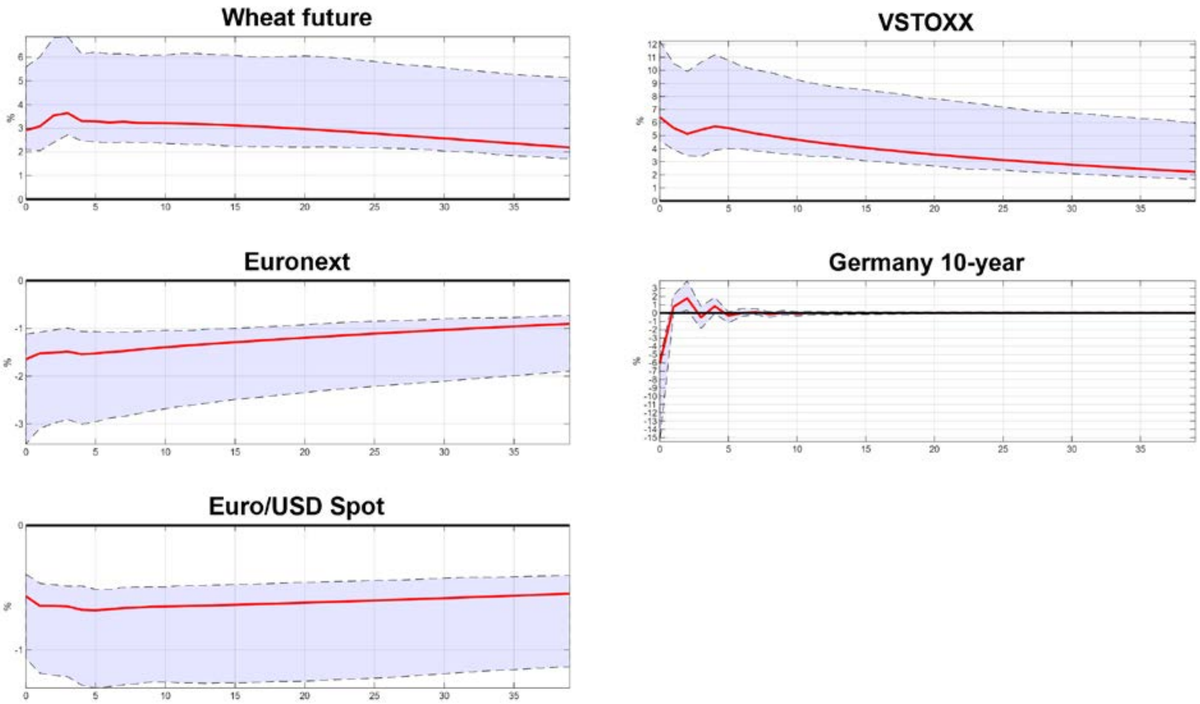
Where Σ_e is the reduced form covariance matrix over the whole sample.

3. Empirical Results

The results from our primary model are presented in Figure 2. Starting with the result for the wheat market, we observe a positive price surge of approximately 3% for the future price as a response to the war shock. This effect is more significant than Tong's (2024) observation, which could be partly due to the difference in event selection. Regarding the financial variables, the results align with our expectations. The European stock market volatility shows a significant increase of 5% in response to the identified events. In line with this heightened volatility, European stocks jump negatively while Euro weakens against the USD.

Additionally, the German 10-year yield undergoes a negative shock and should be interpreted cumulatively. The observations align with our expectations and can be interpreted as the occurrence of the flight-to-safety mechanism. As geopolitical uncertainty increases, US wheat prices increase instantaneously, reflecting the market's concerns over supply disruptions from Ukraine. Notably, the effects remain significant even at longer horizons, with wheat losing significance around day 70.

Figure 2. The effect of heteroskedasticity based war shock on wheat future and financial variables.

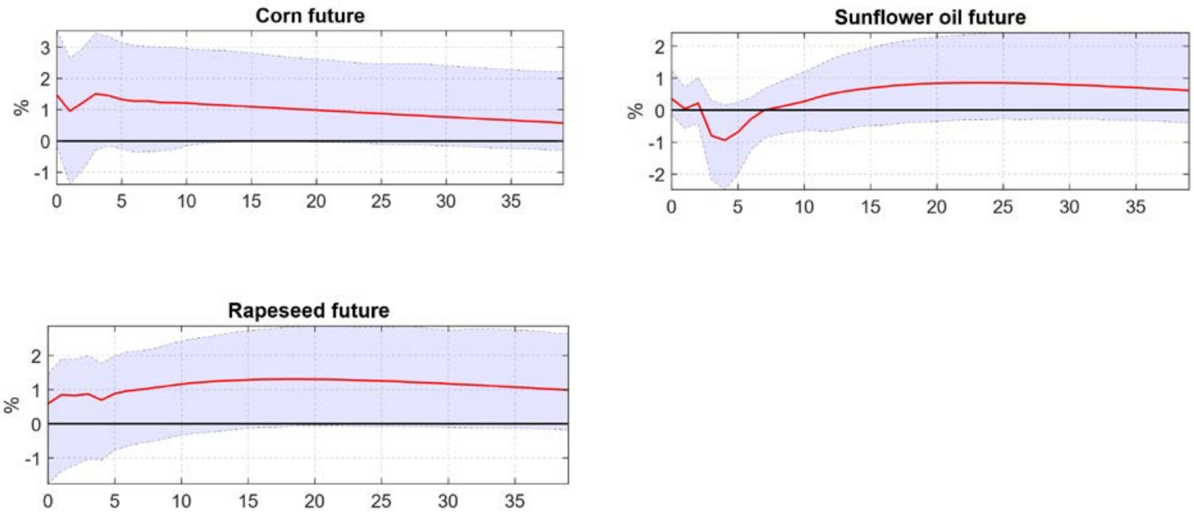


Notes. The red line represents the impulse response function. The shaded area is the bootstrapped (n = 1000) confidence interval of 95%. The x-axis is expressed in days.

