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The Impact of Russia's Invasion of Ukraine on Global Commodity Prices

Analysis of the agricultural (maize and wheat), mineral (nickel, copper, and zinc), and energy (oil and gas) sectors

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Abstract

This thesis investigates the impact of the Russian invasion of Ukraine, which began in February 2022, on global commodity prices. The conflict led to significant disruptions in the supply of key commodities, causing price spikes and increasing volatility. We employ a SVAR model with heteroskedasticity identification to analyze the immediate and long-term effects of conflict-induced shocks on these markets. Our results show that not all commodities react to shocks in a significant way.

Acknowledgments

I would like to begin by expressing my profound gratitude to my supervisor, Professor Romain Houssa, whose unwavering support was instrumental in the successful completion of my thesis. His consistent availability and deep expertise in my field of research were invaluable. I am deeply appreciative of the time and guidance he so generously provided.

I would also like to extend my heartfelt thanks to my girlfriend, my friends, and my family for their unwavering support throughout this journey. University has been a pivotal chapter in my life, and their encouragement and presence have played an essential role in it, for which I am sincerely grateful.

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1 Introduction

1.1 Motivation of this thesis

The motivation to study this subject for my thesis depended on several factors which were essential in my choice. First of all, I was put on the right track by my supervisor, who has a great deal of expertise in this field and who was able to give me a clearer idea thanks to his advice and leads in my search for a subject. I decided to do this event study to understand the impact of this conflict on the world and more specifically on commodity prices. My interest in both economics and geopolitics can be combined in this thesis, and this greatly contributed to my choice of subject.

Secondly, this conflict is a major issue, and understanding the mechanisms that are having such a major impact on prices seems essential for understanding the economic impact, whether in the short, medium or even long term. During our Master's degree, we were trained in various econometric tools and models, so I was keen to adapt these to study a phenomenon as important as the war between Ukraine and Russia.

1.2 Research question

On February 21, 2022, Vladimir Putin made a speech in which he announced a "special military operation", which was nothing less than the invasion of Ukraine that would begin the following day. More than 190,000 troops were deployed on the Ukrainian border. They attempted to capture major cities such as Kiev and Kharkiv, but were then forced to withdraw to the Donbass region. Despite calls for resistance from President Zelensky, millions of Ukrainians have left the country, most of them women and children (Jeffrey Mankoff, CSIS, 2022).

Beyond this human and material catastrophe, which caused the death and displacement of thousands of people, we can also wonder about the impact of the conflict in other areas. Indeed, since the start of the Russian invasion, the world economy has been disrupted in several ways. Firstly, as both countries are major agricultural producers, we have seen food prices change. Energy prices were also affected, with unprecedented increases in gas and petrol prices. Minerals and metals also suffered a shock as a result of the war. The result was an economic crisis. This, like all economic crises, turned market stock prices upside down.

To be more precise, we need to ask ourselves exactly what impact the conflict has had on each of these commodities. Is the impact important , and to what extent? To this end, we will attempt to build an econometric model to study this impact in greater detail.

1.3 Structure of the thesis

To begin with, we analyze what already exists in the scientific literature concerning my research topic. In the first part, we start by setting out the background and historical context of the conflict, in order to understand its origins, while taking stock of the current situation: human and material losses, impact on various commodities, sanctions and other measures taken by governments. We also look at the impact on stock markets and the reaction of monetary authorities.

The second part of the literature review focus on studies using statistical models to examine the impact of different events on commodity prices. We'll start by looking at the structural determinants of global commodity prices and how shocks propagate through transmission chains. We'll also look at how shocks can be interpreted as geopolitical shocks. We then discuss various econometric models: VAR, ARIMA, VECM,...

Following that, we go on to develop the methodology used to assess the impact of the conflict between Russia and Ukraine on the prices of various commodities. We will explain the operations carried out in the preparation of our database and theoretically develop the model used for our analysis. Robustness tests will be carried out to ensure its validity.

Finally, we show and discuss the results obtained and attempt to draw a general conclusion from this thesis: what impact has this war, which began in early 2022, had on commodity prices?

Overall, this thesis comprises 5 main parts: introduction, literature review, methodology, results and conclusion. The bibliography and appendices bring this work to a close.

2 Literature Review

2.1 Background

In this section, we provide a descriptive analysis of the conflict. We set the historical context for understanding the conflict, and give a current account of human and material losses. In order to move on to a more theoretical and statistical study, we will begin with a descriptive analysis of the impact of the war on the various raw materials studied in this thesis.

2.1.1 Historical context

We can go back to 2014 to understand the roots of the war between Ukraine and Russia. It was in this year that Russia forcibly annexed the Ukrainian region of Crimea. At the time, Vladimir Putin claimed that Ukraine was a creation of the Soviet Union, and in particular of Vladimir Lenin, and should therefore be returned to Russia. However, since the fall of the Soviet Union, a strong Ukrainian identity has developed among this people, who have nationalized themselves and are now quite distinct from the Russian people. Indeed, although in the last years of the Soviet Union most of the population spoke Russian, this trend has since been reversed in favor of Ukrainian. Already in 2016, member states feared conflict with Russia, forcing NATO to step up its military presence on Russia's borders.

2.1.2 Human and material assessment

In terms of numbers, the toll of this ongoing war is already quite impressive. As far as Ukrainian civilians are concerned, the UN and Kiev agree that some 10,500 civilians have lost their lives since the start of the conflict, including 3,000 who have been executed. However, some estimates put the civilian death toll as high as 50,000. In terms of military losses, it is estimated that between 107,000 and 120,000 Russian soldiers died in combat, and between 60,000 and 70,000 Ukrainian soldiers were killed. To these we must add all those seriously wounded, most of whom will suffer lifelong injuries as a result of the conflict. The large number of missing persons must also be taken into account. According to the Red Cross, more than 23,000 people have disappeared since the start of the war in 2022. The losses are not only human. The conflict has destroyed a huge amount of civilian and military infrastructure. The UN estimates the damage to Ukraine's buildings and infrastructure caused by the war at over 152 billion dollars

2.1.3 Impact on agriculture and The Black Sea grain initiative

Russia and Ukraine are among the world's biggest producers of agricultural commodities, and therefore also among its biggest exporters. This sector employs nearly 20% of Ukrainians and is responsible for 15% of GDP (Raffray, 2022). Its main products are

sunflowers, potatoes, wheat and corn. It is the world's fourth largest exporter of corn, which alone accounts for 17% of its exports. Over 40% of this cereal is produced in the eastern part of the country, the region most affected by the fighting. It is also the world's largest producer of sunflower seeds and oil (Table 1). As for Russia, it accounts for around 11% of the world's wheat production and is the leading exporter, with 22% of global exports.

Products	Rank
Sunflower oil, Sunflower meal	1
Rapeseed	2
Nuts	3
Corn, barley, rye, sorghum, honey	4
Wheat	5
Rapeseed meal, butter	6
Rapeseed oil, poultry meat, soybeans	7
Oats, milk, oil, and soybean meal	8
Skimmed milk powder	9
Cheeses	10
Source: Franco-Ukrainian Chamber of Commerce and Industry	

Table 1: *Importance of Ukraine in Global Agricultural Product Exports (2018-2019, by volume). Source: Franco-Ukrainian Chamber of Commerce and Industry.*

Fertilizers seen their prices soar (Table 2). There are several reasons for this, but the main one is energy because the war had a significant impact on the rise in energy prices. Not only does this make fertilizer more expensive to produce, it also makes it more expensive to transport. We will develop the consequences of the energy conflict later in this literature review.

IPAMPA base 2015	Evolution December 2020/December 2021
Fertilizers and amendments	+ 90 %
Simple nitrogen fertilizers	+ 138 %
Ammonium nitrate	+ 134 %
Nitrogen solutions	+ 157 %
Urea	+ 151 %
Simple phosphate fertilizers	+ 74 %
Simple potash fertilizers	+ 68 %
NP binary	+ 75 %
PK binary	+ 54 %
Ternary	+ 56 %
Source: Insee	

Table 2: *Price index for agricultural inputs. Source: Franco-Ukrainian Chamber of Commerce and Industry.*

The conflict has also had an impact on wheat and maize prices, as this graph (International Grains Council) shows (Figure 3). Prices were relatively stable before rising sharply with the start of the conflict (the vertical line on the graph shows the start of the conflict, i.e. February 21, 2022). Since then, the trend has been downwards.

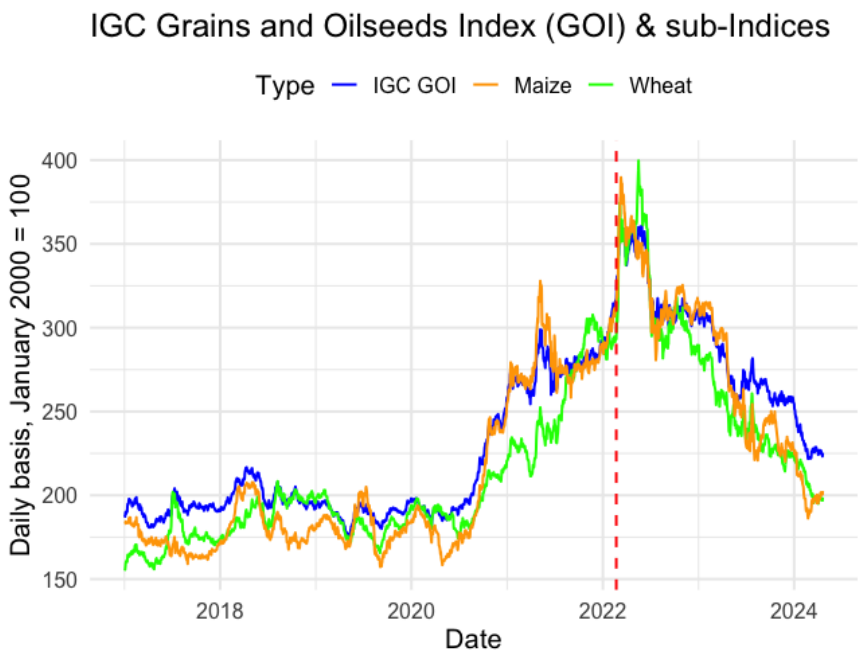

Figure 3: *IGC Grains and Oilseeds Index (GOI) and sub-indices (2017-2024). Source: International Grains Council.*

The fluctuations that followed the start of the war (just after February 2022) can be explained by the Black Sea Grain Initiative. This agreement was signed on July 22, 2022 in Istanbul, between the UN, Russia and Turkey, and provides for a maritime grain corridor. Turkey's position in this conflict is ambiguous: it has condemned the Russian invasion as "unacceptable" and a "clear violation of international law". However, the country refuses to associate itself with the sanctions that Western countries have put in place against Russia. This was already the case in 2014, when Russia annexed Crimea, and is a stance adopted by the majority of Middle Eastern countries (Marcou, 2023).

