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Abstract

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ABSTRACT

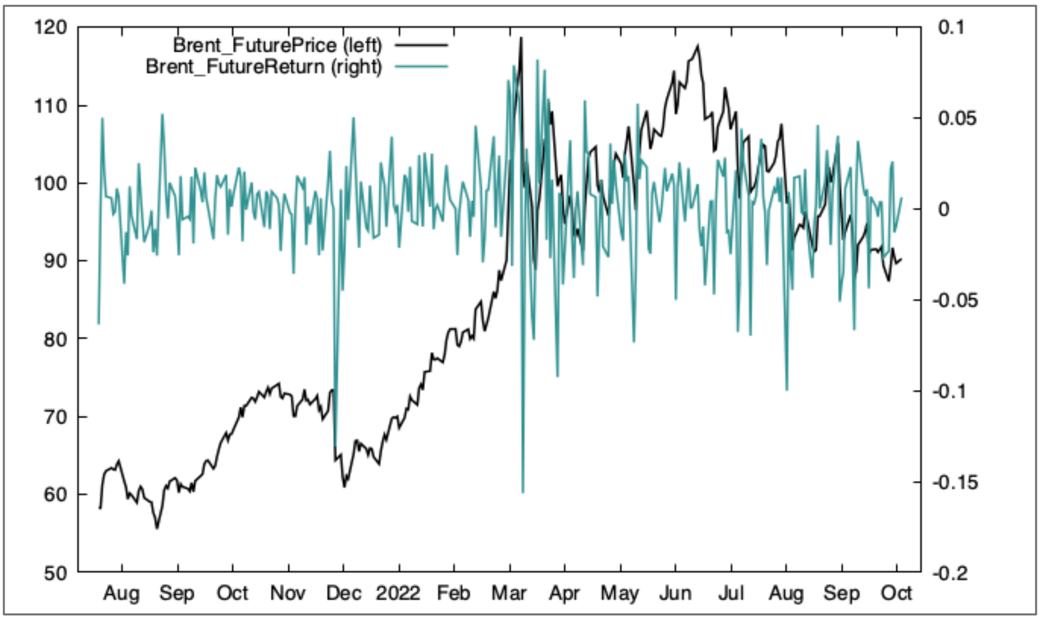
It has already been literarily proven that the past shows a statistical correlation between crude oil prices and certain industries that are influenced by its volatility. In this context, the Russian war in particular leads to reassessable reactions of these industries. In this paper, we investigate this influence during the war period and compare the results with pre-war calculations for 533 companies from 12 industries. Therefore, we use a recursive SVAR model, based on which we illustrate our results graphically with the impulse-response function. We find that the shock responses of industries to Brent volatilities during the war period have a high explanatory power, but we find different results for the individual industries. While oil-producing industries react positively to positive shocks (more so during the war period), the impact on oil-producing industries is rather small, but negative. Oil & Gas Drilling shows an increase of 10% and Tires & Rubber Products a decrease of 8%. Also other industries show surprising results.

1. INTRODUCTION

Hardly any variable changes economic world events as continuously as the oil price (see Chen (2010), Boubaker and Raza (2017), Hammilton (2000), Jones and Kaul (1996)). If this shifts suddenly, this can have an abrupt effect on international financial markets as well as the behavior of their players. This can be referred to the accompanying uncertainties and resulting actions of the actors. The dependence of the global economy – especially commodity prices and share prices of certain industries – on oil was again reflected in the international reaction to the Russian war. Due to the existing indirect substitute products such as gas and coal, a shift in demand from crude oil to alternative commodities can be observed during the time of the conflict. The price development of these raw materials is currently influenced by the Russia-Ukraine conflict. Oil prices play a crucial role in influencing the global economy and economic activity. The rise can also be seen as an important factor in explaining the high volatility of share prices in certain industries.

From an identification perspective, it is admittedly difficult to argue that the war affects the stock market only via the oil price, since it is precisely in this period that many asset prices changed from 24 February 2022. Russia's war is causing dislocations in commodity markets. Even in commodities, the prices of gas, metals, grains, fertilizers and many more have changed in unprecedented ways. Electricity prices in Europe have gone up insanely. The war and sanctions have affected many markets and the ability of many companies to do business. The world's dependence, especially Europe's, on Russian energy commodities is immense. The sanctions imposed so far, voluntary boycotts by many companies and their withdrawal from business with Russia are driving the prices of oil, gas and coal to unprecedented heights.

Figure 1: Brent price and yield trend over the period under review



Rapid changes in the price of crude oil also have a continuous effect on the share prices of commodity-dependent companies[4] , as has already been proven by numerous empirical studies in the literature.[5] Most authors show a negative correlation between the two objects of study in their results, but some also come to the conclusion that an increase in the price of crude oil is accompanied by an increase in the value of share indices. The different results are based on the fact that, on the one hand, different time periods are considered in the studies and, on the other hand, different assumptions are made regarding the general influence of indices.

Usually, country-specific indices or industries are observed to find out how they react to oil price shocks. Summarizing from the literature review, we conclude that the density of investigation of past literature for specific countries, such as the US, is very high and that previous studies come to contrasting results, thereby showing

[4]In this paper, commodity-dependent companies are those that explore, produce, trade or require crude oil for a large part of the production of their products.
[5]The short phases of reaction by the financial market can be attributed in particular to the capital market efficiency and the efficient market hypothesis according to Fama (1965, 1970, 1991, 1998) and Fama and Fisher (1969).

positive, negative or no correlations. Summarizing from the literature review, we conclude that, due to the different results, our contribution is important in that the period of the Russian war has not yet been studied. This prompts us to investigate the impact of oil price shocks on industry returns of oil producing and oil price dependent firms.

In our paper, we analyze the impact of the (high) returns of the Brent spot price during the war and before, each with the same number of days, on the returns of listed firms from 12 different industries, which we weight and select based on their market capitalization. For this reason, we broadly categorize between companies that focus on exploration, production and trading of crude oil and companies that purchase crude oil in large quantities for the production of their goods and products and thus depend on the oil price. Furthermore, since in our study we assume only oil price shocks as the output for industrial reactions and further no macroeconomic variables, it is argued that exchange rate shocks can simultaneously affect stock markets, which in turn affect the industrial production of oil price dependent firms. It is evident from the price rises and falls of industries from 24 February 2022 (the start of the war) that industrial production is sensitive to the sharp rise in oil prices (as shown in Figure 1). Similarly, exchange rates and their cost implications in turn affect companies' cash flows and thus their prices on the stock market. It can be observed that companies that require oil in large quantities to produce their goods and products experience a fall in their share prices, and in turn oil-producing companies experience a rise in their share prices. This affects their business and cash flows, thereby also influencing investors in their actions regarding the purchase or sale of these shares. Consequentially, this underlines the importance of the crude oil price for these companies.

As a methodology, we use a recursive SVAR model, based on which we illustrate our results graphically with the impulse-response function to find out the respective reactions of the yield changes of these industries. As a data basis for our analysis, we use the daily spot prices of Brent crude oil in the overall period of observation from 19 July 2021 to 30 September 2022 and the daily closing prices of certain oil price-dependent companies determined in the same period. We divide the period into two study periods. We compare two periods of equal length from 19 July 2021 to 23 February 2022 and from 24 February 2022 (the start of the war) to 30 September 2022, and thus base each study period on 158 trading days. With our cross-national and cross-industry analysis based on current time series data of the war period, we contribute to new scientific insights and highlight the resulting implications for investors and firms.

We find that oil price shocks have an overall differential impact on industry indices and that one industry shows differential impact between the study periods, revealing that the size of the shocks does not explain the size of the returns at each point in time. This can be seen as a research limitation of the present impulse response analysis. For example, an unexpected oil demand and supply shock leads to either a delayed and sustained increase or an immediate and sustained downturn in industry price differentials. The strongest reaction is shown by the Oil & Gas Drilling industry. We recognize that this industry achieves a 10% increase in returns both before the war (on the second day) and during the war (on the third day). Integrated Oil & Gas and Exploration & Production also show strong reactions, although these are more pronounced during the war than before the war and show several swings. Transportation Services, Refining & Marketing and Service & Equipment react less to shocks during the war than before the war. For Transportation Services and Service & Equipment we can explain this by the moderate price increase, but for Refining & Marketing the shock analysis is too low for its steep price increase at the beginning of the war.

For oil-producing companies, we find that they tend to react negatively to positive shocks, although we cannot explain the behavior of Pharmaceuticals, with its sideways-trending price, a strong negative shock reaction lasting over three days. Containers & Packaging's reaction is higher before the war than during the war, even though they use a lot of oil to produce plastic packaging. The Tires & Rubber Products industry is interesting. Although they generally require a lot of oil as a major part of the production of tires, they are almost unresponsive to oil price shocks before the war. It seems that they become sensitized at the start of the war and the associated oil price increase. The response is -8%, the highest of the oil-producing industries. The industries best explained by the shock are the oil-producing industries and Tires & Rubber Products. There the shock responses are highest and the variation in oil explains much of the variance in this behavior.

Furthermore, our results show the contrasting reactions of the industries, how differentiated both periods turn out to be and how the management of the companies in the individual industries react to high shocks. This motivates us to review the periods separately and also prove how important crude oil is for companies and trade.

The remainder of the paper is as follows. In chapter 2 we give an overview of the current state of research. In Chapter 3, we present the sample data and analyze their descriptive statistics, identify their stylized facts, which are naturally found in returns. Based on the results and preliminary tests of the data in chapter 3, in chapter 4 we describe the method used and our specifications. In chapter 5, we show and discuss the results of our empirical investigation. The thesis concludes with a conclusion and outlook in chapter 6.

2. LITERATURE REVIEW

There are numerous studies in the literature that analyze the effect of volatile oil prices on index and stock returns. Based on this line of investigation, many statistical models have already been applied to examine the influence of shocks in the oil price variable on industry or index variables. Most authors prefer to calculate with a WTI dataset, as it is more strongly related to the returns of US firms. Brent is also frequently used and for other authors the weighted average price, which is composed of the WTI, Brent and OECD reference price, serves as the data basis. Gupta (2016) uses a one-month roll-on futures oil price from NYMEX and checks his results against both the WTI and Brent prices.

Another difference between the studies is the study period: the longest is 18,992 days and the shortest is 1,605 days. For our study, we use the Brent price in the current war period, which, unlike WTI, shows a much higher increase in the study period (19/07/2021-30/09/2022). This is 315 trading days due to the focus of this paper and is divided between the pre-war period (19/07/2021-23/02/2022) and the war period (24/02-30/09/2022).

While most literature is limited to the US equity market, some authors examine specific markets, such as the BRICS countries, the Middle East, Asia, Southeast Asia, Africa, Europe and South America. Literature focusing on the US stock market largely analyses the S&P 500, followed by the Dow Jones and the NASDAQ. We collect data from 12 oil-price sensitive industries, regardless of where they are located, to produce an overall scientific picture.

In the choice of computational methodology, half of the authors use the structural VAR model, followed by copula statistics, ARCH-GARCH models, bivariate GARCH-in-mean models, multivariate stochastic volatility structures, the Q(N)ARDL model and wavelet multiregression analysis. Since the Russian war explains most of the oil price volatility and there are price jumps in the time series, we use a recursive SVAR model and employ the impulse response function to identify the responses of industry stock price differentials due to an orthogonalized oil price shock in Brent returns.

The following literature review shows that a wide range of literature evaluates the relationship between oil price and macroeconomic variables (for this, see Hamilton (1983), Hooker (2002), Lee and Ni (2002), Hamilton (2003), Hamilton and Herrera (2004), Akram (2004), Cunado and De Gracia (2005), Chen and Chen (2007), Huang and Guo (2007), Ratti and Vespignani (2016), Fang, L., B. Chen, H. Yu, and C. Xiong (2017), Al-hajj, Al-Mulali, and Solarin (2018), and Köse and Ünal (2021)). The relationship between crude oil prices and stock markets has also been extensively analyzed by the literature, with most studies showing a relationship between crude oil and index returns, which is subdivided into a positive, negative or no relationship. Most authors, like us, analyze different time periods, countries and industries. For this reason, they also experience different results in their studies regarding the relationship between oil prices and stock market returns.