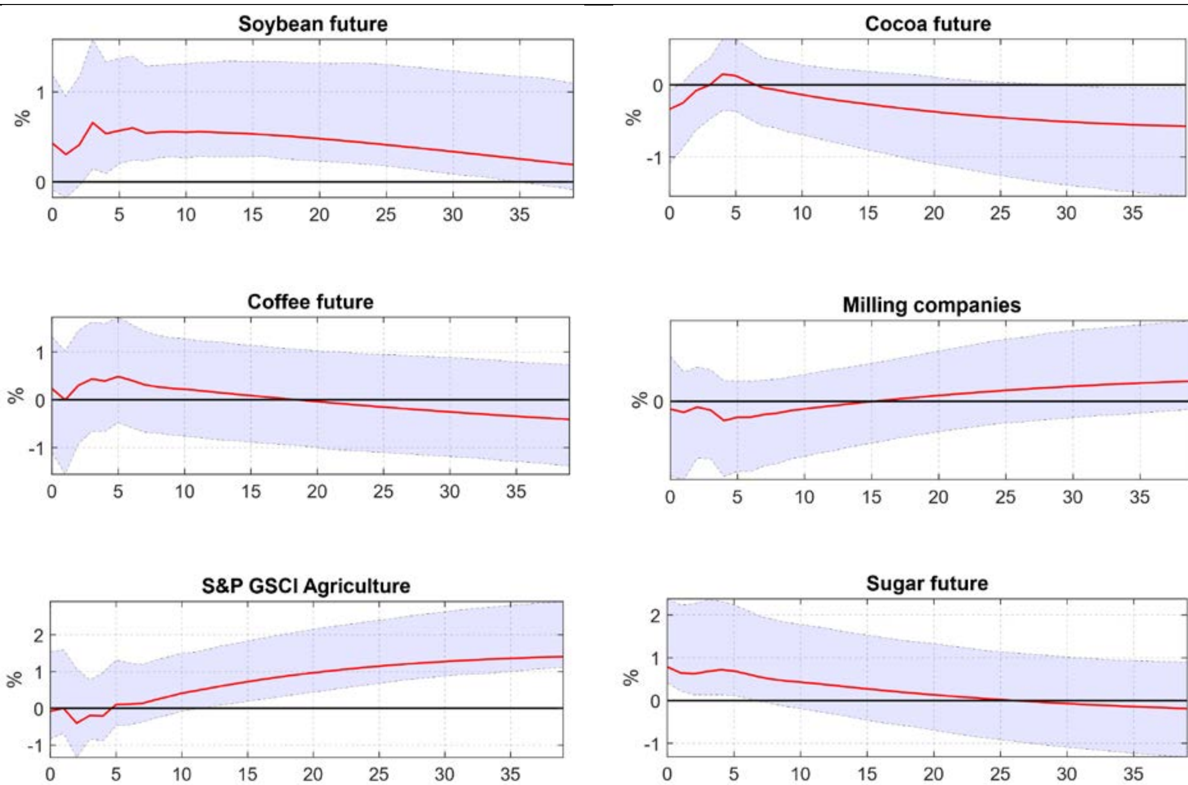
Figure 3 aggregates the results for the remainder of the variables. In contrast to wheat, no significant effect can be found in observing corn future prices, our self-constructed equity index, or sunflower oil futures. Sugar, rough rice, and soybean exhibit a positive price shock but are smaller in magnitude and drop off quicker than wheat prices. A possible reason is that Russia and Ukraine export these commodities but are smaller markets compared to, e.g., wheat. Interestingly, a positive effect is found for the S&P Agricultural Index, but it is only significant around two weeks after the event. This could mean that investors need to be more cautious with pricing regarding the effects of the conflict and its impacts on US agricultural equity.

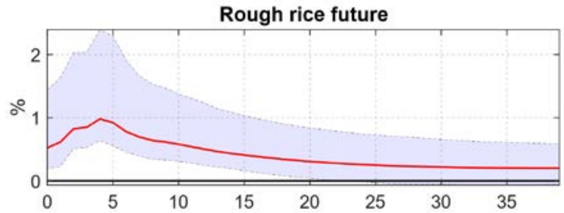
Figure 3. The effect of heteroskedasticity based war shock on commodities.