The aim of this initiative is to enable Ukraine to export its grain by sea. Prior to this agreement, the Russians blocked Ukrainian ports in the Black Sea.Between July 2022 and July 2023, this will have enabled over 1,000 ships to leave Ukraine (via the ports of Yuzhny, Chornomorske and Odesa), carrying no less than 33 million tonnes of grain and other foodstuffs. Most of this was maize (51%) and wheat (27%), and most of the wheat was destined for developing countries, while the maize was divided almost equally between developed and developing countries. However, Russia decided to put an end to the Black Sea Grain Initiative on July 17, 2023 (European Union Council, 2023).

Graphically, we can first see a sharp rise in prices following the start of the war (Figure 3). Wheat peak in March 2022 at 495 dollars a ton. Corn will also peak at 365 dollars per ton. Following the establishment of the humanitarian corridor in the Black Sea, we are witnessing a general drop in grain prices, despite a slight rise in September and October

2022. Prices also rose when Russia withdrew from the agreement in July 2023. This can be explained in part by the fact that when the humanitarian corridor was opened, the supply of grain was able to increase again, helping to bring prices down.

2.1.4 Impact on oil and gas

Russia is the world's third-largest oil exporter, but also the second-largest exporter of crude oil. When we include refined products, it is the world's largest exporter. Following the invasion of Ukraine, sanctions were put in place against Russia, which considerably affected oil prices. These include an embargo on Russian oil, the exclusion of Russian banks from the Swift banking system, and the closure of European Union ports and roads to Russian carriers.

On this graph, we can see that in 2022, i.e. after the start of the war and the sanctions against Russia, we see a very sharp rise in prices (Figure 4)[1]. WTI oil exceeds 120 dollars per barrel in March and June 2022. Brent crude will peak at 128 dollars per barrel in March and June 2022. This comes on the heels of the European Union's announcement of a new sanctions package on May 31, 2022, which caused stock prices to react.

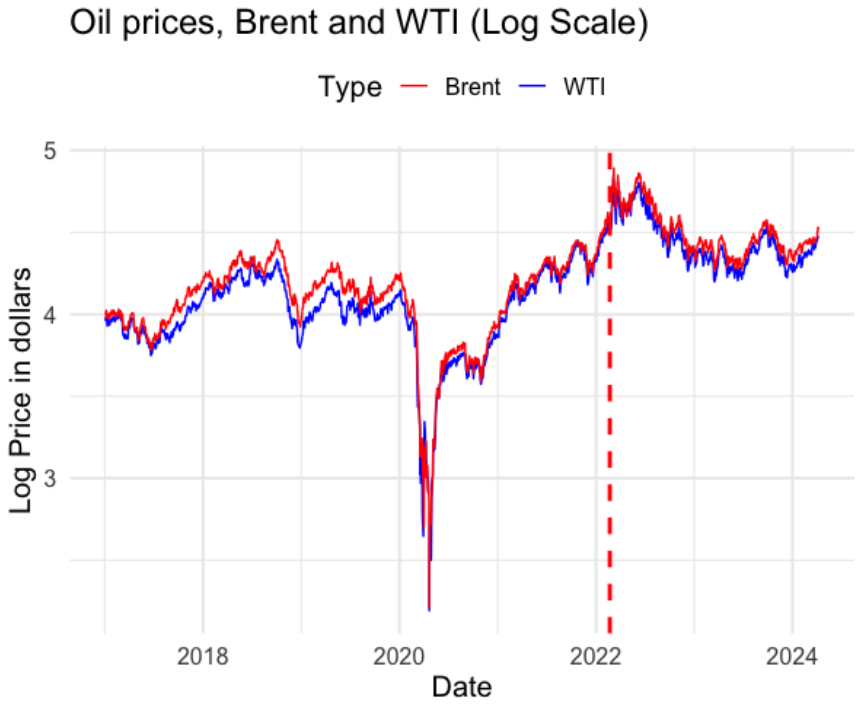

Figure 4: *Oil prices, Brent and WTI, log scales (2017-2024). Source: U.S Energy Information Administration.*

To overcome this problem, the European Union had to find alternatives to oil from Russia. Firstly, in order to guarantee its needs and avoid energy worries, Europe diversified its

[1]The price drop we're seeing in March 2020 is due to a price war between Russia and Saudi Arabia.

partners, notably with the Middle East, the United States and North and West Africa. Massive destocking was also implemented by OECD member countries, in order, among other things, to moderate pressure on oil prices following the war. Finally, a call on spare capacity, which allows oil to be added to the market. According to the US Energy Information Administration, reserve capacity is defined as "the volume of production that can be deployed in 30 days and maintained for at least 90 days". In particular, the reserves held by Saudi Arabia and the United Arab Emirates are mentioned (Zarkik, 2022).

The European Union has also gradually eliminated its dependence on Russia through bans. In the Versailles Declaration of March 2022, the leaders of the member states agreed to gradually rid themselves of dependence on Russian fossil fuels, and on May 30 and 31, 2022, the European Council voted to ban 90% of Russian oil imports by the end of 2022 (European Union Council, 2022).

Russia has also had to act in response to reduced exports to Western countries. Following the sanctions, Russia began to turn to Eastern countries to dispose of its surplus crude oil stock. This was also part of a long-term strategy that had been put in place long before the war, with the aim of increasing its autonomy and taking advantage of its comparative advantage in oil exports. In particular, Russia has increased its exports to China and India, taking Saudi Arabia's place as the leading oil supplier (Zarkik, 2022).

As we saw in the previous section, the war in Ukraine has had a global impact, particularly in the energy sector. The mechanism that has altered trade relations between Western countries is much the same for gas as it is for oil. The conflict has made European countries aware of their dependence on Russian gas, and Russia is using this dependence to its advantage. In fact, Russia is the world's leading exporter of gas, which it mainly transports via pipelines to Europe. As a result, the market has been disrupted by the war: prices have soared (Figure 5), uncertainty has set in, and Russia has stopped supplying certain countries (Eyl-Mazzega, 2022).

In 2021, 44 percent of the European Union's gas imports came from Russia, making it vulnerable to price or supply disruptions (Eyl-Mazzega, 2022). To counter this, the European Union had to gradually eliminate its dependence on Russia through several actions. The first of these, in March 2022, was the Versailles Declaration, which was designed in particular to eliminate dependence on Russia for fossil fuels, as we have already discussed in the case of oil. To maintain security of supply, the Council also set up gas sharing between member countries, and adopted a regulation on reducing consumption. On August 5, 2022, a 15 percent reduction in demand was agreed. This commitment is subsequently extended to March 31, 2024. This commitment to diversification has paid off,

since by 2023, only 8 percent of the European Union's gas imports came from Russian pipelines. The EU's main gas suppliers are now Norway (30% market share), the USA (19.4%) and North Africa (14.1%), followed by Russia. Other countries include the UK and Qatar (European Commission).

Apart from the fact that Europe was heavily dependent on Russian gas, another inherent problem was the ensuing price hikes. The countries of the European Union therefore agreed on a mechanism to limit high gas price peaks. On the one hand, these high prices have a considerable impact on the economy and inflation, and on the other, they are reflected in the bills of European citizens. While prices used to range between €5 and €35 per MWh, they reached a record peak of over €300/MWh in August 2022. This also played its part in the very high inflation of over 11.5% in the European Union in October 2022. This market mechanism caps gas prices while guaranteeing gas supply and security. It was introduced on February 1, 2023 and subsequently extended until January 31, 2025 (European Union Council).

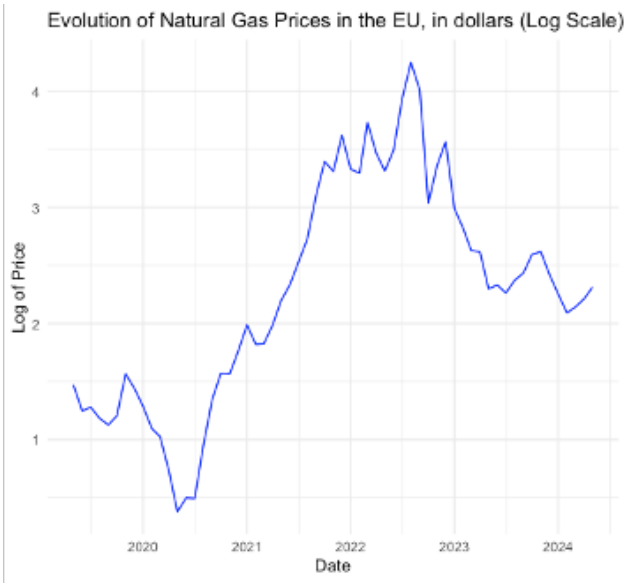

Figure 5: *Evolution of natural gas prices in EU, Dollars per Million Metric (2019-2024). Source: ST Louis FED.*

2.1.5 Impact on stock markets and reaction from monetary authorities

Another interesting area to explore is the potential impact of war on stock markets, and in particular on the stock market indices of different countries. Sandrine Boulerne and Sophie Nivoix have attempted to answer this question in 2023 by analyzing the contagion of war on the financial markets of the CEECs (Central and Eastern European Countries). While the expected consequences for the economy are negative in the event of armed conflict, the

same cannot be said for stock markets.