A negative relationship between oil prices and stock market returns is found by Chen, Roll and Ross (1986) for the US, by Jones and Kaul (1996) for Canada, the US, Japan and the UK, by Sadorsky (1999) for the US, by Papapetrou (2001) for Greece, by Nandha and Faff (2008) for global industrial indices, by Chiou and Lee (2009) for the US, by Chen (2010) for the US, by Lee and Chiou (2011) for the US, by Mohamed (2011) for indices from 18 European countries, by Fowowe (2013) for Nigeria, by Sim and Zhou (2015) for the US, by Christoffersen and Pan (2017) for the US, by Lambertides, Savva and Tsouknidis (2017) for the US, by Al-hajj, Al-Mulali and Solarin (2018) for Malaysia, and by Cakan, Demiralay and Ulusoy (2021) for Turkey.

A positive relationship between crude oil and stock market returns is shown by El-Sharif, Brown, Burton, Nixon and Russell (2005) for the UK, Basher and Sadorsky (2006) for the US and nine Asian countries, Bjornland (2009) for Norway, Kilian and Park (2009) for the US, Mohanty, Nandha, Turkistani and Alaitani (2011) for Gulf Cooperation Council (GCC) countries, Abhyankar, Xu and Wang (2013) for Japan, Kang, Ratti and Yoon (2014) for the USA, Bouri (2015) for Lebanon, Gupta (2016) for 70 countries, Kang, Ratti and Vespignani (2016) for the USA, Shabbir, Kousar and Batool (2020) for Pakistan, Köse and Ünal (2020) for Iran, Kazakhstan and Russia, Alamgir and Amin (2021) for South Asia, and Endri, Rinaldi, Arifian, Saing and Aminudin (2021) for Indonesia.

Most authors are in alignment that oil price fluctuations affect their diverse objects of study differently. Due to the large amount of this kind of literature, we show a literature overview below:

Table 1: Literature overview with different results.

Authors (Year)	Methodology	Objects of study	Time period
Burbidge and Harrison (1984)	VAR model	USA, Japan, Germany, UK and Canada	1961-1982
Kling (1985)	VAR model	Individual industries	1973-1983
Faff and Brailsford (1999)	Two-Factor Model	Australian industries	1983-1996
Lee and Ni (2002)	VAR model	Individual industries	1959-1997
Henriques and Sadorsky (2008)	VAR model	Energy companies (WilderHill Clean Energy Index) and technology industry companies (Arca Technology Index)	2001-2007
Park and Ratti (2008)	VAR model	USA and 13 European countries	1986-2005
Malik and Ewing (2009)	Bivariate GARCH model	Individual industries	1992-2008
Miller and Ratti (2009)	Cointegrated Vector Error Correction Model	International Stock Markets	1971-2008
Arouri and Nguyen (2010)	Market-, Two-Factor-, Multifactor-Model	Dow Jones (DJ) Stoxx 600 and 12 European Sector Indices	1998-2008
Gogineni (2010)	Individual	NAICS Industries	1998-2006
Arouri (2011)	Multifactor asset pricing model	12 European sector indices	1998-2010
Elyasiani, Mansur and Odusami (2011)	GARCH(1,1) model	13 industries globally	1998-2006
Fayyad and Daly (2011)	VAR model	Kuwait, Oman, UAE, Bahrain, Qatar, UK and US	2005-2010
Narayan and Sharma (2011)	GARCH(1,1) model	560 US firms on NYSE	2000-2008
Vo (2011)	Multivariate stochastic volatility structure	S&P 500 index	1999-2009
Broadstock, Cao and Zhang (2012)	CAPM/Fama-French three factor framework	Chinese energy companies	2000-2011
Scholtens and Yurtsever (2012)	VAR model and multivariate regressions	38 industries of European companies	1983-2007
Ciner (2013)	Generalized linear regression model	S&P 500 and NASDAQ Composite indexes	1986-2010
Degiannakis, Filis and Floros (2013)	Multivariate ARCH framework	European industrial sector indexes	1992-2010
Wang, Wu and Yang (2013)	VAR model	16 national stock indices	1999-2011
Broadstock and Filis (2014)	Scalar-BEKK model	Chinese and US industries	1995-2013
Sukcharoen, Zohrabyan and Leatham (2014)	Copula	Market indices of 18 countries	1982-2007
Ahmadi, Manera and Sadeghzadeh (2016)	SVAR model	US stock market returns at both aggregate and industry level	1973-2013
Ding, Kim and Park (2016)	Quantile causality test	S&P 500, Nikkei, Hang Seng, Shanghai, and KOSPI	1996-2012
Mensi, Hammoudeh and Shahzad (2017)	Mariational mode decomposition method and Copula	S&P 500, Stoxx600, DJPI and TSX indexes	1998-2016
Wei and Guo (2017)	SVAR model	Stock market of China	1996-2015
Hashmi, Chang and Bhutto (2021)	ARDL model	Oil exporting countries Russia, Mexico, Venezuela and Norway / Oil importing countries India, China, Japan and Norway	1993-2017

No relationship between crude oil and stock market returns is found by Huang, Masulis, and Stoll (1996) for the US, by Cong, Wei, Jiao, and Fan (2008) for China, by Apergis and Miller (2009) for Australia, Canada, France, Germany, Italy, Japan, the UK, and the USA, by Alsalman (2016) for the USA, by Boubaker and Raza (2017) for the BRICS countries (Brazil, Russia, India, China and South Africa), and by Hawaldar, Rajesha, Lokesha and Sarea (2020) for India.

In summary, we conclude from the literature review that the density of past literature for certain countries, such as the USA, is very high. However, authors may conclude with contrasting results for the same countries, despite using the identical methodology, but in different time periods. For this reason, our contribution is important in that the period of the Russian war has not yet been studied and this gives us the occasion to investigate the impact of oil price shocks on industry returns.

3. SAMPLE AND DATA

3.1 Industries and data sample

We use the spot price data of Brent crude oil in the period from 19 July 2021 to 30 September 2022 and the stock market daily closing prices of the 533 oil price-dependent companies from the 12 industries (see Table 2) determined in the same period. We separate the period as of 24 February 2022 (the start of the war) and thus have the same number of dates before (19 July 2021) and after the start of the war (30 September 2022). We obtain the daily price data from the financial database Refinitiv Eikon of Thomson Reuters, which are uniformly reported in EURO. When estimating the impact of oil price shocks on industries, we consider the Brent crude oil price, as Caspian Basin countries mainly export oil-related products to European or neighboring countries. Moreover, the relationships between the Brent crude oil price and other oil prices are positively correlated with each other. It is therefore not expected that the use of other internationally recognized oil price data would change the results of the analysis.

The listed companies whose share price movements during the war are strongly influenced by the resulting fluctuations in the price of Brent oil. This is proven by the correlation analysis carried out. The company selection is based on the market capitalization as of 01 October 2022, irrespective of the country in which the company is headquartered, so that we present cross-country results. We obtain a *p*-value of 0.1562 for all firms from the respective industry, indicating strong correlation. In an economic sense, it can be assumed that companies from the crude oil exploring and producing industries benefit from high Brent prices as they lead to a higher margin. On the contrary, the other companies benefit from low Brent prices, as they can produce and sell their goods more cheaply. For this reason, we group the companies into one industry index each.

3.2 Descriptive statistics

By means of descriptive and explorative analysis, central statements about the data material are made possible and first concrete statements about the property of the returns can be made. Thus, different dimensions of distributions are characterized with few values.

It can be seen at first glance that the minimum and maximum returns achieved during the war are higher for oil-producing companies compared to the period before the war. The skewness distributions are interesting. They show (with one exception Oil & Gas Drilling) exclusively negative skews, i.e., right-skewed distributions. Positive and higher returns occur more frequently in both periods under consideration, but this is more common during the war (mostly at the beginning of the war) and can be seen in the price trends. The positive kurtosis values of the distributions indicate that the distribution is characterized by more pronounced marginal areas than the normal distribution.

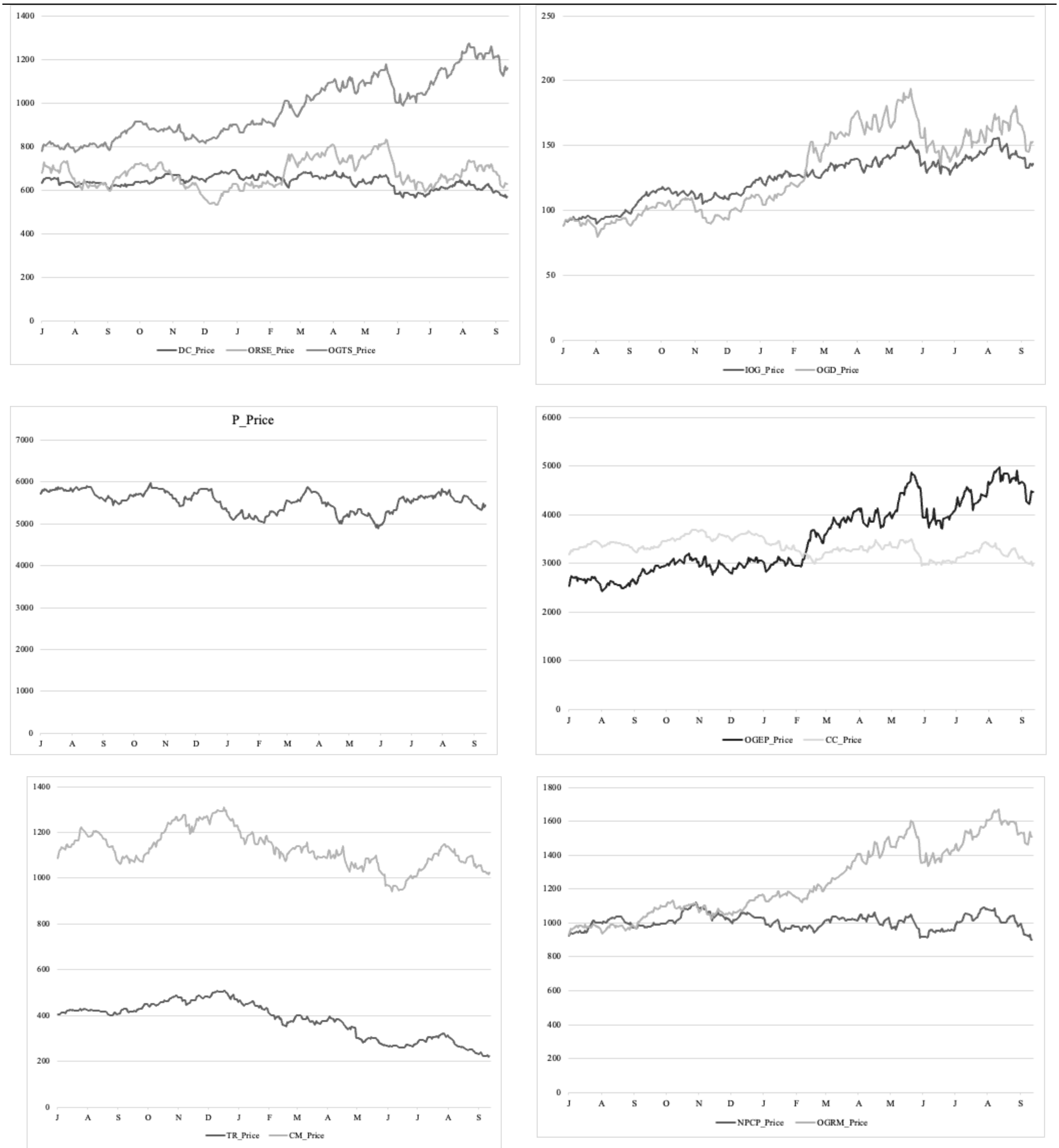
Since the price differences of the industrial indices were determined from the daily closing prices, we interpret these below as they show initial indications regarding the strength of reaction to oil price shocks. Tires & Rubber Products in particular show a declining trend as of 24 February 2022. This is mainly because manufacturers largely need crude oil to produce tiers. Their cash flows decline due to higher production costs, which leads to uncertainty as a result of lower profits and weak forecasts and has a direct impact on the share price. Likewise, the share price of Construction Materials rises. Diversified and Commodity Chemicals as well as Pharmaceuticals and Containers & Packaging show only marginal reaction to higher oil prices. We assume that the shock reactions will not be able to unfold too much.