A. Ukraine export-intensive commodities

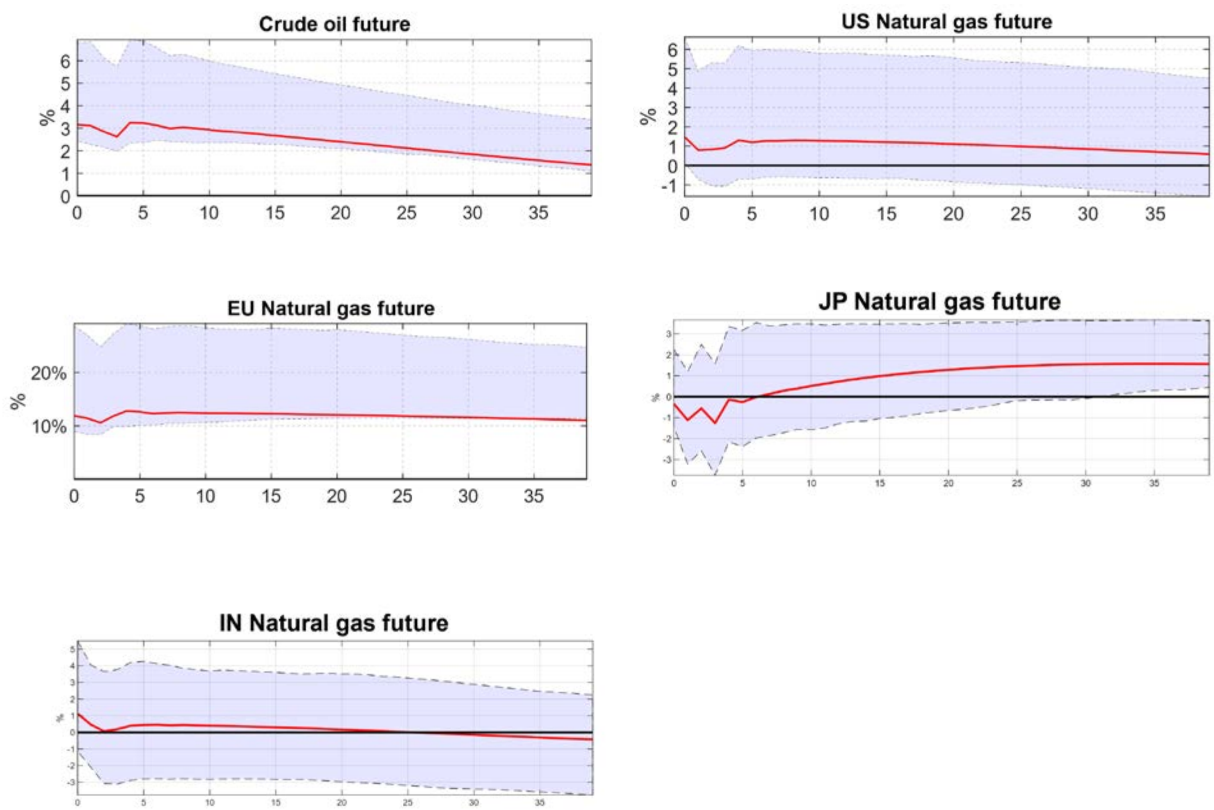


B. Other agricultural commodities





C. Energy commodities



Notes. The red line represents the impulse response function. The shaded area represents the bootstrapped (n = 1000) confidence interval of 95%. The x-axis is expressed in days. All variables in this table are run in a model similar to that of figure 1 but replacing the wheat series and maintaining the other four financial variables.

As for energy, we find a significant positive response to European natural gas of about 12%, with an effect that extends into longer time horizons and a more minor but positive effect on crude oil. Contrarily, we do not find that the shock spreads to US natural gas as the effect is insignificant. We do not find any significant effect on US or Indian natural gas due to the war shock. However, Japanese natural gas shows positive price development at longer time horizons.

3.1 Robustness

As robustness checks, we want to investigate the sensitivity of our results if we were to differ in our selection of events compared to the baseline model. The three different event selections can be found in Table 3. "Restricted" and "Attacks" are the two alternative selections used for robustness checks. Full results for these events can be found in the appendix, figures 5 and 6 for "Restricted" events and 7 and 8 for "Attack" events.

Regarding the responses to "Restricted" events, we find results generally similar to our "Baseline" events but more exaggerated. Wheat prices show a more robust response of 4%, compared to 3% in "Baseline ." The most significant difference is in rapeseed prices, which jump 3% and are significant for longer horizons. Interestingly, while EU natural gas shows a weaker response than "Baseline," US natural gas response becomes slightly significant at around two weeks, but the effect is negligible. In contrast to expectations, crude oil seems to exhibit a smaller response than the "Baseline" model. The financial variables (VSTOXX, Euronext, German 10-year yield, and Euro/USD) exhibit similar but stronger responses to "Baseline" events. As the "Restricted" event selection is meant to select events deemed to be the most pronounced dates relating to the war, the results on financial variables are expected to be more significant.

Our third event series, denoted as "Attacks," focuses solely on events, including more significant attacks and destroying relevant infrastructure (e.g., ports). Responses are broadly similar to the other models but have weakened effects, e.g., wheat responds with less than 3% and a weaker significance. We find the largest difference in the corn response. Other events showed low or no significance for corn, but now we find an increase of 3% that extends into longer horizons. In contrast to "Baseline" events, rapeseed also has a strong positive price response similar to the "Restricted" events. Crude oil has the largest response with the "Attack" events amongst the three alternatives, 4% compared to 3% in "Baseline" and 2% in "Restricted." EU natural gas shows a weaker effect than "Baseline," more similar to the result from "Restricted" events. US natural gas seems to have a slight but negative price response.

In general, we find that the event series used for robustness shows similar results to our "Baseline" model with slight variations. Specifically, corn prices were more affected by attacks on ports than other agricultural commodities. A second noteworthy result is that while our "Baseline" events do now show significance for rapeseed, results from both our robustness checks show a positive price response.