One very important thing to bear in mind when analyzing market movements and the transmission of the effects of an event on them is the way in which agents in the economy form their expectations (in this case, investors). The effects of expectations as generally studied concern future inflation, interest rate trends, exchange rates... They can directly affect prices, but also real interest rates (Mishkin, 1986). In the case of this conflict, investors' expectations are also important: if they expect the conflict to end or the situation to improve, they will be more inclined to invest. A return of investor confidence could then push the market higher. The opposite could increase uncertainty and push the market down.

Another parameter also taken into account is the geographical proximity of the countries studied. Indeed, countries close to or bordering on those at war may find themselves in a higher climate of uncertainty than those at a greater distance from the conflict. Measuring the degree of contagion also enables investors to potentially modify and/or adjust their portfolios. This can be done to avoid having too large a proportion of their investments affected by the shock. What's more, markets that are correlated with each other and affected by this bearish shock can also put a strain on investors' portfolios.

The paper shows that contagion was significant for countries that already had a fairly high correlation with the Russian stock index, even before the conflict. We can also conclude that there was no general contagion. One explanation for this may be that agents had already factored into their expectations the uncertainty associated with the possible outbreak of war, even before it began. We can also point out that, following the collapse of the USSR in 1991, the CEEC countries gradually became less and less "dependent" on Russia. This may also explain why contagion from the Russian stock market index was not widespread (Boulerne and Nivoix, 2023).

Following this conflict, the various monetary authorities had to adapt in order to reduce the negative impact such a war could have on their economies. Such events bring with them a period of uncertainty, which can lead to adverse changes in inflation and interest rates. Here, we will focus on the reaction of the European Central Bank and the US Federal Reserve.

The European Union has been one of the most vulnerable regions to the various shocks generated by the crisis, particularly in terms of food and energy prices, as mentioned above. This is due to a combination of Europe's economic openness and its dependence on imports from Russia and Ukraine. Inflation has been pushed up from 0.3% in 2020 to

almost 8.4% in 2022 (Arce, Koestr, Nickel, 2023). In 2022, energy was the main driver of inflation, but in 2023 we are witnessing an increase of over 14.1% in food prices, showing once again that the effects on food are delayed and indirect. In fact, the agri-food industry is very energy-intensive, so an increase in energy prices inevitably has effects right up to the end consumer of the product.

In June 2022, the European Central Bank took several decisions. To return inflation to its medium-term objective of 2%, the ECB decided to stop its asset purchase program from July 2022. The primary aim of this program is to maintain price stability, and in particular to stimulate investment. Interest rates are also set to rise. These rates also have an impact on investment. By raising them, investment becomes more costly and there are fewer incentives for households to invest.

2.1.6 Impact on minerals

More than 5% of the world's mineral resources come from Ukraine, while more than 20% of the Earth's natural resources are found in Russia. This shows the impact these two countries have on the global minerals market. The effects of the war can be studied on the gold price, the metal exchange,and the exchange rate by examining the following 4 metals: Zinc, Copper, Nickel, and Aluminium, using data from six months before the war and six months after the start of the Russian attack (K.K John and J.N Michael, 2023). The analysis methods used are sample t-tests and regressions.

In the long term, there is a significant negative correlation between prices before and after the war. This change in price trends may indicate that the war has significantly affected price dynamics. However, for aluminum, the null hypothesis that there is no significant impact of the war is accepted, which means that the price of this commodity was not significantly affected by the war. For zinc, copper and nickel, there is indeed a significant impact of the war, with p-values below 0.001. They then analyzed the effects of the conflict from a shorter-term perspective. There was also a significant negative correlation between prices before and after the start of the war. From this perspective, aluminum, zinc, nickel and copper all obtained a p-value of less than 0.005, which shows that the result is significant and supports the alternative hypothesis H1 that there is a significant impact of the war between Ukraine and Russia on the metal exchange. We can therefore see that the war has a significant impact on metal markets in both the long and short term, except for aluminum in the long term.

Metals from Russia are also affected by Western sanctions. Most recently, in April 2024, the United States banned the import of aluminum, copper and nickel from Russia. These sanctions were taken jointly with the United Kingdom, with the aim of reducing Russia's

revenues from the export of the various metals present in large numbers on its territory. As for the European Union, it has a different approach to the subject of Russian metals. In fact, the European Union continues to authorize imports, despite the war unleashed by Russia. Although the amount of these imports has fallen since 2022, it is still significant (over 13 billion euros between the start of the war and October 2023). This is mainly due to the fact that the European Union is dependent on Russia to import these raw materials, which are necessary for industries with a strong presence in Europe, such as aviation and automotive.

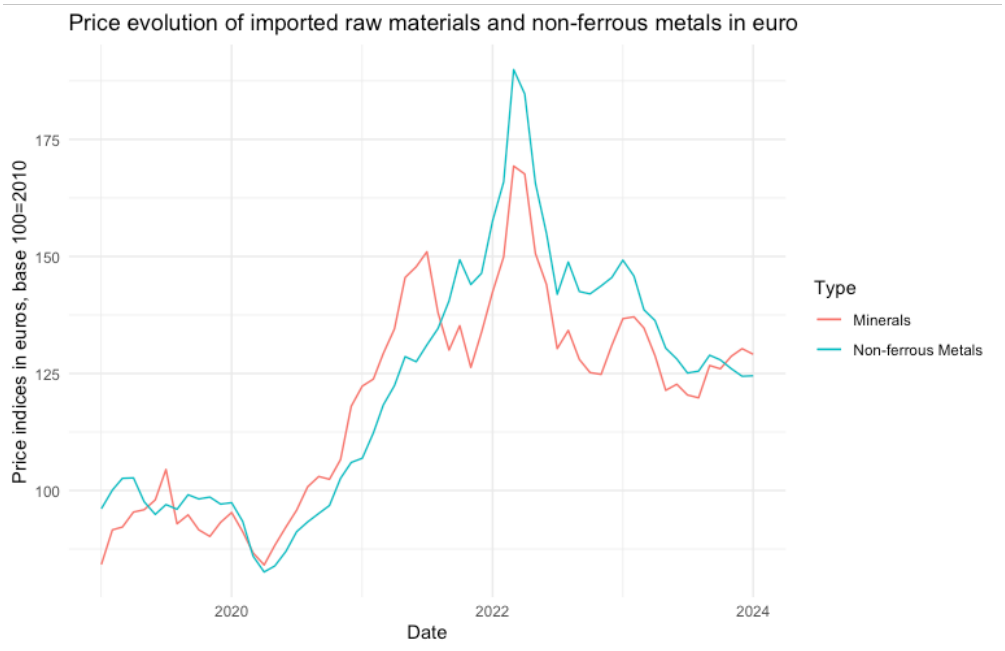

Figure 6: *Price evolution of imported raw materials and non-ferrous metals in euro (2019-2024). Source: World Bank.*

2.2 Analysis with statistical models

After a descriptive analysis of the impact of this war on commodity prices, we analyze it from a more theoretical point of view. We review the structural determinants of global commodity prices and study some econometric models like VAR, VECM, ARIMA or SVAR.

2.2.1 The structural determinants of global commodity prices

In order to study the interactions between different shocks and their impact on commodity prices, it is important to understand the structural determinants of global commodity prices. In this sense, the construction of a two-block model may be of interest in order to explain and study the importance of shocks in macroeconomic fluctuations, as well as the synchronization of cycles (R. Houssa et al., 2023). The first is a domestic block representing a commodity-exporting Small Open Economy, and a foreign block capturing relations with the rest of the world. Shocks are transmitted between the global economy and the domestic block via three transmission channels: a financial channel, a world commodity price channel and a domestic commodity supply channel. In this model, prices are endogenously determined and there are financial frictions. In particular, these financial frictions model the fact that households are financially constrained.

When aggregate demand (AD) shocks occur in foreign countries, they play an important role in determining commmodity prices. This is because it stimulates demand and then induces an increase in commodity prices. The magnitude of this increase depends on the elasticity of substitution with which commodities can be replaced by other production inputs. Conversely, as presented in this study with a SVAR model, a contraction in global aggregate demand results in a contraction in consumption, investment, the employment rate and the supply of commodities (in this case Canada and South Africa).

We can develop this further using transmission channels. If we take the case of a positive demand shock, it is transmitted through the world commodity price channel by the fact that if equilibrium is defined endogenously by global supply and demand, it will be reached with an increase in commodity prices. This then has an upward effect on prices in the domestic economy. Domestic supply is then influenced, since in this model all domestic commodity production is exported (domestic commodity supply channel). The financial dimension is also important in this case, since it can in some cases modify the magnitude of the impact of shocks. Here, a positive demand shock will be transmitted to the domestic economy via the financial channel, as, for example, companies that have seen their exports increase will have easier access to credit from financial institutions.

In the case of this thesis, an important determinant is aggregate supply (AS). Indeed, in the case of the war in Ukraine, the supply of commodities fell drastically as a result of the conflict between the two countries. When aggregate supply falls, the result is an increase in the price of commodities on the world market, because as we said earlier, prices are determined endogenously. On the domestic supply side, this also leads to a contraction. This contraction in domestic supply is due in particular to the fall in demand that this generates, and to higher production costs. For the financial transmission channel, financial frictions can exacerbate the phenomenon in the domestic economy and give rise to uncertainty.

When an economy is in a situation where prices rise sharply in a given economy, as is the case with a supply shock, this makes it less competitive, with a negative impact on its exchange rate. This makes it harder for the economy to find trading partners, which has a negative impact on its trade balance. What's more, the monetary authorities then have to use the tools at their disposal to redress the balance, such as raising key interest rates, which has the effect of driving down prices.

2.2.2 Narrative-based analysis

To understand precisely how this conflict impacted commodity prices, narrative-based selection is used to select events that took place during the war (attacks, fighting) and study their impact (Aizenman et al., 2024). A SVAR model is used to identify heteroscedasticity between days when war-related events occur and days when no events are recorded. This model is a multivariate time series econometric model in which variables are influenced by their own lags and the lags of other variables in the system. This type of model helps us to understand how shocks to one variable have an impact on other variables, and is therefore interesting to use in this context. To add a macroeconomic factor, they also incorporate additional variables into the model, such as the VSTOXX 50, the USD-EUR exchange rate, the German 10-year yield or the Euronext equity index. The VSTOXX50 is interesting for measuring investor confidence in future volatility. If volatility is expected, investors will turn to safer investment products such as bonds, which also makes this variable interesting in this case. The Euronext 50 is the Eurozone's stock market index, and its fluctuations therefore have a major impact on the economic situation in this zone. In particular, the USD-EUR exchange rate provides a measure of the Eurozone's international competitiveness.

