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The Impact of Oil Price Volatility on Inflation in Europe and the United States

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BUSINESS
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Department of Economics

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To my parents, my uncle João and my grandmother Tóia

Resumo

A inflação é um dos maiores desafios atuais e o preço do petróleo constitui uma das suas principais condicionantes. O objetivo é analisar o impacto dos choques do mercado petrolífero na inflação, distinguindo a procura da oferta. A recuperação pós-pandemia e a invasão da Rússia à Ucrânia conduziram a estrangulamentos na oferta, contribuindo para uma subida dos preços energéticos e de alimentação. A questão é compreender se o preço do petróleo pode condicionar de forma preponderante a inflação numa perspetiva europeia e norte americana. Analisamos diferentes economias, nomeadamente Alemanha, França, Portugal e Estados Unidos entre 1990 e 2022, utilizando o modelo SVAR em duas perspetivas: preços do consumidor e preços do produtor.

Os resultados revelam um maior impacto dos choques da oferta do petróleo no IPC referentes a Alemanha e França, enquanto que choques da procura agregada e da procura específica do petróleo influenciam mais significativamente nos preços do consumidor dos Estados-Unidos e de Portugal. O choque da procura especifica do petróleo assume um peso mais expressivo no IPP, destacando os Estados-Unidos e Portugal. Além disso, os preços do produtor demonstram ser mais sensitivos do que os do consumidor. Portugal apresenta um comportamento diferente dos restantes países, sobretudo quando analisado na ótica do produtor, visto que os efeitos inflacionários tendem a intensificar-se ao longo do tempo.

A resposta de cada economia aos choques difere entre o preço do consumidor e o do produtor, revelando a importância de analisar realidades económicas distintas e diferentes medidas de inflação para conclusões mais pertinentes.

Palavras-chave: Inflação, volatilidade do preço do petróleo, choques da oferta, choques da procura, modelo de séries temporais, crises económicas

Classificação JEL: E31, C22

Abstract

Inflation is one of the biggest current challenges and the price of oil is seen as one of the main factors conditioning it. The objective is to empirically analyze the real impact of oil market shocks on the general price level, distinguishing demand from supply shocks. Demand pressures in a post-pandemic economic recovery phase and Russia's invasion of Ukraine contributed to supply bottlenecks, increasing energy and food prices. The question is to understand whether the price of oil can preponderantly condition inflation in Europe and the U.S.. We analyze different types of economies considering their inflation path, namely Germany, France, Portugal and the U.S., from 1990 to 2022, applying the SVAR model to both consumer prices and producer prices.

The results show a greater impact of the supply side on the CPI in Germany and France, while aggregate demand and oil-specific demand shocks influence consumer prices in the U.S. and Portugal more. In turn, the oil-specific demand shock has a more significant impact on the PPI. Inflation in the U.S. and in Portugal appears to be more affected by this shock. Furthermore, producer prices prove to be more sensitive than consumer ones. Portugal shows a different behavior from the other countries, especially when analyzed from the producer's perspective, as the inflationary effects tend to intensify over time.

The response of each economy to the shocks differs from consumer price and producer price perspectives, revealing the importance of analyzing distinct economic realities and using different inflation measures for more robust conclusions.

Keywords: Inflation, oil price volatility, supply shocks, demand shocks, time-series model, economic crisis
JEL classification: E31, C22

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List of Abbreviations

ADF – Augmented Dickey-Fuller

COP – Crude Oil Production

CPI – Consumer Price Index

ECB – European Central Bank

FEVD - Forecast Error Variance Decomposition

FRED - Federal Reserve Economic Data

GBC – Global Price of Brent Crude

GDP – Gross Domestic Product

HICP – Harmonized Indices of Consumer Prices

HIQ - Hannan-Quinn information criterion

IRF – Impulse Response Function

PCE – Personal Consumption Expenditures

PPI – Producer Price Index

SIC - Schwarz Information Criterion

SVAR – Structural Vector Autoregressive

U.S. – United States

WIP – World Industrial Production

1. Introduction

Inflation is defined as a general increase in prices. It is a simple concept, but it plays a crucial role in the proper functioning of an economy, being one of the main concerns for central banks, whose main objective is the stabilization of prices. Furthermore, it is an economic concept that affects all economic agents. In a book published in 2015, "The Truth About Inflation", Donovan (2015: 16) says that:

"Inflation provokes a more powerful, passionate response than almost any other concept in economics (…) Investors express indignation about inflation, consumers express concern about the cost of living, workers express worries about real wages."

Despite being extensively explored over time, this economic variable still raises several issues, especially with the post-COVID phase and the geopolitical situation experienced, a period marked by a significant rise in prices and in particular in the price of oil. The role that energy price has played in increasing inflation is one of the factors that raise the most doubts and is one of the main questions that we intend to answer with the elaboration of this project. The period of greater economic instability since the beginning of the pandemic crisis highlights the importance of continuing to explore this topic.

The impact of the oil price on inflation has generated some controversy. If there are phases in which oil price is a strong driver of the price level, there are others in which this relationship becomes weak, as concluded by Castillo et al. (2020). These authors argue that, from 2002 onwards, it is possible to observe that increases in the oil price do not cause significant effects on the level of inflation, which remains stable. The same authors also state that this situation is explained by the role of monetary policy adopted. In this way, it is possible to conclude the existence of a non-linear relationship between these two variables, since increases in one do not necessarily cause increases in the other.

Another issue focuses on the importance of analyzing the effects that the demand and supply side has had on the functioning of the economy. In the most recent literature, there is no consensus on the factors that assume greater explanatory power. Shapiro (2022) highlights the fact that supply constraints explain more than half of the current level of 12-month PCE inflation while demand factors only account for one-third. On the other hand, Gonçalves and Koester (2022) argue that there are components of HICP inflation that are mostly affected by supply shortages and others that depend on the demand pressures associated with the recovery of economic activity. They also point out that, although supply factors dominated the level of

inflation in the period after the pandemic crisis, demand shocks have come to assume greater importance in explaining inflation in the more recent period. In turn, Christine Lagarde, president of the ECB, argues that the factor driving inflation in the U.S. is demand, contrary to what happens in the Euro Zone which, despite having effects from demand, is significantly dominated by the supply side (Reuters Global News Desk, 2022).

In this sense, the purpose of the present paper is to empirically analyze whether oil price volatility can determine or significantly influence the general level of prices from a European perspective and also in the United States. The impact of this relationship will be analyzed in terms of the magnitude and the persistence, in both headline and core inflation and how these two indices may be correlated. Finally, we intend to investigate whether both demand and supply predominate as explanatory factors for changes in the price of oil. These questions, in addition to the lack of consensus in the literature, will be analyzed with different resources, namely another inflation measure, the Producer Price Index. The analysis of these issues, on the one hand, will allow conclusions to be drawn regarding the factors that effectively contribute to the volatility of oil prices, which, in turn, impact the price of other goods, affecting all economic activity. On the other hand, having these explanatory factors well aware, it will be an asset for the adoption of more efficient monetary policies by central banks to control and maintain the expected level of inflation.

This work is organized as follows: firstly, a Literature Review was carried out, where the main conclusions of previous studies are referred to, contributing to the elaboration of the main questions of the present paper. Posteriorly, the database and the time period used for the respective empirical study are mentioned, ending with a brief analysis of the evolution of the main variables, the Global Price of Brent Crude and both inflation measures, namely the Consumer Price Index and Producer Price Index. The third chapter refers to the methodology chosen in detail for the elaboration of the intended results, which were obtained through the econometric software R. The results are explained in the next chapter, in which a discussion is also made, as well as the most important points to be taken into account in this analysis. Finally, a brief conclusion is presented at the end of this paper, in which the greatest difficulties in the elaboration of this project are mentioned, as well as the main ideas and some recommendations for future studies.

2. Literature Review

The price of energy plays an important role in global inflation since it determines a large part of the costs faced by companies and consumers (European Central Bank, 2021). Furthermore, despite its importance as a driver of inflationary pressures, crude oil prices are also crucial for the production and transportation of several goods and services (LeBlanc & Chinn, 2004). In this way, and according to Garzon and Hierro (2022), the price of oil becomes a key variable in analyzing the dynamics of the general price level due to its crucial behavior in the cyclical variations of inflation in countries with greater dependence on oil imports. In addition, oil price volatility not only affects inflation directly through the price of energy but also indirectly, due to its influence on changes in inflation expectations or when wages are indexed to past inflation.

Based on the literature, most empirical studies conclude that the impact of changes in oil prices on inflation tends to decrease over time. Choi et al. (2018), who analyze this relationship in advanced and developing economies, argue that global oil price shocks have a significant and short effect on individual domestic inflation, only 2 years after the shock. They point out as the main explanatory factors the credibility of monetary policy, limiting the second-round effects of global oil price shocks, and less dependence on oil imports. Kilian and Zhou (2022) provide information on the topic of U.S. inflation and inflation expectations after the Russian invasion of Ukraine, using CPI and PCE as measures of the price level, and their conclusions are similar to the ideas mentioned above, i.e., there is not persistent inflationary effect after oil and gasoline price shocks. Nonetheless, using a VAR model in the period from 1999 to 2021, the authors argue that short-run effects are considerable on headline inflation, in other words, the total inflation of an economy including the prices of the most volatile commodities namely food and energy. They also focus on oil price scenarios that can happen if Russia responds to the sanctions imposed, cutting its crude oil production. Also, under the assumption of the oil price converging to 110 dollars per barrel, between June 2022 and December 2023, the inflationary pressures tend to disappear after the oil price stops rising. However, the aforementioned sanctions might promote a sharp increase in oil prices, leading to more problematic scenarios. Finally, they defend that there are two reasons to expect that gasoline price shocks are associated with broader inflationary pressures, namely the fact that (i) these shocks promote persistent demand shifts and, consequently, cause other consumer price increases and that (ii) gasoline price shocks affect directly and indirectly the cost of producing other goods, subsequently reflected in consumer prices.

Contrary to what several previous studies have argued, Ciner (2011) studied causality and contemporaneous effect between commodity prices and inflation from February 1983 to April 2010, demonstrating, through a frequency-domain methodology, a positive contemporaneous impact as well as long-term causality from commodities to inflation, when there are permanent shocks. Using CPI as a measure of the price level, the author also defends the existence of a significant sensitivity of inflation to commodity price changes in a higher frequency domain. In turn, Cuñado and de Gracia (2003), who analyze the changes in the price of oil for the period between 1960 and 1999 and how this can affect industrial production and inflation in the European Union using the CPI, reach different conclusions through cointegration tests. When structural breaks are not considered, the authors find evidence of a cointegration relationship between oil prices and inflation only in the United Kingdom and Ireland. On the contrary, when cointegration tests take structural breaks into account, they find a long-term relationship in most European countries. They also highlight that when the price of oil is measured in each country's domestic currency, the impact of the commodity price volatility on inflation rates is more significant. These same authors finalize their study with a trivariate VAR model, concluding that, although there is no cointegration relationship between oil prices and economic activity in the long-term, there is a causal relationship that depends not only on the effects that oil price volatility may have on inflation but also on other macroeconomic variables.

Although most of the literature acknowledges a positive relationship between the price of oil and inflation, some studies prove that it is not so strong. Bachmeier and Cha (2011) analyze possible explanations for oil price shocks not causing further increases in the price level using West Texas Intermediate Crude Oil and U.S. inflation as variables in the VAR model. In this study it is evidenced, during the period from 1973 to 2006, that the most significant increase in the price of oil, that occurred between 2002 and 2006, did not promote great volatility in the level of inflation, remaining between 1.2% and 2.6%. The non-linear dependence between the price of commodities and the general price level, in turn, is also defended by Kyrtsou and Labys (2006), who obtained similar conclusions with different methodologies, namely the Mackey-Glass and VAR models. In this way, they argue that an increase in U.S. CPI can promote chaotic behavior in commodity prices and vice versa. In sequence, a more recent study shows the existence of a positive relationship between oil price volatility and inflation up to 2002, which did not occur after that year. Since then, the relationship has become weak, with increases in the price of oil not accompanied by the general level of prices (Castillo et al., 2020). The decrease in the amount of energy used in production and the rise of monetary policy credibility are identified in the literature as predominant reasons to explain these weak inflationary effects.

On the other hand, there are studies that investigate the effects that the oil price has on headline and core inflation. The literature argues the existence of a significant impact of oil price volatility on headline inflation and no effects on the core in the short-run. In the long-term, however, there is no evidence that both are affected by oil prices (Kilian & Zhou, 2022; Hijazine & Al-Assaf, 2022; Choi et al., 2018; Ciner, 2011; Chen & Wen, 2011). Kilian and Zhou (2022) highlight that 65% of the change in the headline CPI is explained by gasoline price shocks, while only 10% of fluctuations in core inflation are explained by the same shocks. When PCE inflation is used the authors observe that the headline metric presents a less significant response to gasoline price shocks when compared to the headline CPI, which only explains 51% of the PCE volatility. Regarding the core PCE, it is also less sensitive as the core CPI. In turn, Van den Noord and André (2007) use the Phillips Curve methodology in order to analyze the impact of energy prices on core inflation in two major economies, the U.S. and the Eurozone, highlighting the existence of a significant core inflation response after oil price shocks in the period from 1970 to 1980. They also refer that the same is not verified in more recent periods, since greater volatility in the price of energy no longer triggers high variations in core inflation. However, Brief (2022) reinforces the differences in the magnitude that oil and gas have on the European economy, emphasizing that oil price shocks promote a more persistent impact while fluctuations in the gas price offer more uncertainty and less substitutability. Despite these differences, both shocks contribute to an instantaneous increase in core inflation and in input costs. However, this effect is temporary, followed by a drop in demand pressures. Chen and Wen (2011), in turn, argue that contrary to what happened in previous periods, the impact of an increase in oil prices and, consequently, in energy prices is not reflected in other goods. It is, however, currently possible to observe that there is evidence of this relationship and how it affects the entire economy, as mentioned by Ball et al. (2021). These authors state that the strong price volatility caused by the COVID-19 pandemic shock promoted changes in both headline and core inflation. Conflitti and Luciani (2019) conclude that fluctuations in oil prices are only transmitted to core inflation through the impact that these prices have on economic activity. Furthermore, and contrary to what previous studies advocate, these authors point out that the transmission is not significant but persistent.

Despite the clear existence of lower volatility in core than in headline inflation, since it does not include the price of food and energy (Hijazine & Al-Assaf, 2022; Bodenstein et al., 2008), there are studies that show a correlation between these two indicators, as is the case of Gamber et al. (2015), through their analysis in the VAR model using both CPI and PCE for the U.S. as measures of the general price level. These authors also conclude that in the presence of

a more accommodative monetary policy, shocks to headline inflation promote more persistent effects on core and also a more important role in forecast error variance of this inflation metric, while in cases where there is not, the similar does not happen. In turn, when the adopted policy is not accommodative, the less volatile inflation becomes more useful in order to anticipate changes in average inflation. However, a monetary policy centered on core inflation still raises some issues since, on the one hand, it presents more effective results due to smaller unpredictable variations (Chen & Wen, 2011; Bodenstein et al., 2008), on the other hand, it is questioned whether it is the most suitable target for better functioning of the economy (Giri, 2022). This question is also raised by Ball et al. (2021), which present an opinion similar to the previously mentioned study, suggesting as an alternative a monetary policy focused on the median and trimmed mean CPI, since it filters more significant changes in the prices of any industry and, consequently, presents a better performance.

Furthermore, there is not much previous literature analyzing the impact of oil prices on headline and core inflation using the PPI as a measure of the price level. However, there is consensus regarding the value that this index adds when analyzing the impact that the real value of oil price causes on inflation since it promotes a more significant effect when compared to the CPI, as well as greater sensitivity to fluctuations in prices. Husaini and Lean (2021) use both PPI and CPI in order to analyze the asymmetric impact of the oil price and the exchange rate on the price level in Indonesia, Malaysia and Thailand. In the period from 1978 to 2018, the authors highlight the importance of analyzing the effects on the PPI, since oil price has direct effects on the production sectors and indirectly affects the price paid by the final consumer. This opinion is also supported by Sek (2022) who also analyzes this topic more specifically in Malaysia, noting that these direct effects on the producer cost explain the existence of more significant impacts on the PPI than CPI, after changes in the price of oil. Regarding the relationship between these two indicators, Azazi (2022) shows, between 2006 and 2021, the presence of a causal relationship from PPI to CPI in Turkey, through the Granger Causality test, noting that the opposite is not true. This conclusion is, in turn, contradicted by Williams (2022), who analyze the causal relationship between both U.S. PPI and CPI, using aggregate and disaggregated form, and concludes that these variables present a bidirectional causality.

As explanatory factors for the volatility of oil prices, and, consequently, of inflation, oil demand and supply shocks are potential candidates. According to Valcarcel and Wohar (2013), this impact differs over time. Based on their empirical study, using the Time-Varying

Parameters (TVP) model, before the Great Moderation Period (1980-2007), prices were predominantly influenced by supply shocks and after that, they were mostly influenced by demand. Nonetheless, there is no consensus in the most recent literature regarding the impact of supply and demand. Wen et al. (2021), using the VAR model and rolling-window method, analyze the impacts of different oil price shocks among G7 countries and conclude that oil supply shocks assume greater importance in inflation not only in the U.S., which is the largest consumer of oil as well as the largest economy, but also in some European countries, namely France and Italy. These authors also highlight the strong ability of both supply and demand shocks to explain oil price fluctuations, since demand assumes greater explanatory power during the financial crisis while supply shocks become more significant before and after this critical period, specifically in the second half of 2014. However, according to their empirical framework, it is possible to observe that supply shocks have greater predominance in the inflation response of most of the countries under analysis. Contrary to what is advocated in the previous study, Kim and Vera (2022), who analyze the period from 1976 to 2017, use alternative models that show positive and more persistent effects of oil-specific demand and aggregate demand shocks on the U.S. CPI. The second shock mentioned earlier also promotes a gradual increase in oil production, which does not happen with oil supply shocks since these cause a negative response to oil production, as well as weak inflationary impacts and a decline in GDP. It is, however, evidence in this study that the source of the shocks is crucial to explain the variance of the response of GDP and CPI. Despite the fact that some previous studies tend to use Kilian's index of global real economic activity in order to determine aggregate demand shocks, these authors emphasize that the World Industrial Production Index contributes to a larger positive response of real GDP. In turn, Garzon and Hierro (2021), who analyze the transmission of different types of shocks to inflation in low and high inflationary environments, argue that oil supply and oil-specific demand shocks are transmitted to headline inflation in a more significant way, contrary to aggregate demand shocks. Regarding the impact of these shocks on oil prices, these authors emphasize that the demand side has a greater impact than supply. Like this study, Baba and Lee (2022) assume that aggregate demand and oil-specific shocks show greater relevance in oil price variations, however, these effects differ over time. If the first shock reveals greater importance in the period of the 2000s and between 2005 and 2012, the second type of shock assumes greater explanatory power during the period of 2010s. These authors also emphasize that oil price shocks promote more notable effects in inflationary environments and with less monetary policy credibility. Hong et al. (2022), which use different models in their analysis such as TVP-VAR to verify the impact of oil price changes on market

panic index in the period from January 1990 to November 2021, also argue that oil-specific demand shocks promote more considerable effects in oil prices than the other ones.

Finally, there is a controversy regarding the sensitivity of inflation to oil price shocks across countries. On the one hand, LeBlanc and Chinn (2004) argue that European inflation is believed to respond more to oil price increases when compared to the U.S.. This argument can be explained by the powerful labor unions in Europe, which can more easily extract wage concessions in response to rising consumer energy prices but also because of the ease of consumer price increases due to less competition in the market. However, by their empirical study, there is no strong evidence of differences in the response of inflation to changes in oil prices between the U.S. and Europe and also shows that, in the period 1980 to 2001, an increase in oil price of 10 percent points causes also an increase between 0.1 and 0.8 percentage points in headline inflation metrics in both economies. These authors pointed out the energy intensity in each country as the main reason for the promotion of differences between economies, with the U.S. and Japan being the ones that assume greater use of oil. European countries, in turn, despite having a lower level of oil consumption due to higher retail energy prices, are more likely to wage-price spirals because of unions. However, they conclude with the fact that production in the U.S. tends to be less energy intensive and European countries tend to have greater capacity to lead with oil price shocks. On the other hand, Barrell and Pomerantz (2008) defend that inflation in the U.S. is more sensitive to changes in oil prices than in other regions, such as the U.K. and Continental Europe. They also explain this situation with the importance of the fuel in that country and, consequently, its frequent use. Like these last authors, Renou-Maissant (2019), which also analyzed Canada, Japan and Australia using the oil-augmented Phillips Curve in the period 1991-2016, argues the significant impact that oil has on U.S. inflation, noting that in 2016 there was an increase of 1% on inflation due to an increase of 10% in oil prices. The author also shows that a similar does not happen in European countries because of the higher taxes and less dependence on oil and also refers that a persistent decline of the commodity price can promote problematic deflationary effects in Europe due to the slow economic growth and weak inflation response to demand pressures. In addition, the author highlights the important role of oil prices on inflation, which tend to increase during the period of analysis and shows an increase in the effects of oil price changes in all countries from 2000 until the financial crisis of 2008, with the exception of Germany which remains constant. However, after this crisis period, the effects tend to decrease in the U.S., Italy, Australia and Japan, largely due to the monetary policy imposed in each country. In the case of France and the U.K., it is the opposite, with a continued increase in the impact on inflation. On the contrary,

Cuñado and de Gracia (2003), argue the strong evidence of persistent effects on inflation among some European countries and this impact becomes greater if the role of the exchange rate is taken into account. They also highlight the fact that an increase in oil prices in 1999 is more likely to have a more significant impact in Europe than in the U.S.. In recently period, Brief (2022) agreed with the existence of significant effects on European inflation due to the volatility of oil and natural gas prices, mainly after the problematic geopolitical situation that has been promoting complications related to the lack of energy resources to respond to the strong dependence on imports. This study also emphasizes that the Russian invasion of Ukraine has aggravated the vulnerability of the European economy, which already existed due to the inability of producers to respond to the strong demand for oil after the pandemic period.

In this way, we can observe that oil price volatility has different effects among countries and this can be seen in a more accentuated way during the COVID-19 pandemic shock in 2020, since the decline in the price of oil promoted a more accentuated drop in the retail price of gasoline in some regions namely Europe, America and South Asia, contrary to what happened in other economies, where the drop was not as sharp. There are several reasons that explain these differences, more specifically between advanced and developing countries, with the latter being more predominant. Kpodar and Liu (2022) argue that energy intensity and lower substitution capacity promote a greater impact on the CPI of these countries, however, it is also due to the lower credibility of monetary policy and the rigidity of the labor market that make this impact more lasting. Regarding the CPI components most affected by fluctuations in fuel prices, these authors point out that 10 of the 12 CPI components show a strong response in developing countries, while in the most advanced, only 7 components are affected. Prices related to transport and food are identified as the most sensitive items to these shocks, more specifically the first one. As in the previously mentioned study, Castillo et al. (2020) assume the credibility of monetary policy as an important role in controlling the price level, since a greater ability of central banks to control inflation will promote a reduction in the effect of the volatility of oil prices. The opposite happens for the level of substitutability of oil, which, being lower, promotes an increase in marginal costs, leading to an increase in the level of inflation. On the other hand, previous studies indicate that inflation in the U.S., compared to other countries, is more reactive to shocks in energy prices, pointing to their greater variability, as well as greater energy intensity in that country (LeBlanc & Chinn, 2004; Van den Noord & André, 2007; Barrel & Pomerantz, 2008; Renou-Maissant, 2019; Wen et al., 2021). This idea is not fully agreed upon by the European Central Bank (ECB), since it is highlighted, in a conference, that the headline inflation of the Eurozone surpassed the headline inflation of the

U.S., due to the existence of a greater inflationary impact of energy and food prices in Europe. However, in terms of core inflation, the scenario is slightly different, since this inflation metric is stronger in the U.S. than in European countries due to its correlation with wage inflation. Core European inflation is, in turn, more related to energy-intensive sectors, due to their higher prices. Still, in the same conference, the monetary authority shows that, despite the existing effects of demand, supply factors assume greater predominance in core inflation (European Central Bank, 2022).

Regarding future prospects, Demary and Hüther (2022) believe that the effects on inflation will be persistent due to the fact that supply constraints are far from responding to the increase in demand and emphasize that the level of oil production, after the pandemic crisis, will not reach the previously existing production level until the end of 2022. These authors state that if production does not increase soon, prices will tend to increase even more leading to the possibility of persistent inflationary impacts in the near future. In the same study, it is also highlighted the importance of the same type of effects in Germany, since its inflation is crucial in determining inflation rates in Europe. Furthermore, the eventual persistence of supply bottlenecks, as well as wage-price spirals, will complicate the decisions of the ECB, which should opt for a restrictive monetary policy leading to a slowdown of the economy. They conclude with the need to adopt another perspective of macroeconomic policy in order to avoid the risk of stagflation in the Eurozone.

3. Contextualization

3.1. Framework

Currently, inflation is a global concern due to the post-pandemic period and, more recently, the Russian invasion of Ukraine. In the first phase, the recovery of economic activity promoted demand pressures which, in turn, led to bottlenecks in supply, promoting an increase in energy and food prices. The geopolitical situation and the sanctions imposed on Russia, on the other hand, caused a significant increase in the price of oil due to energy supply disruptions. In order to control the severe effects of this period of strong economic instability, the ECB has promoted and expects more successive increases in interest rates, with the aim of controlling the factors driving inflation (Reuters Global News Desk, 2022). Aggressive monetary policies are also adopted by the Federal Reserve System, which guarantees that there will be a continuous rise in interest rates until inflation levels return to normal. Powell J., president of the FRED, adds that slow economic growth and an increase in the level of unemployment are expected in a phase of slowing inflation (Diário de Noticias, 2022).

Despite the level of inflation at the beginning of 2023 not being as high when compared to 2022 and the expectation for this coming year to be marked by a continued deceleration in prices, accompanied by a reduction in energy inflation, the prevailing prices level remains above the target inflation of the ECB (European Central Bank, 2022). Currently, and contrary to the forecast for the end of 2022, inflation in France suffered an unexpected slowdown, reaching 6.7%, as well as German inflation, which also slowed down more than expected (Bloomberg, 2023). According to Statista (2023), the inflation rate in Germany reached 9.6% while in Portugal, the previous year ended with a price level of around 9.8%, assuming the highest rate among the three countries.

3.2. Evolution of the oil price and inflation in the period of 1990 to 2022

The evolution of the crude oil price and both inflation measures, CPI and PPI, during the period 1990 and 2022 are presented below.



Figure 3.1: Global Brent Crude index based on year 2015=100

(Source: Data obtained from FRED, own elaboration.)

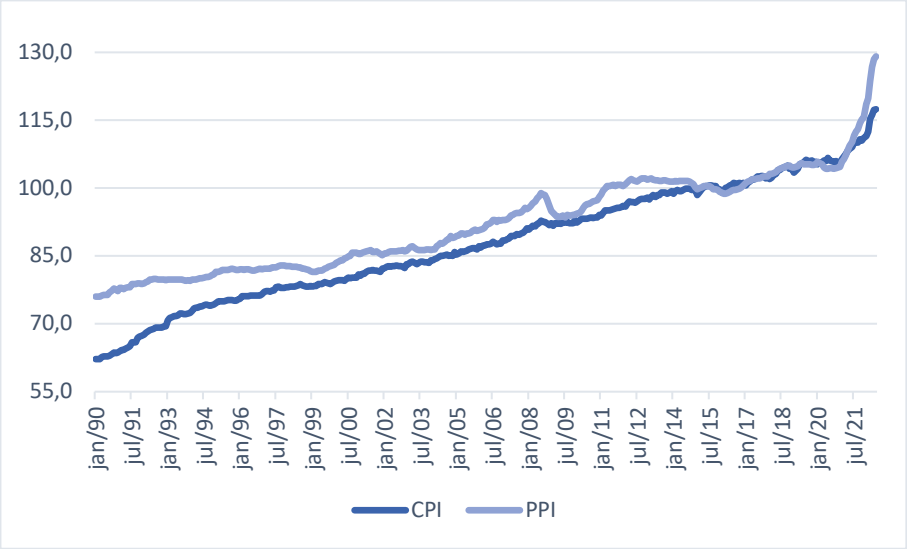


Figure 3.2: Consumer Price Index (CPI) and Producer Price Index (PPI) based on year 2015=100 in Germany

(Source: Data obtained from FRED, own elaboration.)