4. **Conclusion**

The Russian invasion of Ukraine has caused significant disruption to major parts of the global agricultural supply chain. We investigate the effects of this heightened geopolitical risk on agricultural commodities by identifying heteroskedasticity on defined event days occurring between January 2022 and September 2023. Our primary results reveal that the war caused a direct and significant impact on several commodities. The largest positive price shocks can be found in wheat, which Ukraine is a major global exporter of. Furthermore, analysis of financial variables contributes to the literature by showcasing increased volatility in the European stock market and a weakening of the Euro against the USD. These financial shocks align with the flight-to-safety mechanism, signifying concerns about the disruptions and risks emanating from the conflict. In contrast to our findings for the Euronext index, we find an insignificant effect on our constructed equity index. This points towards the fact that the increased risk of conflict is subsumed by the positive consequences, such as increased demand and price on their goods, for these firms. We find mixed results for the remainder of agricultural commodities, but shorter and positive price responses can be found in commodities of which Russia and Ukraine are exporters. Our paper contributes to previous research by examining how the Russian-Ukraine conflict affected agricultural and financial markets and the broader literature of event-based studies.

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Appendix

Table 4. List of companies included in milling index.

Company Name	Market Cap (thousand USD)	Country of Exchange
Grupo Minsa SAB de CV	3 487 935	Mexico
Skane mollan AB	756 800	Sweden
Groupe Minoteries SA	89 437	Switzerland
Loulis Food Ingredients SA	45 523	Greece
Landshuter Kunstmuehle CA Meyer`s Nachfolger AG	32 400	Germany
Granolio dd	14 162	Croatia
Paulic Meunerie SA	10 426	France
Zito Karaorman AD Kicevo	6 874	Macedonia
Flour Mills C Sarantopoulos SA	4 598	Greece
Mitsides PCL	1 885	Cyprus
MPI Mlin dd Ustikolina	368	Bosnia and Herzegovina

Figure 5. Price development of US and EU natural gas.

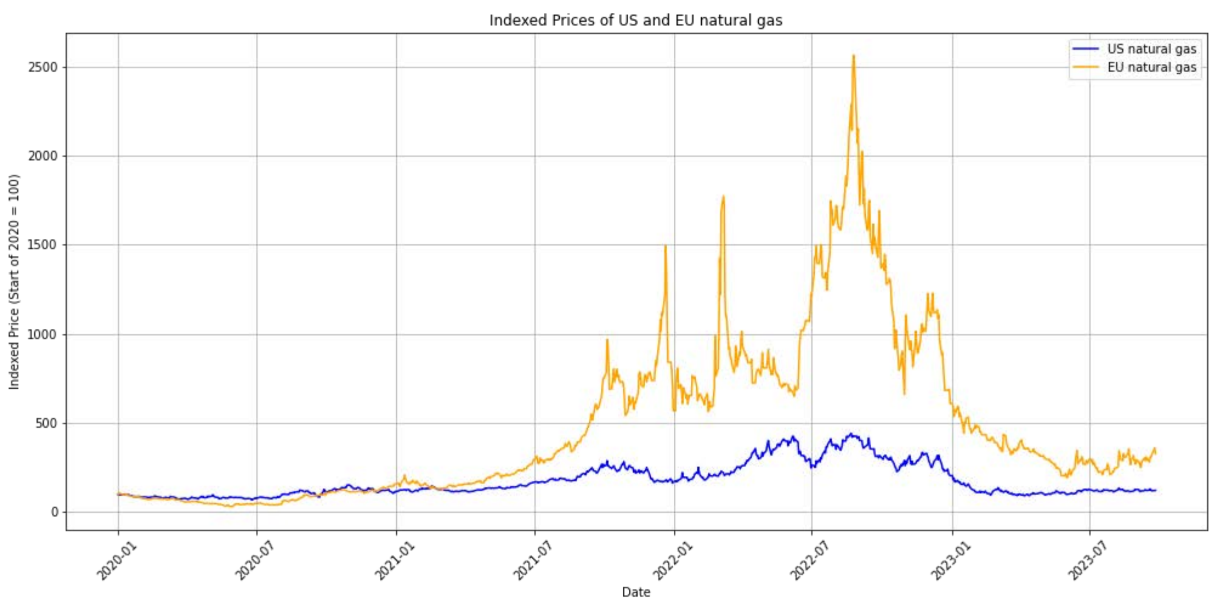
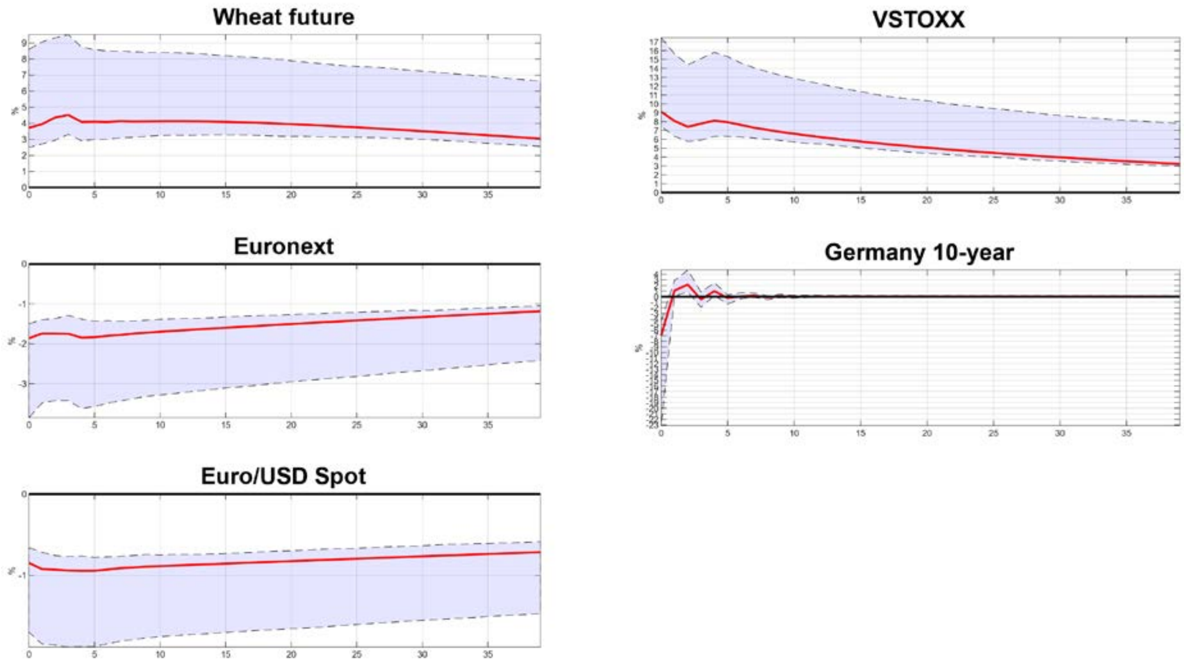