Table 2: Descriptive statistics of industry returns in both periods before (BF) and during (DW) the war.

Industry	*N*	Average		Min		Max		STD		Skewness		Kurtosis	
		BF	*DW*	*BF*	*DW*	*BF*	*DW*	*BF*	*DW*	*BF*	*DW*	*BF*	*DW*
Brent		0,0021	0,0003	-0,1307	-0,1564	0,0525	0,0824	0,0210	0,0346	-1,6140	-0,8019	9,7466	2,5791
Oil & Gas Drilling	6	0,0017	0,0016	-0,0647	-0,0781	0,0572	0,0760	0,0203	0,0318	0,0151	-0,1288	0,7081	0,0289
Integrated Oil & Gas	6	0,0020	0,0004	-0,0655	-0,0591	0,0362	0,0445	0,0154	0,0198	-0,5089	-0,5517	1,8428	0,5176
Transportation Services	40	0,0007	0,0016	-0,0381	-0,0628	0,0308	0,0432	0,0122	0,0176	-0,0781	-0,6988	0,3147	1,2980
Service and Equipment	51	-0,0011	0,0001	-0,0832	-0,0954	0,0736	0,0736	0,0214	0,0253	-0,0440	-0,4317	1,6940	0,8714
Refining and Marketing	36	0,0010	0,0019	-0,0499	-0,0624	0,0284	0,0445	0,0126	0,0178	-0,4900	-0,6773	1,1374	1,2034
Exploration and Production	102	0,0008	0,0026	-0,0696	-0,0974	0,0520	0,0701	0,0212	0,0279	0,0057	-0,6314	0,0532	0,8467
Pharmaceuticals	166	-0,0008	0,0005	-0,0314	-0,0302	0,0271	0,0266	0,0089	0,0111	-0,1191	-0,0240	0,5816	-0,3208
Construction Materials	25	0,0000	-0,0005	-0,0383	-0,0511	0,0264	0,0296	0,0127	0,0141	-0,2853	-0,5114	0,3392	0,5479
Diversified Chemicals	15	0,0001	-0,0009	-0,0495	-0,0578	0,0254	0,0423	0,0106	0,0149	-0,8531	-0,3129	2,9192	0,8454
Commodity Chemicals	56	-0,0002	-0,0004	-0,0319	-0,0542	0,0232	0,0323	0,0096	0,0137	-0,6846	-0,4200	1,1602	0,9779
Containers & Packaging	25	0,0001	-0,0004	-0,0373	-0,0553	0,0348	0,0383	0,0107	0,0147	-0,2599	-0,5768	1,4157	0,9510
Tires & Rubber Products	5	-0,0001	-0,0037	-0,0537	-0,1340	0,0350	0,0568	0,0138	0,0226	-1,0379	-1,0177	2,1771	6,0312

It is remarkable that the oil-producing industries (Oil & Gas Drilling, Integrated Oil & Gas, Transportation Services, Service and Equipment, Refining and Marketing, and Exploration and Production) show such strongly rising price trends. The rise continues until the end of May 2022 for all these industries and then falls until mid-June 2022, after which they rise sharply again until the end of August. In general, the prices of all industries fall from September 2022 onwards, as can be seen in Figure 2.

Figure 2: Price trends of the industries in the overall period under review.



3.3 Time series analysis: Pre-checks for SVAR model

The following tests the statistical properties that can be observed in both time periods of the respective industry. The results in Table 2 show that the null hypothesis of normal distribution can be rejected, which is explained by the high volatility of the prices. As a result of the high volatility of prices, it is highly probable that there will also be high fluctuations in returns in certain time phases of the study period. The volatility clustering that occurs here is another property that often occurs in the same way with returns. Following Brockwell and Davis (2002), we analyze the time series with the augmented Dickey-Fuller test and test for stationarity to find out this type of property of the returns.

Table 3: Test on stationarity. We start from the Dickey-Fuller estimating equation $\Delta Y_t = (\rho - 1)Y_{t-1} + \mu + \beta \times t + U_t$ for $\rho = 1$ and $\beta = 0$ in a random walk with drift. For our study, we reject the t-value by testing down from the maximum lag length using the AIC criterion. We define the null hypothesis about the presence of a random walk with drift, with $H_0: \rho - 1 = 0$, i.e. $\rho = 1$. To do this, we test before and during the war with constant as well as with constant and trend for the alternative hypothesis of trend stationarity $H_1: \rho - 1 < 0$, i.e. $\rho < 1$.

	Before War		**During War**	
	With constant	With constant and trend	With constant	With constant and trend
Brent	-12.808***	-12.775***	-7.999***	-8.022***
Oil & Gas Drilling	-11.249***	-11.219***	-9.468***	-9.599***
Integrated Oil & Gas	-8.484***	-8.458***	-11.049***	-11.079***
Transportation Services	-13.337***	-13.303***	-11.392***	-11.406***
Service and Equipment	-12.956***	-12.903***	-10.999***	-11.072***
Refining & Marketing	-13.799***	-13.799***	-9.465***	-9.591***
Exploration & Production	-13.396***	-13.375***	-12.240***	-12.280***
Pharmaceuticals	-11.457***	-11.563***	-11.136***	-11.161***
Construction Materials	-11.857***	-12.011***	-12.508***	-12.468***
Diversified Chemicals	-12.050***	-12.007***	-12.386***	-12.378***
Commodity Chemicals	-10.882***	-11.199***	-11.316***	-11.364***
Non-Paper Packaging	-7.351***	-7.513***	-11.319***	-11.426***
Tires & Rubber Products	-3.765***	-4.185***	-11.983***	-11.974***

We assume the null hypothesis H_0 about the presence of non-stationarity, i.e., random walk with drift, and assume random fluctuations around a linear trend. Non-Paper Packaging and Tires & Rubber Products show more stationary paths in returns before the war and thus slightly larger *t*-values than the other industries. Brent also shows a clearer path during the war, i.e., increasing returns, but is also non-stationary overall. For this reason, we accept H_0. The results are thus in line with our expectations of overall volatile time series, which we graphically reinforce below. Figures 2 and 3 show the volatility clusters of Brent and industrial yields before and during the war. Brent in particular shows high volatilities at the beginning of the war compared to the pre-war period.

Industrial returns show strong and volatile manifestations almost throughout the period under consideration, but they are more pronounced during the war. Based on the high price increases caused by the war, which also affect the level of returns, the Oil & Gas Drilling, Transportation Services, Diversified and Commodity Chemicals industries are non-stationary, which we consider in our analysis. We infer non-stationary properties from all observations and for this reason use a recursive SVAR model for our analysis, for which the assumption of stationarity is not fundamental.