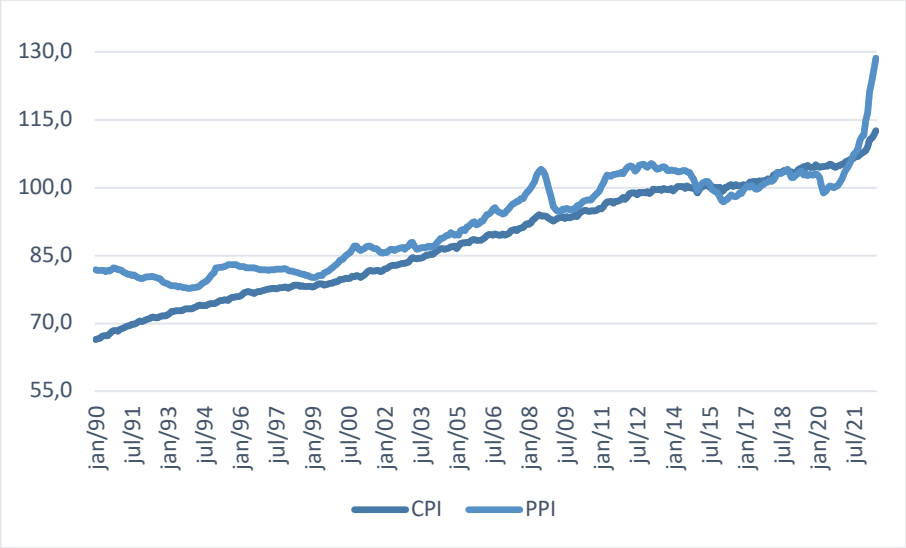


Figure 3.3: Consumer Price Index (CPI) and Producer Price Index (PPI) based on year 2015=100 in France

(Source: Data obtained from FRED, own elaboration.)

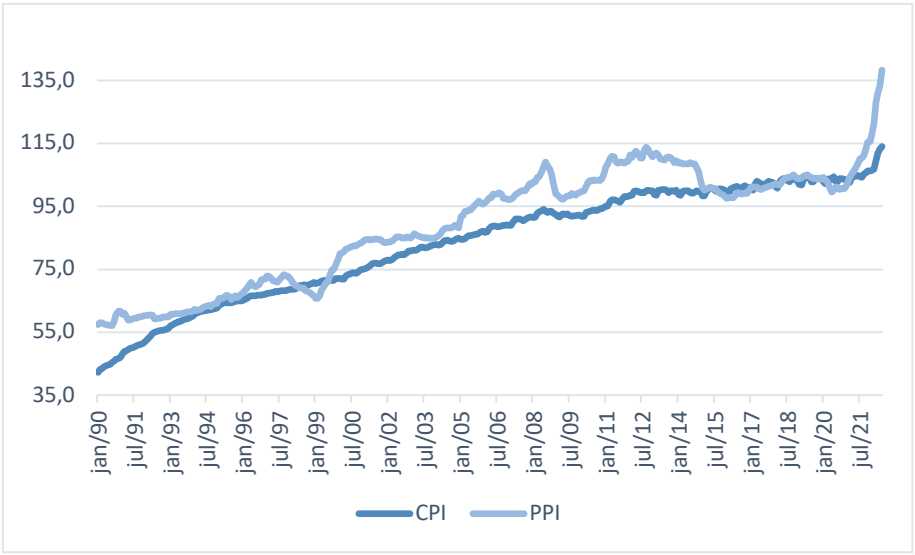


Figure 3.4: Consumer Price Index (CPI) and Producer Price Index (PPI) based on year 2015=100 in Portugal

(Source: Data obtained from FRED, own elaboration.)

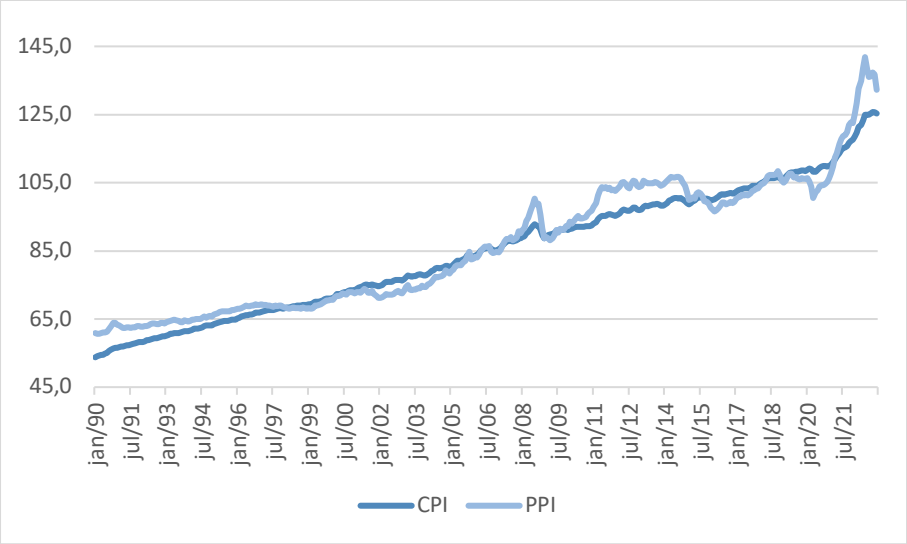


Figure 3.5: Consumer Price Index (CPI) and Producer Price Index (PPI) based on year 2015=100 in United States

(Source: Data obtained from FRED, own elaboration.)

Through the analysis of the three graphs presented, we verified three most striking moments during the period considered, between the years: 2008 and 2009, 2014 and 2015 and, finally, 2020 and 2022. According to Figure 3.1, it is possible to observe a strong volatility of the crude oil price throughout the period under analysis. Strong growth is seen at the beginning of 2005 extending to 2008, in which it reached its maximum peak during the period between 1990 and 2022. This peak is followed by a sharp decrease in prices, driven by the Great Recession of 2008. The same can be seen in both inflation indicators presented in the following figures in the three countries analyzed: Germany, France and Portugal. The CPI and PPI indicators, with emphasis on the latter, highlight strong price growth in 2008 followed by a sharp drop until 2009. This phase of great economic instability determined the most significant decline in the general price level over these 31 years. With the recovery of this economic crisis, the price of oil as well as inflation, show a new upward behavior, quite accentuated between 2010 and 2011, which extends until the year 2014. This increase is evidenced with greater expression in the PPI indicator than in in the CPI, promoting a greater discrepancy between the two inflation gauges.

Between the last quarter of 2014 and the first of 2015 is a period marked by a new drop in prices, however less significant than that seen in 2008. It should be noted that this phase contributed to the approximation of the PPI and CPI indicators, which show identical and stable behavior until 2020 in the three countries. The price of oil, on the other hand, manifests a strong volatility during this period.

In turn, the first quarter of 2020 was marked by the most recent crisis, the COVID-19 pandemic, which encouraged a further reduction in prices. The effects of this more critical phase were significant but temporary on oil prices, with an immediate recovery from May of that year. The same did not happen with inflation, whose impact of the pandemic crisis caused longer-lasting consequences, until the end of 2020. During this period, it is interesting to note that the PPI indicator is below the CPI in the three countries analyzed, with emphasis on the French country, where this behavior is more notorious. The post-pandemic economic recovery that began in 2021 and Russia's invasion of Ukraine, which started in February 2022, has driven strong oil price growth to this day. This behavior was accompanied by a significant inflationary effect reaching a maximum peak in 2022, highlighting once again the PPI which is considerably distant from the CPI in that year.

Regarding inflation gauges in the U.S., as can be seen in Figure 3.5, there are more significant impacts on the PPI compared to the CPI in periods of greater oil price volatility. About the behavior of the first indicator, it is stable in the initial phase, showing a more significant increase at the beginning of 2008. After that, a sharp decrease is observed until the beginning of 2009. Between the time period of 2014-2016 and at the beginning of the year 2020, the PPI shows a notable drop that is quickly recovered in 2021 with the post-pandemic economic recovery. It should be noted that between the years 2010 and 2015, the PPI maintains a considerable distance from the CPI as well as in 2022, in which both indicators reach their maximum point during the entire time horizon. It is also possible to verify in the same figure that in more critical periods, the PPI is more sensitive, demonstrating more pronounced drops than the CPI as is the case for the periods 2001-2004 and 2016-2021. CPI, in turn, shows a gradual increase over the entire time horizon, remaining less volatile than that seen in the PPI. However, periods of strong volatility such as the Great Crisis of 2008 and, more recently, the War between Russia and Ukraine promote considerable increases in the CPI.

After this brief review, it is possible to conclude that the PPI shows greater sensitivity during the most critical periods when compared to the CPI. In addition, there is a different evolution of the inflation indicators in Portugal, namely the fact that (i) in an initial phase, more specifically in the beginning of 1999, there is a sharp drop in the PPI, which is not verified as expressive in the remaining countries analyzed and that (ii) the PPI is more volatile in Portugal than in Germany, France and United States during the period considered.

4. Methodology

4.1. Data

4.1.1. The Countries

We decided to analyze it from a European and North American perspective and, for that, we chose three European countries with different economic realities namely Germany, France and Portugal, in order to obtain a more complete picture of the relationship between oil price and inflation in Europe, and also in the United States due to the importance of oil in that economy. The first two countries assume a greater economic expression at the European level and are among the largest economies in the world. In addition, both assume relevant positions in the rank of the top crude oil importers in 2019, with Germany being the first European country with the greatest dependence on energy resources while France assumes the fourth country at the European level (Wang et al., 2022). Portugal, in turn, despite its lower economic expression, has a more significant price growth in periods of high inflation compared to the other countries mentioned. Furthermore, there are no recent studies on this topic covering Portugal, making it interesting to analyze it.

4.1.2. The Variables

In this empirical study, we use monthly data from 1990M1 to 2022M12. Regarding the variables used in this empirical study, the Global Price of Brent crude in U.S. dollars per barrel represents the oil price changes and, in this way, this variable will be deflated by U.S. CPI, transformed into euros through U.S. dollars to Natural Currency Spot Exchange Rate when analyzing European countries and, finally, represented in natural log. Producer Price Index and Consumer Price Index are used to measure inflation, being the latter analyzed in its aggregated form, known as headline, and in its disaggregated form, also known as core inflation or inflation less food and energy. According to previous studies, the CPI is the most used measure of the general price level, however, this index itself does not explain the impact of the crude oil price on inflation because it only reflects the final amount paid by the consumer including labor costs and taxation (Donovan, 2015). Producer prices, as the name implies, reflect changes in prices paid by the producer for his output, without additional costs included in the final price. Although these two indicators have limitations, analyzing not only the CPI but also the PPI, which is still not widely used in the literature, will promote more robust results. The U.S. CPI

is obtained from FRED, as well as the Global Price of Brent crude and the exchange rate. In turn, the PPI and CPI based on the year 2015=100 are obtained from OECD for European countries and from FRED for the United States.

In this empirical study, three types of oil price shocks will be identified, namely oil supply shocks, aggregate demand shocks and oil-specific demand shocks, like in previous studies (*e.g.,* Kilian, 2009; Garzon and Hierro, 2021; Clerides et al., 2022; Kim & Vera, 2022). For this purpose, the variables Crude Oil Production in the U.S. thousands of barrels, the World Industrial Production Index for the OECD and 6 non-member countries (namely, Brazil, China, India, Indonesia, Russian Federation and South Africa), and Global Price of Brent crude are used for the identification of these shocks, respectively. The first one reflects the oil supply bottlenecks and is obtained from the U.S. Energy Information Administration, while the second represents global economic activity and is taken from Baumeister's website, where we can achieve this variable in a more up-to-date form.[1] The variables expressed in U.S. dollars must be expressed in their domestic currency when analyzing European countries.

Despite the strategy of identifying shocks by Kilian (2009) being common in the analysis of the oil market and inflation, there are not many studies to analyze with more recent data in Europe, including the economic consequences that arose with the pandemic and the war between Russia and Ukraine using both inflation indexes, CPI and PPI. In addition, the representative variable of the aggregate demand shock is the Index of Global Real Economic Activity developed by Kilian (2009). However, this indicator contains factors that are not taken into account by previous studies, namely in terms of correlation with World GDP and in forecasting the price of different commodities. Industrial Production presents a better performance in both factors, compared to the Kilian's index, being the most appropriate measure to represent global real economic activity (Hamilton, 2021).

4.2. The Model

In this empirical study, the SVAR model will be used in order to analyze the impact that oil prices have on headline and core inflation.

[1]World Industrial Production Index can be obtained through the website https://sites.google.com/site/cjsbaumeister/datasets, which it is taken from Baumeister and Hamilton (2019).

The VAR model represents the relationship between different time-series variables, capturing the impact of the dynamics of external shocks on the other variables included in the system, which are considered as endogenous, and, for this reason, it is used by several analysts to estimate the effects of shocks on macroeconomic activity (Peersman, 2018). The SVAR use economic theory to recover the structural innovations or restrictions from the shocks at the unrestricted VAR. The identification focuses on the errors of the system instead of identifying the parameters.

The SVAR(p) model can be represented as follows:

$$A_0 Y_t = \alpha + \sum_{i=1}^{p} A_p \, Y_{t-p} + \varepsilon_t \tag{1}$$

where:

- $\boldsymbol{Y_t}$ represents a 5×1 vector, which includes the endogenous variables namely COP, WIP, GPC, headline inflation (π) and core inflation (π^{core}).
- $\boldsymbol{A_0}$ captures instantaneous relationships between the variables included in the Y_t vector, corresponding to a 5×5 matrix of contemporaneous coefficients.
- $\boldsymbol{A_p}$ corresponds to a 5×5 matrix of autoregressive coefficients.
- $\boldsymbol{\varepsilon_t}$ denote the structural shocks modeled as an interdependent system of linear equations. Due to its unpredictability, ε_t are white noise and mutually uncorrelated.
- $\boldsymbol{p}$ represents the number of lags defined based on the information criteria model.

The reduced form of the SVAR model is then defined as:

$$Y_t = A_0^{-1}\alpha + \sum_{i=1}^{p} A_0^{-1} A_p \, Y_{t-p} + A_0^{-1}\varepsilon_t \tag{2}$$

equivalent to:

$$Y_t = c + \sum_{i=1}^{p} \phi_p \, Y_{t-p} + v_t \tag{3}$$

where c represents $A_0^{-1}\alpha$, ϕ_p corresponds to $A_0^{-1}A_p$ and v_t is defined as $v_t = A_0^{-1}\varepsilon_t$, which represent the reduced-form errors as linear combinations of structural shocks ε_t.

4.3. Identification of the Restrictions: Cholesky Decomposition Method

After representing the model, we proceed to the identification of the restrictions in order to obtain an estimate for the parameters. In this sense, it is necessary to define constraints for the 5×5 matrix A_0. This identification is made through the recursive structure strategy, also used in other previous studies (Clerides et al., 2022; Garzon & Hierro, 2021; Wen et al., 2021; Kim & Vera, 2022), in which A_0^{-1} is assumed as a lower-triangular matrix and, consequently, obtained by the Cholesky Decomposition method.[2]

The errors in the reduced-form (v_t) will be identified in 2 models: the first will include CPI while in the second, the inflation index is replaced by the PPI. It should be noted that the variables representing the structural shocks were previously presented. The identification of these shocks will be defined as follows:

$$v_t = \begin{pmatrix} v_t^{COP} \\ v_t^{WIP} \\ v_t^{GPC} \\ v_t^{\pi} \\ v_t^{\pi^{Core}} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{Oil\ Supply\ Shock} \\ \varepsilon_t^{Aggregate\ Demand\ Shock} \\ \varepsilon_t^{Oil-Specific\ Demand\ Shock} \\ \varepsilon_t^{4} \\ \varepsilon_t^{5} \end{pmatrix} \quad (4)$$

In the Cholesky Decomposition method, it is important to define the order of the variables in the model and this is done according to their importance. The first variable assumes greater relevance due to its ability to affect all the others and it is, therefore, considered the most exogenous. In turn, the last variable is defined as the least exogenous or, in other words, the most endogenous and, as such, it does not affect the remaining variables but it is influenced by all of them. In this way, we consider COP as the most exogenous variable, thus assuming the first position, and π^{core} the most endogenous.

Through the representation of the structural shocks presented above, it is possible to verify the assumptions taken into account in their identification, also used in the aforementioned literature:

[2] The remaining possible orders can be found in the Appendix E in order to guarantee the effectiveness of the results, assuming inflation as the most endogenous variable in all, since this empirical study focuses on the impact that the three identified shocks have on the both inflation gauges, the CPI and the PPI. In the case of the PPI, only this index is included in its aggregated form (headline inflation) assuming the last position and, as such, the most endogenous variable of the model.

- COP only responds contemporaneously to the oil supply shock in the same month, not being influenced by the other shocks. In this way, only the first identified structural shock has the capacity to affect the production level.
- WIP responds contemporaneously only to the oil supply shock and aggregate demand shock in the same month.
- Oil price is influenced by the first three shocks identified, not responding to the others.
- The same strategy is used for both headline and core inflation rates. Like Killian and Zhou (2022) and Clerides et al. (2022), the driving shocks of inflation and inflation less food and energy are not specifically represented. In this way, possible innovations that could boost inflation without being related to oil reasons will be included in these shocks (Clerides et al., 2022).

4.4. Stationary Condition

Before proceeding with the estimation of the SVAR, it is necessary to verify the stationary condition. The Unit Root test is performed for each variable in order to verify whether they are stationary or non-stationary. To this end, an ADF test will be performed, represented as follows:

$$\Delta Y_t = \emptyset_0 + pY_{t-1} + \sum_{j=1}^{p-1} \widetilde{\emptyset_j} \Delta Y_{t-j} + \varepsilon_t \quad (5)$$

where $\emptyset_0$ is a constant and p is defined as $p = (\emptyset_1 + \cdots + \emptyset_p) - 1$.

The null hypothesis (H_0) assumes the existence of non-stationary variables, in which $p = 0$, and the inverse as an alternative hypothesis (H_1), where $p < 0$. If t-statistic is greater than the critical value, H_0 is not rejected and then, we verified that the variables are non-stationary and therefore, we transformed them into their 1st and/or 2nd differences in order to be used in the SVAR model.

4.5. Dummy Variables

Due to the size of the sample and the inclusion of important events that arose over the analyzed period, namely crisis situations, we introduced dummy variables, such as Cuñado and de Gracia

(2003). As such, dummy variables were added in periods marked by greater oil price volatility: 2008M08 – 2009M01, 2014M09 – 2015M03, 2020M03 – 2020M12 and 2022M03 – 2022M06.

4.6. Impulse Response Function

After verifying the stationary condition, we proceed to the IRF in order to verify the impact that structural shocks have on the endogenous variables included in Y_t. The Impulse Response analysis is performed using the following equation:

$$Y_t = \mu + \sum_{s=0}^{\infty} C_s \, v_{t-s} \tag{6}$$

in which emerges the IRF defined as:

$$C_{ij,h} = \frac{\partial \mathrm{Y}_{i,t+h}}{\partial v_{j,t}} \tag{7}$$

where Y_t represents endogenous variables of the model and v_t denotes previously identified shocks.

Through IRF, we observe the dynamic responses of each endogenous variable included in the model over **m** periods after a unit change in each shock, with special attention to the response of core and headline inflation to oil shocks.

4.7. Forecast Error Variance Decomposition

For a more complete analysis, the FEVD test is performed in order to identify which of the three shocks: oil supply, aggregate demand and oil-specific demand contribute most significantly to the variability of inflation. This analysis is carried out at the end of the 1st quarter and at the end of 1 year, in order to understand whether there is any change in results in the short and long term.

4.8. Granger Causality Test

This empirical work is finalized with Granger Causality Test, through which is verified whether or not one variable is useful in forecasting another. For this, the null hypothesis (H_0) means

that there is no causal relationship between the variables since for this to happen at least one of the parameters tested must be different from zero, in other words, there is no interdependence.

5. Results and discussion

5.1. Descriptive Statistics

The model chosen for the empirical analysis is the SVAR to analyze the different structural shocks in the oil market, namely oil supply shock, aggregate demand shock, and oil-specific demand shock as well as their transmission to inflation, measured either by the CPI or the PPI. In this way, we can observe which of the shocks impacts the general price level more. For this, restrictions were imposed on the SVAR model according to the Cholesky Decomposition method, duly explained in section 4. This empirical analysis focuses on the period from 1990M1 to 2022M12 with 396 monthly observations. To facilitate the process, this analysis starts from the year 1990, in which the reunification of Germany took place. Given the relevance of the 1973 oil crisis, which has been extensively analyzed by the existing literature, our main focus is to investigate the crises that emerged more recently.

First, we proceeded to analyze the correlation between the variables used in this empirical study. Through Table A5.1, in Appendix A**,** we can verify that there is a lower and negative correlation between COP and the GBC (-0.07), while between the WIP and the GBC, the correlation is more significant and positive (0.67). In the following tables, we found that both the inflation indicators of each country and the global oil price (GBC) in U.S. dollars assume a strong correlation with each other, presenting a variation of 0.65-0.84 (Tables A5.2 to A5.5). The same is true when the oil price is defined in euros (Tables A5.6 to A5.9), however, the level of correlation slows down slightly, ranging from 0.59 to 0.78. Among the countries under analysis, we conclude that the correlation is more significant in France and Portugal, with emphasis on the PPI indicator.

Table A5.10 shows the standard deviation referring to the GBC, in U.S. dollars and euros, and the inflation indicators referring to Germany, France, Portugal and the United States. According to the first variable presented, prices defined in euros have a higher standard deviation (32.86 and 22.38, respectively). Regarding the CPI and core CPI for Germany, France and the United States, the standard deviation of the core CPI is slightly smaller than the CPI. Thus, we can conclude that the core CPI shows less variability than the CPI in the three countries. In turn, Portugal shows the opposite behavior with a smaller standard deviation of the CPI when compared to the core CPI, revealing less volatility in the former. In terms of the PPI in Portugal and the United States, these indicators show a more significant standard deviation, and therefore greater variability, than that observed in Germany and France.

Table B5.11 in Appendix B presents the Dickey-Fuller Tests. Firstly, we performed this test for the variables in the log, in which the null hypothesis is not rejected with a significance level of 5%, confirming the existence of the unit root. Therefore, the variables were transformed into first and second differences to obtain stationary data, in which the unit root hypothesis is then rejected.

5.2. Impulse Response Analysis: CPI and core CPI

The IRFs presented in this document convey the estimated inflation metrics response to a forecast error impulse in each of the three types of shocks in a 10-month horizon with 95% bootstrapped error bands.

5.2.1. Germany

The model was tested for the lag order, having been concluded based on the SIC an estimation of the SVAR with order 2, as shown in Figures 5.1 and 5.2.

Figure 5.1 (a) shows that the oil supply shocks do not promote considerable effects on the CPI, since this inflation metric shows an oscillation around zero along the time horizon, indicating that the impact is not statistically significant. An identical scenario happens with the core CPI (Figure 5.2 (a)).

In Figure 5.1 (b), initial positive aggregate demand shocks promote a null impact on inflation and strong volatility afterward, showing less significant effects after 6 months. The same happens for the core CPI over the same time horizon (Figure 5.2 (b)).

Regarding the oil-specific demand shocks, as shown in Figure 5.1 (c), in an initial phase they promote a negative behavior in the CPI that lasts up to 4 months, showing once again little significant long-term effects. Regarding the core CPI, the transmission of oil-specific demand shocks is more significant in an initial time phase, since during the first two periods prices show positive upward behavior, surpassing 5%. (Figure 5.2 (c)).

Choi et al. (2018) and Garzon and Hierro (2021) argue that oil shocks promote less significant and less persistent impacts on core inflation, however, despite the inflationary effects being more lasting in the CPI of Germany, these effects are more notorious in the core CPI.

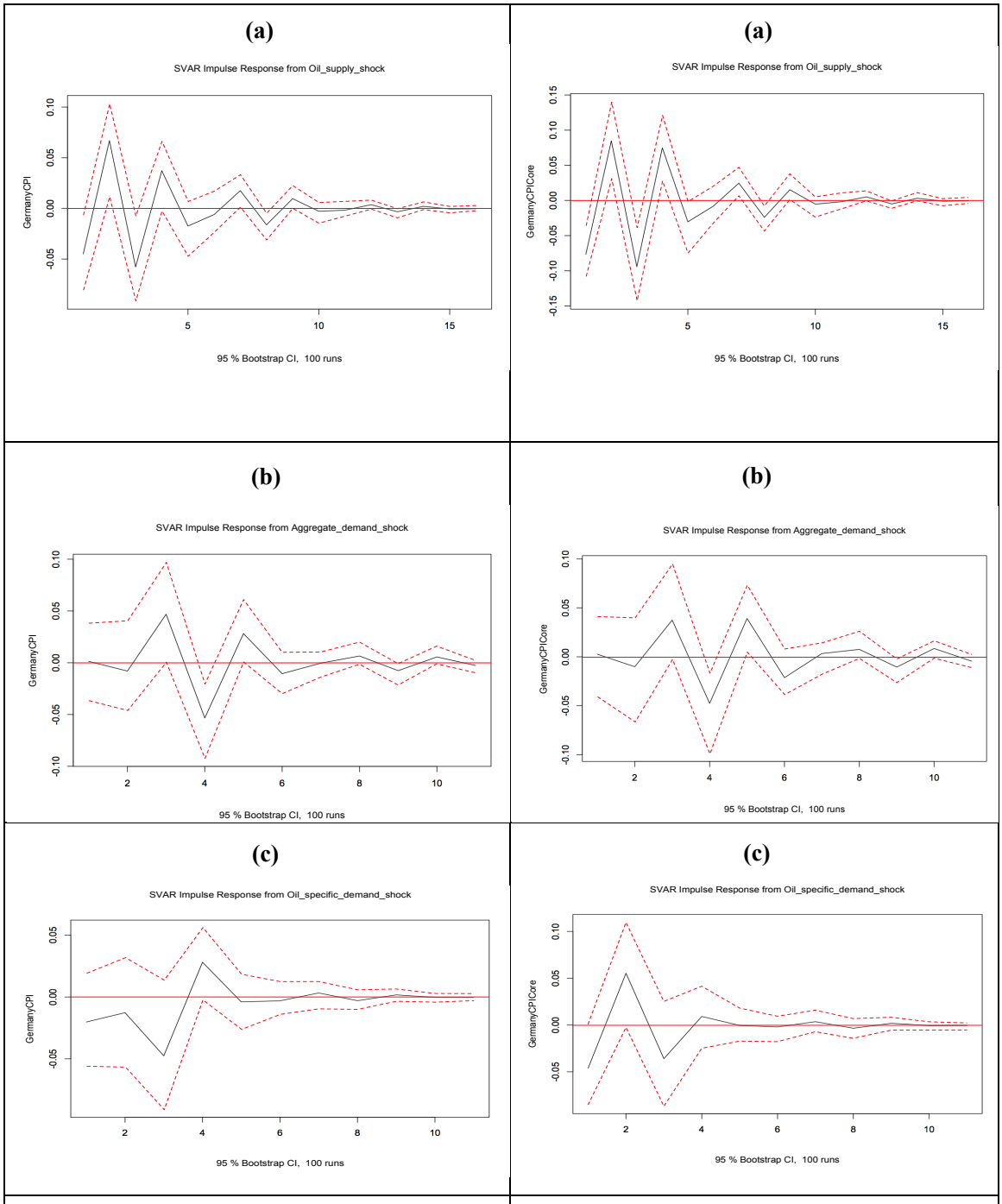


Figure 5.1 - Impulse Response Functions of Germany CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c)

Figure 5.2 - Impulse Response Functions of Germany core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c)

Source: Results obtained by econometric software R, own elaboration.

The FEVD for the CPI and core CPI of Germany are shown in Figure C5.3, presented in Appendix C, where we can confirm the aforementioned conclusions. Regarding the first indicator, there is a small portion responsible for oil supply and aggregate demand shocks, which becomes more noticeable towards the end of the first quarter, at approximately 5%. The

core CPI also assumes explanatory power, although not significant, showing a greater contribution from 3 months. After 1 year, there are no significant differences in shock weight. With regard to the variation in the core CPI, oil supply shocks make a more significant contribution after 3 months, reaching approximately 10% at the end of the first quarter, while CPI has a more considerable weight in the first month of approximately 60%, decreasing slightly throughout the first quarter. There were no changes over the 12 months, remaining constant in the long-term.