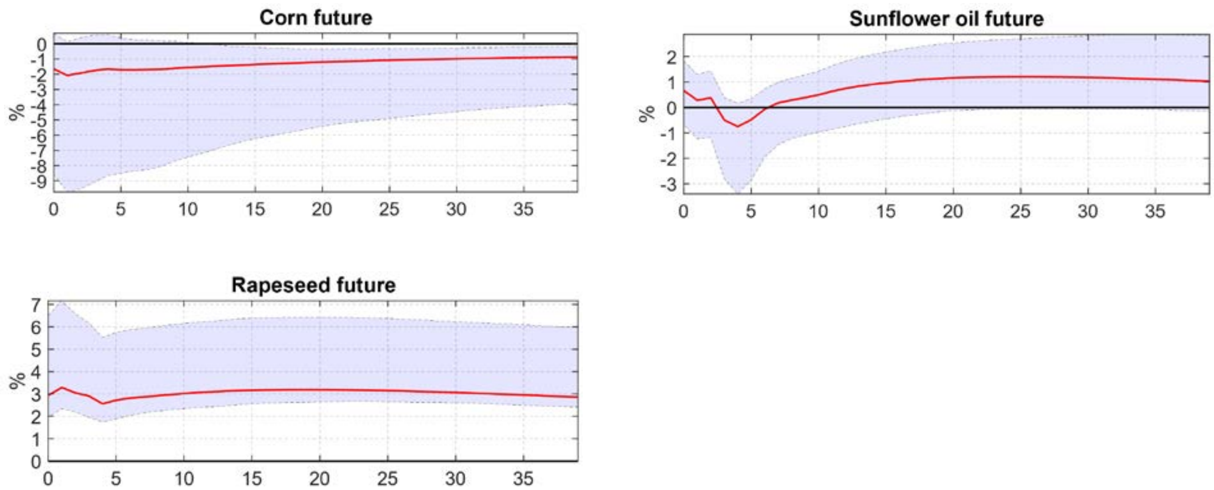
Figure 6. The effect of heteroskedasticity based war shock on wheat future and financial variables. Results of "Restricted" events in table 3.



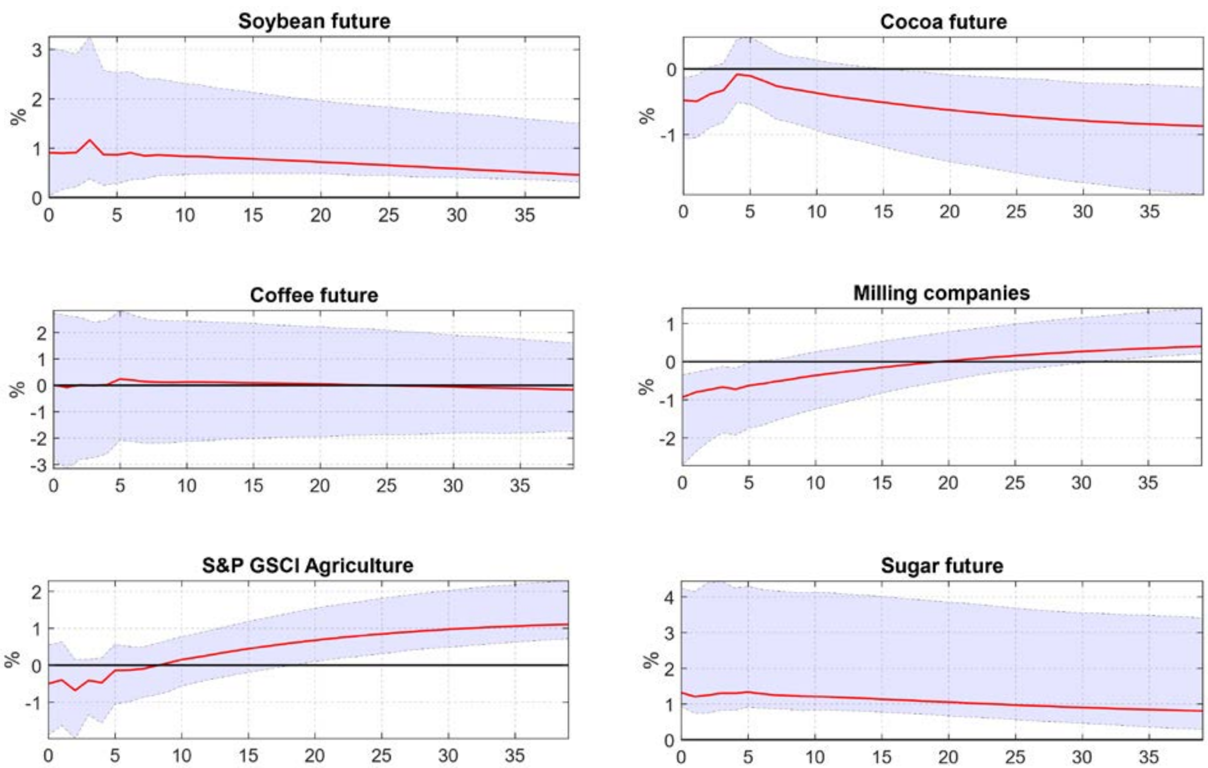
Notes. The red line represents the impulse response function. The shaded area is the bootstrapped (n = 1000) confidence interval of 95%. The x-axis is expressed in days.