Figure 3: Brent volatility cluster

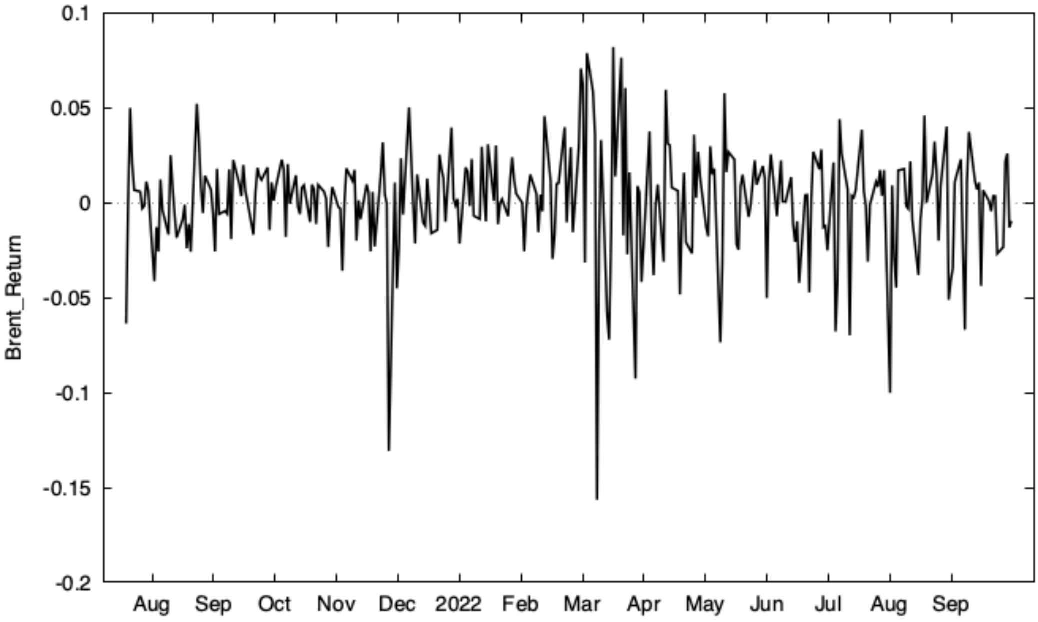


Figure 4: Oil producing industries volatility cluster

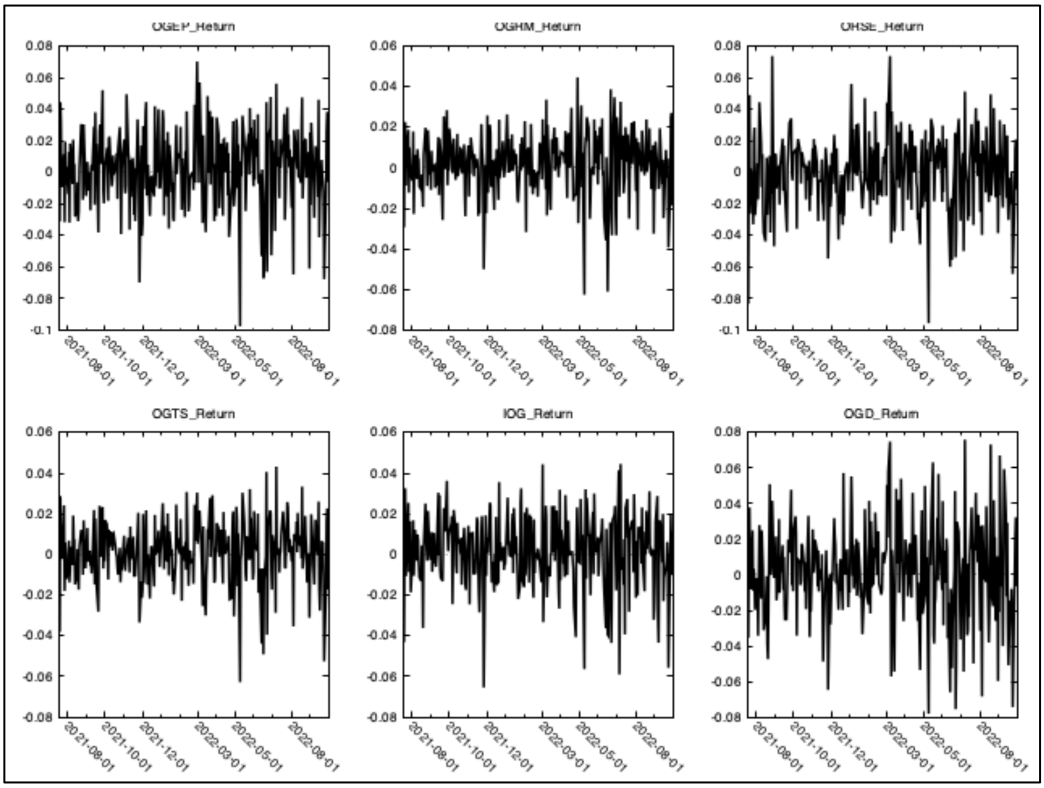
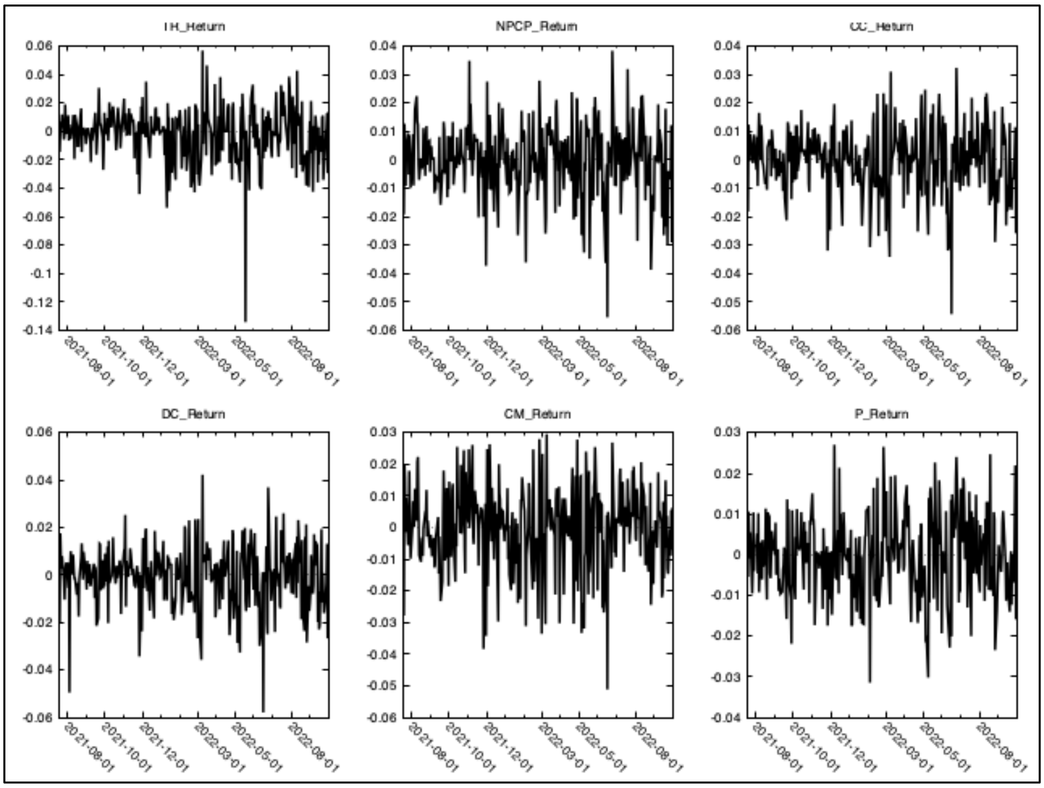


Figure 5: Oil processing industries volatility cluster



4. METHODOLOGY

Based on the results of the data pretest, we use the recursive SVAR model for our investigation. Due to the flexible goodness of fit of this model to datasets, numerous studies find a relationship between oil price shocks and the volatility of various indices, as shown in the literature review. Most studies that use a VAR model for their investigation suffer from the limitations associated with it (Chen, Roll and Ross (1986), Kilian and Park (2009), Bjornland (2009), Abhyankar, Xu and Wang (2013) and Köse and Ünal (2020), as does our study. Since in our study we assume only oil price shocks as the output for industrial reactions and further no macroeconomic variables, it is argued that further exchange rate shocks may simultaneously affect stock markets, which in turn affect the industrial production of oil price sensitive firms. However, they in turn are not affected by their shocks. It is also argued that costs in an economy rise due to the declining output of industrial production, which also raises inflation. In addition, falling industrial growth has a negative impact on stocks in the stock market. Finally, inflation shocks affect stock markets, but are not themselves affected by stock markets. For example, rising inflation is a signal to industry that macroeconomic stability is under threat, which affects stocks on the stock market. All these macroeconomic parameters are reflected in the share prices of companies on the stock exchanges.

The effects of oil price shocks on the yield curves of the twelve industries must be isolated from the industry-specific shocks. For this purpose, the industries are considered individually, as it is not possible to include all industries in one model. For the impulse response function, we first estimate the SVAR model, which is based on a univariate or multivariate time series model such as a VAR model and graphically illustrates the dynamic effects of a structural or reduced-form disturbance on the variables of interest. This feature allows us to track the transmission of a single shock within an otherwise noisy system of equations.

In our study, the random variables consist of the Brent and industry returns and thus of real numbers $X_t = \mathbb{R}$ which occur under the probability ω probability. The endogenous variable is lagged because of its dependence on its own past values, as we assume abnormal industry returns due to shocked Brent price differentials. Under the above restrictions, we express the VAR process of order p as:

$$Z_t = \alpha + \sum_{i=1}^{3} A_i \, Z_{t\text{-}i} + \varepsilon_t, \tag{1}$$

where Z_t is a k×1-vector of all endogenous variables is with X_t=$(X_{1t}, ..., X_{Kt})'$. A_i is the *i-th* matrix of autoregressive coefficients for i=*1*, 2, ... , p and indicates the order of the model, α is an intercept vector and ε_t=$(\varepsilon_{1t};...;\varepsilon_{Kt})'$ is a normally distributed disturbance variable with $\bar{\mu}$=0 and σ^2. Furthermore, for ε_t stochastic independence and its expected value is assumed to be zero. We define the constant as the exogenous component. Our model specifies a block recursive structure for the simultaneous relationship between the reduced form disturbances and the underlying structural disturbances. We refer to our model as "structural", in which we assume that the one-step prediction errors ε_t from a statistical model can be viewed as linear functions of the structural shocks μ_t can be viewed with:

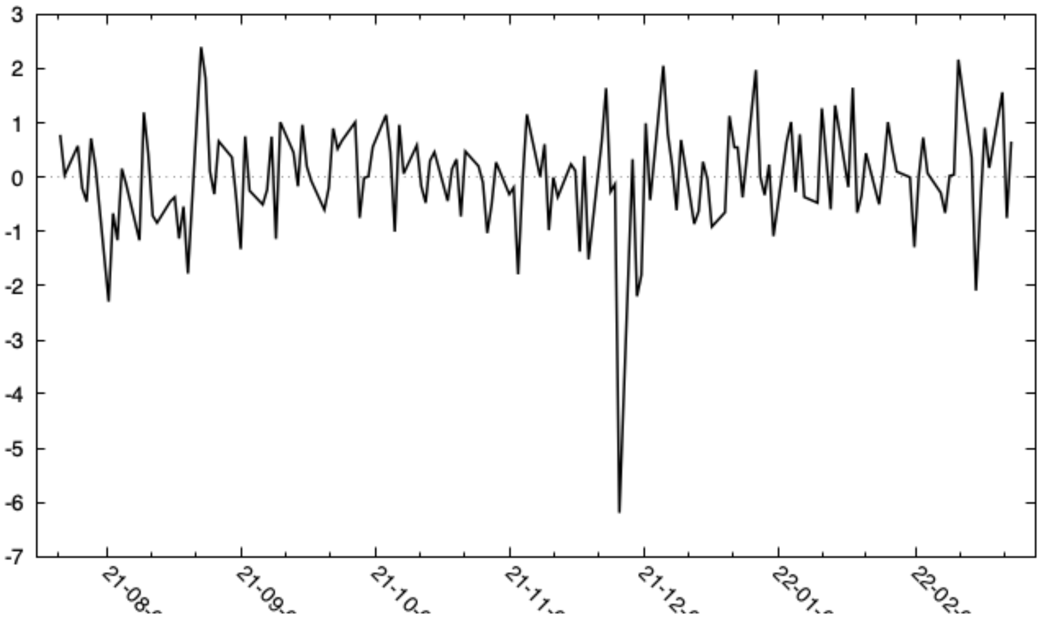
$$\begin{aligned} \varepsilon_t &= y_t - E(y_t | \mathcal{F}_{t\text{-}1}) \\ A\varepsilon_t &= B\mu_t \end{aligned} \tag{2}$$

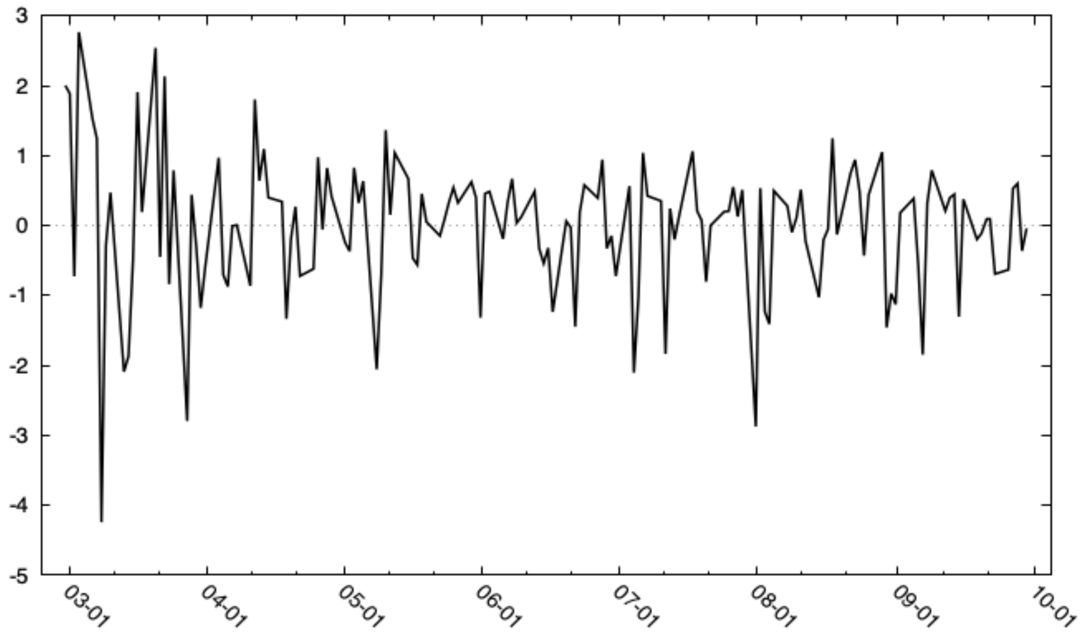
where $\mathcal{F}_{t\text{-}1}$ is the information $t-1$ is the information available at the time. Following the maximum likelihood procedure, we estimate the squared matrices A and B, applying the *C model* of Sims (1980) and defining C as $A^{-1}B$ so that the relationship between the prediction errors and structured shocks becomes $\varepsilon_t = C\mu_t$ becomes. Following Lee, Ni and Ratti (1995), we specify oil price shocks in the Brent variable with:

$$\begin{aligned} pops_t &= max\left(0, \hat{\varepsilon}_t / \sqrt{h_t}\right) \\ nops_t &= min\left(0, \hat{\varepsilon}_t / \sqrt{h_t}\right) \end{aligned} \tag{3}$$

where *pops* and *nops* stand for positive oil price shock and negative oil price shock. To do this, we assume that shocks to other variables do not affect oil price shocks and that there are no simultaneous relationships between positive and negative oil price shocks. The shock trajectories from Figure 5 show uniform spikes before the war. There are only conditionally high shocks in mid-August 2021, mid-late November and early February 2022. At the beginning of the war, the shocks are enormously high and last until April 2022 due to uncertainties. From April onwards, the spikes are more even, but at a higher level than before the war. Between phases with small spikes, they repeatedly show points in time with high spikes.