Based on the Granger Causality Test, shown in Table D5.12 in Appendix D, we verified that the Global Price of Brent Crude contributes to estimating the CPI only with orders 1 and 2, however, it does not cause core CPI at a significance level of 5%. In the opposite situation, we conclude that the CPI granger causes the Global Price of Brent Crude and, therefore, there is a bidirectional causal relationship, while the core CPI does not granger cause the price of oil, having no causal relationship with this last variable.

5.2.2. France

According to SIC, we determined SVAR(3) for France and derived its impulse responses, displayed in Figures 5.4 and 5.5.

Figure 5.4 (a) shows the impact of oil supply shocks on the CPI, through which we verify an instantaneous negative impact, exceeding 5%, and a more expressive and positive impact during the first 2 months, becoming less significant in the subsequent periods. The core CPI shows a similar behavior with a more pronounced initial impact that reaches negative 10% (Figure 5.5 (a)). We can thus conclude that the reaction of inflation after an oil supply shock tends to be considerable in an early period, however, it is short-lived.

Through Figure 5.4 (b) is observable that aggregate demand shocks promote an instantaneous increase in CPI, reaching 3%, however, this increase is short-lived, tending to decline rapidly over the time horizon. Figure 5.5 (b) shows a slightly more significant initial impact on the core CPI, however, it quickly assumes a behavior identical to that seen in the CPI. We also verify a lower oscillation in the core CPI than in the CPI after aggregate demand shocks.

The transmission of the oil-specific demand shocks in the CPI, as observable in Figure 5.4 (c), promotes a different scenario when compared to the other shocks. It is possible to verify a more notorious impact on CPI during the first 6 months, highlighting more lasting negative effects in prices than positive ones, exceeding negative 5% in period 2. Regarding the core CPI,

there was an instantaneous increase of more than 2%, however, it is less expressive and statistically significant than that seen in the CPI over the time horizon (Figure 5.5 (c)).

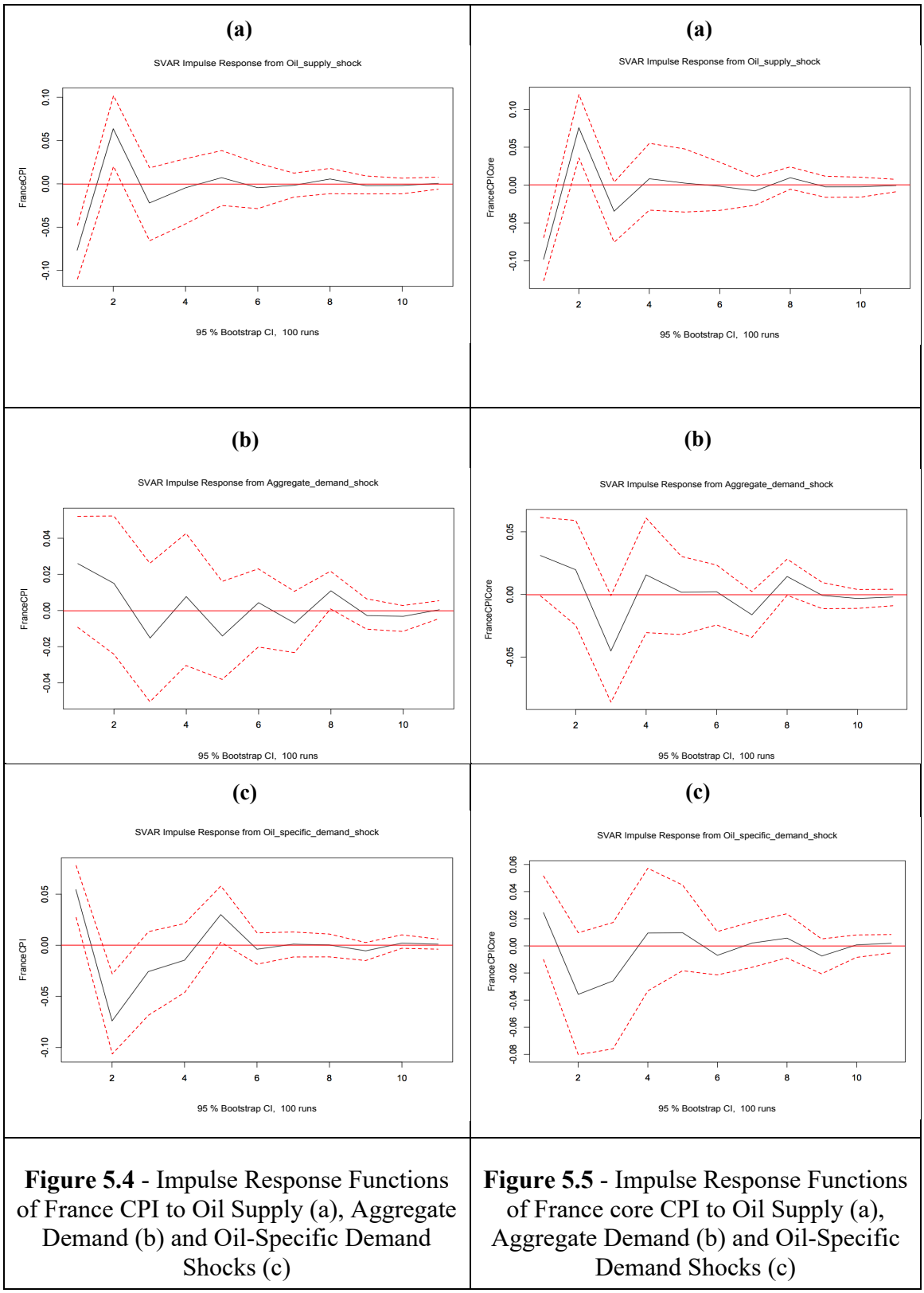


Figure 5.4 - Impulse Response Functions of France CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c)

Figure 5.5 - Impulse Response Functions of France core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c)

Source: Results obtained by econometric software R, own elaboration.

According to Figure C5.6, it is evident that the CPI derives in part from oil supply and oil-specific demand shocks in the first quarter, with almost 10%, each representing an identical share of approximately 5% from period 2 onwards. In addition, there is also a slight contribution from the core CPI, becoming more sizeable over the first few months. Throughout the year, we verify a constant weight of shocks, except for the core CPI which assumes a more accentuated explanatory power of approximately 5% from period 7 onwards. French core CPI shows a significant and majority share of the CPI around approximately 65%. The oil supply shock makes a contribution of close to 10% in the first period, decreasing in the following ones. From the subsequent period onwards, there were no significant changes.

According to the results obtained from the Granger Causality Test in Table D5.13, we can conclude the existence of a causal relationship between the oil price and both CPI and core CPI. We were able to observe a bidirectional causal relationship between the Global Price of Brent Crude and CPI, as one variable causes the other and vice versa. However, there is only a unidirectional causal relationship with the core CPI, in other words, the Global Price of Brent Crude causes core CPI, however, the opposite is not verified.

5.2.3. Portugal

For Portugal, impulse responses derive from SVAR(5) according to SIC and HIQ, as shown in Figures 5.7 and 5.8.

By looking at Figure 5.7 (a), we infer a strong oscillation around zero of the CPI after oil supply shocks with an initial negative impact of almost 10%. The response of the CPI is not statistically significant over the time horizon. Figure 5.8 (a) also shows a similar behavior in the core CPI after the transmission of these shocks, however, we verify an anticipated and more persistent response of the core CPI when compared to the CPI.

Figure 5.7 (b) shows that an increase in aggregate demand promotes a more significant and positive impact on the CPI only at the initial phase, exceeding 5%. As has been observed in previous countries, this impact is not persistent, decreasing quickly and assuming greater volatility around zero in the subsequent periods. Similar conclusions on the core CPI are observed: there is a strong oscillation and the impact tends to be short-lived (Figure 5.8 (b)).

Figure 5.7 (c) shows the transmission of the oil-specific demand shocks in the CPI, which is statistically insignificant over the time horizon. As shown in Figure 5.8 (c), the core CPI manifests an initial negative behavior, the opposite of the CPI. However, as CPI, this indicator remains quickly close to zero and is statistically insignificant.

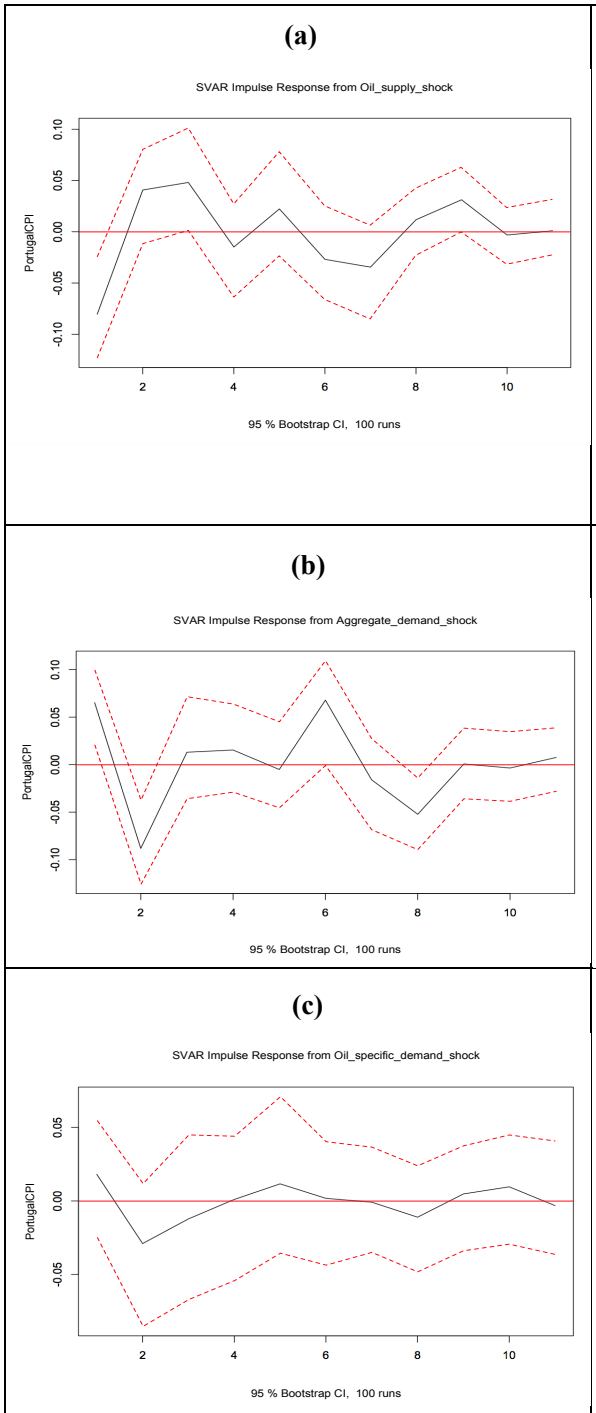


Figure 5.7 - Impulse Response Functions of Portugal CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c)

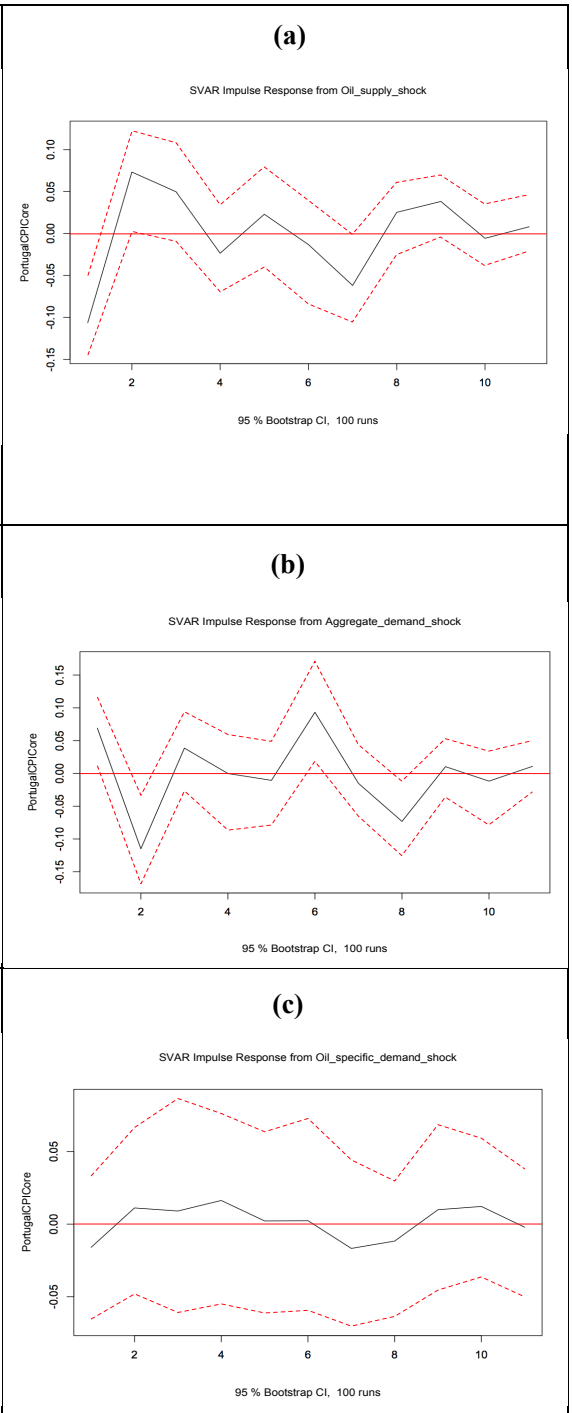


Figure 5.8 - Impulse Response Functions of Portugal core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c)

Source: Results obtained by econometric software R, own elaboration.

According to Figure C5.9, which represents the FEVD for the CPI, we can see that this indicator is strongly explained by the core CPI, which assumes a more pronounced contribution at the end of the first quarter. Oil supply and aggregate demand shocks assume a more notorious

impact over the first quarter, assuming together an explanatory power of almost 10%. Even so, we can observe that the weights tend to change throughout the year, with an increase in the explanatory portion of core CPI, reaching approximately 10% from period 8 onwards, and aggregate demand shocks, which assume a more visible weight in the 6th month. Regarding the core CPI, this is also largely explained by shocks in the CPI of approximately 60% in the first month. Aggregate demand and oil supply shocks are, once again, more pronounced compared to the oil-specific demand shock. While the first one assumes a more notorious impact from the 2nd month, oil supply shock keeps constant over the first quarter, representing together a portion of approximately 10%. Throughout the year, we observed a slight increase in aggregate demand, especially during the second half.

Through the results obtained by the Granger Causality Test in Table D5.14, the null hypothesis is not rejected, and, therefore, the Global Price of Brent Crude does not granger cause CPI nor core CPI. The same happens in the opposite situation, concluding that there is no causal relationship between both inflation indicators and the price of oil.

5.2.4. United States

For the U.S., the estimated SVAR is of order 2, according to the SIC, as shown in Figures 5.10 and 5.11.

As observed in Figure 5.10 (a) the transmission of the oil supply shocks in the U.S. CPI is not persistent, promoting an initial negative impact of almost 2% and a more positive and statistically significant response in period 4, subsequently disappearing. Figure 5.11 (a) shows the behavior of the core CPI, which assumes a strong volatility, becoming more pronounced in the period 2-4, where the CPI achieves the maximum and the minimum point. It is observable that oil supply shocks promote a more pronounced and anticipated impact on the core CPI.

Figure 5.10 (b) shows an increase in the U.S. CPI after an increase in aggregate demand shocks, although it is not especially accentuated, keeping positive and more pronounced until the 6th month. Figure 5.11 (b) revealed a different behavior of the core CPI with an initial impact of almost nil during the first period, keeping around zero onwards.

With regard to the oil-specific demand shocks in the CPI, Figure 5.10 (c) shows a pronounced inflationary effect exceeding 10% at the initial phase and 15% after 2 months, however, it is short-lived. On the other hand, the core CPI presents a more volatile and less significant behavior than that seen in the CPI, rapidly converging to zero (Figure 5.11 (c)). In

this sense, the oil-specific demand shocks promote a more accentuated and less lasting effect on the CPI compared to the core CPI.

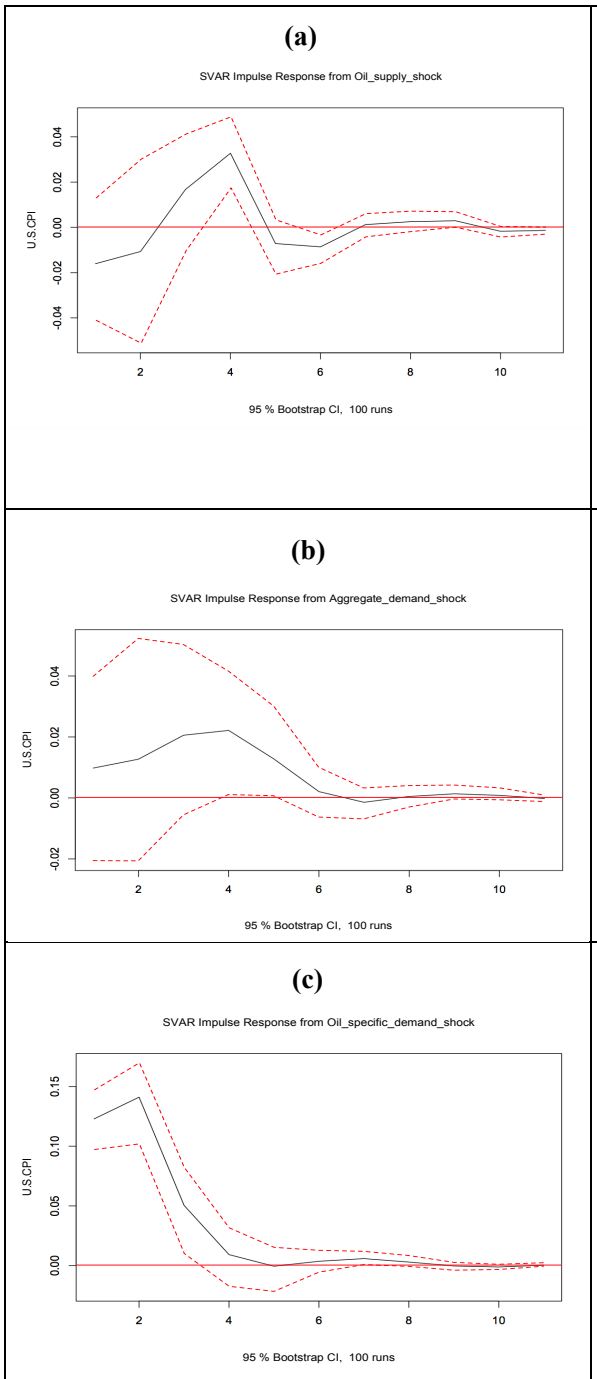


Figure 5.10 - Impulse Response Functions of U.S. CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c)

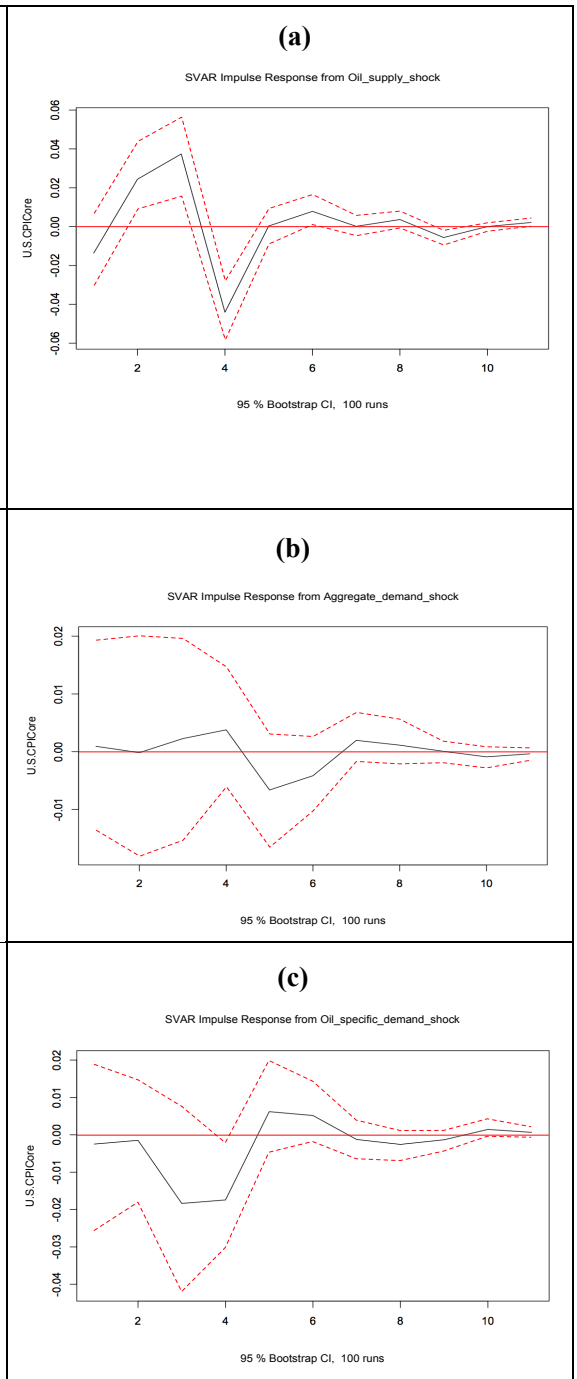


Figure 5.11 - Impulse Response Functions of U.S. core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c)

Source: Results obtained by econometric software R, own elaboration.

According to Figure C5.12, which presents the FEVD for the U.S. CPI, we observe that the oil-specific demand shock is responsible for a significant explanatory portion of approximately 30% from period 2 onwards, while oil supply shock promotes less significant contribution, more notorious at the end of the first quarter. As expected, the core CPI also has a notorious explanatory power, which becomes more significant in the 3rd month, reaching almost 20%. There are no significant changes throughout the year. Concerning the FEVD for the core CPI, oil supply shocks contribute considerably, mainly at the end of the first quarter of approximately 10%. A slight contribution of the CPI is also observable but not very significant. These results remain constant over the remaining months, with no differences in the long-term.

Through the Granger Causality Test, in Table D5.15, we observed that the Global Price of Brent Crude, in U.S. dollars, granger causes CPI with a significance level of 5%. However, the opposite is not verified concluding that there is only a unidirectional causal relationship between these two variables. In turn, the Global Price of Brent Crude does not granger cause core CPI, however, this last indicator contributes to estimating the oil price.

Despite Shapiro (2022) highlighting the idea that supply dominates inflation, demand continues to assume greater importance in post-COVID periods. In consumer prices, we can see that supply and demand factors continue to promote increases in the general price level, with no significant differences between both in the analyzed European countries. In turn, inflation in the United States is essentially derived from the oil-specific demand, with little impact on the supply side.

5.3. Impulse Response Analysis: PPI

5.3.1. Germany

The optimal number of lags was determined based on the SIC. After we determined the SVAR(1), the respective IRFs for Germany were calculated, as shown in Figure 5.13.

Through the observation of Figure 5.13 (a), there is a positive effect of PPI response to oil supply shocks at an early stage, reaching close to 1% in the initial month, however, the impact is not persistent and statistically significant over the time horizon. We can also observe an opposite behavior of the CPI and core CPI after the occurrence of the same shock, which assumes an initial negative impact and is more volatile than that of the PPI.

Figure 5.13 (b) shows a growth in the PPI up to 2 months after positive aggregate demand shocks, reaching 2%, followed by a gradual decrease, which led to an insignificant effect on PPI from 6 months onwards. We can conclude that the PPI and both the CPI and core CPI indicators assume slightly different reactions since the latter oscillate around zero over the time horizon, however, these shocks do not promote significant inflationary impacts on any of them.

Figure 5.13 (c) shows the transmission of the oil-specific demand shocks to producer prices, which promotes a more pronounced inflationary impact, exceeding 15% after an initial shock. Although this impact is statistically significant, it does not promote persistent consequences on the German economy. In this sense, we conclude that the transmission of the oil-specific demand shocks assumes a more noticeable impact when compared to the remaining. We can also verify that the reaction of the PPI is more pronounced and less volatile after these types of shocks than in the CPI and core CPI.

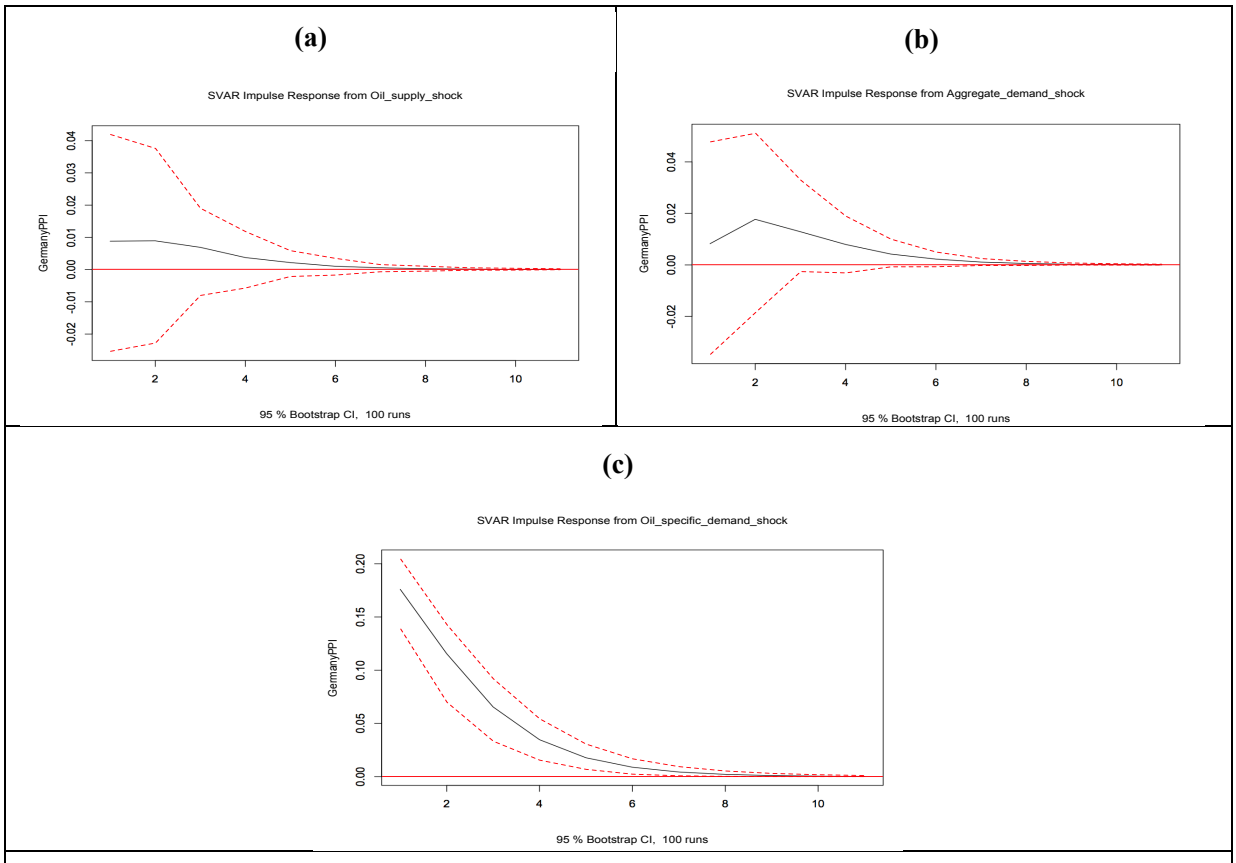


Figure 5.13 - Impulse Response Functions of Germany PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c)

Source: Results obtained by econometric software R, own elaboration.

The FEVD depicted in Figure C5.14 confirmed the strong explanatory share of the oil-specific demand shock, which is responsible for 30%. In the long-term, there are no significant

differences, concluding that oil price shocks assume a greater contribution. Comparing the FEVDs from the producer and consumer perspective in Germany, we observe that the weight relating to supply and demand shocks differs markedly. Contrary to what is observed in the PPI, oil-specific demand shocks are not significant in the variability of the CPI and core CPI, standing out only oil supply and aggregate demand shocks.

Finally, we analyze the causal relationship between the Global Price of Brent Crude and the German PPI. According to the Granger Causality Test, as shown in Table D5.16, with order 3, it is concluded that the Global Price of Brent Crude granger causes PPI. The reverse is also verifiable, which means that there is a bidirectional causal relationship between the two variables. The same is observable between the Global Price of Brent Crude and the German CPI, however the same is not verified for the core CPI, since it does not establish causality with the price of oil.

5.3.2. France

According to the SIC, the optimal lag length is 1, so we determined the SVAR(1) for France's PPI, as shown in Figure 5.15.