The model can be represented as follows:

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

where Y_t is the $p \times 1$ vector of variables and ϵ_t is the reduced-form errors.
And the relationship between the reduced-form errors and the structural shock is represented as:

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

where η are the structural shocks coming from the different events while R is the vector of coefficients.

The results of this study using this model showed that the commodities analyzed reacted significantly to the shock of war. The data used included wheat, corn, natural gas and crude oil futures. In terms of financial variables, the response to the events studied was a 3% increase in the volatility of the European stock market. This analysis also showed that the war had an impact on the depreciation of the Euro against the US Dollar. The results make a valuable contribution to the existing literature. Indeed, most of the studies took into account a fairly limited period of time, whereas this study captures the effects of the war over a longer period of time. Also, while studies had already investigated the effects of the war in Ukraine on financial markets, no one had yet done so for agricultural commodities in particular.

To measure the impact of geopolitical shocks, the GPR Index can be used. This index measures the frequency of words related to geopolitical events published in US newspapers. The disadvantage is that it can capture the effect of several overlapping events. To avoid this, in this paper, war-related events are listed in order to understand their impact on the various commodities.

Measuring the effect of commodity shocks is also important during other events such as the Covid-19 crisis. This may be related to our research topic, as these events can also be the cause of jumps in commodity or financial market prices. To identify these shocks, Miescu and Rossi (2022) used a heteroskedasticity identification method too to identify Covid-19 induced shocks. Their study focuses on the period from January 13 to October 31, 2020, corresponding to the first months of the Covid-19 crisis. They use daily data, and more specifically financial data (S&P 500, VIX index) and economic data (employment and private spending indicators). Event days here are days on which movements of more than 2.5% in the S&P500 are observed.

Shocks are identified using the heteroskedasticity identification method. The basic assumption is that the variance of residuals is higher on event days. The model used in this

analysis is a VAR model specified as follows:

$$Y_t = X_t\beta + \mu_t \tag{3}$$

where Y_t is a vector of endogenous variables, X_t is a vector of exogenous variables (including lags), β represents the coefficients, and μ_t is the vector of residuals.

The identification of shocks is based on two assumptions: a shock must have a higher volatility than other non-event days, and this shock must be unique. This is expressed by a difference in the variance-covariance matrices of the residuals of event and non-event days respectively. The results are then analyzed using IRFs to show the reaction of the various variables to Covid-19 induced shocks. The results show that Covid-19 induced shocks have prolonged contractionary effects on financial markets. They also have an impact on agents' confidence. Economic variables also contract after pandemic-related events. In particular, there was a significant short-term contraction in private expanditure, but also in employment.

To interpret these shocks structurally, a comparison is made with uncertainty, using the VIX index. The Cholesky Decomposition identifies the uncertainty shock by assuming that the VIX index is ordered first and does not respond to other contemporaneous shocks. The results show that Covid-19 shocks and uncertainty shocks are highly correlated (0.86), suggesting that Covid-19 shocks can be interpreted as uncertainty shocks.

2.2.3 VAR and VECM models

As mentioned above, Ukraine and Russia are major producers and exporters of agricultural commodities such as sunflower oil, corn and wheat. It is therefore possible to study the interactions between these different commodities and use econometric models to attempt to predict future price trends. Three statistical methods have been used to study these relationships and trends (Florin Aliu, Jirí Kucera, Simona Hašková, 2023).

The first is the Vector Autoregressive Model (VAR) with one autoregressive lag and four variables is represented as follows:

$$y_t = a_1 + a_{11}y_{t-1} + a_{12}x_{t-1} + a_{13}z_{t-1} + a_{14}b_{t-1} + u_t \tag{4}$$

$$x_t = a_2 + a_{21}y_{t-1} + a_{22}x_{t-1} + a_{23}z_{t-1} + a_{24}b_{t-1} + v_t \tag{5}$$

$$z_t = a_3 + a_{31}y_{t-1} + a_{32}x_{t-1} + a_{33}z_{t-1} + a_{34}b_{t-1} + l_t \tag{6}$$

$$b_t = a_4 + a_{41}y_{t-1} + a_{42}x_{t-1} + a_{43}z_{t-1} + a_{44}b_{t-1} + e_t \tag{7}$$

where u_t,v_t,e_t represent the shocks and y_t,x_t,z_t and b_t are the orders of the variables.

This study also uses the VECM: Vector Error Correction Model. This model is useful when there is at least one cointegrating relationship between the different variables. Johansen's cointegration test can be used in this case. In this study, the VECM is used to forecast the performance of agricultural commodities over the coming months. Granger's causality test is also used to understand the relationships between variables. The representation of Johannsen's cointegration is:

$$s_t = A_1 s_{t-1} + e_t \tag{8}$$

where:

$$\Delta s_t = A_1 s_{t-1} - s_{t-1} + e_t \tag{9}$$

$$= (A_1 - I) s_{t-1} + e_t \tag{10}$$

The VAR estimated results show the results show that corn prices have a significant influence on barley, wheat and sunflower oil prices, while wheat also has an effect, but less significant than corn. The Granger causality test shows that only barley has no significant impact on the other commodities. In other words, movements in its price do not significantly influence the prices of other products. The null hypothesis of no-granger causality is rejected for wheat, corn and sunflower oil, showing that only these three commodities have significant causal relationships with each other.

As for VECM, we can separate the results into two parts. In the short term, wheat and corn have significant effects on the other variables. This model also showed that corrections following a price imbalance are quicker for corn and wheat than for the others. Next, the study focuses more specifically on forecasting using fancharts, and the forecast concentrates on the next ten periods.

As we said earlier in the analysis of this study, the model has a lag, a VAR(1). This was determined by the use of several criteria such as AIC (Akaike information criterion), HQ (Hannan-Quin criterion), FPE (Akaike Final Prediction Error) or SC (Schwarz criterion). As for price forecasts, the VAR model predicts a drop in each of the 4 commodities over the next ten months, the biggest drop being for barley at almost 12.8%. If we were to take an average, this would mean a drop of 9.92% over the next ten months. For the VECM model fancharts, we first had to carry out cointegration tests, in particular the Johansen test. Next, the error correction terms (ECT) had to be estimated. This shows how quickly price imbalances are corrected. Once this had been done, price forecasts could also be

made: here, the estimated fall is 9.32% for the next ten months. However, we must not overlook the fact that econometric models such as these cannot capture exogenous factors that are difficult to model, be they conflicts or environmental events. It also lacks more fundamental factors such as transport, storage and inflation expectations.

2.2.4 DCCA, DMCA and DMC

To assess the impact of the conflict between Russia and Ukraine on world prices for refined products and crude oil, bivariate and multivariate cross-correlation can be used (Inacio Jr, Kristoufek, David, 2023).

Three distinct periods are studied. The first (P0) runs from February 2019 to February 2020 and corresponds to the period before the war, but also before the Covid-19 pandemic. The second period (P1) runs from February 2021 to February 2022: the Covid-19 pandemic has begun, but not yet the war in Ukraine. The final period (P2) runs from February 2022 to February 2023: both the pandemic and the war have begun. The prices used for the analysis are daily futures contracts for diesel (LGO), heating oil (HO), Brent crude oil (CO), natural gas (TTF and Henry Hub) and RBOB (reformulated gasoline for oxygenate blending).

Three methods are used in this study. The first is Detrending Cross-Correlation Analysis (DCCA), which evaluates correlations between different time series that may exhibit non-stationarity. Detrending Moving-Average Cross-Correlation Analysis (DMCA) is similar to the first but uses a moving-average approach for detrend. Finally, Detrend Multiple Cross-Correlation Analysis (DMC) allows us to study the effects of correlation in a multivariate context.

The results obtained suggest several facts. For the pre-war periods (P0 and P1), we can see a strong cross-correlation between crude oil and refined product prices for almost the entire period which means that the prices of refined products closely followed the fluctuations in crude oil prices. Also, we see a weaker cross-correlation between the HHNG (Henry Hub)-CO and TTF-CO pairs for most periods. Falling periods in the cross-correlation are not observed when we increase the size of the window sizes. This may show us that dynamic changes can be non-structural as long as the long term and horizon are not affected.

We can also observe that during the P2 period, the TTF-CO pair shows a negative cross-correlation, which returns to its level after 40 days. We can see here a fairly significant impact of the short-term war. Finally, comparing the P1 period with the P2 period, we note that there is no significant difference for HO-CO, whereas a significant

difference is observed for LGO-CO. This shows that the invasion of Ukraine had a greater impact on European diesel prices than on US market prices because LGO-CO represent the European market while HO-CO represents the American one.

3 Methodology

3.1 Data

We build a data set compiling daily informations for several commodities gathered in the databases of Trading Economics. First, there are two agricultural commodities: wheat futures (sep 24, ZWU4) and corn futures (dec 24, ZCZ4). We also include energy prices: Brent oil futures (oct 24, LCOV4) and UK natural gas futures (NGLNMc1). Price futures are used here because they incorporate current market conditions but also expectations of change, which can be interesting in a shock study like the one we are doing. They are also more stable. Like Aizenman et al,(2024), we add macroeconomic variables such as the Euronext 100, which is the stock market index of the most capitalized stocks on Euronext. We also add the Vstoxx 50, which is a volatility index of the Eurostoxx 50 stock market index and the Dollar-Euro exchange rate. The addition of these macroeconomic variables allows us to capture the ineractions between financial and commodity markets. What's more, the addition of the VSTOXX 50 allows us to add the notion of volatility and uncertainty to our analysis. For the analysis, we use the logarithms of the data.

Unlike Aizenman et al,(2024), we also add mineral commodities, as both countries are major mining producers. These commodities are also important in most of the technology sectors: telephones, batteries, etc. We therefore use zinc futures (MZNc1), copper futures (sep 24, HGU4) and nickel futures (nickel c1). Unlike Aizenmann et al. (2024), we use French 10-year yield bonds (unlike German yield bonds)to see if the results are similar for government bonds from another country.