Figure 6: Cumulative shock curve of the Brent variable before and during the war





Because the ML estimator of C *is* the Cholesky decomposition of $\hat{\Sigma}$, the sample covariance matrix of the VAR residuals, we use the Cholesky decomposition in our model and maximize the likelihood with numerical iteration.

When arranging the variables in the VAR model, the temporal response structure must be considered. Since we study several industries, the Cholesky decomposition of the variance-covariance matrix assumes a recursive structure of the system ($\Sigma_U = QQ^T$) and transforms orthogonal shock variables v_t. All shock variables in v_t have a variance of one. For the methodology we define the following sequence dependence:

$$\varepsilon_t = \begin{bmatrix} \alpha_{11} & 0 \\ 0 & \alpha_{22} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{Brent} \\ \varepsilon_t^{Industries} \end{pmatrix} = \begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix} \begin{pmatrix} u_t^{pops} \\ u_t^{nops} \end{pmatrix} \tag{4}$$

We can now calculate the unconstrained elements of A and B via the information matrix. From the VMA representation we calculate the impulse response function with:

$$I_{i,j,h} = \frac{\partial y_{i,t}}{\partial \mu_{j,t-h}} = \frac{\partial y_{i,t+h}}{\partial \mu_{j,t}}. \tag{5}$$

The shock strength is obtained from the Brent variable with two shocks of one standard deviation (positive and negative) and is scaled up or down with a bootstrap replication of 1,000 in the Brent time series. We determine the lag order of the VAR model using the AIC information criterion for model reductions. Reducing the lags to 3 lags was acceptable at the 5% level in all tests. Using three lags in the VAR, there is no evidence of autocorrelation in the residuals. Furthermore, the VAR is stable. We define the time horizon as t=15 periods to track and graph the time profile of this shock. After t periods, we observe how the function approaches zero, which means that the shock runs out, should the VAR model be stationary. The importance of a one-time shock decreases with the distance of the innovation from the current period.

5. DISCUSSION OF RESULTS

5.1 SVAR results from oil price shocks and its impact on oil related firms

The lag length test based on the AIC criterion yields an optimal lag length of three for all time periods. For the estimation of the SVAR system, we use heteroskedasticity-robust standard errors and obtain the regression results shown in Table 4.

Table 4 SVAR estimation of the variables. The SVAR estimation is done for the period before and during the war. A model is specified for each industry with the Brent variable and the industry variables. We estimate the log-likelihood function, the determinants of covariance matrix, the AIC criterion, the Portmanteau-Ljung/Box test to test for autocorrelation, and the OLS and C-model regression results. (BW=Before War; DW=During War)

	Log-likelihood		**Det. COV matrix**		**AIC**		**Port. LB test (*p*)**		**OLS Coefficient(***) (Lag)**		**C-model coefficient with Bootstrap(***)**	
	BW	*DW*	*BW*	*DW*	*BW*	*DW*	*BW*	*DW*	*BW*	*DW*	*BW*	*DW*
1 Oil & Gas Drilling	804.03	652.68	0.00	0.00	-10.19	-8.29	136.60 (0.57)	120.13 (0.89)	0.113 (2)	0.117 (3)	0.011***	0.200***
2 Integrated Oil & Gas	862.87	727.24	0.00	0.00	-10.95	-9.26	136.9 (0.56)	131.62 (0.68)	0.055 (2)	0.067 (1)	0.012***	0.204***
3 Transportation Services	891.70	733.01	0.00	0.00	-11.33	-9.34	117.38 (0.92)	116.25 (0.93)	0.057 (3)	0.039 (3)	0.012***	0.016***
4 Service and Equipment	789.36	692.39	0.00	0.00	-10.00	-8.81	121.17 (0.87)	116.37 (0.93)	-0.139* (1)	-0.041 (1)	0.008***	0.021***
5 Refining & Marketing	886.16	726.33	0.00	0.00	-11.25	-9.25	100.02 (0.99)	138.18 (0.53)	0.052 (2)	0.009 (2)	0.012***	0.016***
6 Exploration & Production	818.87	679.15	0.00	0.00	-10.39	-8.64	125.39 (0.81)	131.95 (0.67)	0.118 (3)	0.075 (2)	0.013***	0.020***
7 Pharmaceuticals	904.01	786.35	0.00	0.00	-11.48	-10.03	121.05 (0.87)	117.87 (0.91)	0.064* (2)	-0.044* (1)	0.002	-0.002
8 Construction Materials	856.48	747.05	0.00	0.00	-10.87	-9.52	126.72 (0.78)	164.28 (0.08)	-0.078* (3)	-0.060* (3)	0.006**	-0.003
9 Diversified Chemicals	892.82	734.89	0.00	0.00	-11.34	-9.36	112.47 (0.96)	120.02 (0.89)	0.067* (2)	-0.027 (2)	0.008***	0.002
10 Commodity Chemicals	902.46	749.29	0.00	0.00	-11.46	-9.55	125.88 (0.80)	140.67 (0.47)	0.062* (2)	-0.029 (3)	0.007**	-0.001
11 Non-Paper Packaging	878.70	738.74	0.00	0.00	-11.16	-9.41	140.24 (0.48)	146.94 (0.33)	0.0668 (2)	-0.024 (2)	0.005**	-0.002
12 Tires & Rubber Products	831.23	670.49	0.00	0.00	-10.54	-8.53	130.68 (0.70)	122.27 (0.86)	-0.008 (1)	-0.081 (2)	0.001	0.001

From our SVAR estimation results, we find for all industries that the fit of the data to the models is better before the war than during the war. We attribute this to the high volatility of returns during the war, which is fundamentally higher during this period than before the war. We can confirm plausibility with the values of the AIC, which show smaller values before the war. Furthermore, our models show that they are not autocorrelated, as the Ljung/Box statistic shows no significant values. Unfortunately, the OLS estimation rarely shows significant effects from the Brent to the industry variables. However, before the war, the Service & Equipment, Pharmaceuticals, Construction Materials, Diversified and Commodity Chemicals industries show significant responses at the 10% level. However, the lag lengths differ from each other, so we suspect random results.

However, the results of the coefficients of the *C model* with bootstrap are interesting. Before the war, almost all industries (except Pharmaceuticals and Tires & Rubber Products) react significantly to oil price jumps. Most are significant even at the 1% level, but the impact effects are not particularly high. During the war, only oil-producing industries react very sensitively to oil price jumps. Here, the impact effects for Oil & Gas Drilling and for Integrated Oil & Gas are above the level of the other industries, with 0.20 and 0.24, respectively, with less than 0.021. This is in line with the preliminary research of Lee and Ni (2002).

The increases in petrol prices associated with the sharp rise in oil prices also lead to higher production costs and regulate the demand for automobiles. Contrary to this, however, supply bottlenecks for automobiles can be observed in Germany, among other countries, which in turn triggers a high demand for materials. Consequently, we conclude that the price movements and reaction of the stock returns of construction materials do not react too much to the strongly increased oil price for precisely this reason. It should also be added that not only the oil price, but also many other commodity prices have risen sharply and this is increasingly reflected in these dependent industries. The Transportation Services industry, which provides logistics between the oil fields and the refineries, is heavily dependent on this, as it must calculate with the enormously increased petrol prices.

The impact of the oil crises on the machinery industry has historically been varied. Demand for some automotive-related machinery declined, but not all machinery manufacturers were equally affected. Demand for certain machines increased, especially for the conversion of car manufacturers to small cars, for mining, for drilling for oil and gas development and for the construction of railways and pipelines. The packaging industry is also struggling with the increased oil prices, as oil makes up most of the resource of plastic packaging.

5.2 Shock results from oil price and its impact on oil related firms

The oil price shock is normalized to represent a negative shock with one standard deviation. All intervals were calculated based on appropriate bootstrap methods. For this we use the scoring algorithm and a bootstrap of 1000 with a confidence interval of 0.90, shown in the grey area. The bootstrap median is represented by the thin line and the IRF by the thick black line. A word about the unit of measurement of the IRFs: Due to their definition $I_{i,j,h}=[M_h]_{ij}$ and the fact that unit variance is assumed for the structural shocks, their unit of measurement is clearly the same as that of the corresponding observable variable $y_{i,t}$. However, since we adopt a different convention, and represent the IRFs graphically, we normalize $I_{i,i,0}=1$.

As can be seen from Figure 5, the shock variable is a vectorial sequence of shocks with different signs at different points in time. For this reason, the timing and magnitude of crude oil market reactions are not limited to a single shock but are due to multiple shocks. To this end, historical periods are identified for the shocks, which provide a historical decomposition of the impact of each of these shocks on the real oil price. The historical fluctuations in the real oil price in Figure 1 suggest that oil price shocks in the past were mainly caused by a combination of aggregate demand and precautionary demand shocks rather than oil supply shocks. Figure 6 shows the IRFs of the indices in the periods before the war and during it. The key findings are that, overall, these shocks have very different effects on the industry indices. Industries all react differently and the reaction of one industry even differs between the pre-war and war periods. For example, an unexpected oil demand and supply shock leads to either a delayed and prolonged increase or an immediate and prolonged downturn in industry price differentials. This is usually followed by smaller or larger declines or smaller or larger increases.

At first glance it is also visible that the shock reactions of the indices are most pronounced in the war period. Furthermore, the 90% confidence interval is most intense in the war period compared to the other periods, which we explain by the high oil price fluctuations. Furthermore, it can be stated that the variances of the confidence bands after the shock only converge towards zero from t_8 onwards, but all show different characteristics and courses over time until t_8 and converge towards zero in the further course. We explain this by the already volatile phase in which investors make daily adjustments to their oil price-related underlyings in their portfolios, which can quickly dilute the shock responses. The IRF point estimate of all indices before and during the war all track the same overall with the bootstrap median. We assign the calculation of the bootstrap-based confidence intervals for the estimated coefficients (see Table 4, C-model coefficients) and for the impulse responses to the SVAR boot function. The function contains the following explanatory aspects 1. the pointer of the model bundle, 2. the required number of bootstrap replications (here 1000) and 3. the size of the confidence interval α. With the function, we obtain a scalar in each case that records how many bootstrap replications could not converge. We can state that there are no bootstrap replications that could not converge, see the following figures.

The Oil & Gas Drilling industry shows the largest reaction. Here it can be seen that this industry achieves a peak return increase of 10% both before the war (on the second day) and during the war (on the third day). This result is consistent with the rise in oil prices and the simultaneous rise in prices at the start of the war. While there is only one shock reaction before the war, there are three reactions during the war, all of which are high and significant for this industry and its customers. As oil refineries are the largest consumers of crude oil in the manufacturing sector, their production and purchasing success depends significantly on the price of oil. Integrated Oil & Gas and Exploration & Production also show significant responses, although these are more pronounced during the war than before and show several spikes. These have an impact from day one. In the case of Exploration & Production, the reaction even lasts for two days and only intensifies after the shock. Journal publications also reflect the view that the impact of oil price shocks on demand for petroleum products is not significant in the short run. Although Lee and Ni (2002) cite reports to the effect that oil price shocks reduce demand for certain chemical products, most reports deal with the supply-side effects of oil price shocks.