It is possible to verify through Figure 5.15 (a) that oil supply shocks promote a temporary negative behavior on the PPI, converging to zero after 4 months. In this sense, the supply side assumes less statistically significant impact on the producer prices, when compared to CPI and core CPI.

In turn, the dynamic response of the producer prices after aggregate demand shocks is observed in Figure 5.15 (b), which was close to 6% in the first phase. After a positive initial shock, the effect shows a gradual decrease, becoming insignificant after 6 months. It is observable, in this way, a positive impact after these shocks on the PPI and both the CPI and core CPI, however, it is short-lived.

Figure 5.15 (c) shows a more lasting and significant transmission of the oil-specific demand shocks on the PPI when compared to the remaining, contributing to an initial increase in inflation reaching approximately 30%. Once again it is confirmed a more impactful scenario for inflation due to variations in the oil-specific demand shocks. Furthermore, the producer prices are more reactive to this type of shock than consumer ones.

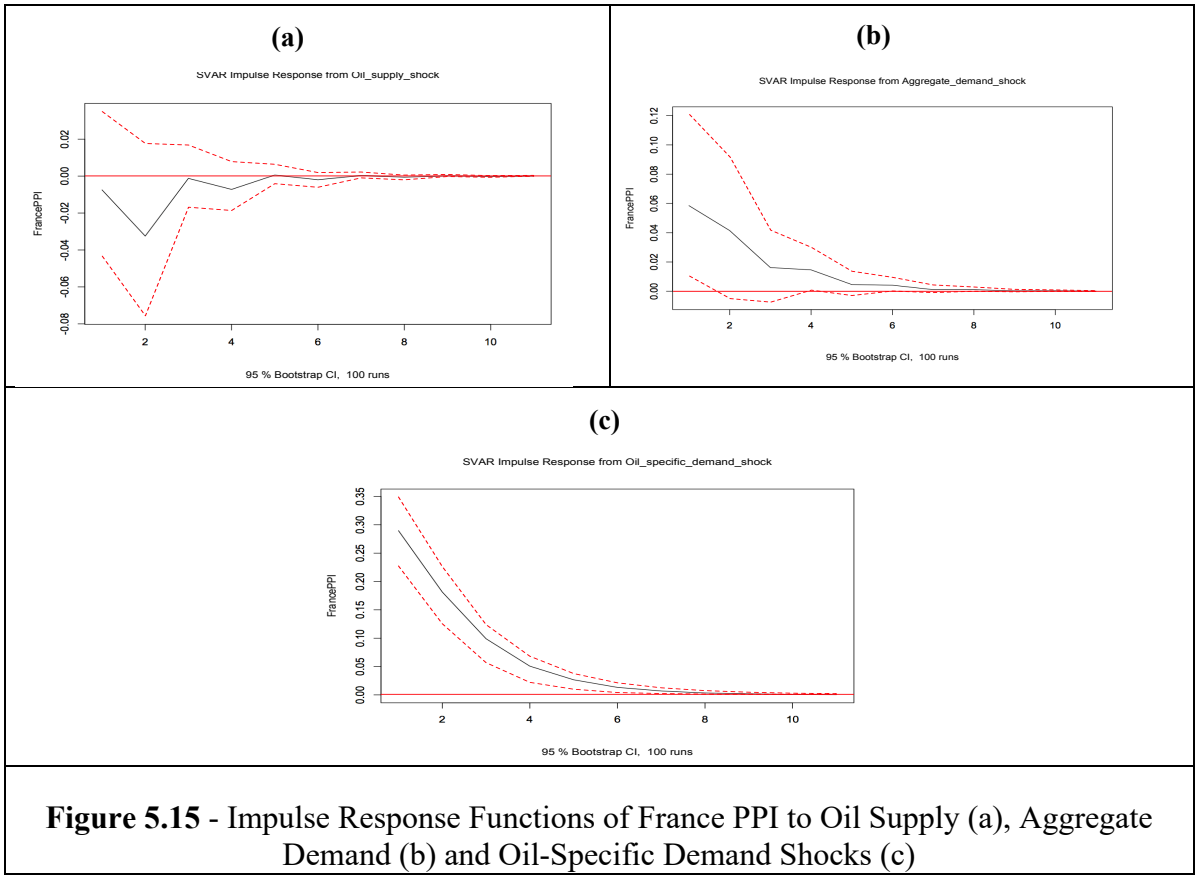


Figure 5.15 - Impulse Response Functions of France PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c)

Source: Results obtained by econometric software R, own elaboration.

Through Figure C5.16, where FEVD for PPI is presented, we observe that approximately 40% is explained by oil-specific demand shock throughout the year. There are no significant differences in the short and long-term. In comparison with FEVDs in the consumer perspective, we see a strong sensitivity of the PPI to oil-specific demand shocks that are not observed in the CPI and core CPI to the same extent. While in the CPI variation, this shock only assumes a share of 5%, in the core CPI it does not present a sufficiently notorious weight. These last two indicators also derive an explanatory share of the oil supply shocks, which does not occur in the PPI.

According to the Granger Causality Test, as shown in Table D5.17, there is no causal relationship between the price of oil and the PPI. Contrary to expectations, a causality relation with the price of oil is verifiable only in consumer prices.

5.3.3. Portugal

For Portugal, we determined SVAR(1), defined by the SIC as the optimal lag length, as shown in Figure 5.17.

According to the impulse response observed in Figure 5.17 (a), the transmission of oil supply shocks in the PPI causes a negative effect instantaneously. Despite a more accentuated upward trend of inflation during the 2-3 months, achieving close to 4%, this effect tends to disappear in the long-term. The supply side promotes oscillating and insignificant inflationary effects in both producer and consumer prices.

Figure 5.17 (b) shows that an increase in aggregate demand promotes a significant increase in inflation only from period 2, reaching approximately 15%. This impact is accentuated, although short-lived, gradually converging to zero. Despite the impact of aggregate demand being more visible and positive on the CPI and core CPI in the initial phase, the PPI reveals more pronounced effects in the subsequent period.

Through Figure 5.17 (c) verified a significant response of PPI after an initial oil-specific demand shock, reaching approximately 40% up to 2 months. Once again, a more reactive behavior of the PPI has confirmed aftershocks in the oil-specific demand than in consumer prices, which reveal little significant effects. Based on these dynamic responses, the demand side has a greater impact on the PPI in Portugal compared to the supply one, with a greater highlight for the oil-specific demand shock.

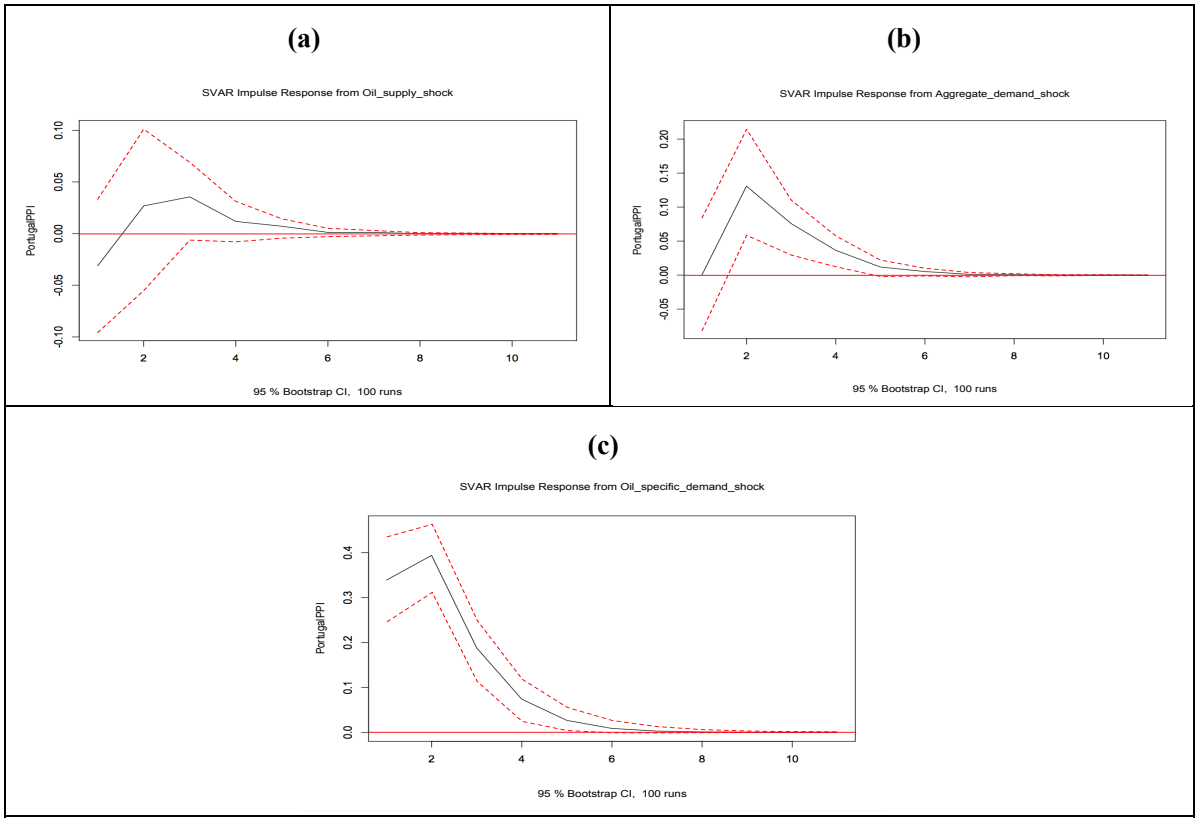


Figure 5.17 - Impulse Response Functions of Portugal PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c)

Source: Results obtained by econometric software R, own elaboration.

According to Figure C5.18, the FEVD for the PPI is presented, through which we verify that oil-specific demand shock assumes greater explanatory power over the year, contributing close to 40% to changes in the producer prices after 2 months. Contrary to the PPI, the CPI and core CPI are mostly explained by oil supply and aggregate demand shocks with no notable contribution of oil-specific demand shocks. A marked discrepancy in the weights of each shock in the variation of consumer and producer prices is confirmed.

As we can observe in Table D5.18, the causal relationship between the price of oil and the PPI is only unidirectional, as the Global Price of Brent Crude Granger causes PPI but the reverse is not verified. In turn, there is no causality between the Global Price of Brent Crude and both CPI and core CPI indicators, confirming a more expressive relationship between oil prices and producer prices in Portugal.

5.3.4. United States

Regarding the United States, the SVAR(1) was determined as we can see in Figure 5.19. The optimal lag length was based on the HIQ and SIC.

Figure 5.19 (a) shows that oil supply shocks have an instantaneous and temporary negative impact on the PPI, however, it is statistically insignificant. It is confirmed an initial negative impact in the PPI and both the CPI and core CPI, however more pronounced and less volatile from the producer's point of view.

An opposite scenario is also observed in Figure 5.19 (b) after positive aggregate demand shocks which promote, as expected, an increase in inflation instantaneously, exceeding 10%. This impact is not persistent, assuming a null effect in after 5 months. We thus verify that aggregate demand shocks have a more considerable impact on the PPI than on the CPI and core CPI, which despite becoming more significant over the time horizon, the effects on consumer prices are not so noticeable.

Figure 5.19 (c) shows the transmission of the oil-specific demand shocks in producer prices, which promote a more impactful and significant effect, reaching close to 50%. Once again inflation response confirmed a significant impact at an early stage that tends to disappear in the long-term. This shock, as observed in other countries, has a visibly more prominent impact on the PPI compared to the CPI and the core CPI. Through these results, we see that there is a positive relationship between U.S. inflation and oil price volatility during the period under analysis, which goes against the idea of Castillo et al. (2020) that this ratio had declined since 2002.

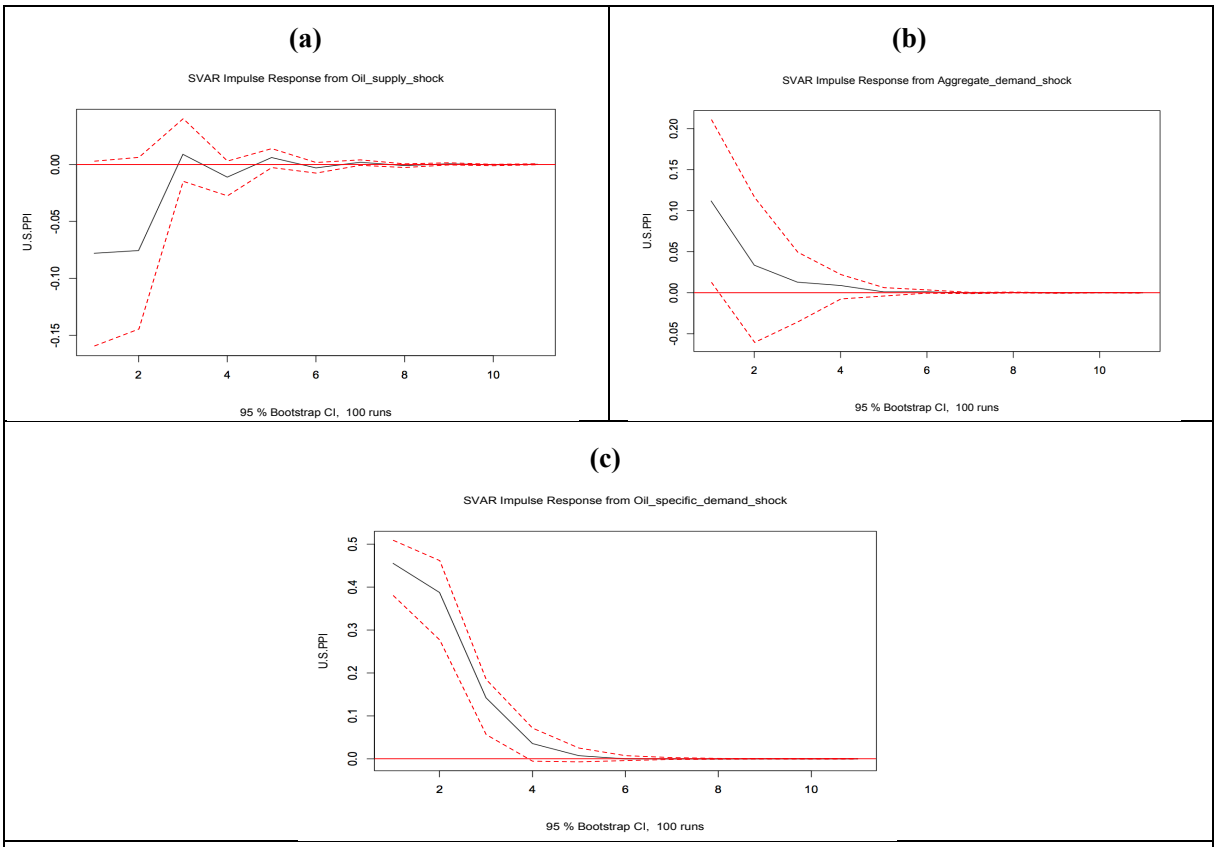


Figure 5.19 - Impulse Response Functions of U.S. PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c)

Source: Results obtained by econometric software R, own elaboration.

The FEVD for the inflation of the United States, as can be seen in Figure C5.19, shows a significant weight of the oil-specific demand shock in the contribution to the variation of the producer prices, reaching close to 60%. In this way, we verify that the oil-specific demand shock assumes a dominant power in the U.S. producer price level, becoming more pronounced during the first quarter. Once again, we observe different impacts of shocks on producer and consumer prices, since there is a larger contribution of oil supply to consumer prices.

Through the Granger Causality Test, shown in Table D5.19, we observed the existence of a unidirectional causal relationship, since the Global Price of Brent Crude Granger causes PPI, however the same does not happen in the opposite situation. A similar scenario arises with the U.S. CPI, however, in core CPI, only the inflation indicator contributes to estimating the Global Price of Brent Crude. As expected, a strong sensitivity of both inflation indicators, PPI and CPI, is verified to oil price variations, revealing a crucial factor in determining the general level of prices in the U.S. economy.

5.4. Main Conclusions

According to the results obtained from the transmission of different shocks to the CPI and the core CPI, we highlight the main points. The first one is related to the oil supply shock, which promotes a more significant impact on consumer prices in Germany and France when compared to the other shocks in both CPI and core CPI, with a more expressive impact in the latter. In this way, we observe that the supply side assumes a greater relevance in inflation in France, as defended by Wen et al. (2021). The other point to take into account is the relevance of the demand side, which is more pronounced in Portugal and in the United States: (i) in the case of Portugal, aggregate demand shocks stand out with a more expressive explanatory share in both CPI and core CPI while (ii) in the U.S. country, a pronounced contribution to the variability of the CPI is explained by the oil-specific demand shock. In addition, the oil-specific demand shock promotes more accentuated impacts only on the CPI of the United States and France, with emphasis on the former. In this way, and contrary to what Le Blanc and Chinn (2004) argue, the U.S. stands out from European countries with regard to the effects caused by the volatility of oil prices on inflation. Another important point refers to the behavior of the CPI and the core CPI, which differs between countries with a more significant and persistent impact from oil price volatility in the former in France, contrary to what happens in Portugal and the United States, where the core CPI stands out with more persistent effects. In Germany, although the impact of changes in oil prices is more noticeable on core inflation, it is less lasting when compared to the CPI. Kilian and Zhou (2022) state that the effects are more significant and less persistent in headline inflation than in the core, however the same is not true in Germany and France. We can also conclude that the majority of external shocks in these two countries promote a greater percentage amplitude and, in turn, greater volatility in core inflation, which contradicts the idea argued by Hijazine and Al-Assaf (2022) and by Bodenstein et al. (2008). There is also a strong correlation between the CPI and the core CPI since the latter derives mostly from shocks to the CPI.

Concerning the results relating to the PPI, we were able to conclude some relevant points: firstly, the oil-specific demand shock has a more pronounced impact on inflation and is the one that contributes most significantly to the fluctuations in the PPI in all countries when compared to the other shocks, with emphasis on U.S and Portugal. Another point to highlight is the oil supply shock, which promotes statistically less significant effects on the PPI, and aggregate demand shocks, which are slightly significant but do not impact the PPI as noticeably as the oil-specific demand. In this sense, we observe that the demand side has a greater impact on the

PPI than the supply one. Subsequently, we find that inflation in Portugal behaves differently than in other countries, since the impact of oil shocks on the PPI is not immediate, becoming more significant over the time horizon, as is the case of aggregate and oil-specific demand shocks. This behavior promotes a more volatile general level of producer prices in Portugal when compared to France and Germany. According to Esteves and Neves (2004), the greater sensitivity of Portuguese inflation to oil shocks can be explained by a strong dependence on oil imports and a high degree of openness in the economy. This strong link with international trade assumes greater vulnerability to external shocks.

Through the results obtained, we conclude the existence of different responses from producer and consumer prices, more perceptible the strong sensitivity of the PPI to increases in the price of oil than that verified in the CPI in all the countries analyzed, a scenario identical to that which occurred in Malaysia (Sek, 2022), as well as in Indonesia and Thailand (Husaini & Lean, 2021). Finally, and contrary to expectations in this critical period that we are currently experiencing, the impacts of the oil shocks on both inflation indicators are evident and more significant only in the short-term, becoming statistically insignificant in the long-term. Therefore, we confirm little persistence of the inflationary effects resulting from oil price shocks, coinciding with the conclusions defended by Brief (2022) and Kilian and Zhou (2022).

There are some possible reasons that could explain the main conclusions mentioned above. Energy intensity is pointed out, by many previous articles, as one of the main explanatory reasons for the impact of oil price volatility on inflation and more specifically in the U.S. (LeBlanc & Chinn, 2004; Van den Noord & André, 2007; Barrel & Pomerantz, 2008; Renou-Maissant, 2019; Wen et al., 2021; Kpodar & Liu, 2022).

There is also a strong dependence on imports of fossil fuels in European countries, as is the case of oil, coal and natural gas, however, a greater focus on renewable energy is expected over the coming years, which will contribute to greater energy autonomy for Europe (Parlamento Europeu, 2023). Also concerning European countries, the sanctions imposed on oil exports from Russia due to its invasion of Ukraine promoted a greater restriction on the supply of this raw material, which may explain the more pronounced impact of shocks on the oil supply in the CPI and the core CPI. However, curiosity focuses on the fact that the oil supply does not have such a noticeable impact on the PPI. In turn, the inability of supply to respond to the increases in demand that emerged with the post-pandemic economic recovery promotes, as expected, a significant impact of aggregate demand shock in both PPI and CPI.

Lastly, the credibility of the monetary policy of central banks may be a key reason for the different responses of inflation to variations in the price of oil between countries (Van den

Noord & André, 2007; Bachmeier & Cha, 2011; Choi et al., 2018; Renou-Maissant, 2019; Castillo et al., 2020; Baba & Lee, 2022; Kpodar & Liu, 2022; Sek, 2022), which through interest rates help to contain inflationary effects, contributing to a more sustainable economic growth in the long-term.

5.5. Robustness Checks

To validate the effectiveness of the results obtained previously, we tested the remaining possible orders of the variables in the model, more specifically in the reduced form of the errors. The combinations are identified by the following numbering: Order 1 (Crude Oil Production (COP), Global Price of Brent Crude (GBC), World Industrial Production (WIP) and inflation metrics (CPI and core CPI or PPI)); Order 2 (WIP, COP, GBC and CPI and core CPI/PPI); Order 3 (WIP, GBC, COP and CPI and core CPI/PPI); Order 4 (GBC, WIP, COP and CPI and core CPI/PPI) and, finally, Order 5 (GBC, COP, WIP and CPI and core CPI/PPI). The results obtained can be found in the Appendix E.

Through them, we verify that different orders do not promote significant differences in consumer prices compared to the results obtained from the combination defined in section 4, except for the impact of aggregate demand shocks which differ slightly in the initial period, mainly when the Global Price of Brent Crude variable takes the first position (as is the case of Figures E5.32, E5.33, E5.37, E5.38, E5.42, E5.43, E5.47, E5.48 in the Appendix E), remaining similar over the time horizon in all analyzed countries. The same is verified in Portugal, i.e., CPI is more sensitive to changes after initial aggregate demand shocks, however, the core CPI is more susceptible to changes from initial oil-specific demand shocks. In any case, oil supply continues to be the type of shock that most contributes to CPI and core CPI volatility in European countries, while in the U.S. this shock assumes greater weight only in the core CPI, with oil-specific demand being more expressive in the CPI. In this way, we verify that despite small changes, there are no material differences regarding the level of statistical significance.

Regarding producer prices, it is observable a strong sensitivity to aggregate demand shocks, and also to oil supply shocks in the case of Portugal, verifying opposing behaviors to those observed previously in combinations where the Global Price of Brent Crude assumes the first position (Figures E5.52, E5.53, E5.57, E5.58, E5.62, E5.63, E5.67 and E5.68) as well as Crude Oil Production (Figures E5.49, E5.54, E5.59, E5.64), remaining negative and statistically more significant over the time horizon. However, in all cases we verified that oil-specific demand shocks assume a greater weight in PPI variability. It should be noted that from the producer's

point of view, there are no changes in the United States regarding the results obtained in most of the combinations made.

6. Conclusion

The main objective of this dissertation is to analyze the impact of the oil price on the inflation of Germany, France, Portugal and the United States between 1990 and 2022. For a more robust analysis, two inflation measures are used to distinguish how oil price volatility can impact consumer and producer prices. To obtain more comprehensive results, we identify three different shocks, namely oil-specific demand, oil supply and aggregate demand, for an assessment of the main explanatory reasons that led to an exponential price increase in recent years. The producer price perspective, defined according to the PPI, is still little explored and valued, and this project serves to clarify the importance that this indicator assumes and how it stands out from the best-known inflation measure: CPI.

According to the analysis, we conclude in the first point that oil-specific demand causes a more evident impact on producer prices than consumer ones in all countries analyzed, emphasizing the United States in both PPI and CPI. From a European perspective, the PPI of Portugal differs from the other two countries, showing greater volatility in response to this type of shock.

The previous point leads us to conclude the existence of a greater sensitivity of the PPI to the volatility of oil prices when compared to the CPI, revealing a greater weight of this fossil fuel in the level of inflation. We also conclude the existence of some limitations of consumer prices in determining the real price level of an economy, being important central banks take into account different inflation metrics in order to adopt more effective monetary policies.

The third point focuses on oil supply, which has a less significant impact on producer prices, with slightly more noticeable effects on consumer ones, as in the case of the CPI for France and Germany.

With regard to the European countries analyzed, Portugal behaves differently from the others, not only in terms of the impact of shocks on the economy, with the demand side being more prominent, but also in terms of the response to them, which tends to be more pronounced over time. This behavior also highlights the great adversity of that country in the fight against inflation, with the strong dependence on foreign trade and, in particular, on imports of fossil fuels, being the main reasons that contribute to the strong volatility of the Portuguese economy. In this sense, the adoption of renewable energies becomes increasingly crucial, which despite having shown more significant growth in recent years, still represents a negligible share to overcome this dependence that translates into a great sensitivity to external shocks.

In the course of this empirical analysis, we were confronted with some limitations. Firstly, the objective was to use inflation indicators in their aggregate and disaggregated form, the core inflation, which was not possible for the Producer Price Index, since it could not be found for all the countries analyzed. Therefore, the analysis from the producer's perspective was not as extensive as intended.

Another caveat is the limitations of the model used. The SVAR method was chosen due to the possibility of including uncorrelated shocks, requiring the imposition of restrictions on the variance-covariance matrix of the errors. To this end, we decided to use the Cholesky Decomposition method, in which it is necessary to stipulate a certain order of the variables that, if changed, can compromise the final results. The initial order stipulated in section 4.3 was tested and the results changed slightly in some cases of the PPI, however, the final observations regarding the impact of the oil price on the producer price perspective remain, confirming the reliability of the results obtained.

Due to the importance that this topic assumes today and that will continue to assume in the coming years due to the impact that the most recent economic crisis has had worldwide, it is interesting to further analyze other components that can promote such high changes in inflation as is the case of the price of food and natural gas that have been quite volatile and, as such, promote a strong impact on the economy. Moreover, it would be pertinent to use another econometric method in order to mitigate the limitations mentioned above about the SVAR model. That analysis will be more valuable if different inflation indicators are used, in addition to the CPI and PPI, for a better understanding of the real impact of prices on the economy. Integrating more than one indicator into the analysis will help make it more complete, reflecting more substantiated results.

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Appendix A – Descriptive Statistics

Table A5.1 – COP, WIP and GBC - Correlation between the variables (in U.S. dollars)

	COP (U.S. dollars)	**WIP** (U.S. dollars)	**GBC** (U.S. dollars)
COP (U.S. dollars)	1	0.38	-0.07
WIP (U.S. dollars)		1	0.67
GBC (U.S. dollars)			1

Source: Results obtained by econometric software R, own elaboration.

Table A5.2 – Germany - Correlation between the variables (in U.S. dollars)

	Germany CPI	**Germany PPI**
COP (U.S. dollars)	0.39	0.37
WIP (U.S. dollars)	0.99	0.98
GBC (U.S. dollars)	0.65	0.71

Source: Results obtained by econometric software R, own elaboration.

Table A5.3 – France - Correlation between the variables (in U.S. dollars)

	France CPI	**France PPI**
COP (U.S. dollars)	0.39	0.29
WIP (U.S. dollars)	0.99	0.93
GBC (U.S. dollars)	0.66	0.83

Source: Results obtained by econometric software R, own elaboration.

Table A5.4 – Portugal - Correlation between the variables (in U.S. dollars)

	Portugal CPI	**Portugal PPI**
COP (U.S. dollars)	0.38	0.20
WIP (U.S. dollars)	0.99	0.92
GBC (U.S. dollars)	0.66	0.84

Source: Results obtained by econometric software R, own elaboration.

Table A5.5 – United States - Correlation between the variables (in U.S. dollars)

	U.S. CPI	**U.S. PPI**
COP (U.S. dollars)	0.39	0.35
WIP (U.S. dollars)	0.99	0.98
GBC (U.S. dollars)	0.66	0.75

Source: Results obtained by econometric software R, own elaboration.

Table A5.6 – Germany - Correlation between the variables (in euros)

	Germany CPI	**Germany PPI**
COP (in euros)	0.53	0.53
WIP	0.83	0.86
GBC	0.59	0.65

Source: Results obtained by econometric software R, own elaboration.

Table A5.7 – France - Correlation between the variables (in euros)

	France CPI	France PPI
COP	0.53	0.51
WIP	0.83	0.88
GBC	0.60	0.77

Source: Results obtained by econometric software R, own elaboration.