In order to identify shocks that may have an effect on prices, we use a narrative-based approach. we search the newspapers for events linked to the invasion of Ukraine, mainly using the keywords "attack", "port", "strikes" or "drone", a weapon increasingly used in this conflict. We also include dates linked to political decisions that could influence the conflict and commodities markets, such as the announcement of an aid plan for Ukraine or economic sanctions against Russia. Aizenman et al,(2024) use 84 dates starting from February 24, 2022, to March 30, 2024 (Tables 1,2,3 in A.1). We add to these events 25 new dates up to July 24, 2024, allowing us to see the impact of the war until very recently and allowing to capture the long-term effects of the war (Table 4 in A.1). If the event doesn't take place during a trading day, we postpone it to the next trading day so that we can still capture the effect.

Among the important events we have added, we can mention several events. First, the massive air attack of April 11, 2024 destroyed the Tripilska thermal power plant, a major facility located not far from Kiev. This period also saw the announcement of a financial aid

plan by the USA to the tune of over 60 billion dollars, as well as 1.9 billion dollars in financial aid from the European Union. Another important event was the bombing of the Swiss Foundation for Mine Action, which further strained relations between Russia and Western countries (Table 4 in A.1).

3.2 The model

To determine which days are considered "shock days," we identify days where there is a significant change in the VSTOXX 50, which shows an increase in volatility. A day is considered a shock day if the VSTOXX 50 increases by more than 2,5%, indicating a significant market reaction potentially linked to an event related to the Ukraine war. Once these shock days are identified, we correlate them with the events we have catalogued to determine if the significant market movement can be attributed to those events (Tables 1,2,3,4 in A.1). This approach ensures that our analysis focuses on days where the conflict had a measurable impact on market volatility, allowing us to isolate and analyze the effects of specific war-related events.

Once these shock days are identified, we proceed with a formal statistical analysis. First, I use a heteroskedasticity identification method to confirm and quantify these war-related shocks (Aizenman et al., 2024; Miescu, Rossi, 2021). This method is based on the difference in variance in the model's residuals between days with events (i.e., conflict-related events) and days with no war-related events in our database. The central assumption in this case is that the variance in residuals is significantly higher on event days. We then use a VAR model to analyze these shocks, defined as follows:

$$Y_t = X_t\beta + \mu_t \tag{11}$$

where Y_t is a vector of endogenous variables, X_t is a matrix of regressors, β represents the coefficients, and μ_t is the vector of residuals. Our model includes five endogenous variables such that $y = (P_{i,t}, STOCK_t, VSTOXX_t, YIELD_t, FX_t)$, where $P_{i,t}$ represents each commodity we use ton analyze the impact of the conflict. I use a VAR model with 10 lags (Miescu and Rossi, 2021), which allows us to capture longer-term relationships between variables than we would have been able to do if we had chosen fewer lags. In order to carry out our analysis, we have adapted the MatLab code provided with this paper.
To identify the shocks, we need to find the Γ matrix that relates the observed residuals μ_t to a vector of orthogonal shocks ϵ_t :

$$\Gamma\epsilon_t = \mu_t \tag{12}$$

The identification of conflict-related shocks is based on two key assumptions. Firstly, system volatility is higher during these identified shock days. Secondly, this different

volatility is attributed to a single orthogonal shock, specifically a shock due to a war-related event (Miescu and Rossi, 2021). This can be expressed as follows:

$$\Sigma_H - \Sigma_L = \Gamma_1 \Gamma_1' (\sigma_H^2 - \sigma_L^2) \tag{13}$$

where Σ_H and Σ_L are the variance-covariance matrices of the residuals on shock days and non-shock days respectively, σ_H^2 and σ_L^2 represent the variance of the conflict-induced-shocks on event and non event days. Γ_1 is the vector corresponding to the war-related event shock. We use Bayesian estimation for the VAR model, to take into account parameter uncertainty. The variance-covariance matrices mentioned above are calculated separately for shock days and non-shock days.

The Γ_1 vector corresponding to the war event shock is estimated by minimizing the difference between the observed difference in the variance-covariance matrices and that expected under the single shock assumption. This can be defined as follows:

$$\Gamma_1 = \arg\min_{\Gamma_1} \left[\text{vech}\left(\hat{\Sigma}_H - \hat{\Sigma}_L\right) - \text{vech}\left(\Gamma_1 \Gamma_1'\right)\right]' \left[V_H + V_L\right]^{-1} \left[\text{vech}\left(\hat{\Sigma}_H - \hat{\Sigma}_L\right) - \text{vech}\left(\Gamma_1 \Gamma_1'\right)\right] \tag{14}$$

Once this has been done, we can move on to impulse response analysis (IRF). This allows us to visualize the impact of shocks on the various variables. We test this with several different variables, sometimes adding or removing some, in order to analyze the impact of shocks more precisely.

4 Results

After limiting the events we identified as war-related to those showing high market volatility, we end up with 31 events including 5 events that we have added (Tables1,2,3,4 in A.1). We call these events conflict-induced-shocks. In the table, these are the events with a cross in the "shock" column. These days of events show a VSTOXX 50 variation higher than 2.5%, but also a link with the conflict between Ukraine and Russia. We divide the results into several sections, in order to analyze precisely each type of variable used. The IRFs show responses to shock over a 60-day post-shock horizon. Each time, we add to the model the 4 macroeconomic variables in addition to the commodities analyzed in each category. In each graph, the black line is the median. Shaded areas correspond to 68 and dotted lines to 90 credibility sets.

To go a step further and check for the robustness, we test the model with all days of high market volatility as event days, disregarding war-related shocks. This allows us to check whether our model can be adapted to other shocks and circumstances.

4.1 Agricultural commodities

We analyze wheat and maize prices for agricultural commodities. For wheat, we can observe that the war-induced-shock which raises the VSTOXX50 by more than 2.5% has the effect of increasing the wheat future price by 2%, which is in line with the results of Aizenman et al.,(2024). A peak of 4% is reached before stabilizing at around 2.5%. The shocks in question have the effect of reducing supply, pushing prices upwards. We can see that the trend is bearish after 40 days, even if this shows that after 60 days, the shock has still not been absorbed by the market. After 120 days, the effect of the shock is almost entirely absorbed, as can be seen in the appendix (Figure 11).

We also see a rise of 1% in maize prices just after the shock, but the credibility interval at 90% shows us that the shock reaction is no longer significant after 3 days (Figure 7). To explain the difference between wheat and maize, we can look at their yields. Corn has a 58% higher yield than wheat (Agritel). This makes maize prices more resilient to shocks, as corn production is more flexible.

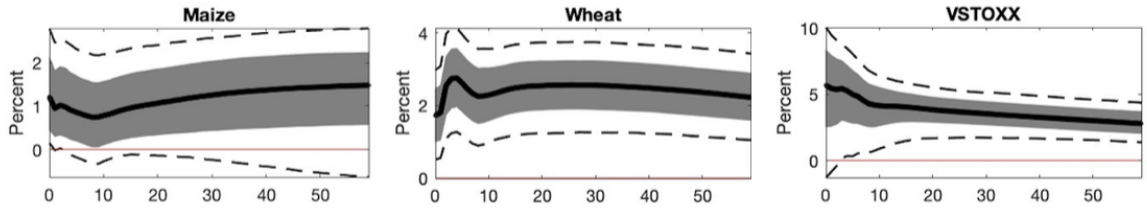

Figure 7: *IRFs to a conflict-induced-shock increasing VSTOXX 50 by more than 2.5%. The black line is the median. Shaded areas are 68% and the doted lines are 90% credibility sets.*

4.2 Mineral commodities

Mineral commodity include nickel, zinc and copper. We can see the IRF graphs showing the response of these variables to conflict-induced shocks (Figure 8). We can see that when there is a conflict-induced-shock, none of the 3 commodities shows a significant response to 90%. This can be explained by the already high volatility of these commodities, which would not be affected by movements in the VSTOXX50. The graphs in the Appendix (Figures 131514) clearly show the volatility of these commodities, once transformed into logarithms. On the other hand, these commodities are quite special in that, unlike others, supply is quite rigid. In fact, since they are produced in mines and are not inexhaustible, their supply is more difficult to adjust, their price fluctuates even more when new deposits are tapped which can cause market movements to be larger and more frequent.

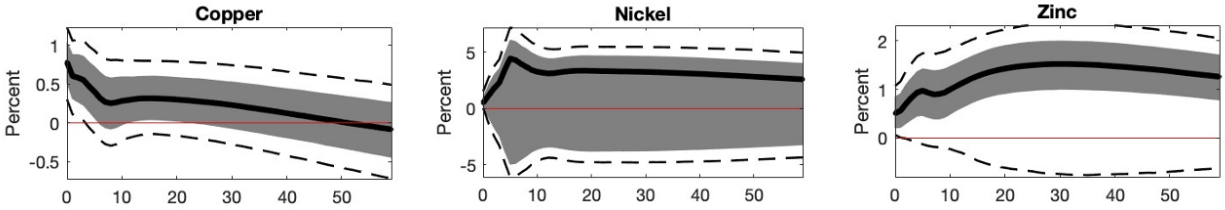

Figure 8: *IRFs to a conflict-induced-shock increasing VSTOXX 50 by more than 2.5%. The black line is the median. Shaded areas are 68% and the doted lines are 90% credibility sets.*

4.3 Financial variables

We can now move on to the financial variables. The ones we have chosen are important because they are a good indicator of financial market fluctuations, particularly for Europe in our case. We have the STOCK variable, which represents the index of the 100 most capitalized companies in Europe. We also have the VSTOXX 50, a volatility index which reflect the market expectations. To this we add the Yield variable, which represents the yield on 10-year French bonds. We use French Bonds to compare our results with German Bonds (Aizenman et al., 2024). Finally, we use the Dollar-Euro exchange rate. The depreciation or appreciation of the euro against the dollar is a very important factor to analyze.