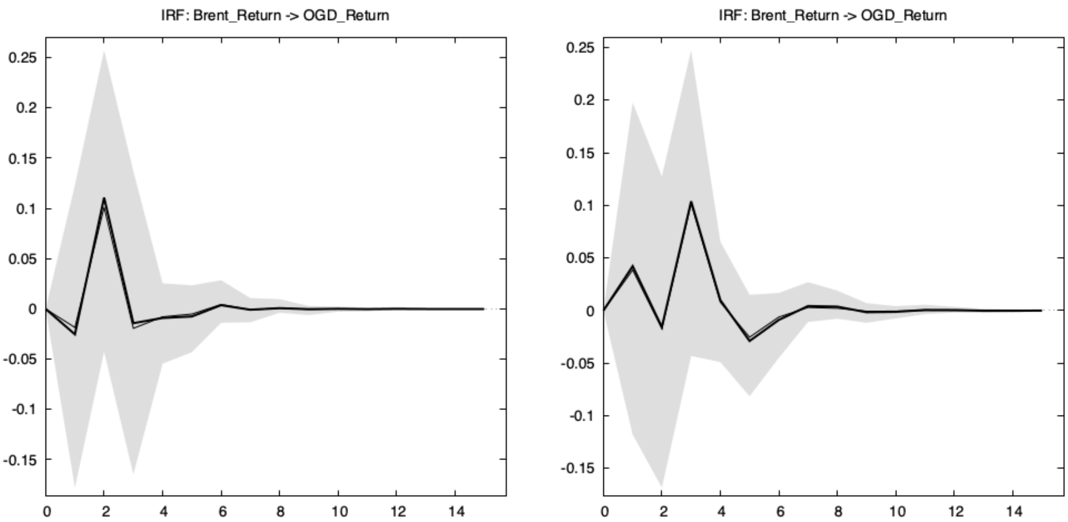
Surprisingly, Transportation Services, Refining & Marketing and Service & Equipment react less to shocks during the war than before the war. For Transportation Services and Service & Equipment we can explain this by the not too high price increase, but for Refining & Marketing the shock analysis is too low for its very high price increase at the beginning of the war. However, the empirical evidence does not provide any statistically significant results.

Also inexplicable is the reaction of Pharmaceuticals. Based on the sideways price trend, we cannot explain such a strong negative shock reaction lasting over three days. Construction Materials and the already "related" industries Commodity and Diversified Chemicals show a similar course. Before the war they reach a level of over 5% and, with the exception of Construction Materials, they converge towards zero afterwards. During the war, their reaction is reversed, which also goes hand in hand with the price movements. They reach their lowest point of over -2% from the second or third day of the war.

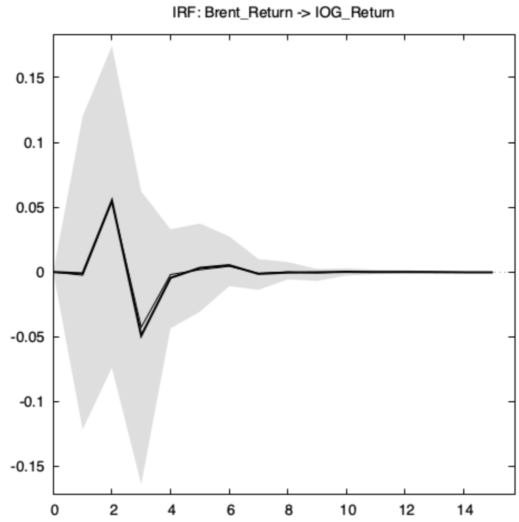
Figure 7: Impulse response functions of Brent on the industries in both periods.