Table A5.8 – Portugal - Correlation between the variables (in euros)

	Portugal CPI	Portugal PPI
COP	0.53	0.41
WIP	0.83	0.90
GBC	0.60	0.78

Source: Results obtained by econometric software R, own elaboration.

Table A5.9 – United States - Correlation between the variables (in euros)

	U.S. CPI	U.S. PPI
COP	0.53	0.52
WIP	0.83	0.87
GBC	0.60	0.69

Source: Results obtained by econometric software R, own elaboration.

Table A5.10 – Standard deviation of the variables

Variables	Standard Deviation
GBC (in U.S. dollars)	22.377
GBC (in euros)	32.865
Germany CPI	13.294
Germany Core CPI	12.020
Germany PPI	11.382
France CPI	12.225
France Core CPI	10.755
France PPI	10.908
Portugal CPI	17.966
Portugal Core CPI	19.220
Portugal PPI	19.031
U.S. CPI	18.187
U.S. Core CPI	17.446
U.S. PPI	18.759

Source: Results obtained by econometric software R, own elaboration.

Appendix B – Dickey-Fuller Test

Table B5.11 – Dickey-Fuller Tests

Variables		**Test value**	**Critical Values** (5% of significance level)	**P-value**
COP (in U.S. dollars)	log	0.0374	-2.87	< 2.2e-16
COP (in U.S. dollars)	1st diff	-4.4882	-2.87	< 2.2e-16
COP (in Euro)	log	-0.927	-2.87	< 2.2e-16
COP (in Euro)	1st diff	-5.8583	-2.87	< 2.2e-16
WIP (in U.S. dollars)	log	-1.2329	-2.87	0.00144
WIP (in U.S. dollars)	1st diff	-5.7371	-2.87	< 2.2e-16
WIP (in Euro)	log	-1.1775	-2.87	0.5051
WIP (in Euro)	1st diff	-6.1973	-2.87	< 2.2e-16
GBC (in U.S. dollars)	log	-1.8008	-2.87	0.0002377
GBC (in U.S. dollars)	1st diff	2.2897	-2.87	< 2.2e-16
GBC (in Euro)	log	-1.7133	-2.87	4.397e-05
GBC (in Euro)	1st diff	-5.9515	-2.87	< 2.2e-16
Germany CPI	log	0.4387	-2.87	< 2.2e-16
Germany CPI	2st diff	-10.9878	-2.87	< 2.2e-16
Germany core CPI	log	-0.6563	-2.87	< 2.2e-16
Germany core CPI	2st diff	-12.727	-2.87	< 2.2e-16
Germany PPI	log	0.7972	-2.87	< 2.2e-16
Germany PPI	1st diff	-4.0871	-2.87	< 2.2e-16
France CPI	log	0.9458	-2.87	< 2.2e-16
France CPI	2st diff	-9.9937	-2.87	< 2.2e-16
France core CPI	log	0.1508	-2.87	< 2.2e-16

France core CPI	2st diff	-12.6433	-2.87	< 2.2e-16
France PPI	log	0.0253	-2.87	< 2.2e-16
France PPI	1st diff	-4.2517	-2.87	< 2.2e-16
Portugal CPI	log	0.937	-2.87	< 2.2e-16
Portugal CPI	2st diff	-8.0031	-2.87	< 2.2e-16
Portugal core CPI	log	-0.1131	-2.87	< 2.2e-16
Portugal core CPI	2st diff	-8.9948	-2.87	< 2.2e-16
Portugal PPI	log	-0.8644	-2.87	< 2.835e-15
Portugal PPI	1st diff	-4.4422	-2.87	< 2.2e-16
U.S. CPI	log	0.424	-2.87	< 2.2e-16
U.S. CPI	1st diff	-4.0531	-2.87	< 2.2e-16
U.S. core CPI	log	2.2897	-2.87	< 2.2e-16
U.S. core CPI	2st diff	-7.4001	-2.87	< 2.2e-16
U.S. PPI	log	0.1033	-2.87	4.189e-12
U.S. PPI	1st diff	-4.982	-2.87	< 2.2e-16

Source: Results obtained by econometric software R, own elaboration.

Appendix C – Forecast Error Variance Decomposition

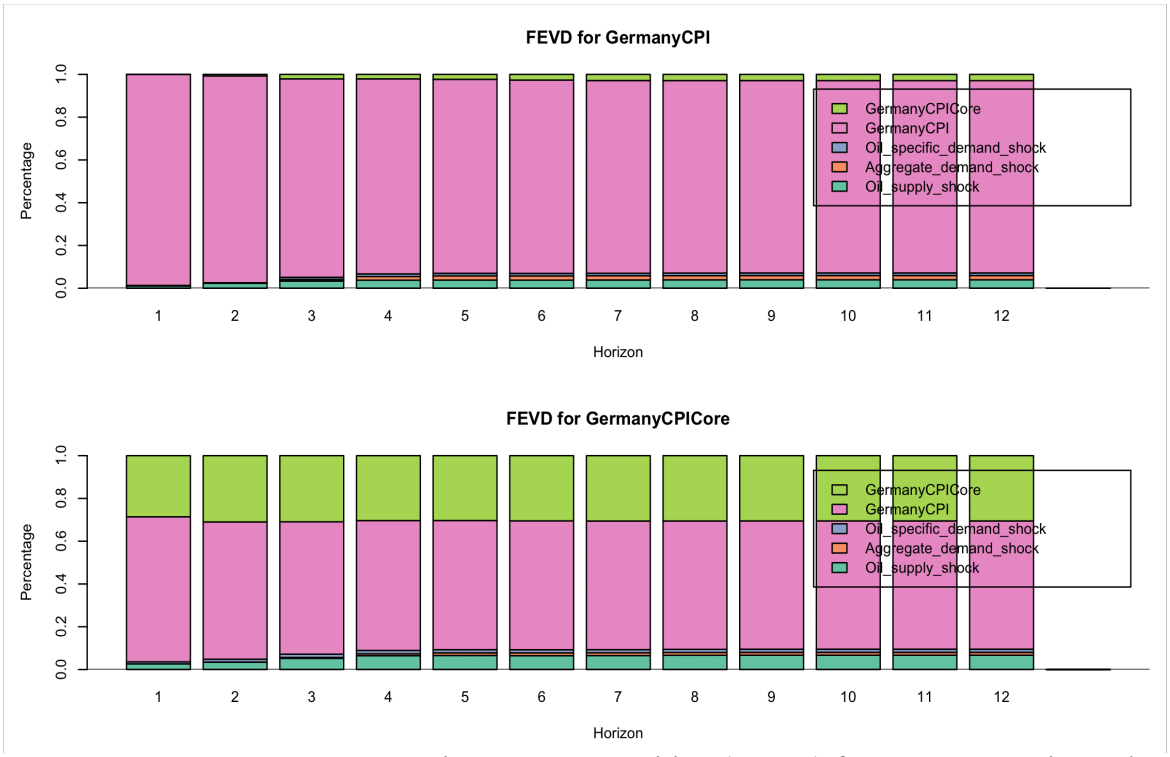


Figure C5.3 – Forecast Error Variance Decomposition (FEVD) for Consumer Price Index and core Consumer Price Index of Germany
(Source: Results obtained by econometric software R, own elaboration.)

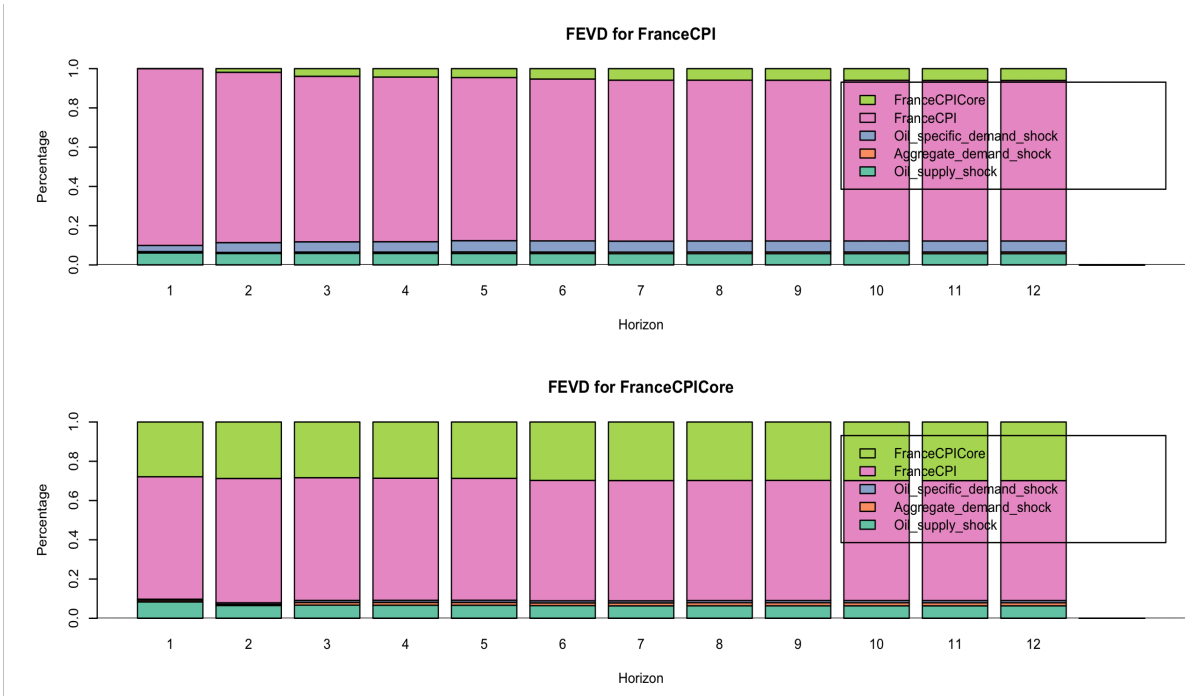


Figure C5.6 – Forecast Error Variance Decomposition (FEVD) for Consumer Price Index and core Consumer Price Index of France
(Source: Results obtained by econometric software R, own elaboration.)

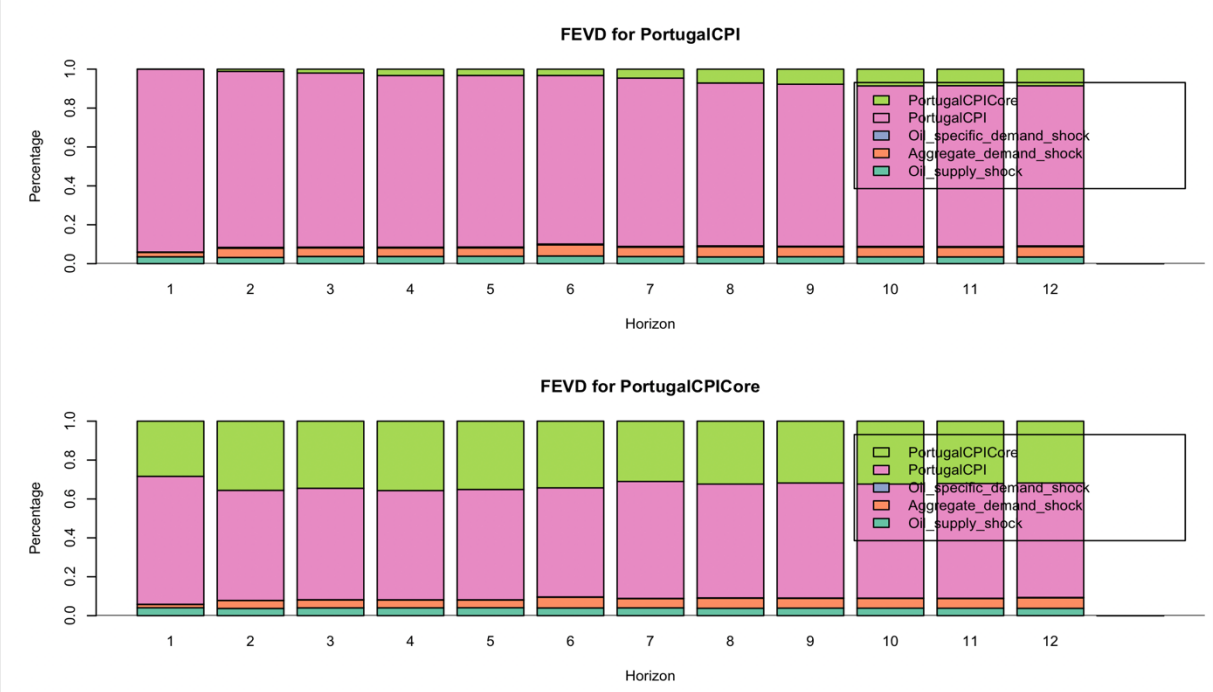


Figure C5.9 – Forecast Error Variance Decomposition (FEVD) for Consumer Price Index and core Consumer Price Index of Portugal
(Source: Results obtained by econometric software R, own elaboration.)

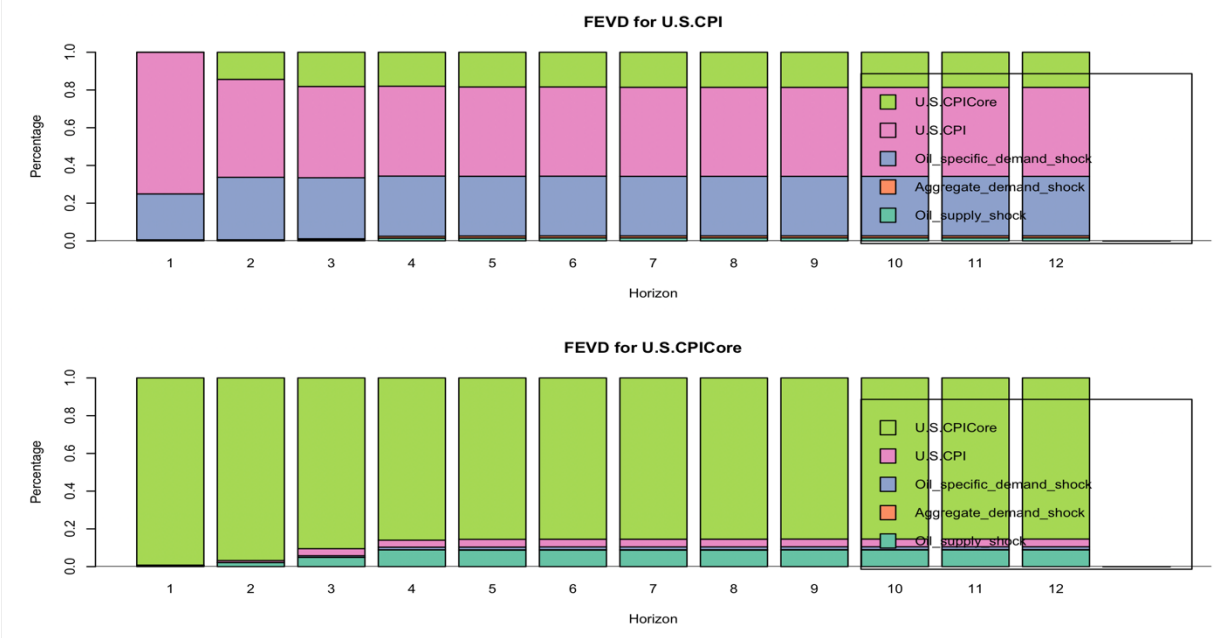


Figure C5.12 – Forecast Error Variance Decomposition (FEVD) for Consumer Price Index and core Consumer Price Index of United States
(Source: Results obtained by econometric software R, own elaboration.)

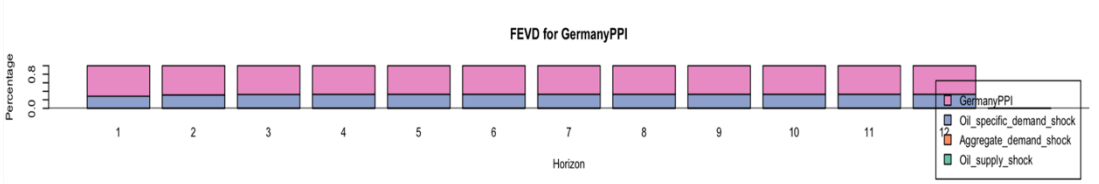


Figure C5.14 – Forecast Error Variance Decomposition (FEVD) for Producer Price Index of Germany
(Source: Results obtained by econometric software R, own elaboration.)

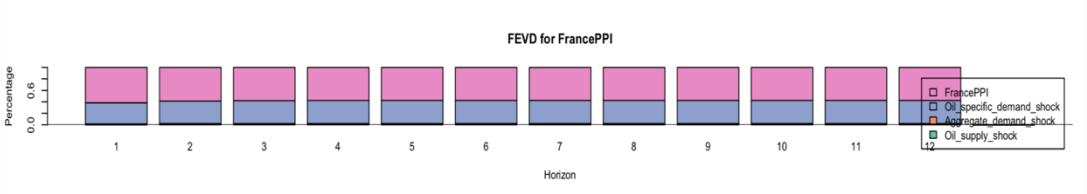


Figure C5.16 – Forecast Error Variance Decomposition (FEVD) for Producer Price Index of France
(Source: Results obtained by econometric software R, own elaboration.)

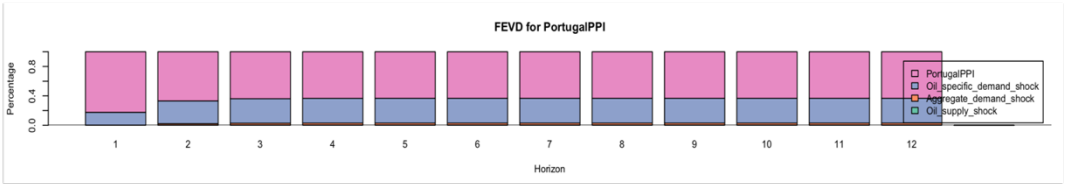


Figure C5.18 – Forecast Error Variance Decomposition (FEVD) for Producer Price Index of Portugal
(Source: Results obtained by econometric software R, own elaboration.)

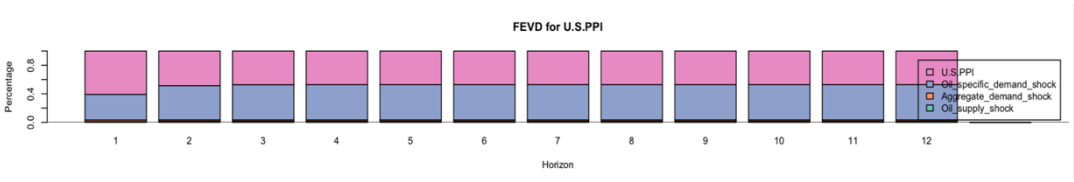


Figure C5.20 – Forecast Error Variance Decomposition (FEVD) for Producer Price Index of United States
(Source: Results obtained by econometric software R, own elaboration.)

Appendix D – Granger Causality Test

Table D5.12 – Granger Causality Tests for consumer prices of Germany

Null Hypothesis	Order	F-test	P-value
GBC does not cause Germany CPI	1	5.5558	0.01891 *
	3	2.065	0.1044
Germany CPI does not Granger cause GBC	3	5.3358	0.001304
GBC does not cause Germany core CPI	1	1.0096	0.3156
	3	0.1556	0.926
Germany core CPI does not cause GBC	3	0.5212	0.6679

* indicate the rejection of the null hypothesis in 5% of significance level.
Source: Results obtained by econometric software R, own elaboration.

Table D5.13 – Granger Causality Tests for consumer prices of France

Null Hypothesis	Order	F-test	P-value
GBC does not cause France CPI	1	15.308	0.0001077
	3	9.5592	4.203e-06
France CPI does not Granger cause GBC	3	8.6693	1.401e-05
GBC does not cause France core CPI	1	0.5083	0.4763
	3	4.4378	0.004413
France core CPI does not cause GBC	3	0.434	0.7288

Source: Results obtained by econometric software R, own elaboration.

Table D5.14 – Granger Causality Tests for consumer prices of Portugal

Null Hypothesis	Order	F-test	P-value
GBC does not cause Portugal CPI	1	2.0274	0.1553
	3	0.5645	0.6387
Portugal CPI does not Granger cause GBC	3	0.6193	0.6029
GBC does not cause Portugal core CPI	1	0.092	0.7618
	3	0.2256	0.8786
Portugal core CPI does not cause GBC	3	0.3191	0.8116

Source: Results obtained by econometric software R, own elaboration.

Table D5.15 – Granger Causality Tests for consumer prices of United States

Null Hypothesis	Order	F-test	P-value
GBC does not cause United States CPI	1	32.875	1.964e-08
	3	9.3812	5.346e-06
United States CPI does not Granger cause GBC	3	0.7826	0.5042
GBC does not cause United States core CPI	1	2.9676	0.08574 **
	3	1.2649	0.2861
United States core CPI does not cause GBC	3	3.7582	0.01106 *

* and ** indicate the rejection of the null hypothesis in 5% and 10% of significance level, respectively.
Source: Results obtained by econometric software R, own elaboration.

Table D5.16 – Granger Causality Tests for producer prices of Germany

Null Hypothesis	Order	F-test	P-value
GBC does not cause Germany PPI	1	1.9767	0.1605
	3	3.4251	0.0173 *
Germany PPI does not Granger cause GBC	1	2.2214	0.1369
	3	2.5943	0.05228 **

* and ** indicate the rejection of the null hypothesis in 5% and 10% of significance level, respectively.
Source: Results obtained by econometric software R, own elaboration.

Table D5.17 – Granger Causality Tests for producer prices Index of France

Null Hypothesis	Order	F-test	P-value
GBC does not cause France PPI	1	0.7274	0.3943
	3	1.6395	0.1798
France PPI does not Granger cause GBC	3	0.8349	0.4753

Source: Results obtained by econometric software R, own elaboration.

Table D5.18 – Granger Causality Tests for producer prices of Portugal

Null Hypothesis	Order	F-test	P-value
GBC does not cause Portugal PPI	1	54.731	8.479e-13
	3	20.523	2.33e-12
Portugal PPI does not Granger cause GBC	3	0.6489	0.5841

Source: Results obtained by econometric software R, own elaboration.

Table D5.19 – Granger Causality Tests for producer prices of United States

Null Hypothesis	Order	F-test	P-value
GBC does not cause United States PPI	1	43.192	1.584e-10
	3	15.805	1.032e-09
United States PPI does not Granger cause GBC	1	3.1697	0.07579 **

** indicate the rejection of the null hypothesis in 10% of significance level.

Source: Results obtained by econometric software R, own elaboration.

Appendix E – Robustness Checks

Equation E9 – Order 1- COP in the first position, followed by GPC and WIP

$$v_t = \begin{pmatrix} v_t^{COP} \\ v_t^{GPC} \\ v_t^{WIP} \\ v_t^{\pi} \\ v_t^{\pi^{Core}} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{Oil\ Supply\ Shock} \\ \varepsilon_t^{Oil-Specific\ Demand\ Shock} \\ \varepsilon_t^{Aggregate\ Demand\ Shock} \\ \varepsilon_t^{4} \\ \varepsilon_t^{5} \end{pmatrix} \quad (9)$$

Equation E10 – Order 2 - WIP in the first position, followed by COP and GPC

$$v_t = \begin{pmatrix} v_t^{WIP} \\ v_t^{COP} \\ v_t^{GPC} \\ v_t^{\pi} \\ v_t^{\pi^{Core}} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{Aggregate\ Demand\ Shock} \\ \varepsilon_t^{Oil\ Supply\ Shock} \\ \varepsilon_t^{Oil-Specific\ Demand\ Shock} \\ \varepsilon_t^{4} \\ \varepsilon_t^{5} \end{pmatrix} \quad (10)$$

Equation E11 – Order 3 - WIP in the first position, followed by GPC and COP

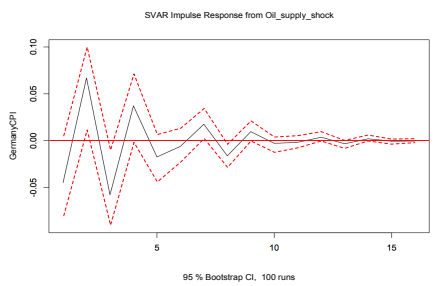
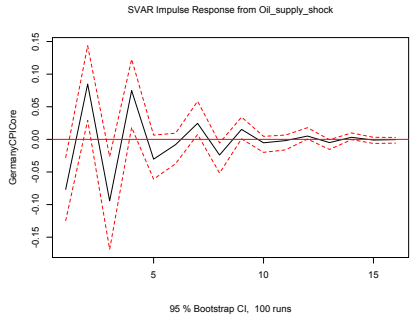
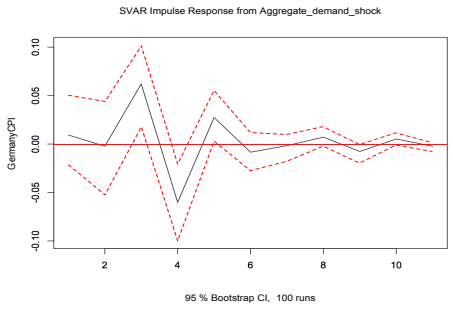
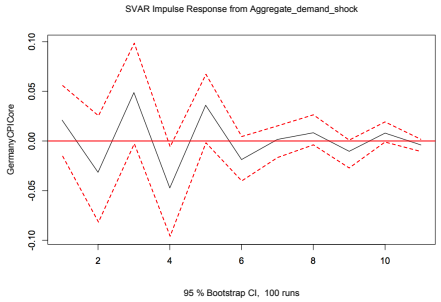
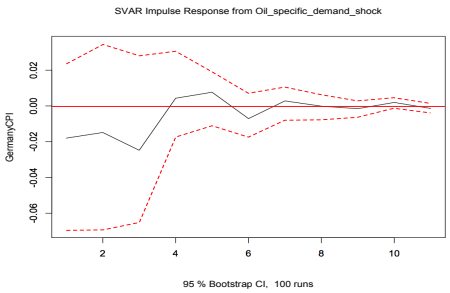
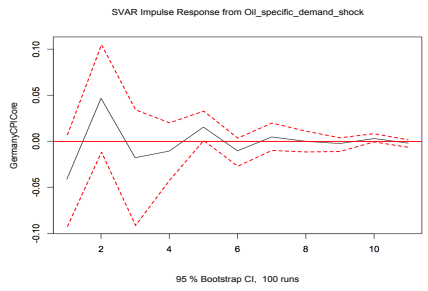
$$v_t = \begin{pmatrix} v_t^{WIP} \\ v_t^{GPC} \\ v_t^{COP} \\ v_t^{\pi} \\ v_t^{\pi^{Core}} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{Aggregate\ Demand\ Shock} \\ \varepsilon_t^{Oil-Specific\ Demand\ Shock} \\ \varepsilon_t^{Oil\ Supply\ Shock} \\ \varepsilon_t^{4} \\ \varepsilon_t^{5} \end{pmatrix} \quad (11)$$

Equation E12 – Order 4 - GPC in the first position, followed by COP and WIP

$$v_t = \begin{pmatrix} v_t^{GPC} \\ v_t^{COP} \\ v_t^{WIP} \\ v_t^{\pi} \\ v_t^{\pi^{Core}} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{Oil-Specific\ Demand\ Shock} \\ \varepsilon_t^{Oil\ Supply\ Shock} \\ \varepsilon_t^{Aggregate\ Demand\ Shock} \\ \varepsilon_t^{4} \\ \varepsilon_t^{5} \end{pmatrix} \quad (12)$$