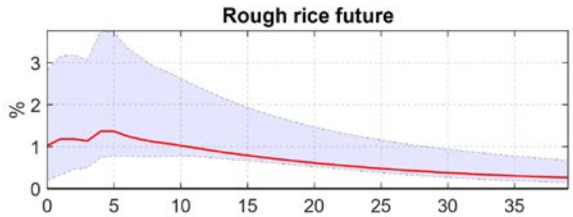
Figure 7. The effect of heteroskedasticity based war shock on commodities. Results of "Restricted" events in table 3.

A. Ukraine export-intensive commodities

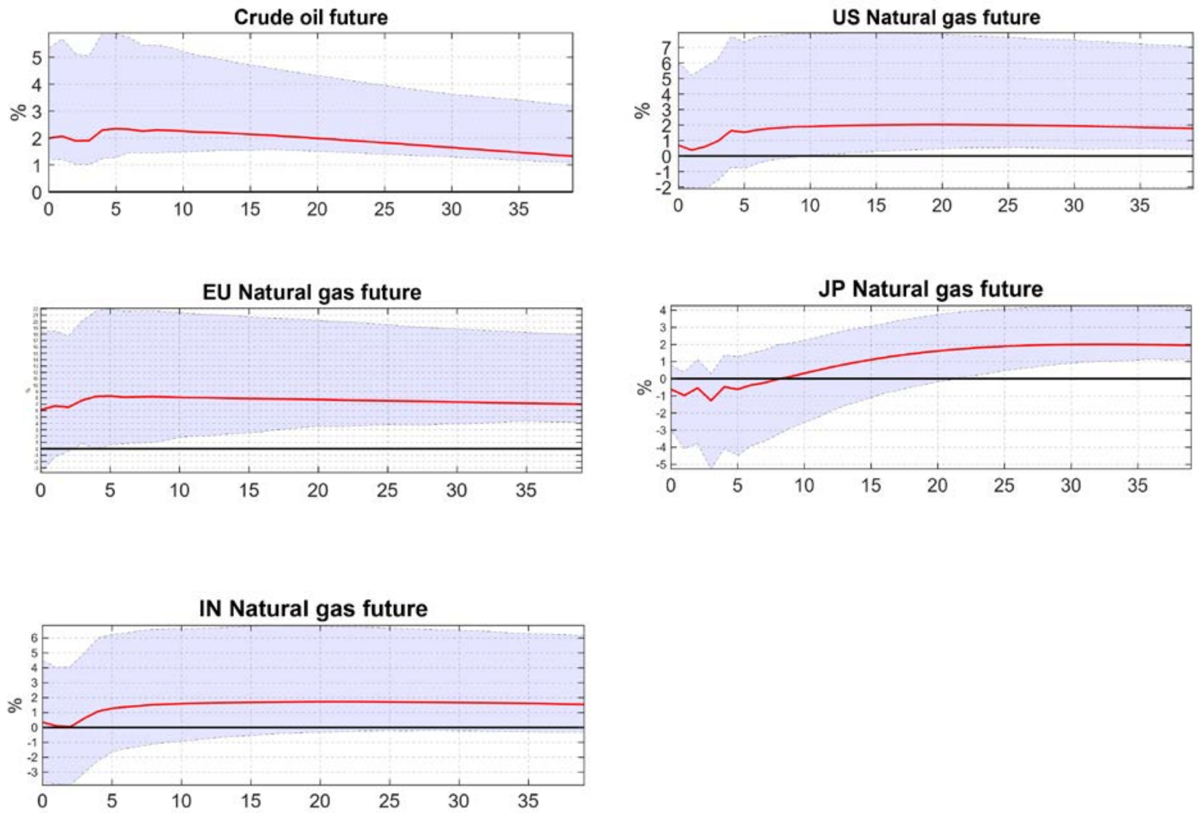


B. Other agricultural commodities



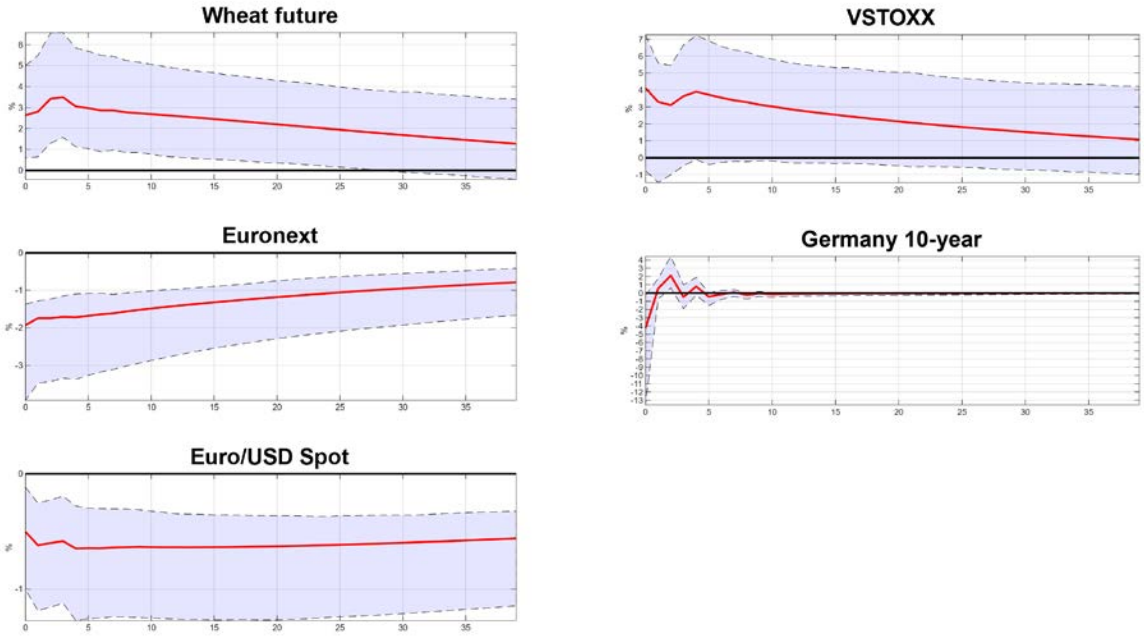


C. Energy commodities



Notes. The red line represents the impulse response function. The shaded area represents