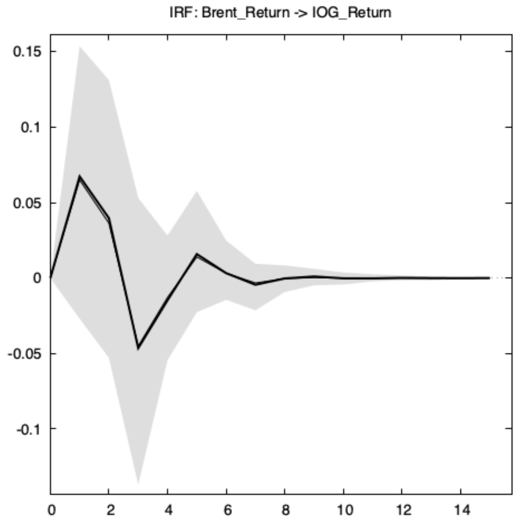
Before War	**During War**

Oil & Gas Drilling

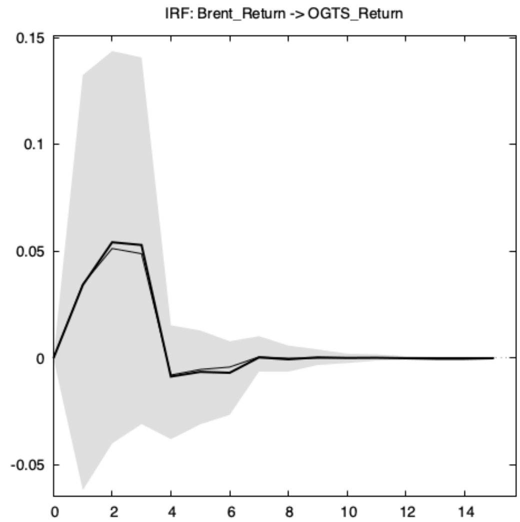


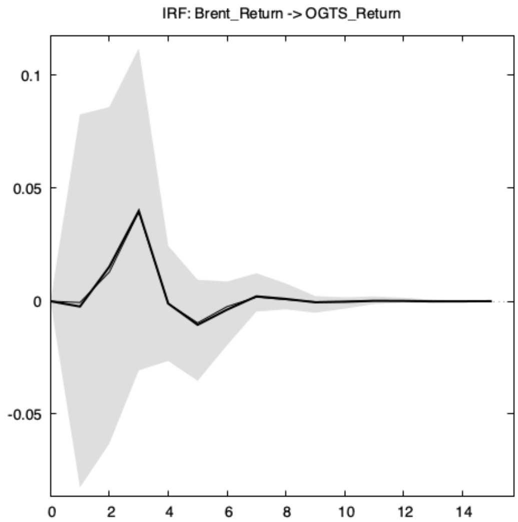
Integrated Oil & Gas



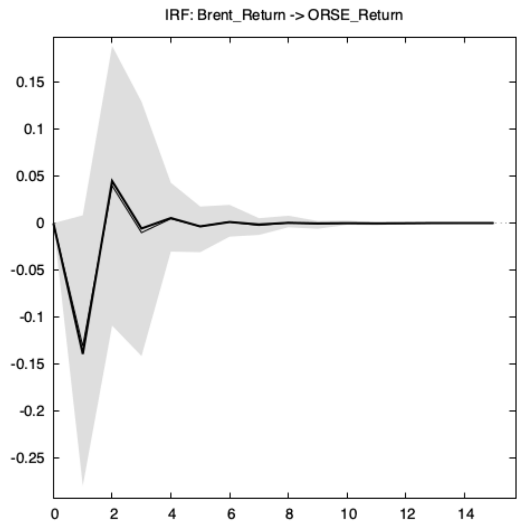


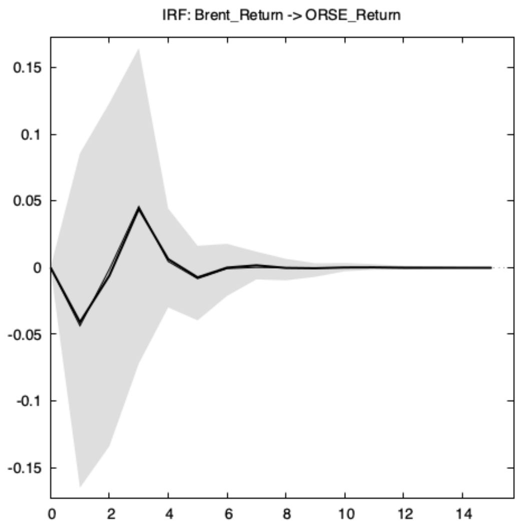
Transportation Services



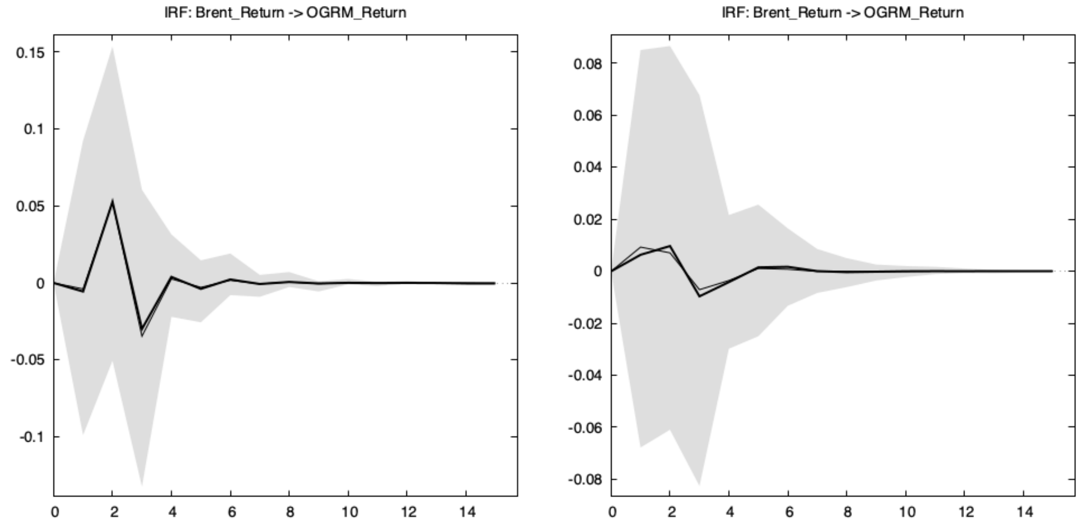


Service and Equipment

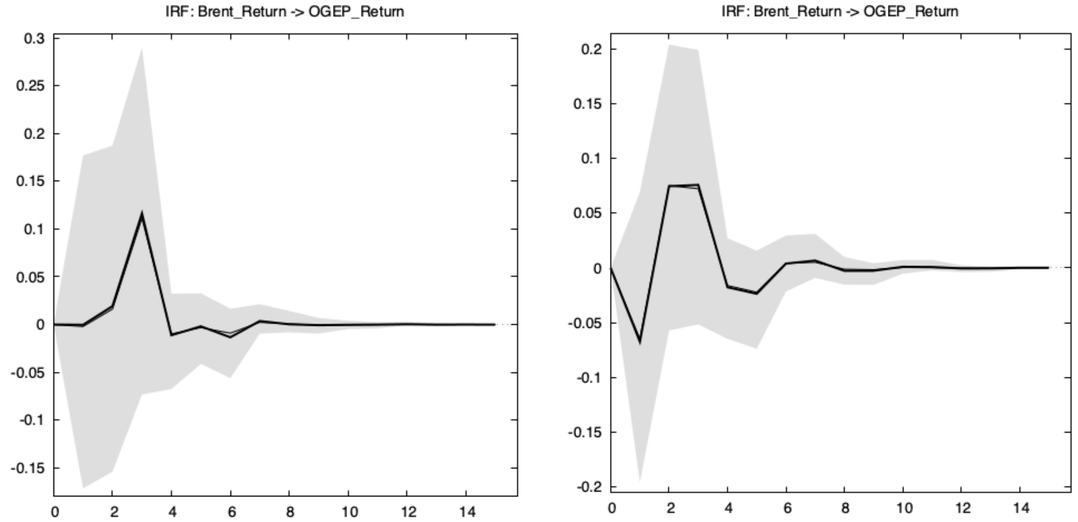




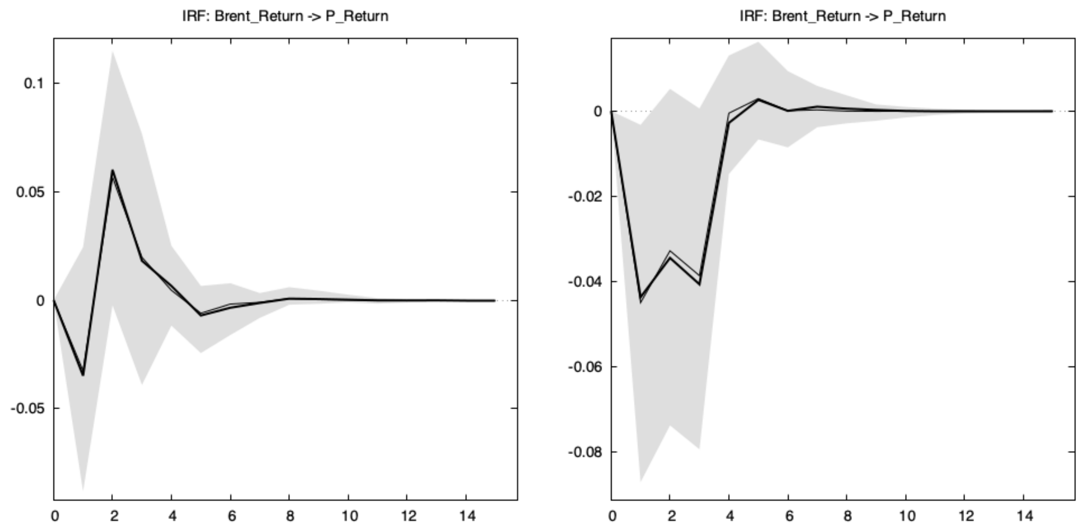
Refining and Marketing



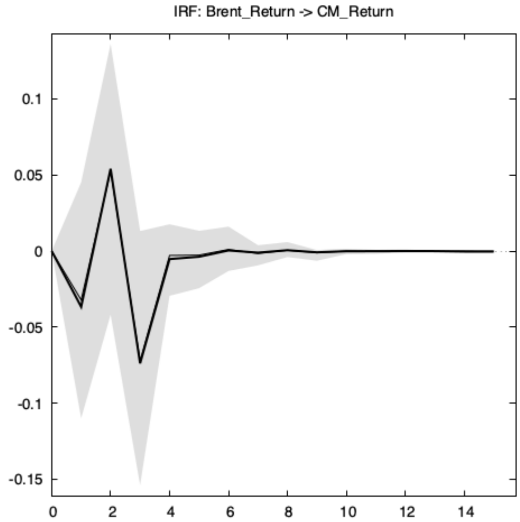
Exploration and Production

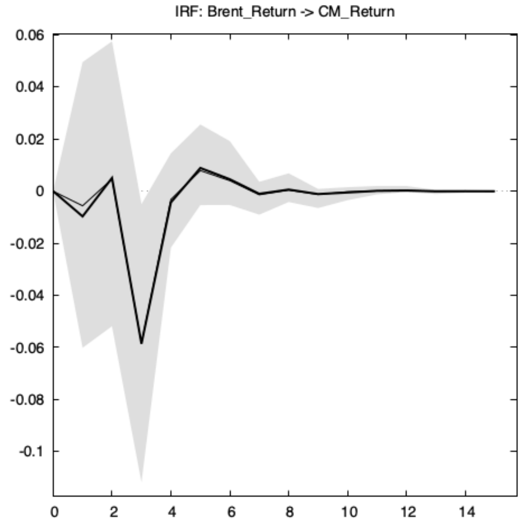


Pharmaceuticals

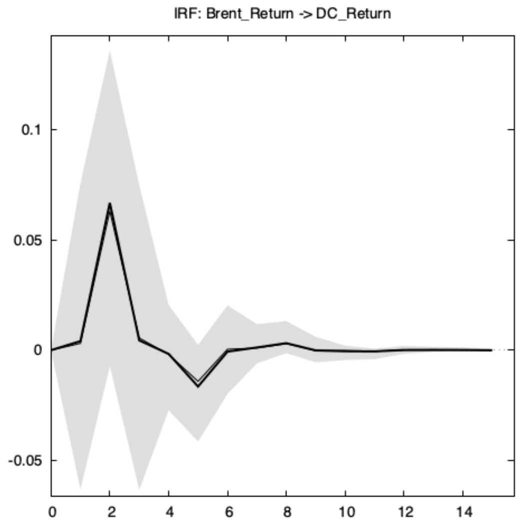


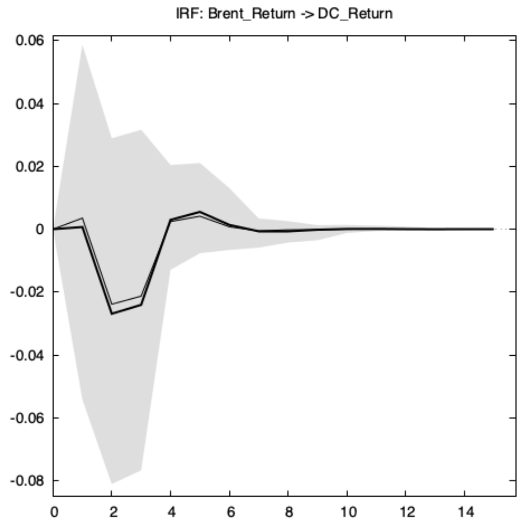
Construction Materials



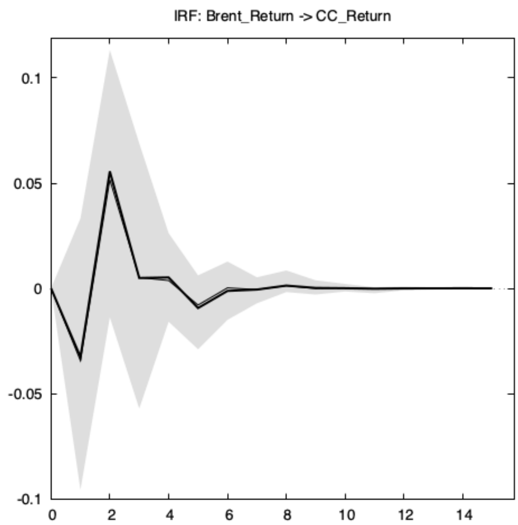


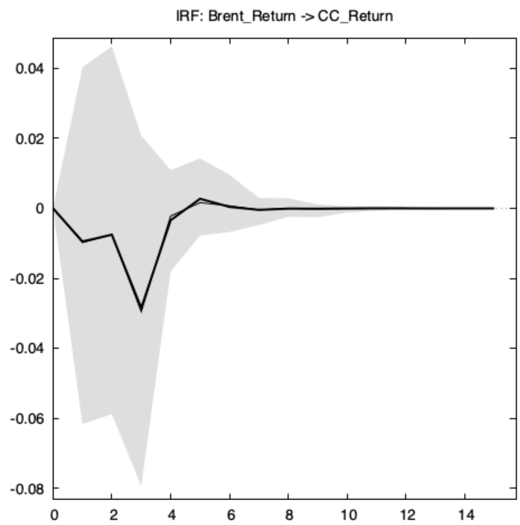
Diversified Chemicals



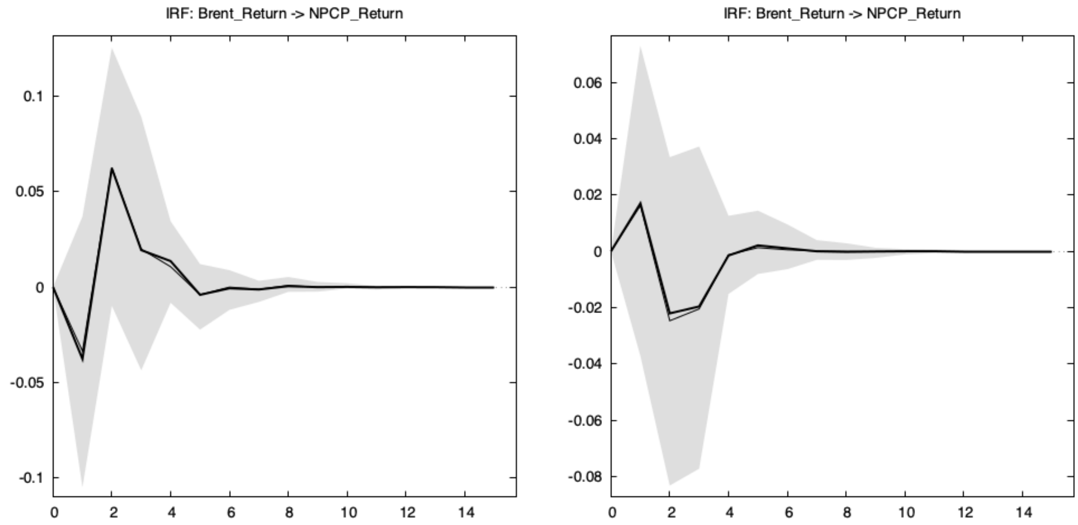


Commodity Chemicals

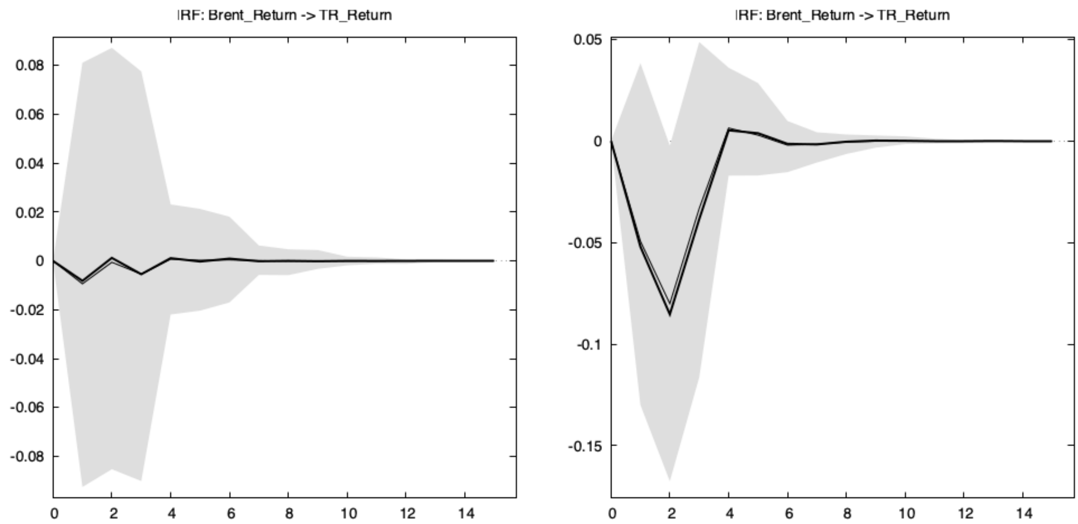




Containers & Packaging



Tires & Rubber Products



According to Kilian and Park (2009), it is often assumed in the literature that the stock returns of companies in the chemical industry are particularly sensitive to disruptions in the crude oil market because they rely heavily on oil products as raw materials. Based on the input-output table data from the Survey of Current Business, the chemical industry ranks second only to oil refineries in terms of its share of both direct and total energy costs. Here, the paper industry ranks third, but we find no evidence for this in our results, as Containers & Packaging's pre-war responses are higher than those during the war.

The Tires & Rubber Products industry is interesting. Although they generally need a lot of oil as a major part of the production of tires, before the war they react almost not at all to oil price shocks. It seems that they become sensitized at the beginning of the war and the associated oil price increase. The reaction is -8%, the highest of the industries that need to procure a lot of crude oil to produce their goods.

The contrasting reactions of the industries show overall how differentiated both periods turn out to be and how enormously the management of the companies in the individual industries react to the high shocks.