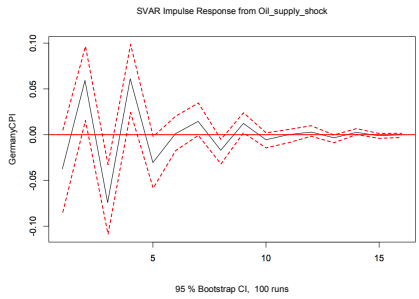
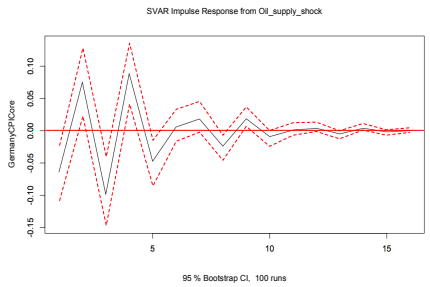
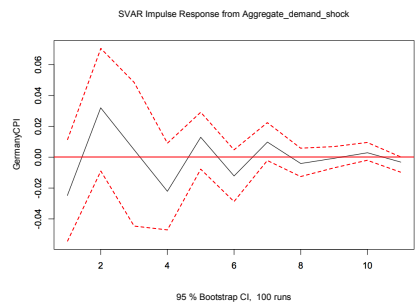
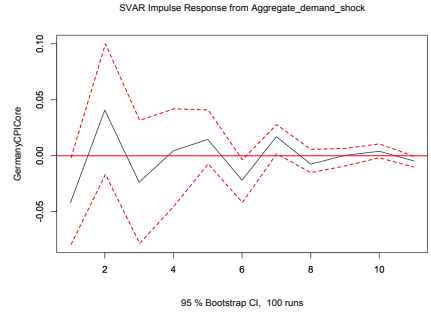
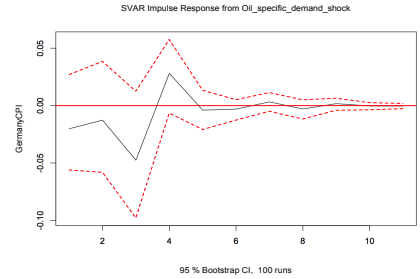
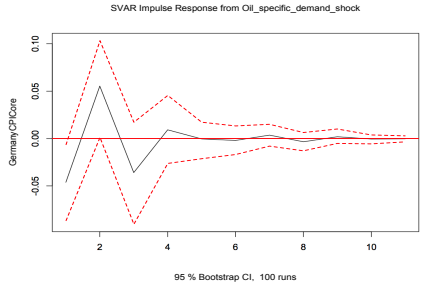
Equation E13 – Order 5 - GPC in the first position, followed by WIP and COP

$$v_t = \begin{pmatrix} v_t^{GPC} \\ v_t^{WIP} \\ v_t^{COP} \\ v_t^{\pi} \\ v_t^{\pi^{Core}} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{Oil-Specific\ Demand\ Shock} \\ \varepsilon_t^{Aggregate\ Demand\ Shock} \\ \varepsilon_t^{Oil\ Supply\ Shock} \\ \varepsilon_t^{4} \\ \varepsilon_t^{5} \end{pmatrix} \quad (13)$$

Impulse Response Functions of Germany CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of Germany core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

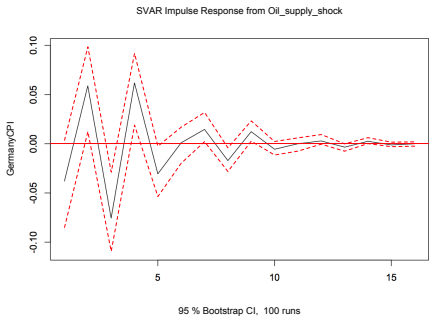
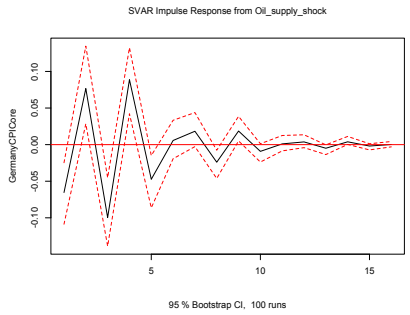
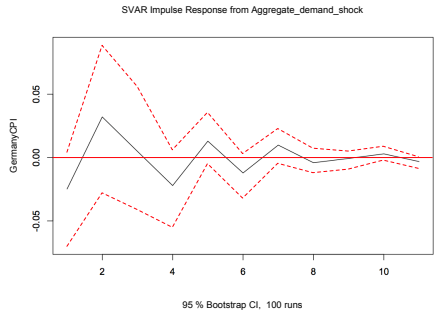
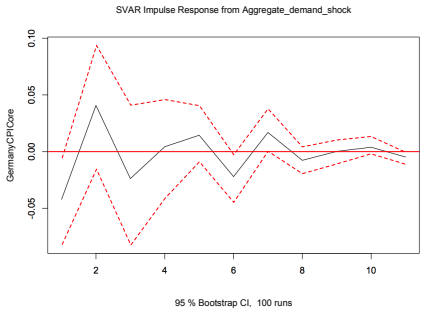
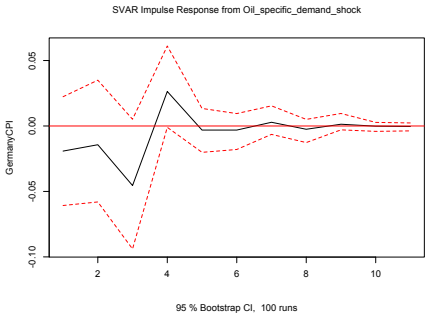
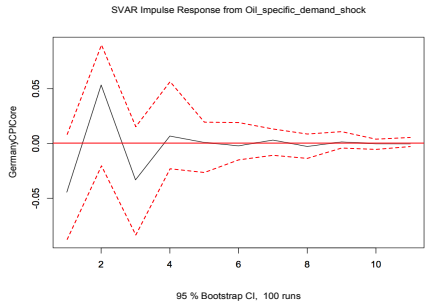
* Order of the variables: COP, GBC, WIP, Germany CPI and Germany core CPI.

Figure E5.29 – Impulse Response Functions of Germany CPI and core CPI with Order 1 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of Germany CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of Germany core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a)	**(a)**
	
(b)	**(b)**
	
(c)	**(c)**
	

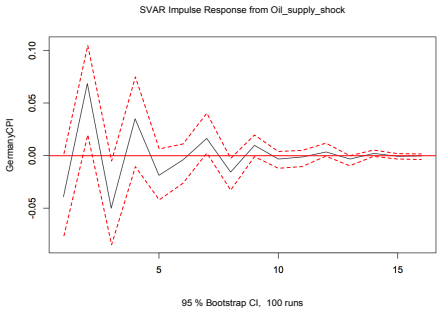
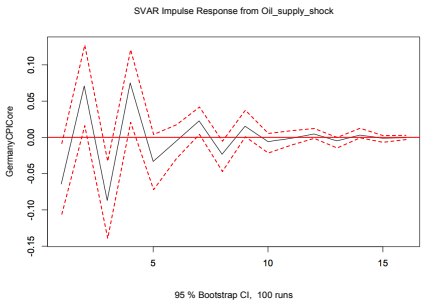
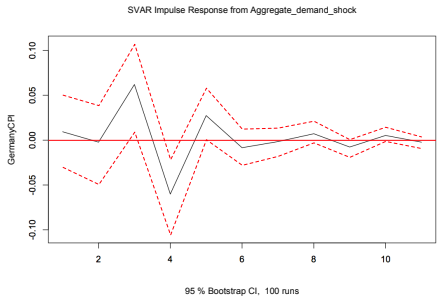
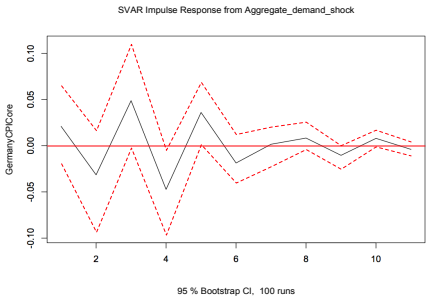
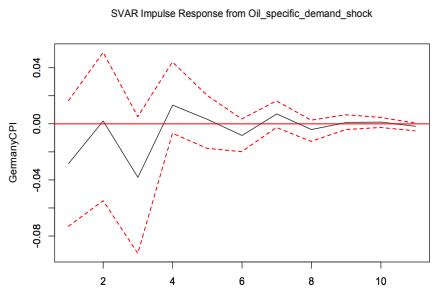
* Order of the variables: WIP, COP, GBC, Germany CPI and Germany core CPI.

Figure E5.30 – Impulse Response Functions of Germany CPI and core CPI with Order 2 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of Germany CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of Germany core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a)	**(a)**
	
(b)	**(b)**
	
(c)	**(c)**
	

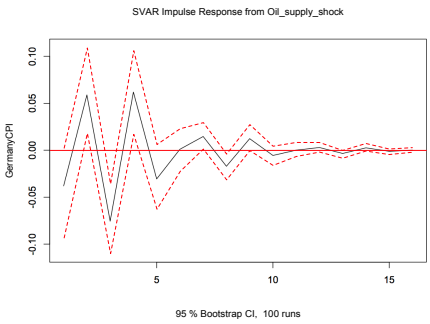
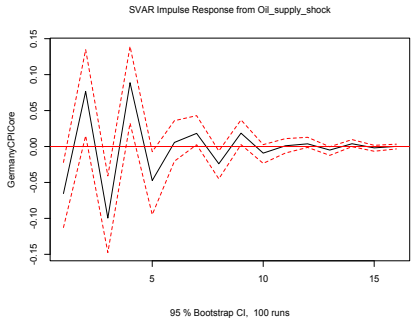
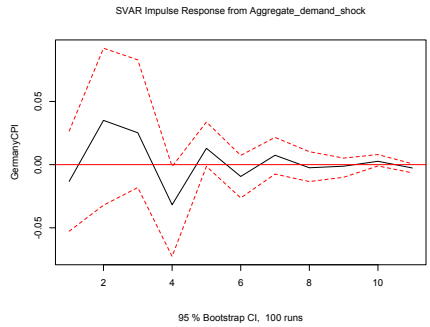
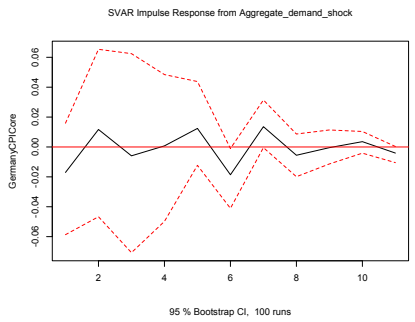
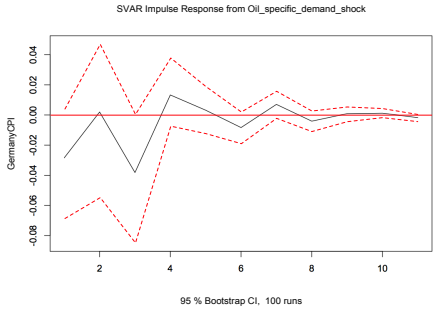
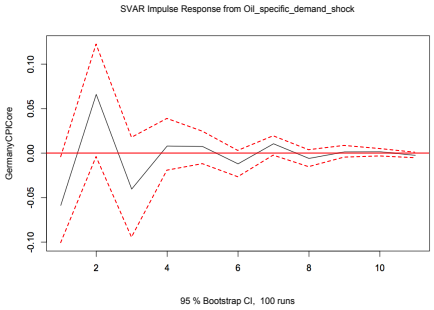
* Order of the variables: WIP, GBC, COP, Germany CPI and Germany core CPI.

Figure E5.31 – Impulse Response Functions of Germany CPI and core CPI with Order 3 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of Germany CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of Germany core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a)	**(a)**
	
(b)	**(b)**
	
(c)	**(c)**
	

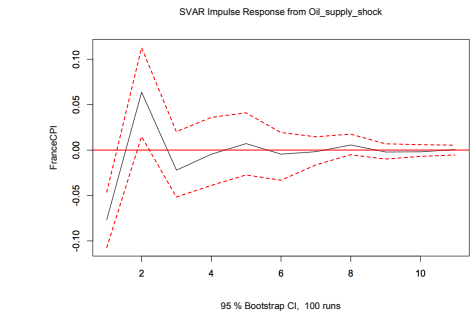
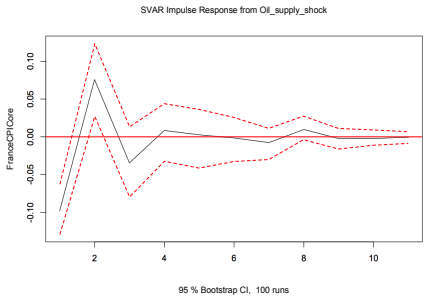
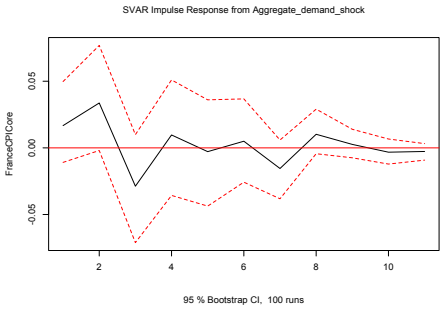
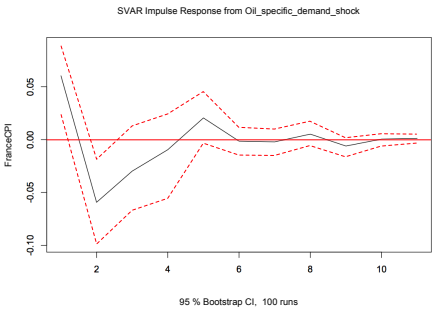
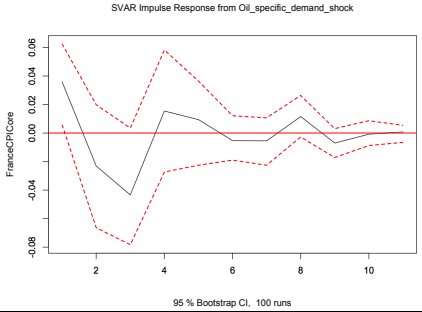
* Order of the variables: GBC, COP, WIP, Germany CPI and Germany core CPI.

Figure E5.32 – Impulse Response Functions of Germany CPI and core CPI with Order 4 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of Germany CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of Germany core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a)	**(a)**
	
(b)	**(b)**
	
(c)	**(c)**
	

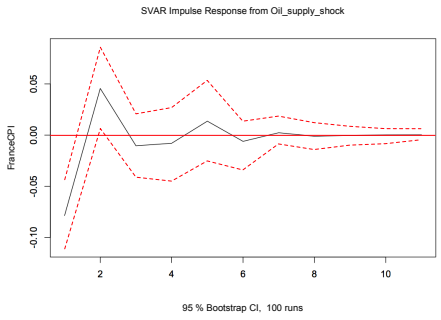
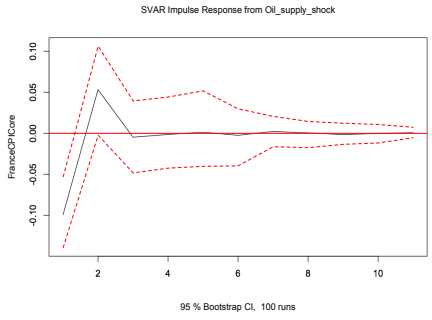
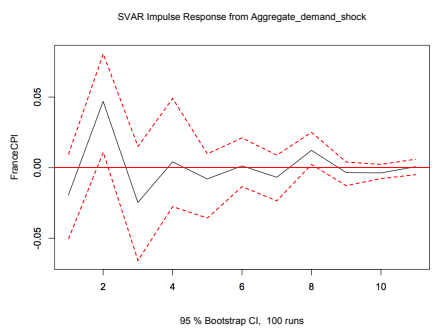
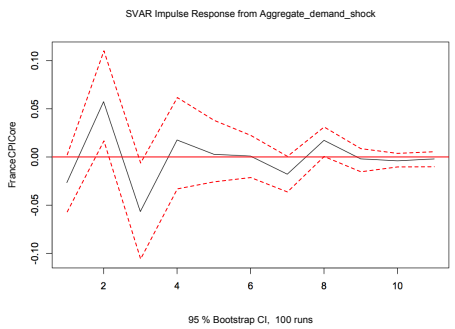
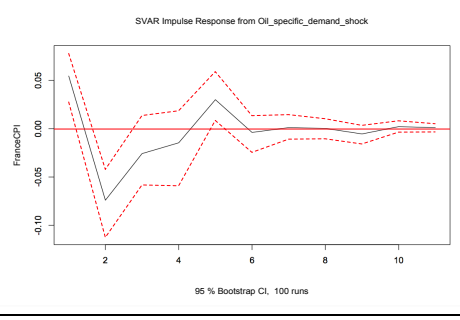
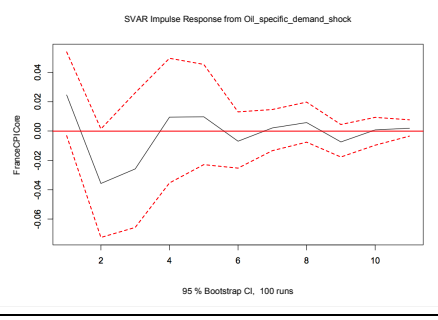
* Order of the variables: GBC, WIP, COP, Germany CPI and Germany core CPI.

Figure E5.33 – Impulse Response Functions of Germany CPI and core CPI with Order 5 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of France CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of France core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

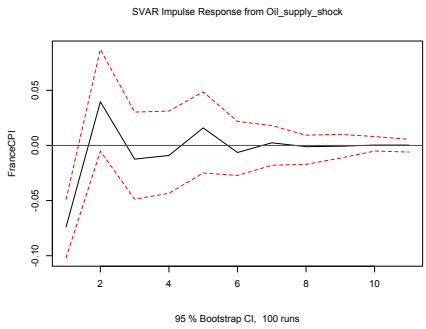
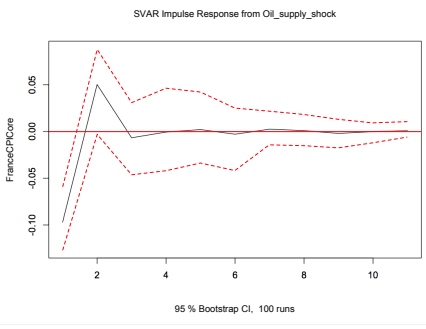
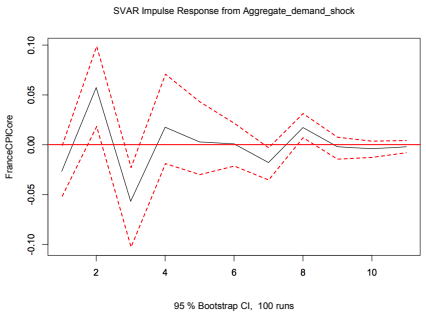
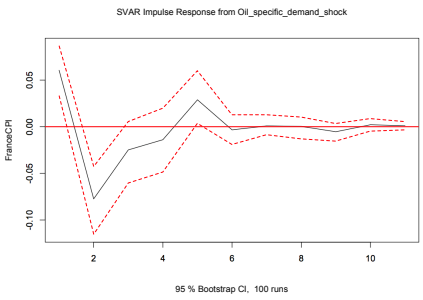
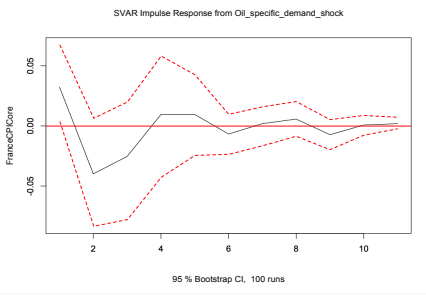
* Order of the variables: COP, GBC, WIP, France CPI and France core CPI.

Figure E5.34 – Impulse Response Functions of France CPI and core CPI with Order 1 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of France CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of France core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

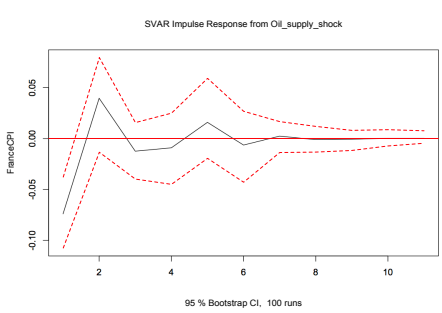
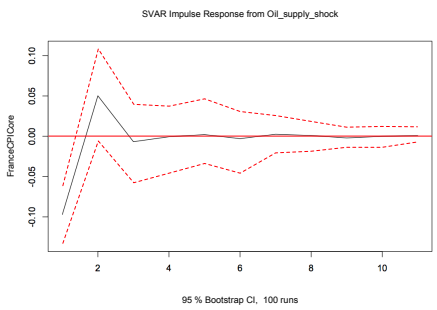
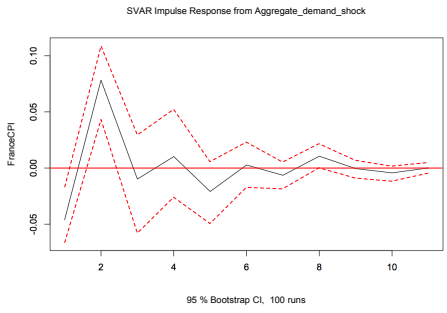
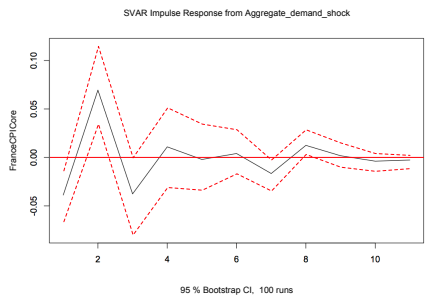
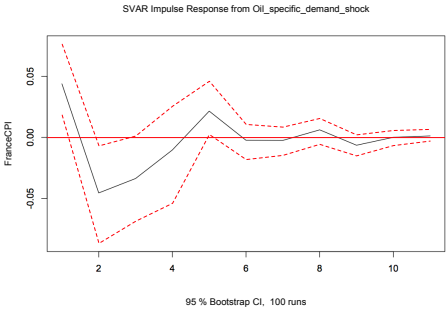
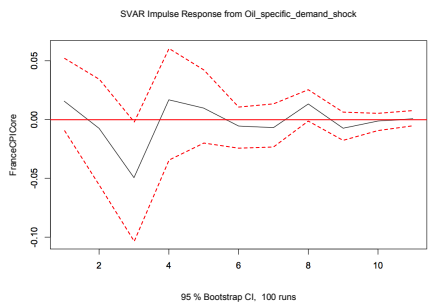
* Order of the variables: WIP, COP, GBC, France CPI and France core CPI.

Figure E5.35 – Impulse Response Functions of France CPI and core CPI with Order 2 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of France CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of France core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

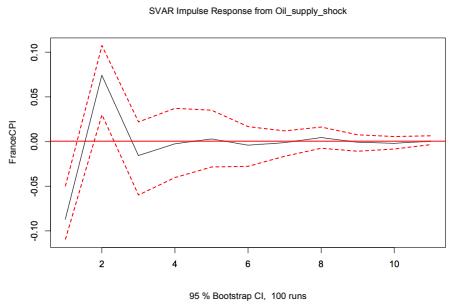
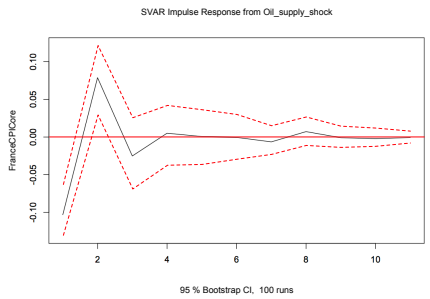
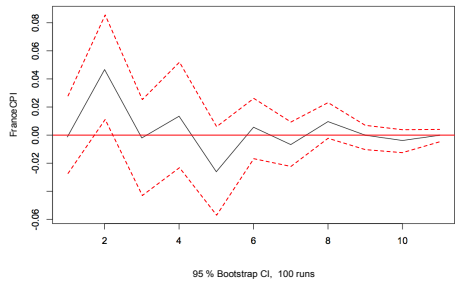
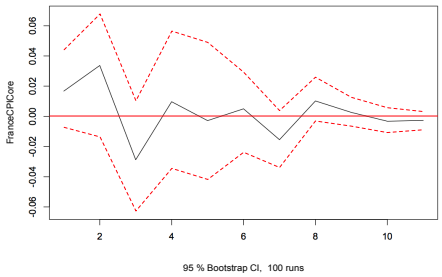
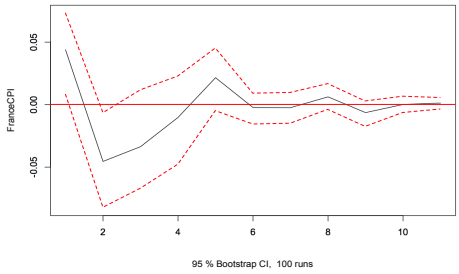
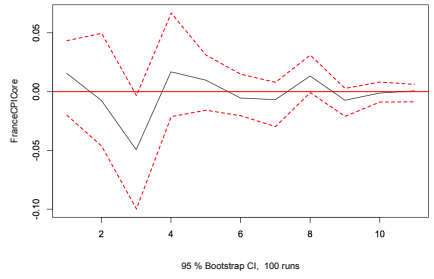
* Order of the variables: WIP, GBC, COP, France CPI and France core CPI.

Figure E5.36 – Impulse Response Functions of France CPI and core CPI with Order 3 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of France CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of France core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

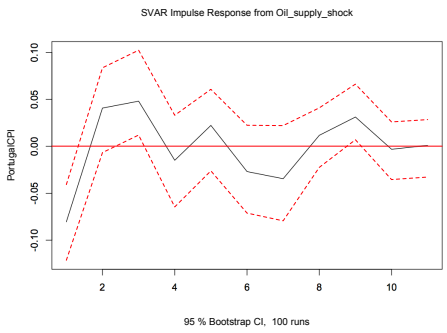
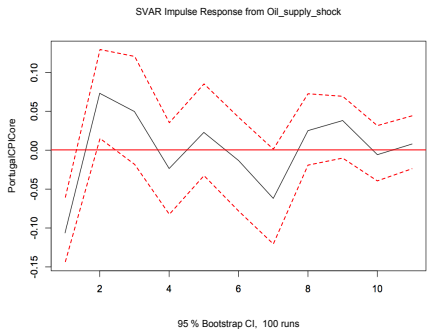
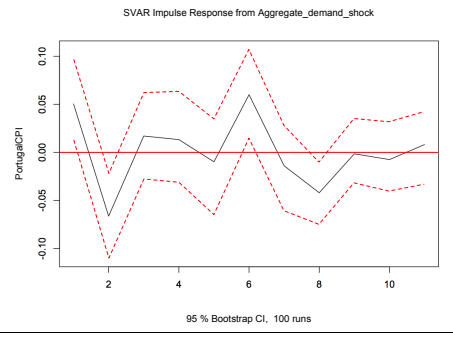
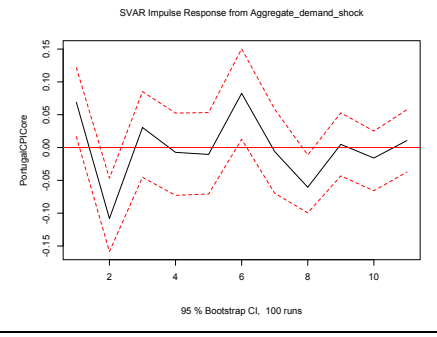
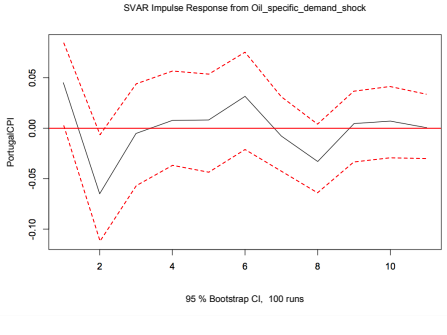
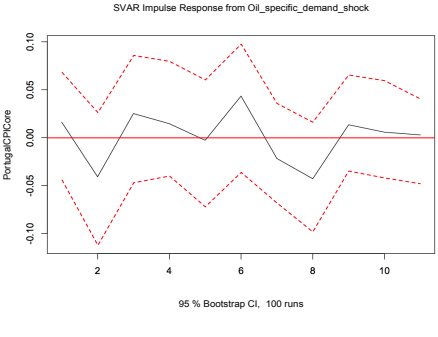
* Order of the variables: GBC, WIP, COP, France CPI and France core CPI.