the bootstrapped (n = 1000) confidence interval of 95%. The x-axis is expressed in days. All variables in this table are run in a model similar to that of figure 1 but replacing the wheat series and maintaining the other four financial variables.

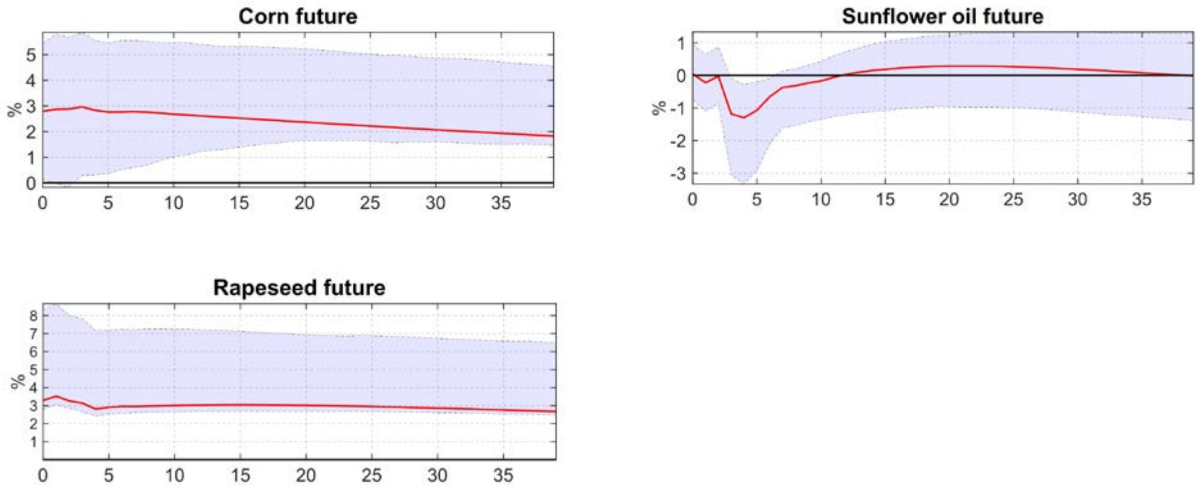
Figure 8. The effect of heteroskedasticity based war shock on wheat future and financial variables. Results of "Attacks" events in table 3.