We can make a number of observations by analyzing the IRF graphs of the financial variables (Figure 7). Firstly, we can see that the VSTOXX reaction to the shock is not confident at 90%. The Euronext100 (STOCK) suffered a significative and negative shock of 1%, which then seems to be persistent and stable over time, as it remains almost at the same level even after 60 days.When we plot the IRF graph with a 180-day horizon, we can see that for the 90% credibility interval, the STOCK returns to its pre-shock level after 125 days. This graph can be found in the Appendix (Figure 16).

The FX graph shows the response of the Dollar-Euro exchange rate to the conflict-induced shock. The shock results in a slight increase (0.3%) in this exchange rate. Here, the Euro depreciates against the Dollar. When we plot the IRF over a 180-day horizon, however, we see that it remains stable over time. YIELD, representing the interest rate on 10-year bonds issued by the French government, shows a significant drop following the shock. We can see that the decrease is in excess of 10%. This shows that French bonds were more affected by the shock than German bonds, who react with a 5% drop, absorbed in 5 days (Aizenman et al., 2024).However, unlike the other variables analyzed here, the shock seems to be less persistent but if we look at Figure 16, we see that the effect is longer than expected.

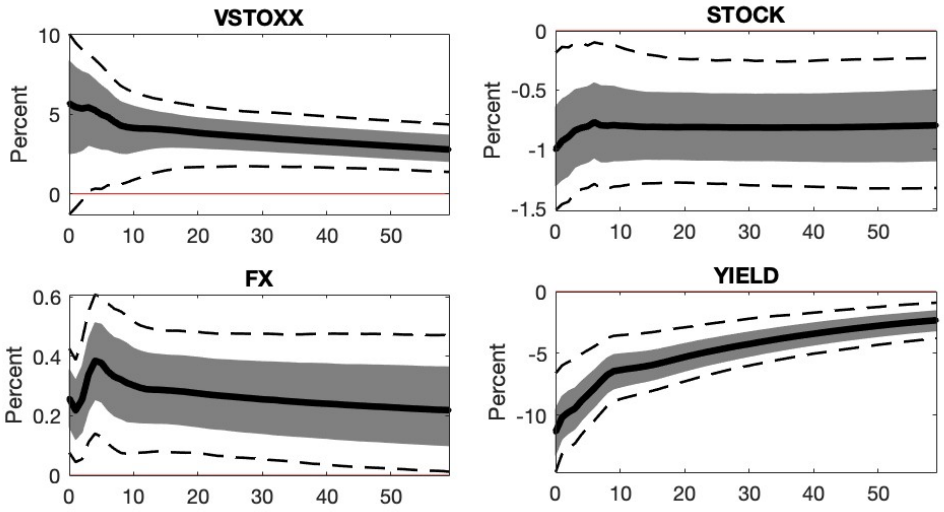

Figure 9: *IRFs to a conflict-induced-shock increasing VSTOXX 50 by more than 2.5%. The black line is the median. Shaded areas are 68% and the doted lines are 90% credibility sets.*

4.4 Energy commodities

In energy commodities, we have chosen Brent oil, also known as "North Sea crude oil", and we will use the price per barrel in dollars. The second energy commodity is natural gas, and more specifically UK natural gas futures.

A conflict-induced-shock has the effect of sharply raising gas prices. We can see a direct increase of 6%, which continues to rise for a further 5 days, before gradually decreasing (Figure 10).After 20 days, we can see that the gas shock response is no longer significant at 90%. In the case of oil, it can be seen that the shock had the effect of increasing prices by 1%. It then falls back, and like gas, its trend is not restored after 60 days, but it seems to be gradually recovering, at least more rapidly than gas.

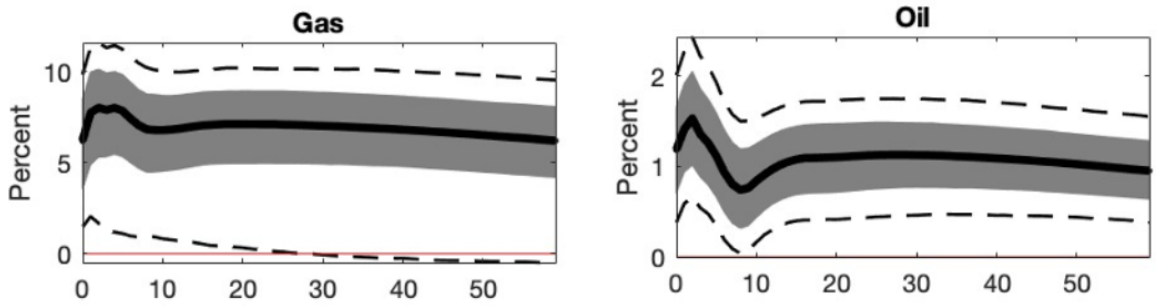

Figure 10: *IRFs to a conflict-induced-shock increasing VSTOXX 50 by more than 2.5%. The black line is the median. Shaded areas are 68% and the doted lines are 90% credibility sets.*

4.5 Discussion of results

The results obtained from our model have enabled us to highlight the significant impact of the Ukraine-Russia conflict on most of the variables used, whether financial, mining, agricultural or energy-related. Following on from the descriptive analysis above, this section will discuss these results, providing a broader perspective on the implications of these price shocks. Indeed, these results allow us to study price dynamics during geopolitical shocks from several perspectives.

The reaction of agricultural commodities to shocks has shown us that wheat prices are continuing to rise, and this is having a major impact worldwide, particularly on global food security. According to a United Nations report from July 2023, between 691 million and 783 million people suffered from the end in 2022, mainly due to the conflict in Ukraine. Indeed, we have seen that a number of infrastructures linked to this industry have been bombed or attacked, and this instability is disrupting supply chains. This can exacerbate food crises in certain regions of the world that are dependent on this grain supply. More than 65% of Ukraine's wheat and 51% of its corn exports go to developing countries (European Council). What's more, consumers in developing countries could be hardest hit by rising grain prices as a result of these shocks, further exacerbating food security problems. The Black Sea Grain initiative that was set up helped to minimize the effects of these shocks and ensure food stability in the countries that depended on it. However, prices rose sharply again when Russia withdrew from the agreement. These dynamics show that international crisis management mechanisms need to be strengthened to prevent such shocks from aggravating existing food crises in certain regions of the world.

Mineral commodities reacted in different ways, with the copper market showing a certain resilience to the shock, as it was quickly absorbed, while nickel and zinc did not show a significant reaction. These reactions to shocks can have implications for many sectors dependent on these raw materials. Copper is used extensively in the manufacture of electrical cables for the construction and automotive industries (EIA, 2023). Clearly unable to substitute these materials, industries can turn to other sourcing strategies to counter rising prices and guarantee sufficient supplies.

We focused our analysis of macroeconomic variables on those linked to the European market, which is one of the most likely to be affected, given its geographical proximity but also its trade relations with the two countries in the throes of conflict.The results show that investors quickly incorporated war-related uncertainty into their strategies, resulting in a rise in volatility on financial markets, captured by the VSTOXX 50 index. Looking at the bigger picture, the impact of geopolitical shocks on financial markets underlines the importance of policymakers acting accordingly. Central banks must use their tools to mitigate the adverse effects of shocks. This is what the European Central Bank has been doing, with adjustments to key interest rates and asset purchase programs in march 2022 (ECB, 2022). On the other hand, the fact that the Dollar-Euro exchange rate is so little affected (the shock is absorbed after 50 days) can be explained by the fact that the crisis is not European but global, and that the USA is also suffering the consequences.

The two commodities analyzed in the energy sector showed a significant reaction to the conflict-induced-shock, particularly gas. One of the main causes of this sharp rise was the almost total shutdown of gas supplies to Europe via pipelines from Russia. Not only has this led to higher prices, it has also meant that Europe has had to find new trading partners. These new trading partners include the USA, Africa and the Middle East. This energy dependence on Russia has also had the effect of drastically increasing energy costs for consumers, reducing their purchasing power. In the future, this could prompt European countries to examine their dependence on fossil fuels, and try to turn progressively more and more towards more environmentally-friendly energies produced by European countries themselves.

The interactions between these markets are numerous and significant, which means that these shocks spread rapidly to the rest of the economy and do not remain confined to a single affected sector. The rise in energy prices is undoubtedly the one that spreads fastest through the economy, as it has implications in many areas like transport or manufacturing. The production of other commodities is also impacted, as industries need them. What's more, the spread of these shocks to commodity markets is worrying investors, and we have seen the consequences on financial markets. These market movements and shocks in the

various sectors are challenging policy-makers and central banks in their management of this crisis.

The social dimension is also important. Rising energy and food prices can lead to social instability. Certain regions and populations in particular may be more affected than others, due to their dependence on certain foodstuffs or their fragility even before the crisis. In Europe, the biggest impact on consumers has been the rise in energy prices. Almost all households depend on energy, and it has taken several interventions by the various states to enable their populations to continue to be able to heat their homes or fill their car tanks.

The results obtained were therefore in line with what we had been able to analyze during the literature review. The shocks that have occurred have major implications in all the areas studied, and the shocks are not limited to certain areas in particular, due to the numerous interconnections between them. This conflict has generated an unprecedented crisis, and the monetary and political authorities have a major role to play in managing the consequences of this war.

4.6 Robustness check

To ensure the robustness of our model, we modify what qualifies days as event days or not. Now, any day on which we notice a variation in the VSTOXX 50 of over 5% is considered an event day, whether war-related or not. We can then see whether periods of very high volatility, but which are not war-related, give us similar results. These results can be found in the appendix (Figure 12).

Agricultural commodities show slightly different results. The reaction to shock is slightly lower for both variables. Wheat reacted to the shock with an increase of just under 1%, while maize reaction was not significant. Nor did the effect dissipate after 60 days in either case, as it did in our base model. It can potentially be explained by the fact that, in the base model, a significant number of event days contain attacks on market infrastructures: grain reserves, ports, etc. This measures the impact more directly on the market's infrastructure. This then measures more directly the impact on these commodities, whereas here we ignore the nature of the event, the importance being the variation in VSTOXX 50 attributed to it.