Figure E5.37 – Impulse Response Functions of France CPI and core CPI with Order 4 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of France CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of France core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a)	**(a)**
	
(b)	**(b)**
	
(c)	**(c)**
	

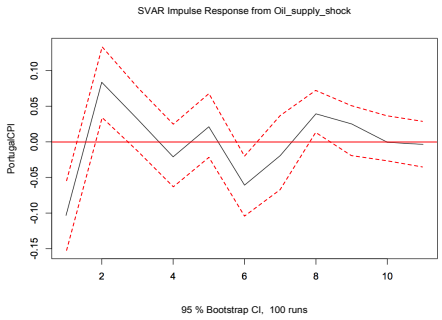
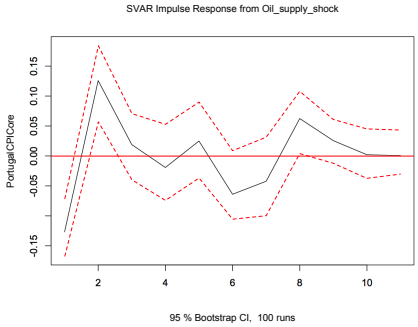
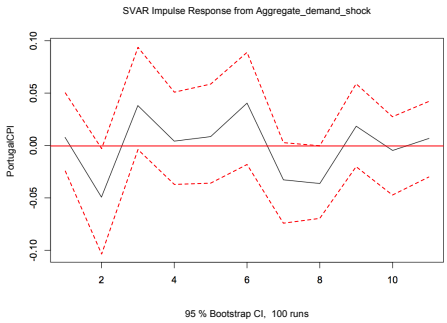
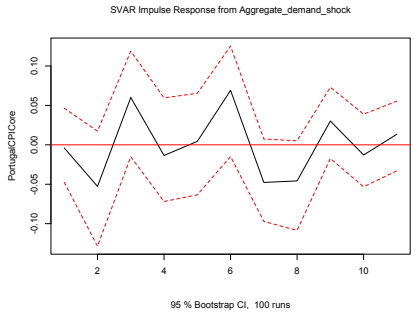
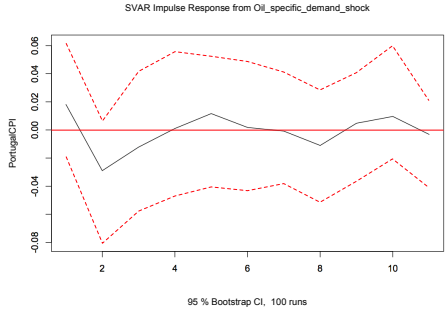
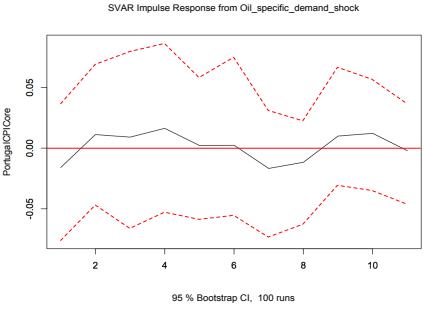
* Order of the variables: GBC, COP, WIP, France CPI and France core CPI.

Figure E5.38 – Impulse Response Functions of France CPI and core CPI with Order 5 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of Portugal CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of Portugal core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

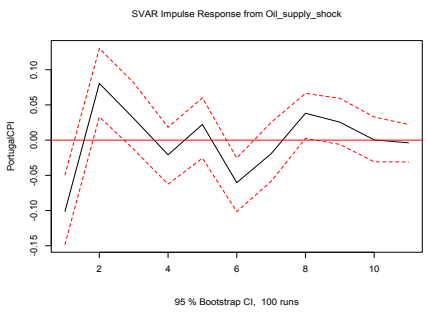
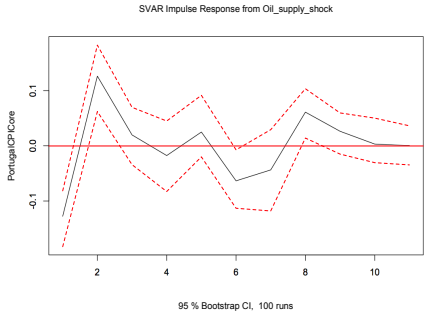
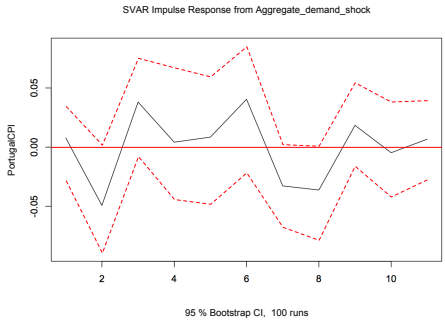
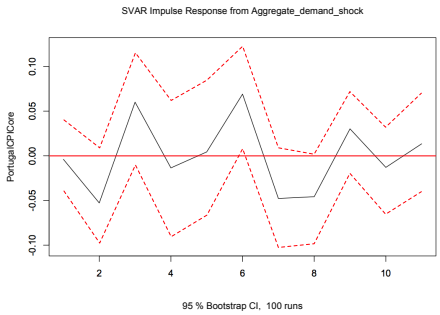
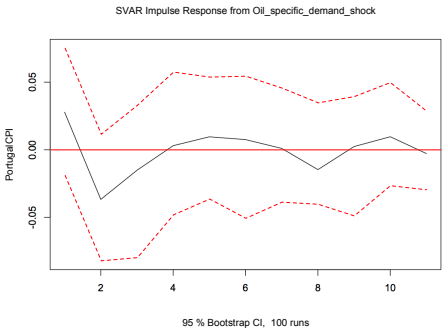
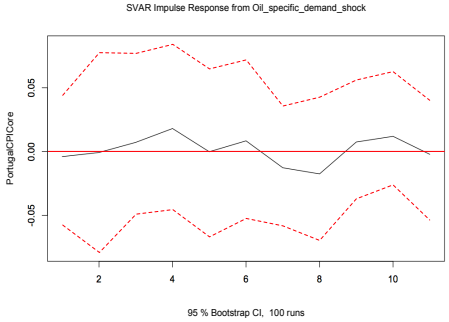
* Order of the variables: COP, GBC, WIP, Portugal CPI and Portugal core CPI.

Figure E5.39 – Impulse Response Functions of Portugal CPI and core CPI with Order 1 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of Portugal CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of Portugal core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

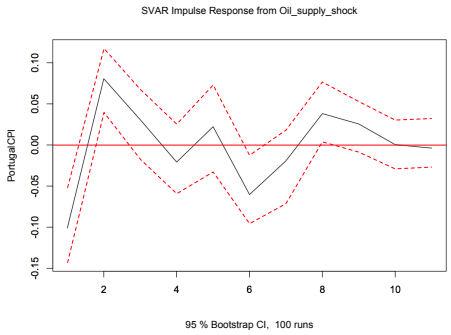
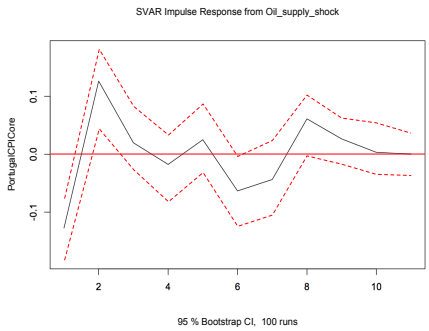
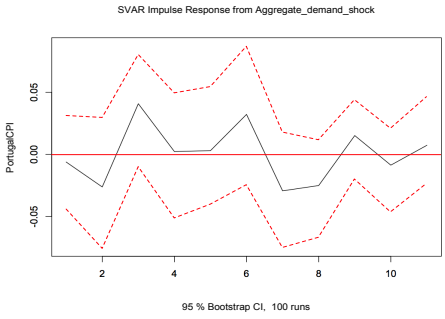
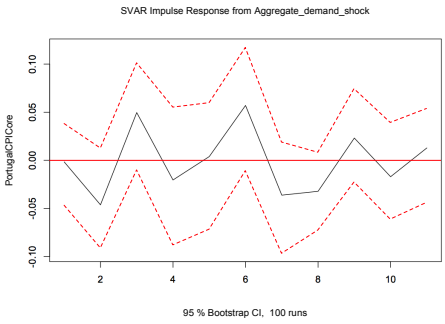
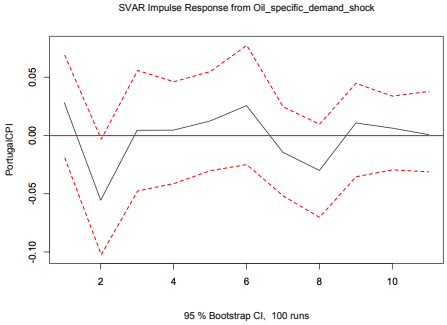
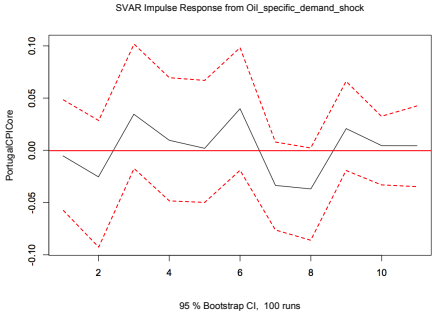
* Order of the variables: WIP, COP, GBC, Portugal CPI and Portugal core CPI.

Figure E5.40 – Impulse Response Functions of Portugal CPI and core CPI with Order 2 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of Portugal CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of Portugal core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

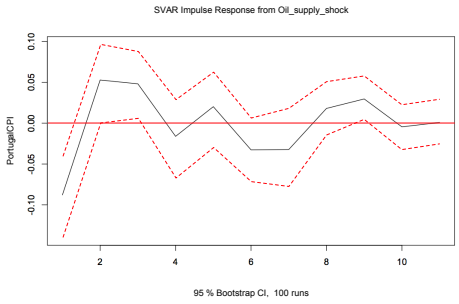
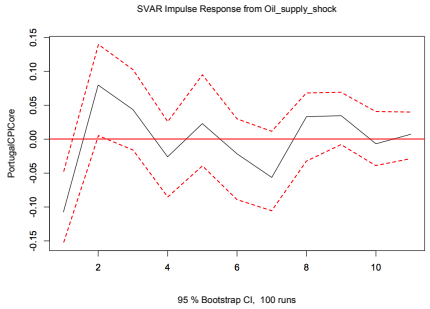
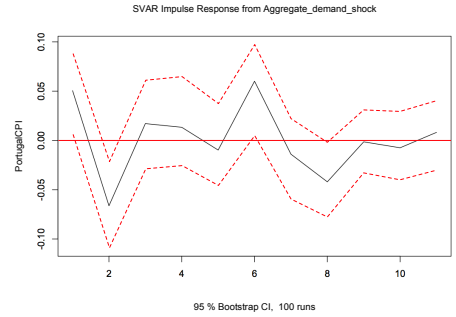
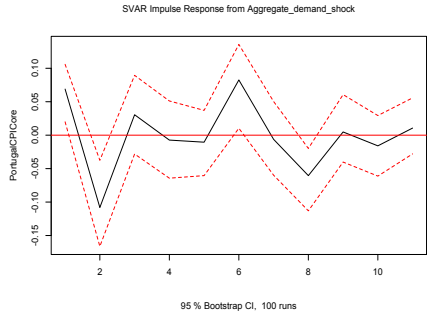
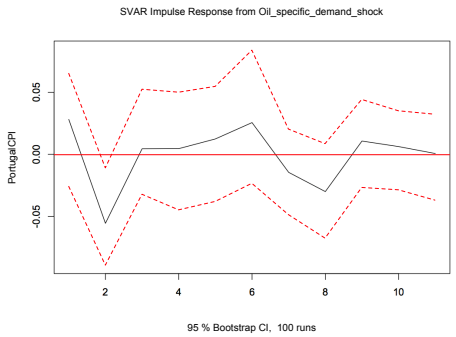
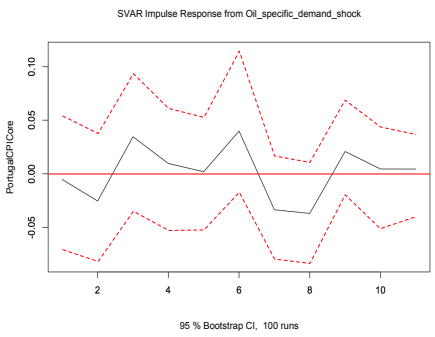
* Order of the variables: WIP, GBC, COP, Portugal CPI and Portugal core CPI.

Figure E5.41 – Impulse Response Functions of Portugal CPI and core CPI with Order 3 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of Portugal CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of Portugal core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

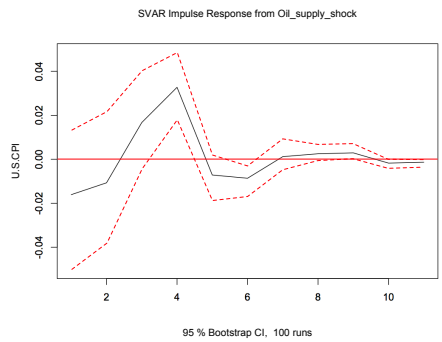
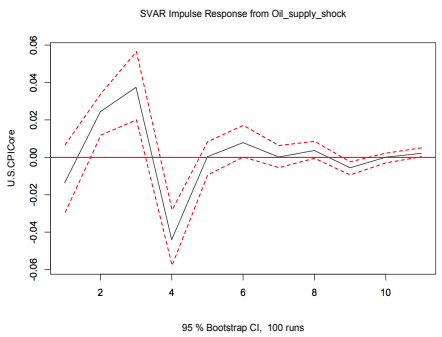
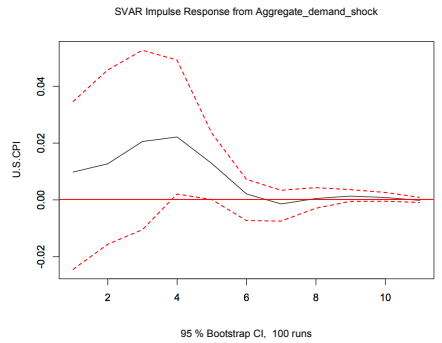
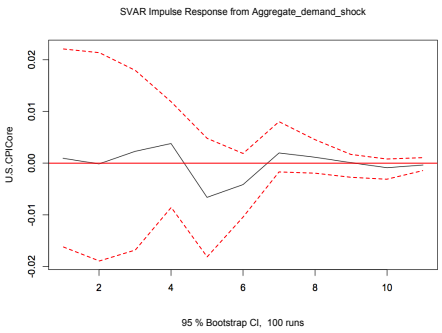
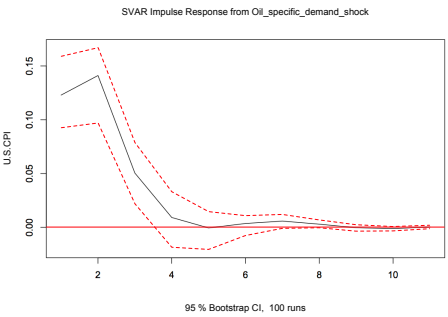
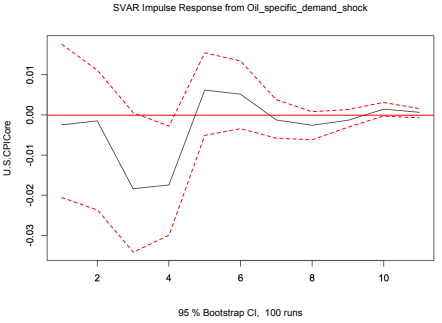
* Order of the variables: GBC, WIP, COP, Portugal CPI and Portugal core CPI.

Figure E5.42 – Impulse Response Functions of Portugal CPI and core CPI with Order 4 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of Portugal CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of Portugal core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

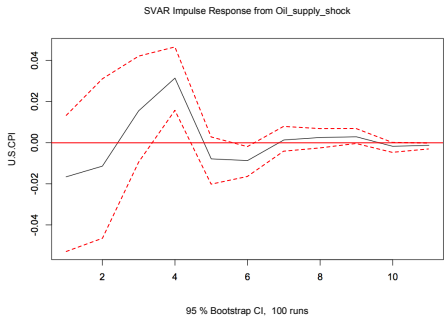
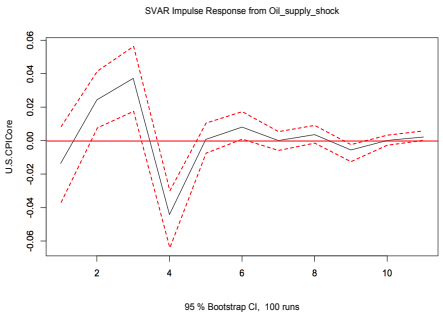
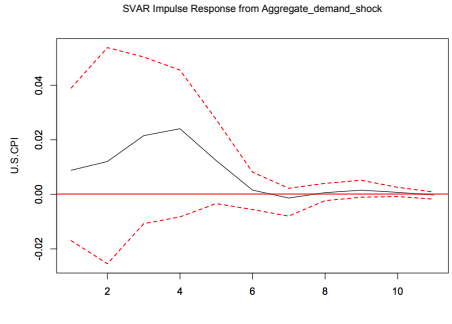
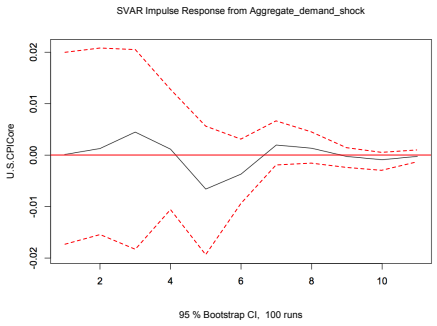
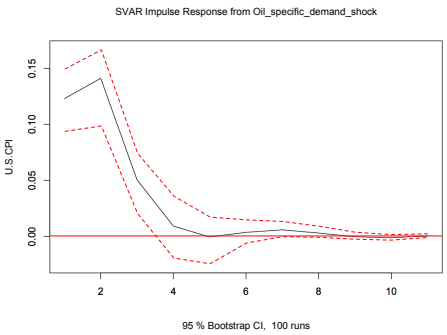
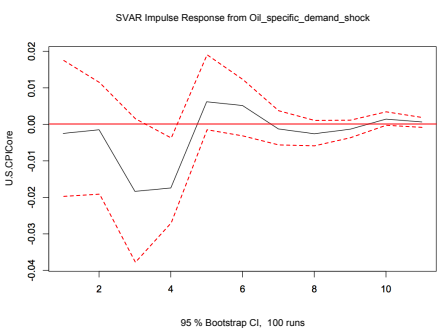
* Order of the variables: GBC, COP, WIP, Portugal CPI and Portugal core CPI.

Figure E5.43 – Impulse Response Functions of Portugal CPI and core CPI with Order 5 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of U.S. CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of U.S. core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

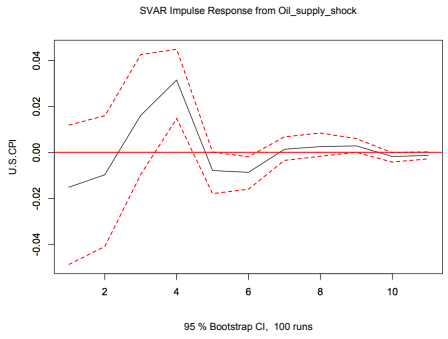
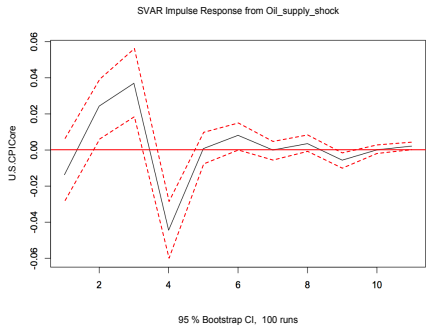
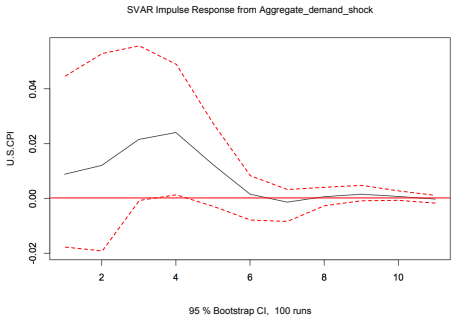
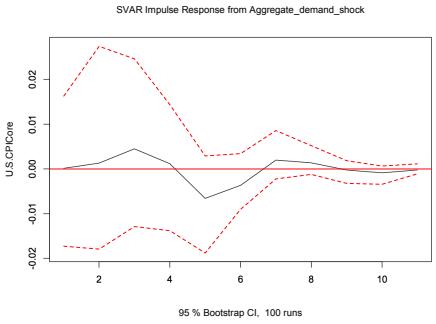
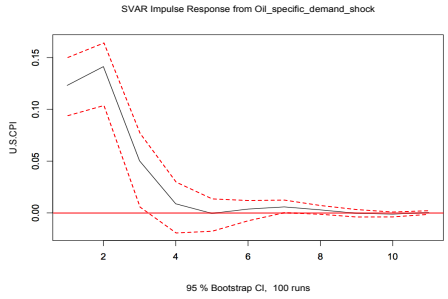
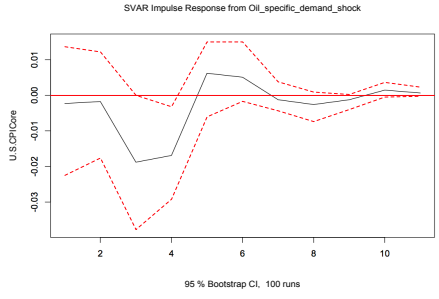
* Order of the variables: COP, GBC, WIP, U.S. CPI and U.S. core CPI.

Figure E5.44 – Impulse Response Functions of U.S. CPI and core CPI with Order 1 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of U.S. CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of U.S. core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

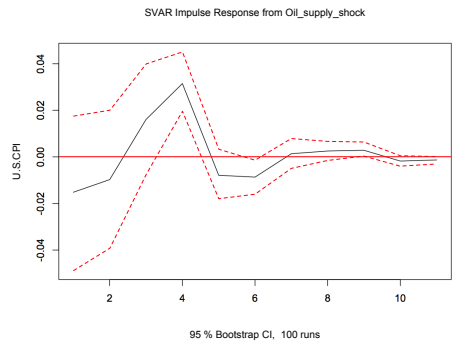
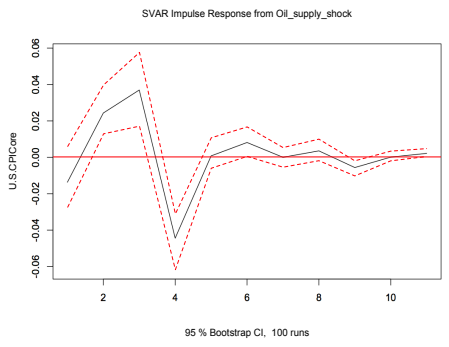
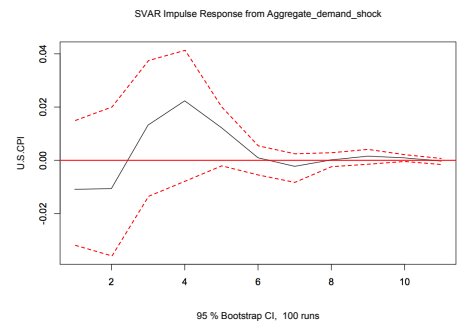
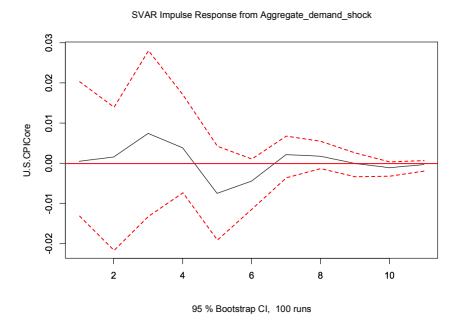
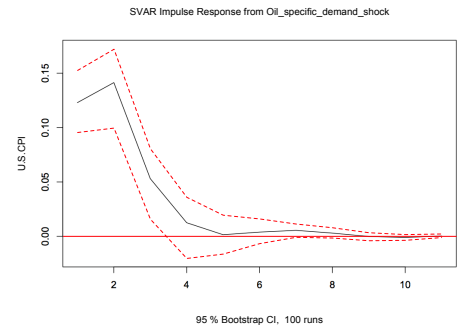
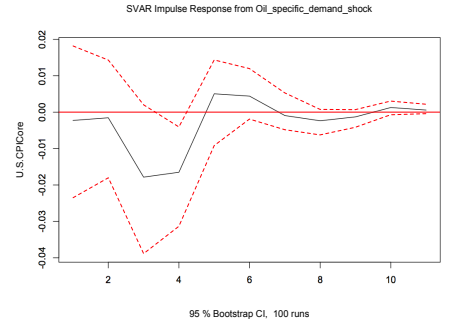
* Order of the variables: WIP, COP, GBC, U.S. CPI and U.S. core CPI.

Figure E5.45 – Impulse Response Functions of U.S. CPI and core CPI with Order 2 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of U.S. CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of U.S. core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

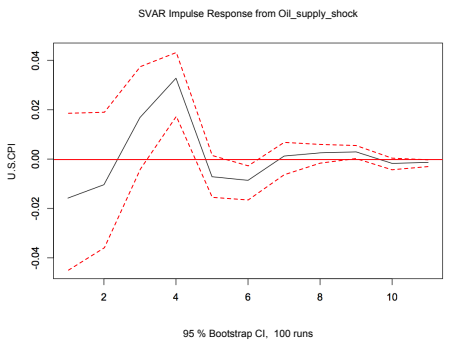
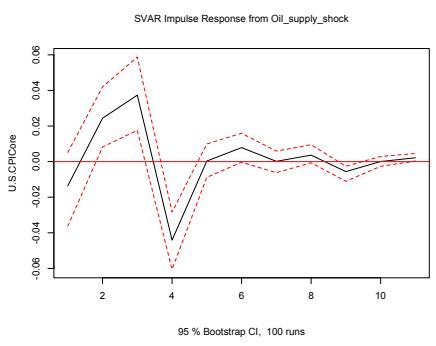
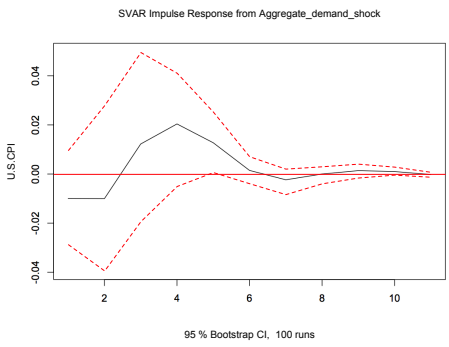
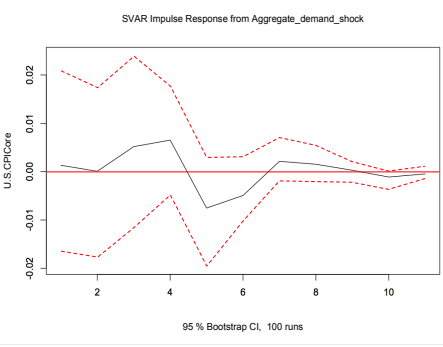
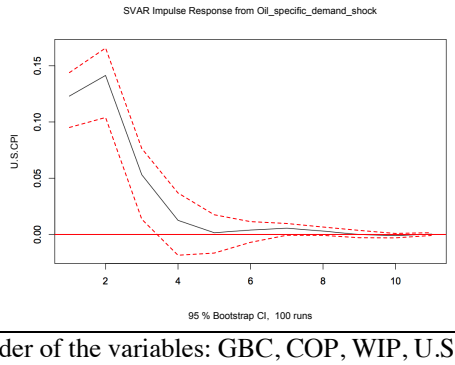
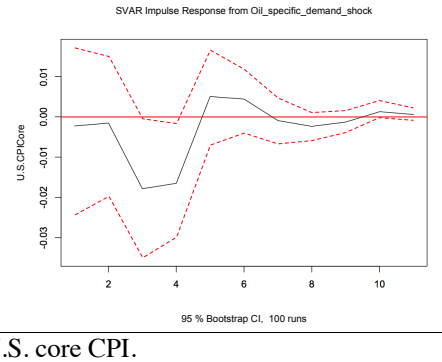
* Order of the variables: WIP, GBC, COP, U.S. CPI and U.S. core CPI.

Figure E5.46 – Impulse Response Functions of U.S. CPI and core CPI with Order 3 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of U.S. CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of U.S. core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

* Order of the variables: GBC, WIP, COP, U.S. CPI and U.S. core CPI.