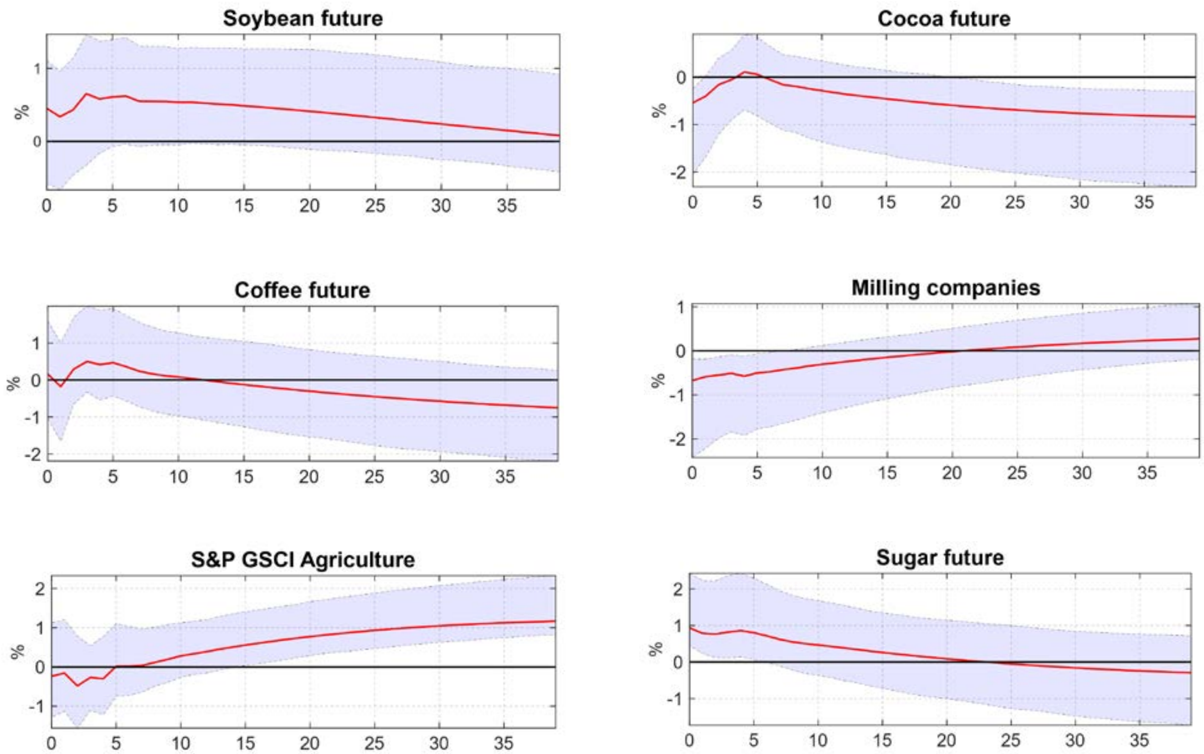
Notes. The red line represents the impulse response function. The shaded area is the bootstrapped (n = 1000) confidence interval of 95%. The x-axis is expressed in days.

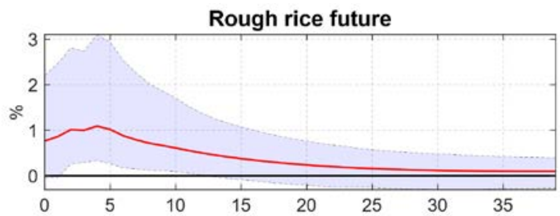
Figure 9. The effect of
heteroskedasticity based war shock on commodities. Results of “Attacks” events in table 3.

A. Ukraine export-intensive commodities

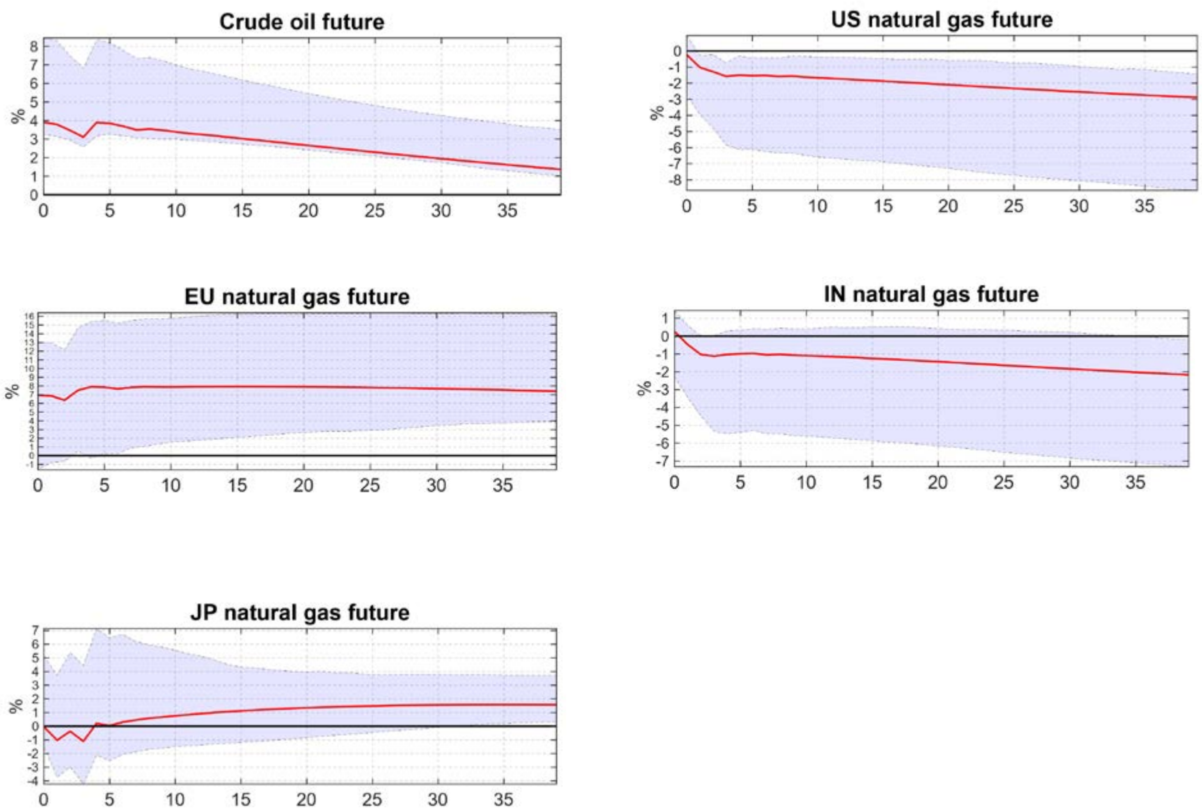


B. Other agricultural commodities





C. Energy commodities



Notes. The red line represents the impulse response function. The shaded area represents the bootstrapped (n = 1000) confidence interval of 95%. The x-axis is expressed in days. All variables in this table are run in a model similar to that of figure 1 but replacing the wheat series and maintaining the other four financial variables.