5.3 Results of historical error variance decomposition

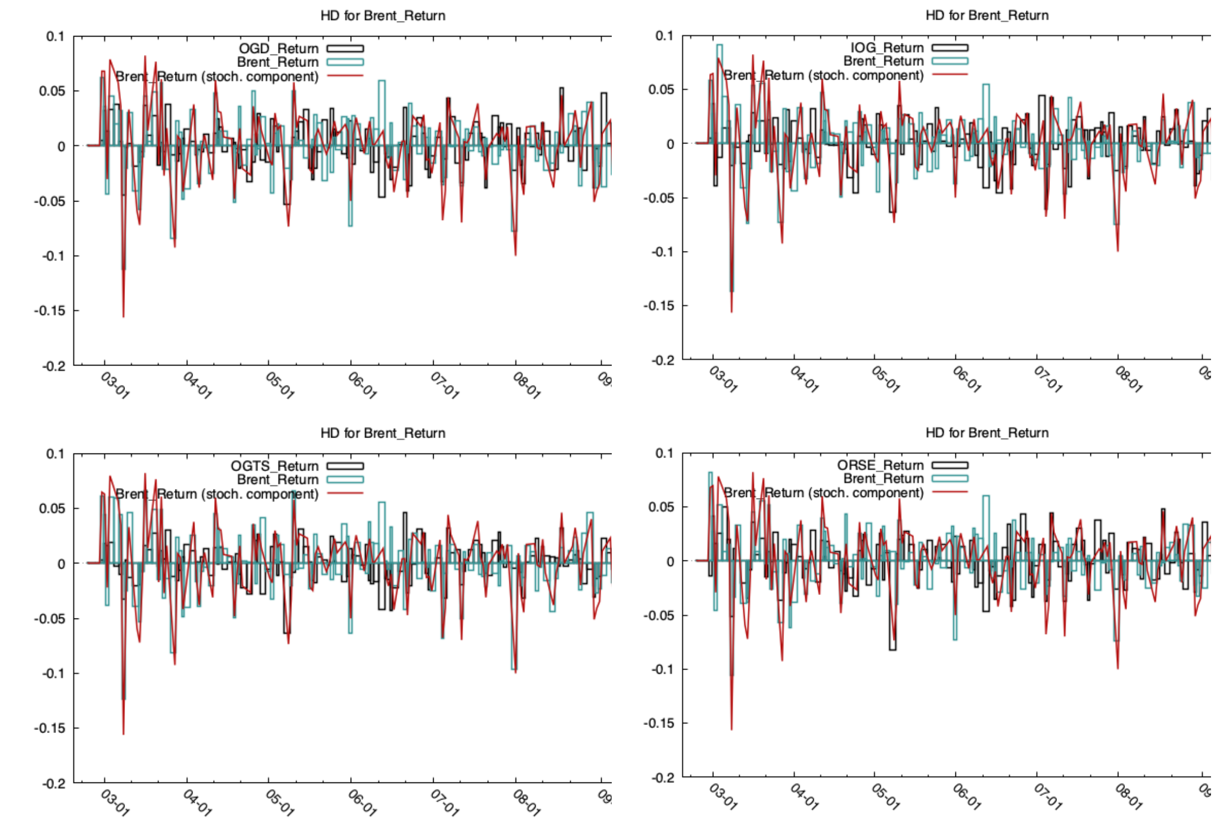
Finally, we use the forecast error variance decomposition (FEVD) to help interpret the VAR model after it has been fitted. The variance decomposition indicates the amount of information that each variable contributes to the other variables in the autoregression. This determines how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables. Since the FEVD for our industry variable is expressed in terms of proportions, we plot it below quite simply in a histogram, with the horizon on the x-axis. Based on our VAR model, the structured VMA representation with

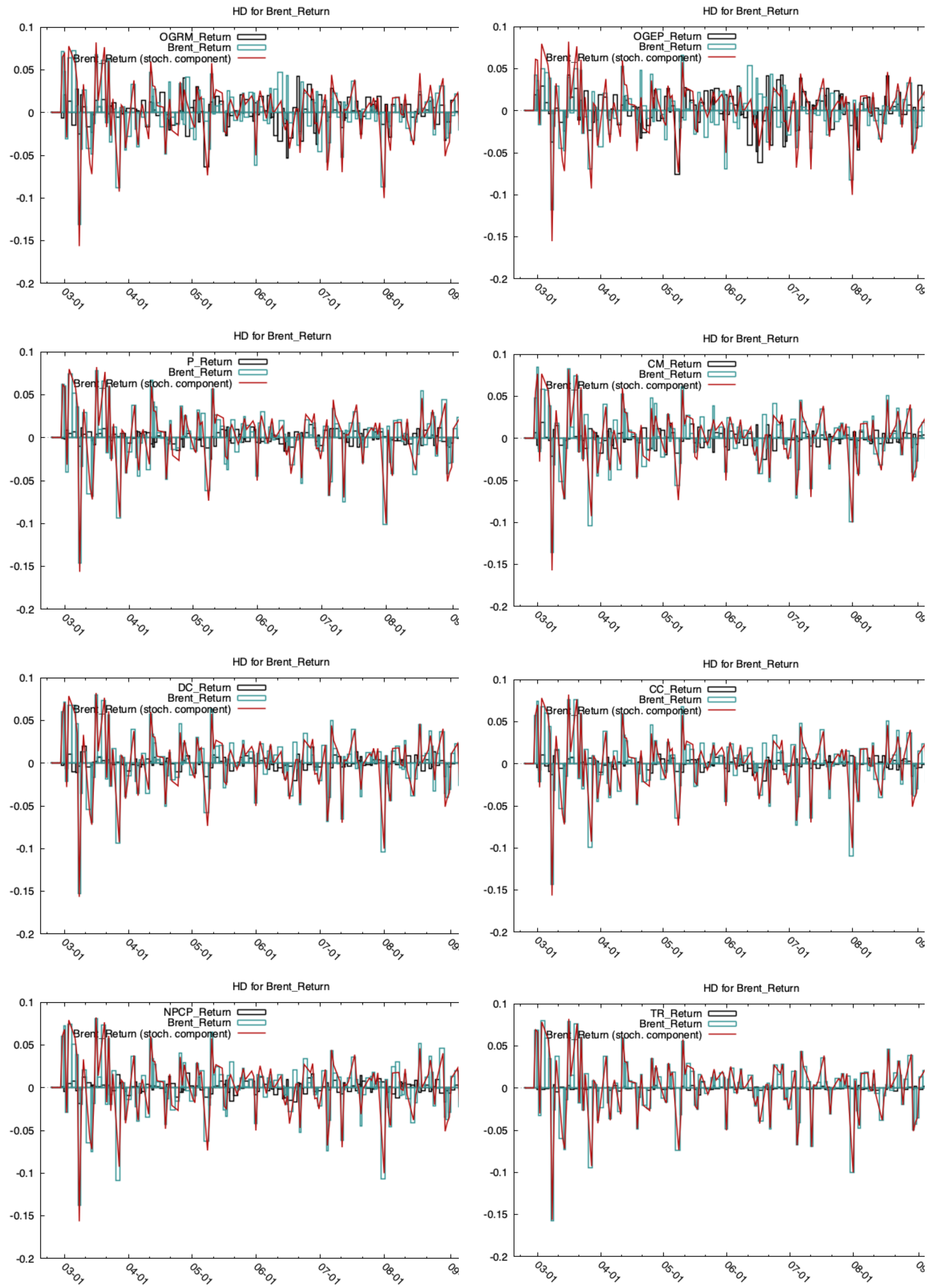
$$y_t = C\mu_t + \ominus_1 C\mu_{t-1} + \ldots = M_0\mu_t + M_1\mu_{t-1} + \ldots \tag{5}$$

and the observation of the system parameters (the coefficients of the Φ(-)-polynomial and the matrix μ) and the sequence of structural shocks μ_t, we decompose the observed path of the y_t-variable into $n + 1$ distinct components: First, into a purely exogenous component that includes the term $\mu' x_t$ and secondly all feedback effects given by the lag structure $\Phi(L)$. d_t. The remainder y_t-d_t can therefore be viewed as the superposition of separate contributions given by each structural shock. Below we consider each component $M_{i,j}(L)\mu_{j,t}$ which shows what the evolution of $y_{i,t}$ would have been if the j^{th} shock had been the only one affecting the system.

Each figure contains the shock to the Brent variable, shown as a stochastic component (red line). Furthermore, we see the explained Brent and industry returns responding to this shock in their time profile. It can be postulated that the size of the shocks does not explain the impact on returns at each point in time. This can be interpreted as a criticism of the impulse-response analysis. The industries best explained by the shock are the oil-producing industries and Tires & Rubber Products. There, the shock responses are the highest and the variations in oil explain much of this behavior. All industries can be shown below as follows:

Figure 8: Historical error variance decomposition of industries during the war.





6. CONCLUSIONS

The article examines the reactions of 12 industries, including 533 firms, to orthogonalized Brent oil price shocks in the periods 19 July 2021-23 February 2022 and 24 February-30 September 2022 in order to compare the impact of the oil price volatility triggered by the Russian war on the shares of oil-producing and oil-trading companies as well as oil-processing industries. For this purpose, we use the impulse response analysis in the SVAR model and confirm plausibility for the estimate with the historical error variance decomposition.

Industrial returns show strong and volatile characteristics almost throughout the entire period under consideration, but they are more pronounced during the war. Due to the high price jumps caused by the war, which also have an impact on the level of returns, the industries Oil & Gas Drilling, Transportation Services, Diversified and Commodity Chemicals are not stationary, which we consider in our analysis. In an economic sense, it can be assumed that companies from the oil exploration and production industries benefit from high Brent prices, as they lead to higher margins. On the contrary, the other companies benefit from low Brent prices, as they can produce and sell their goods more cheaply.

We find that the indices as a whole and the same industry react differently in the periods, but they are more pronounced during the war. Triggered by the high oil price fluctuations and increases, and the fact that during this volatile period investors make daily adjustments to their oil price-related underlyings in their portfolios, explains why the 90 per cent confidence interval is most intensely pronounced during the war period compared to the other periods. The IRF point estimates of all indices before and during the war all trend the same overall with the bootstrap median. The goodness of the models are also higher in the war period than before the war, implying that the models are significantly explained by the oil price fluctuations induced by the war.

We can show below the price rise with the buy-and-hold abnormal return at the time of 23 February 2022 at different points in time, at which the price trajectories all rose or fell sharply, and in parallel the reaction of the respective industry:

Table 5: BHAR and IRF result of industries. We calculate BHAR of industries as of 23 February 2022 (immediately before the war) at specific points in time when prices realized rising or falling trajectories until then and document the IRF result before and after the war.

	BHAR from 23.02.2022 until			**IRF**	
	14.06.2022	*15.07.2022*	*30.09.2022*	*BW*	*DW*
Oil & Gas Drilling	0,6232	0,1675	0,2823	+	+
Integrated Oil & Gas	0,2052	0,0201	0,0693	+ -	+ -
Transportation Services	0,3104	0,1676	0,2907	+	+
Service and Equipment	0,3512	-0,0327	0,0177	- +	- +
Refining & Marketing	0,4207	0,2722	0,3400	+ -	+ -
Exploration & Production	0,6312	0,3537	0,5018	+	- +
Pharmaceuticals	-0,0220	0,1131	0,0800	- +	-
Construction Materials	-0,0872	-0,0922	-0,0768	+ -	- +
Diversified Chemicals	-0,0555	-0,1321	-0,1304	+	-
Commodity Chemicals	-0,0081	-0,0428	-0,0627	+	-
Non-Paper Packaging	0,0098	-0,0064	-0,0565	+	-
Tires & Rubber Products	-0,3315	-0,3415	-0,4406	n.a.	-

For almost all industries, the positive or negative shock reaction within the war is accompanied by an increase or decrease in BHAR. The Oil & Gas Drilling industry shows the largest reaction. From the IRF it can be stated that this industry achieves a 10% increase in returns both before the war (on the second day) and during the war (on the third day). What is amazing is how sharply rising price trajectories the oil-producing industries show. The rise continues until the end of May 2022 for all these industries and then falls until mid-June 2022.

While the oil-producing industries react more strongly, the shocks to the oil-procuring industries are rather small, with the major exception of Tires & Rubber. At -8%, the reaction is the highest among the industries that must procure a lot of crude oil for the production of their goods. Their cash flows decline due to higher production costs, which leads to uncertainty because of lower profits and weak forecasts and has a direct impact on the share price. Diversified and Commodity Chemicals as well as Pharmaceuticals and Containers & Packaging show almost no reaction to higher oil prices. We assume that the shock reactions cannot unfold too strongly.

We further find with our results how contrasting the reactions of the industries as a whole are. This means that by looking at both periods in a differentiated way, we can conclude that the management levels of the companies in the individual industries react sensitively to the high shocks.

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