Some macroeconomic variables also show quite different responses to the shock than in the base model. For a start, the VSTOXX 50 shows a greater response to shock, with an increase of 8%. It may seem logical that this should be higher in this case, as we are only targeting days when the Vstoxx50 showed a variation of more than 5%. Also, the effect of the shock on the VSTOXX 50 seems to be dissipating faster, reaching almost its pre-shock

level again after 60 days. This may indicate that conflict-induced shocks are prolonging the outlook for volatile markets. The Yield variable shows a much less pronounced decline in this case. While it responded to the shock with a decrease of 10% in the basic model, the decrease here is only 3%. As mentioned earlier, we can interpret this as a sign that war-related shocks are more likely to generate periods of uncertainty than more common shocks. The last two macroeconomic variables show no significant change from the base model, except that the STOCK variable returns more quickly to its pre-shock level in this case.

The results of this check on energy market variables show that gas reacts less significantly to the shock, with a price increase of 3%, but was no more significant after 5 days. In this case, it's clear that the results obtained for gas are due to the fact that, in this robustness check, not all event days are as strongly linked to the commodity as the conflict. Indeed, the price and supply of gas is one of the major political and economic issues at stake in this war, which is why it is normal to observe greater fluctuations in our basic model.

Finally, Zinc reacts to the shock with a very slight fall, before rising and returning to its pre-shock level. In this case, the fluctuation is so small that we can associate it with classic market fluctuations. Nickel has a different reaction, with a smaller rise than in the basic model, its prices here increasing by around 1% following the shock. Copper also reacts differently here, with a very slight drop following the shock. This can be explained by the high volatility of this commodity, even in the absence of shocks.

In conclusion, we have seen that, with a few exceptions, our model is robust to changes in the days of events and the conditions under which they are selected. It can be used in cases other than conflict-induced shocks. All the differences in variation we observed can be logically explained by comparing the two contexts, making it a useful model for many types of analysis.

5 Conclusion

Through the literature review, we were able to obtain crucial information for the dissertation. On the one hand, the background is important for a better understanding of the scale of this conflict and the issues associated with it. The historical context allows us to better understand the origins of this war, and the scale of the human and material catastrophe it caused. In addition, the descriptive analysis of the impact on commodities has enabled us to obtain an initial response. For each commodity category, we were able to see the price variations observed since the start of the war, as well as the policies put in place to try and counter these negative effects.

In addition, the second part of the literature review brought a theoretical notion to this. Through the use of various econometric models, we were able to take stock of the scientific literature already available. The discussion of the structural determinants of global commodity prices was also a crucial part, enabling us to better understand the relationships behind these movements. Overall, this literature review enabled me to build my methodology by drawing inspiration from already existing models, and to replicate on war-induced-shocks a method that had proved its worth for the Covid-19 crisis.

To ensure the relevance of the data we use, we have separated our commodities into several areas to cover different sectors of the economy. There are agricultural commodities, which include wheat and maize, essential commodities for food. We also include mineral commodities, which are used in more and more fields, in a world where innovation is central. Energy commodities also play an important role in the dataset, since other industries inevitably depend on them in one way or another.

We were then able to specify my methodology more precisely by defining the model used. The VAR model incorporates the commodities, but also macroeconomic variables, useful for capturing the interactions between these different variables. What's more, using the VSTOXX 50 to identify shocks adds a dimension of uncertainty and volatility to the model.

We have divided the results into several parts and, as we have explained in the discussion of the results, most of the commodities and variables used react significantly to a war-related impact. The commodities showing the strongest reaction are energy commodities, and gas in particular. This result is in line with our literature review. Agricultural commodities were also affected by significant and persistent increases, again in line with our descriptive analysis. This thesis has added an analysis of mineral commodities to our literature review. This dimension is important when we know Russia's mining production, and my results also showed a significant response, particularly for Zinc and Nickel. Finally, the addition of

macro-economic variables, and more specifically those linked to Europe, shows a response to shocks in the form of high volatility and uncertainty among investors. This explains the measures implemented by the European Central Bank in particular.

The research question can be answered in the affirmative. After analyzing the impact of conflict-induced shocks, we were able to see that every commodity category was affected. However, some are more affected than others, and we were able to explain the probable causes when discussing the results. In the future, it will be interesting to see the evolution of Europe's and the world's dependence on these two countries, which, as we have seen, is a source of volatility and uncertainty in times of conflict.

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7 Appendix

7.1 A.1

Date	Description	Shock
2022-02-24	Russian invasion begins	X
2022-02-25	First attacks on Kyiv	
2022-03-01	Siege of Mariupol and attacks on Kharkiv	X
2022-03-04	Seizure of Zaporizhzhia nuclear power plant	X
2022-03-09	Mariupol hospital attack	
2022-03-16	Mariupol theater bombing	
2022-03-23	Mykolaiv port attack	X
2022-03-29	Attack on Mykolaiv regional state administration building	
2022-04-02	Russia retreats from Kyiv	
2022-04-08	Attack on Kramatorsk railway station	
2022-05-09	Biden signed act to lend defensive support to Ukraine	X
2022-06-27	Attack on Kremenchuk	
2022-07-01	Attack on Odesa	
2022-07-22	Black Sea Agreement begins	
2022-07-24	Attack on Odesa port	
2022-09-21	Russia extends mobilization and draft	
2022-10-08	Crimean bridge attack	
2022-10-10	Attack on Kyiv, blackout in city	X
2022-10-29	Russia leaves Black Sea Agreement	
2022-11-02	Russia re-enters Black Sea Agreement	
2022-11-19	Black Sea Agreement extended to 18^{th} of March	
2022-12-12	Odesa port attacked	X
2023-01-25	Germany ships military equipment	
2023-03-18	Black Sea Agreement extended another 60 days	
2023-05-02	Poland, and others, ban Ukrainian grain imports	X
2023-05-17	Black Sea Agreement extended another 60 days	
2023-05-29	Attack on Odesa port	
2023-07-17	Russia leaves Black Sea Agreement	X
2023-07-18	Attack on Odesa port	
2023-07-19	Attack on Chornomorsk port and Poland extends import ban	X
2023-07-20	Attack on Odesa port. Chinese consulate damaged	
2023-07-21	Attack on Odesa port. Grain terminals and silos damaged	
2023-07-23	Attack on Danube port. 13,000-ton grain destroyed	X
2023-07-27	Attack on Odesa port	

Table 1: Timeline of Events (Part 1)

Date	Description	Shock
2023-08-02	Attack on Odesa port	X
2023-08-04	Attack on Novorossiysk port. Russian grain port in the Black Sea	
2023-08-14	Attack on Odesa	
2023-08-16	Attack on Reni port	
2023-08-23	Attack on Danube port	
2023-08-28	Attack on vegetable oil facility	
2023-09-03	Attack on Odesa port	X
2023-09-06	Attack on Danube port	X
2023-09-07	Attack on Danube port	
2023-09-13	Attack on Danube port	
2023-09-17	Attack on agricultural facility in Odesa	X
2023-09-19	Attack on Lviv	
2023-09-20	Attack on oil refinery in Kremenchuk	
2023-09-21	Large attacks around Ukraine. Energy facilities damaged.	X
2023-09-25	Attack on Odesa port	X
2023-09-26	Attack on Izmail port	X
2023-10-05	Attacks on southern Ukraine. Ports in Odesa and Mykolaiv	
2023-10-06	Attack on grain silos and port on Danube	
2023-10-12	Attack on Danube port	
2023-10-18	Attack on Zaporizhzhia	X
2023-10-30	Attack on ship repair yard in Odesa	
2023-11-08	Cargo ship attacked when entering Odesa	
2023-11-15	Grain deliveries by train stopped due to railway damage, headed to Odesa	
2023-11-18	Attacks on energy infrastructure, large outages	
2023-11-21	Attack on Odesa port	
2023-11-26	Attack on Kyiv	X
2023-12-07	Attack on Danube port	
2023-12-14	Attacks in Odesa region. Damages to port and grain storage facilities	
2023-12-17	Attack on Odesa	X
2023-12-29	Large attacks around Ukraine	
2023-12-31	Large attacks on southern regions	

Table 2: Timeline of Events (Part 2)

Date	Description	Shock
2024-01-01	Attack on Odesa port	X
2024-01-02	Large attacks around Ukraine	X
2024-01-06	Attacks on Pokrovsk	
2024-01-17	Attack on Odesa port	X
2024-01-24	Attack on Odesa port	
2024-02-07	Attack on Kyiv	
2024-02-09	Attack on Kharkiv	
2024-02-15	Large attacks around Ukraine	
2024-02-20	Attacks on around northern Ukraine	X
2024-02-24	Attack on Odesa port	
2024-03-02	Attack on Odesa port	
2024-03-06	Attacks on power infrastructure. Attack on Odesa port	
2024-03-08	Attack in north-eastern Ukraine	
2024-03-13	Attacks around Ukraine	
2024-03-15	Large attack on Odesa	
2024-03-17	Attack on Odesa. Damage to port, agricultural companies, and infrastructure	
2024-03-20	Attack on Kharkiv	
2024-03-21	Attacks on Kyiv and Mykolaiv	
2024-03-30	Attack on power facilities, significant damage to power plants	X

Table 3: Timeline of Events (Part 3)

Date	Description	Shock
2024-04-05	Kamikaze drone attacks	X
2024-04-11	Massive air attack: destruction of the Tripilska thermal power plant	X
2024-04-13	Missile strikes in Luhansk	
2024-04-17	Missile strikes in Chernihiv	
2024-04-20	US adopts $60.8 billion aid plan	
2024-04-29	Attack on Odesa	
2024-05-05	Russian strikes on Sloviansk thermal power plant	
2024-05-10	Bombing of Kharkiv	
2024-05-11	US announces an additional $400 million in aid	
2024-05-12	Strikes on the city of Vovchansk	
2024-05-21	Russia launches nuclear land maneuvers	
2024-05-25	Bombing of Kharkiv	X
2024-06-01	Missile and drone attacks on energy facilities	
2024-06-12	Strikes on Kryvyï Rih	
2024-06-19	Kim Jong Un pledges unconditional support for Russia	
2024-06-22	Bombing of Kharkiv	
2024-06-27	Agreement signed in Brussels between the EU and Ukraine: 1.9 billion dollars for long-term security	
2024-06-28	Bombing raids on several towns in eastern Ukraine	
2024-07-01	Bombings in Oukraïnkdk	
2024-07-02	Russia launches attack on Mhyrorod air base	
2024-07-03	Drone and missile strikes in Dnipro	
2024-07-08	More than 40 Russian airstrikes hit a paediatric hospital in Kiev	
2024-07-14	Missile attack in Myrnorhud	X
2024-07-20	Bombings in Mykolaïv and Kherson	
2024-07-24	Swiss Foundation for Mine Action building bombed in Kharkiv	X

Table 4: Timeline of Added Events

7.2 A.2

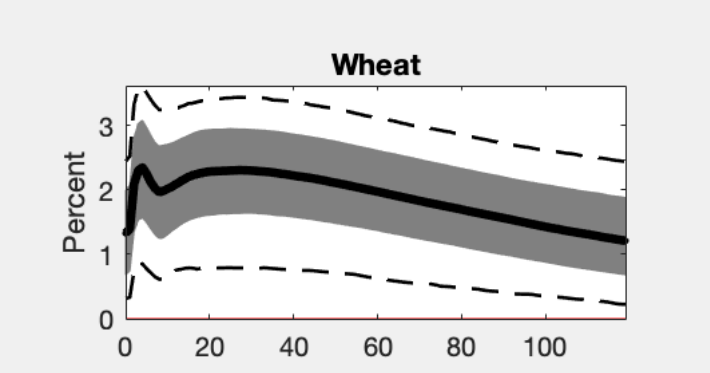

Figure 11: *IRFs to a conflict-induced-shock increasing VSTOXX 50 by more than 2.5%. The black line is the median. Shaded areas are 68% and the doted lines are 90% credibility sets.*

7.3 A.3

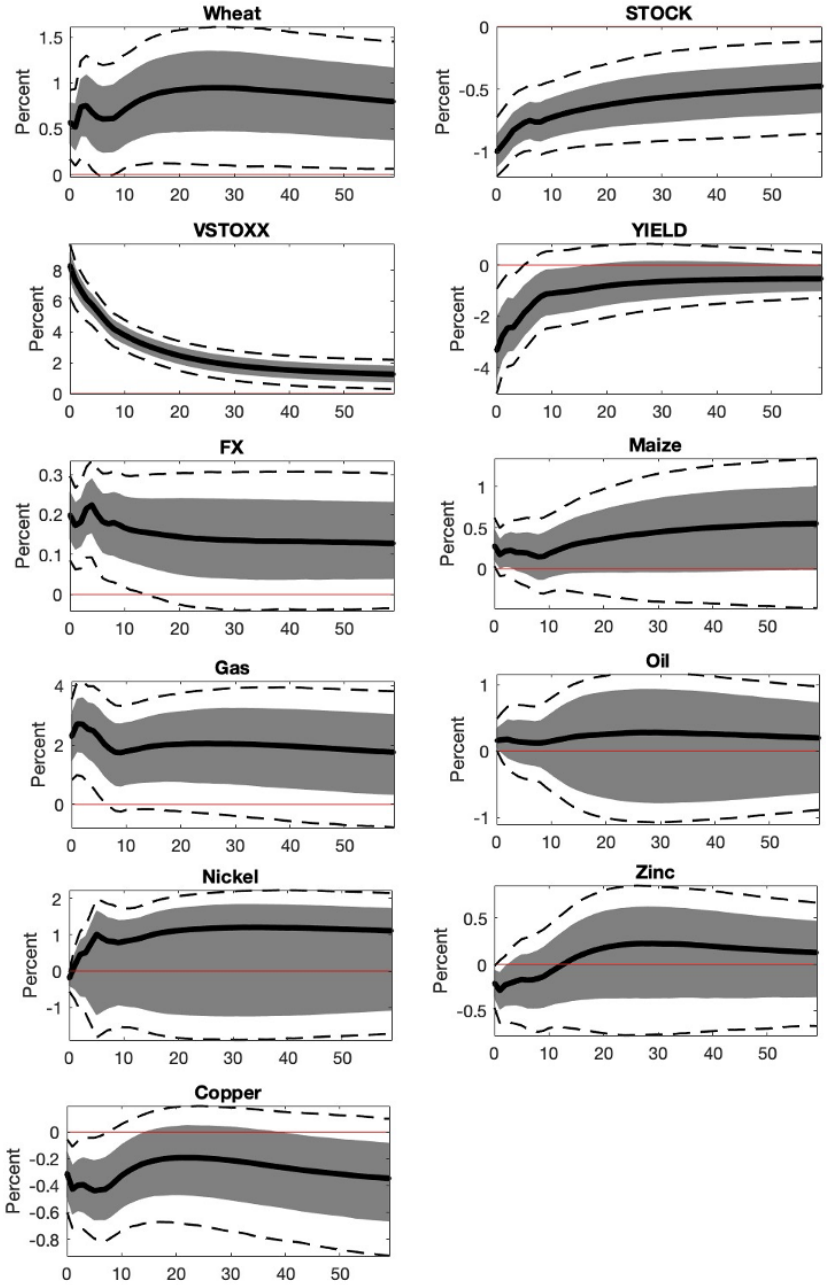

Figure 12: *IRFs to a shock increasing VSTOXX 50 by more than 5%. The black line is the median. Shaded areas are 68% and the doted lines are 90% credibility sets.*

7.4 A.4

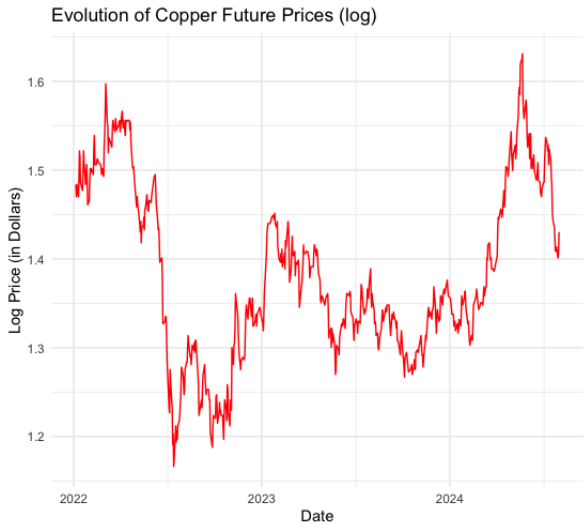

Figure 13: *Evolution of Copper future Prices (2020-2024).*

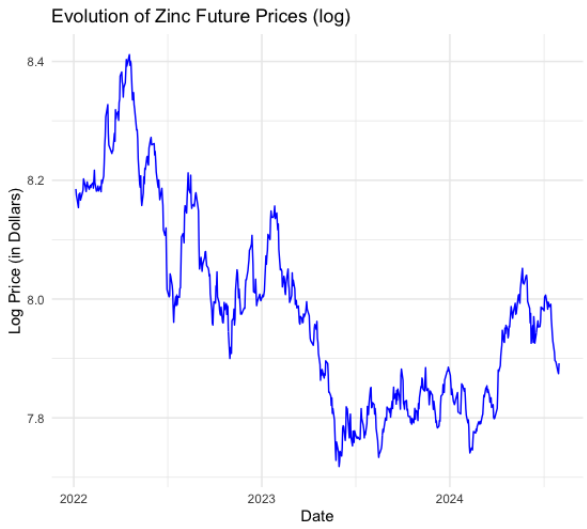

Figure 14: *Evolution of Zinc future Prices (2020-2024).*

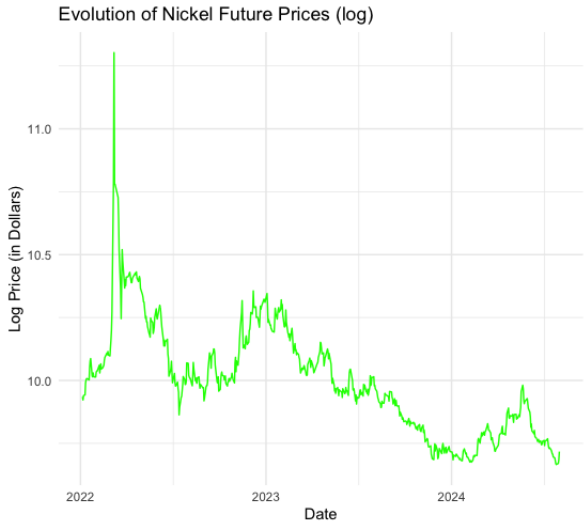

Figure 15: *Evolution of Nickel future Prices (2020-2024).*

7.5 A.5

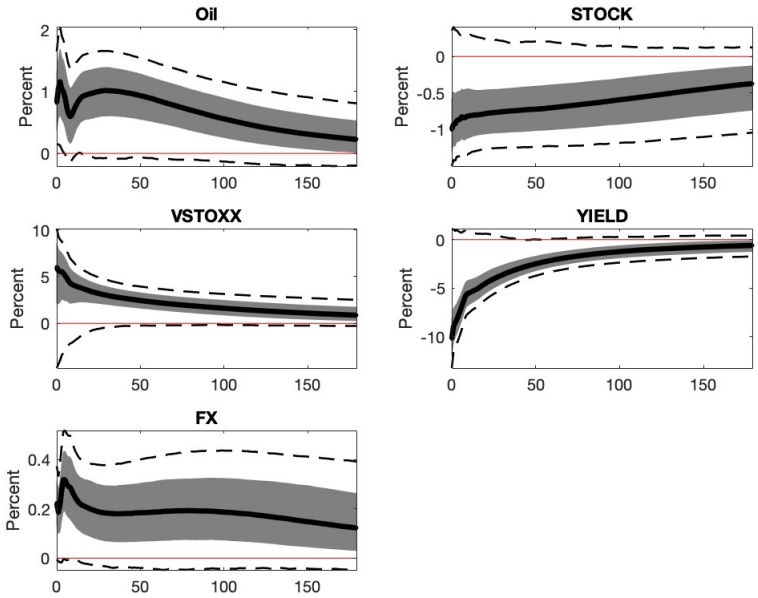

Figure 16: *IRFs to a conflict-induced-shock increasing VSTOXX 50 by more than 2.5%. The black line is the median. Shaded areas are 68% and the doted lines are 90% credibility sets.*