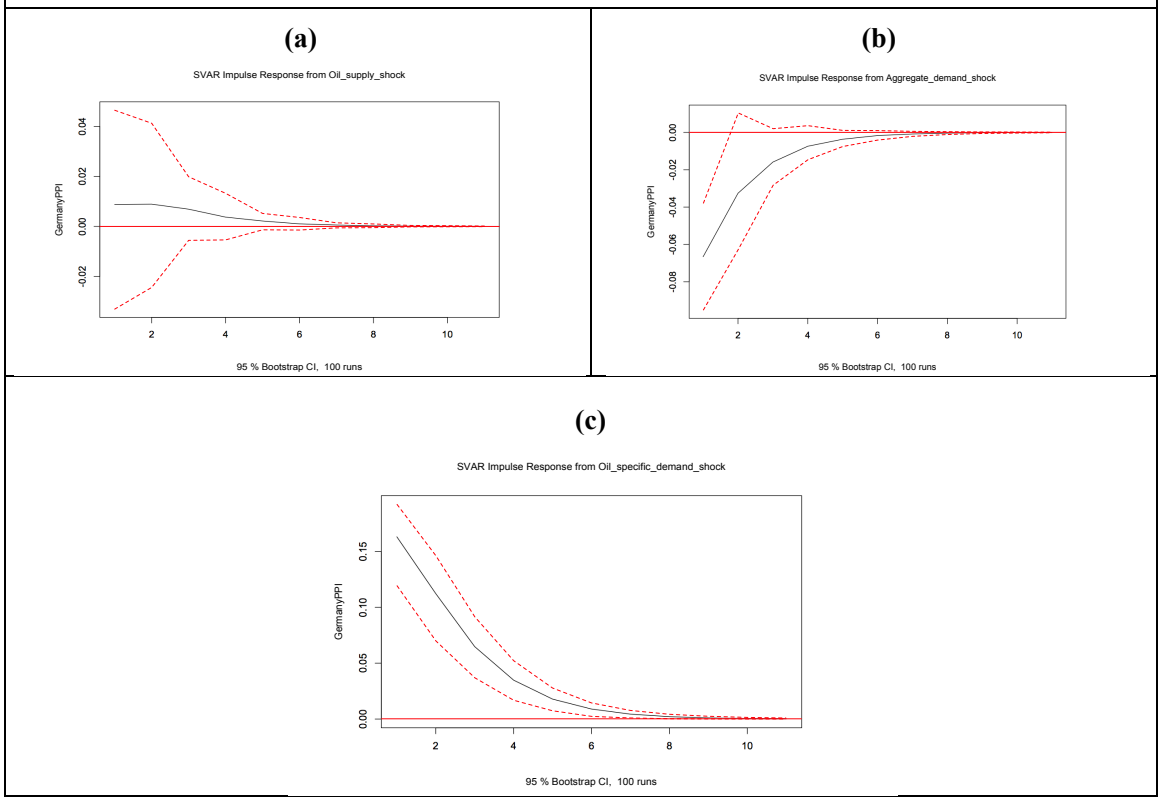
Figure E5.47 – Impulse Response Functions of U.S. CPI and core CPI with Order 4 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of U.S. CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *	Impulse Response Functions of U.S. core CPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *
(a) 	**(a)** 
(b) 	**(b)** 
(c) 	**(c)** 

* Order of the variables: GBC, COP, WIP, U.S. CPI and U.S. core CPI.

Figure E5.48 – Impulse Response Functions of U.S. CPI and core CPI with Order 5 (Source: Results obtained by econometric software R, own elaboration.)

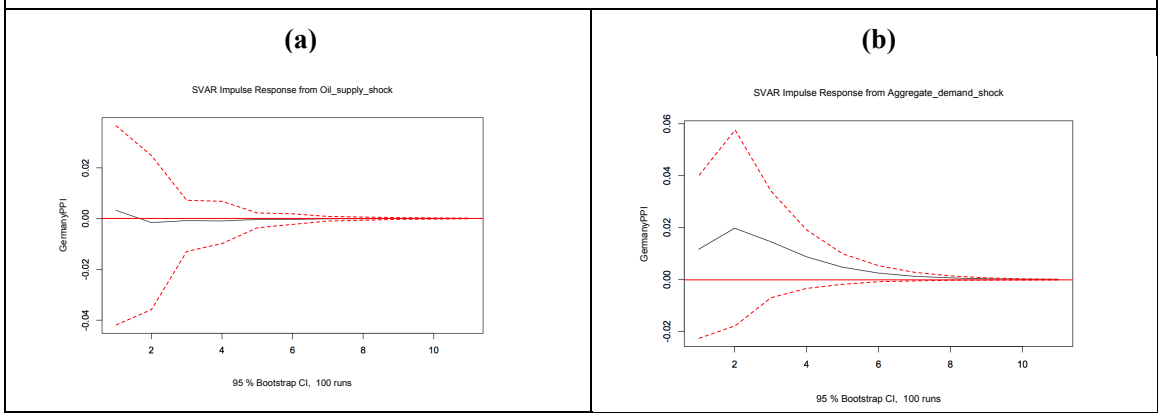
Impulse Response Functions of Germany PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *

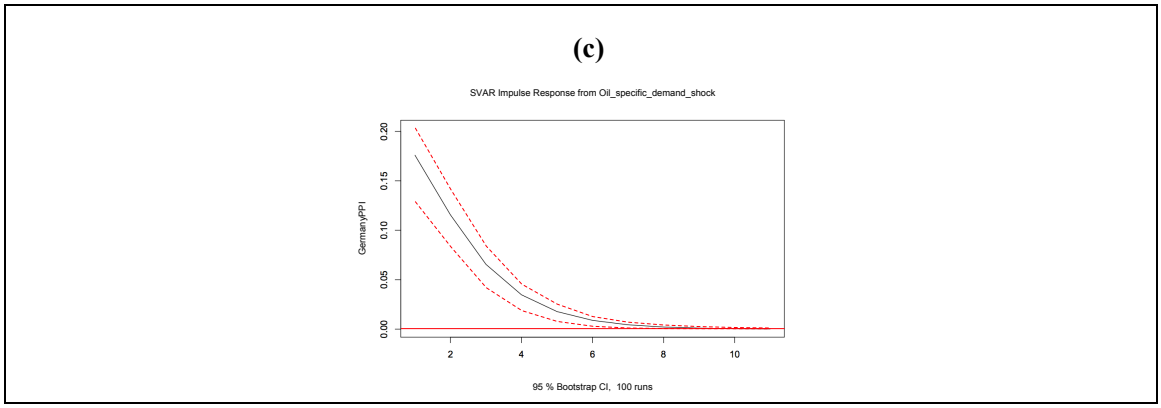


* Order of the variables: COP, GBC, WIP and Germany PPI.

Figure E5.49 – Impulse Response Functions of Germany PPI with Order 1 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of Germany PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *

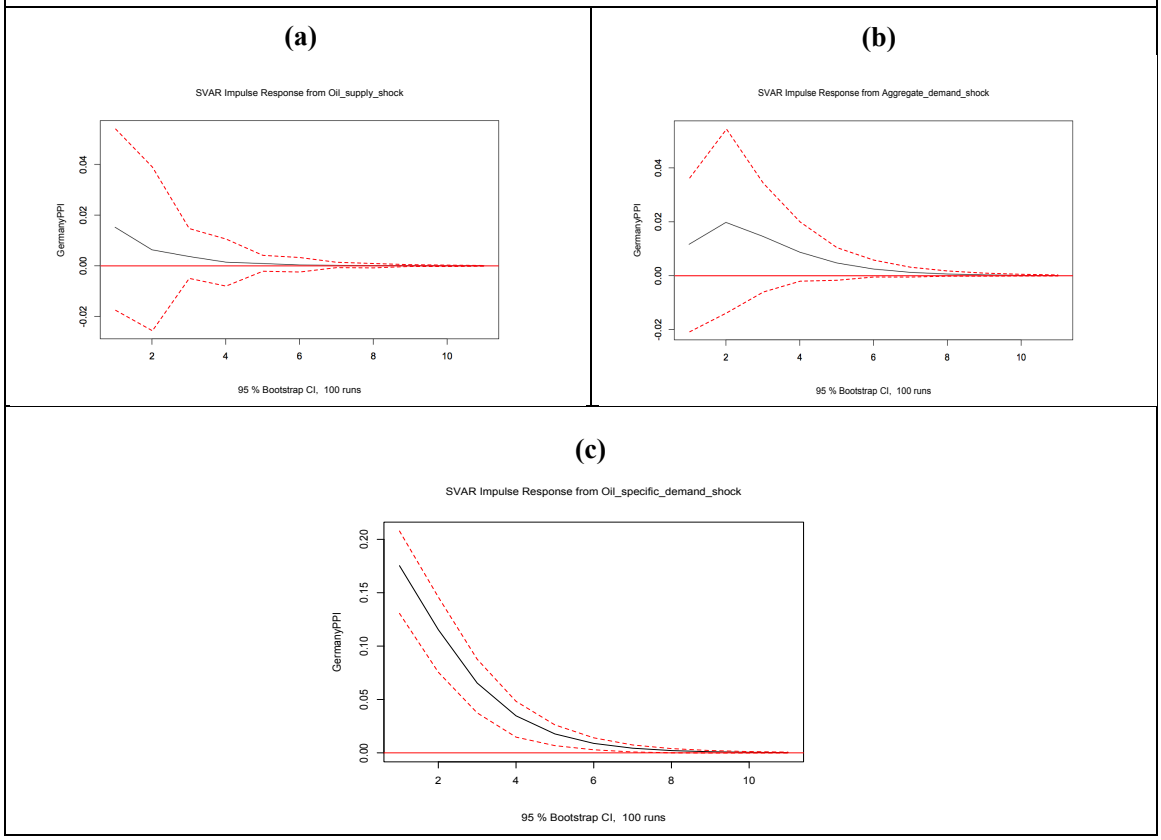




* Order of the variables: WIP, COP, GBC and Germany PPI.

Figure E5.50 – Impulse Response Functions of Germany PPI with Order 2
(Source: Results obtained by econometric software R, own elaboration.)

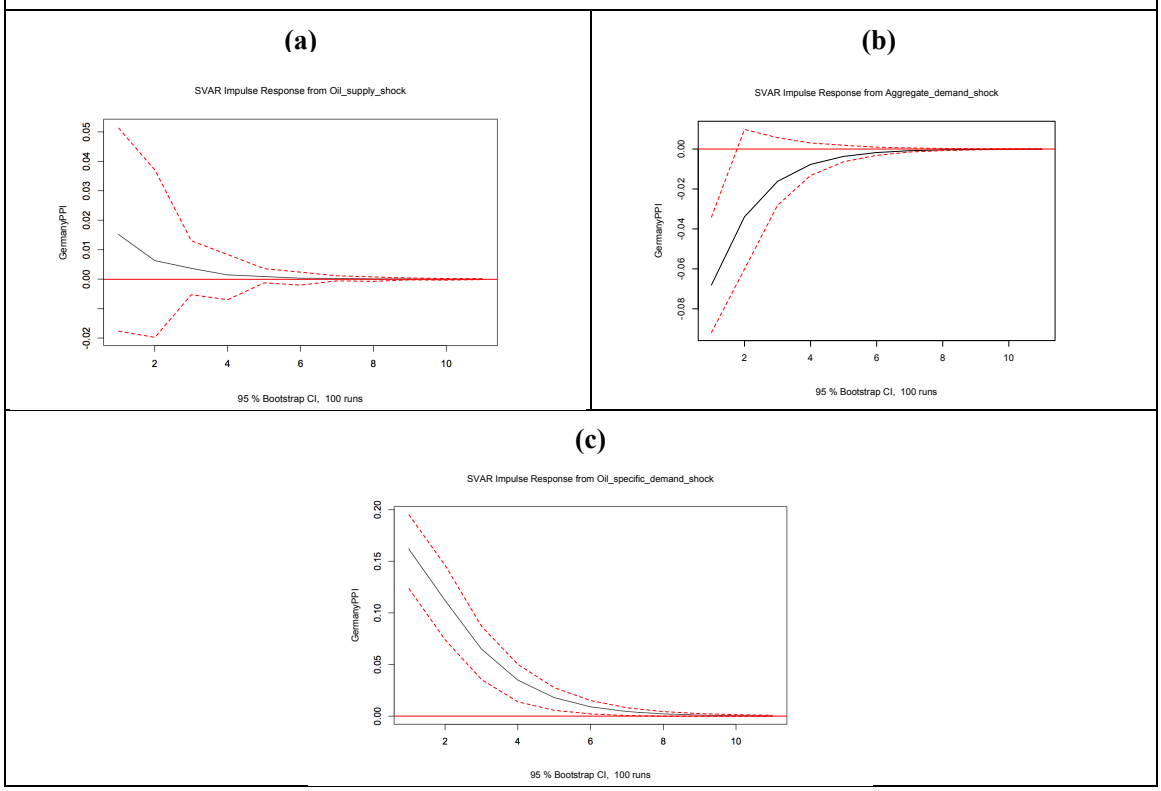
Impulse Response Functions of Germany PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *



* Order of the variables: WIP, GBC, COP and Germany PPI.

Figure E5.51 – Impulse Response Functions of Germany PPI with Order 3
(Source: Results obtained by econometric software R, own elaboration.)

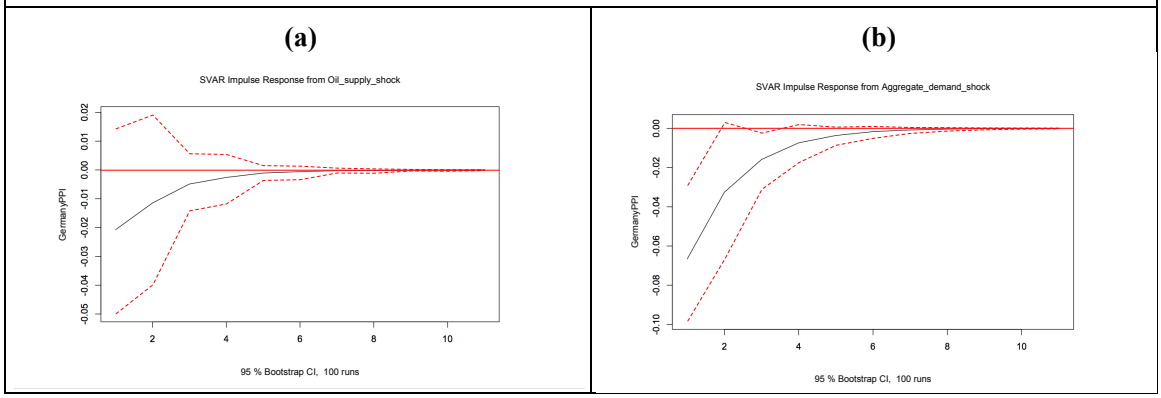
Impulse Response Functions of Germany PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *

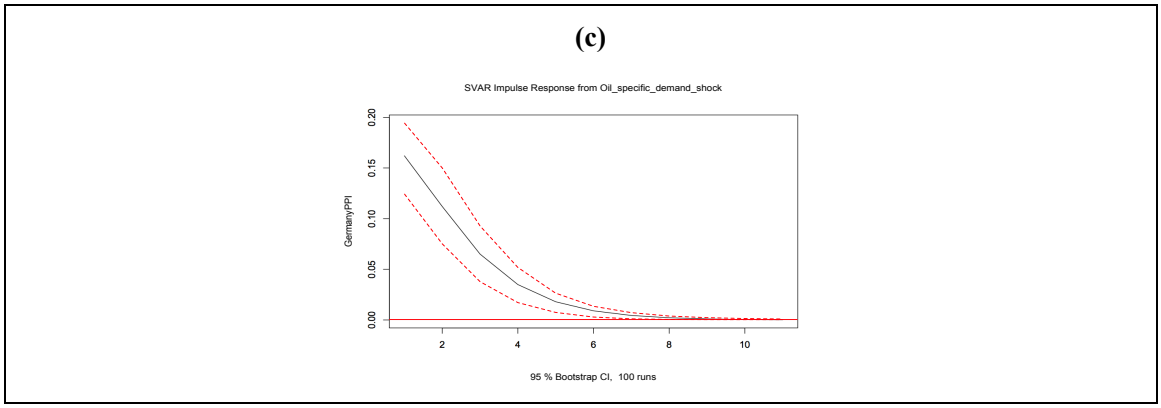


* Order of the variables: GBC, WIP, COP and Germany PPI.

Figure E5.52 – Impulse Response Functions of Germany PPI with Order 4 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of Germany PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *

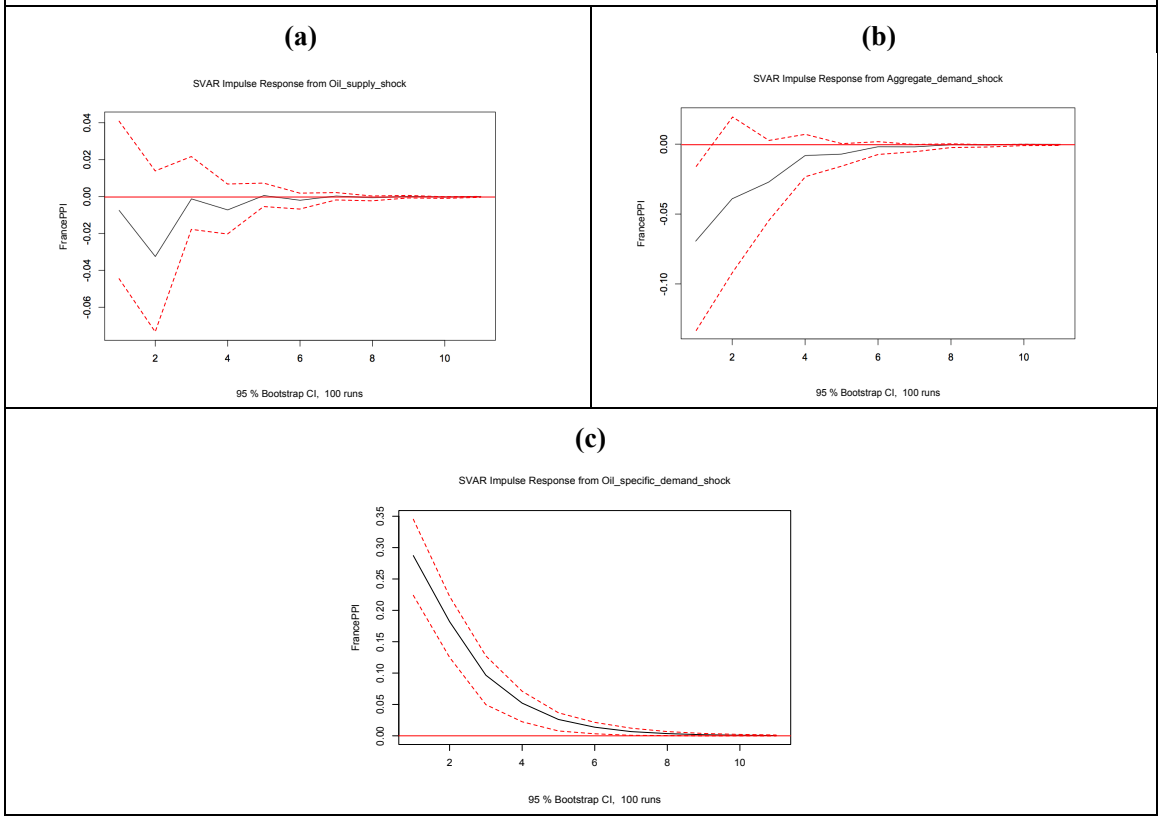




* Order of the variables: GBC, COP, WIP and Germany PPI.

Figure E5.53 – Impulse Response Functions of Germany PPI with Order 5
(Source: Results obtained by econometric software R, own elaboration.)

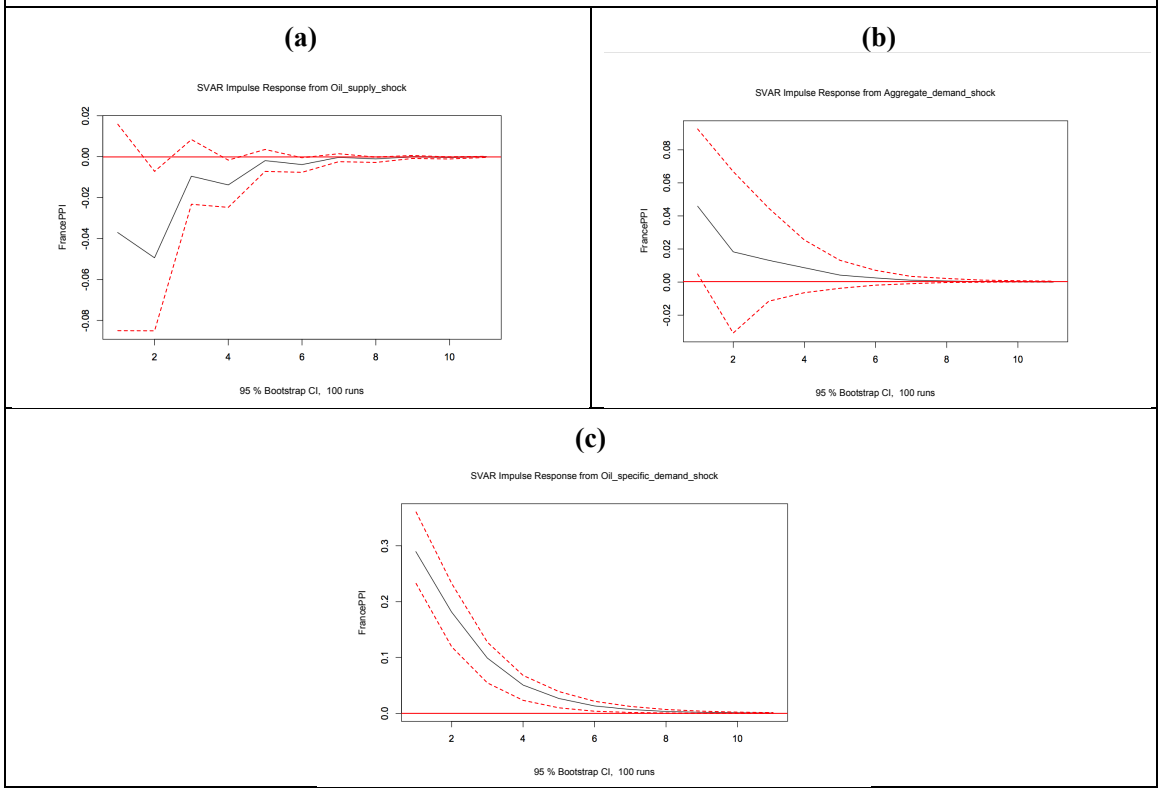
Impulse Response Functions of France PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *



* Order of the variables: COP, GBC, WIP and France PPI.

Figure E5.54 – Impulse Response Functions of France PPI with Order 1
(Source: Results obtained by econometric software R, own elaboration.)

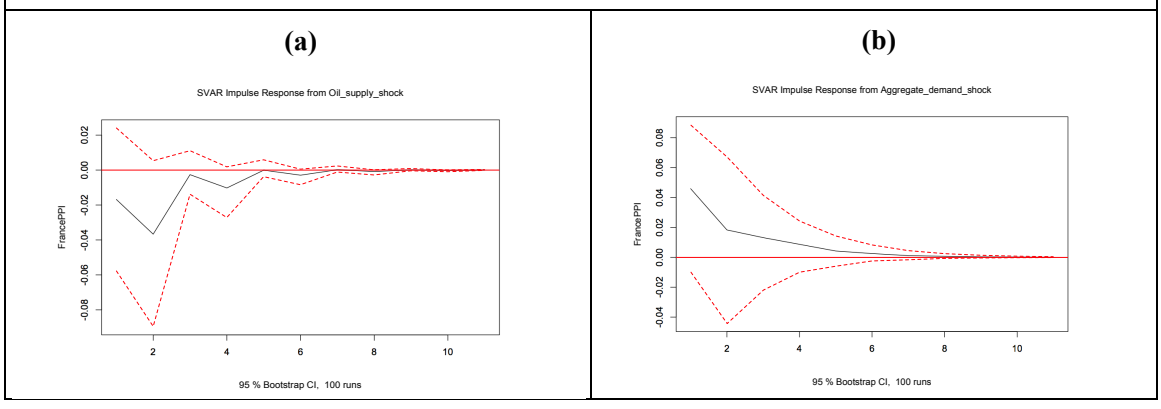
Impulse Response Functions of France PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *

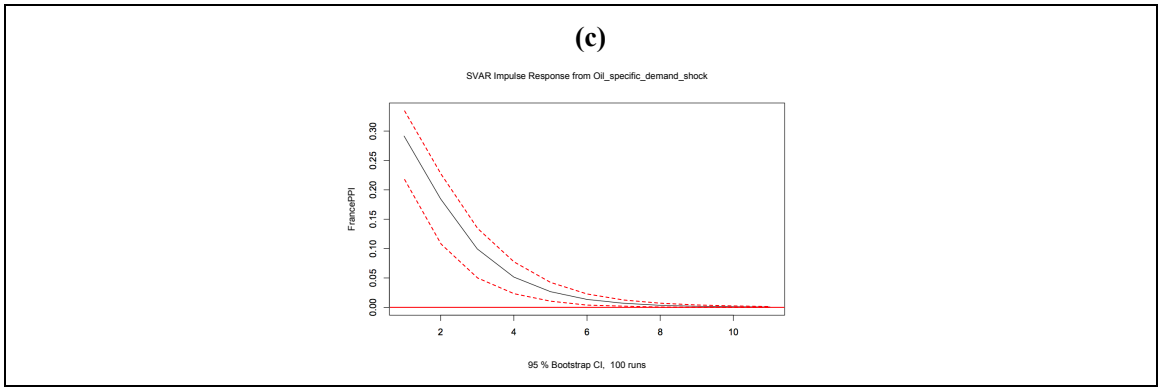


* Order of the variables: WIP, COP, GBC and France PPI.

Figure E5.55 – Impulse Response Functions of France PPI with Order 2 (Source: Results obtained by econometric software R, own elaboration.)

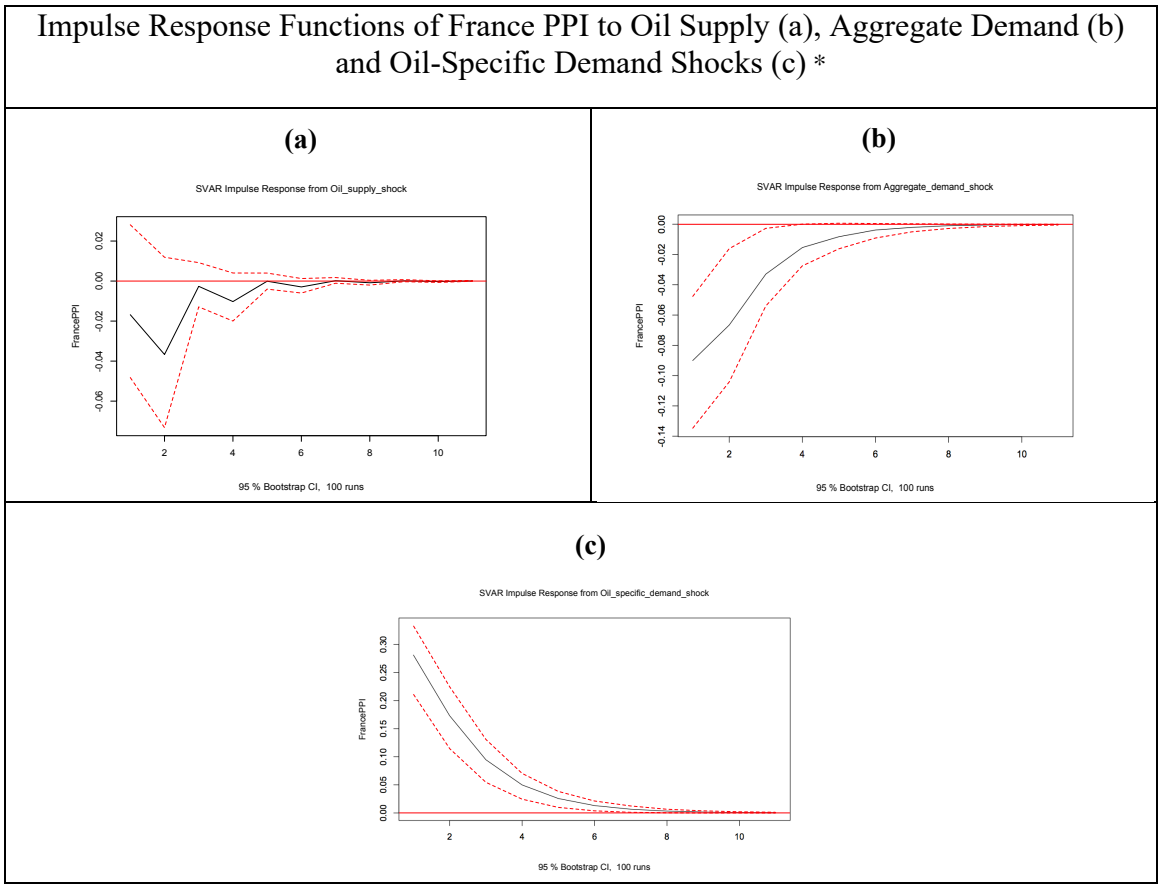
Impulse Response Functions of France PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *





* Order of the variables: WIP, GBC, COP and France PPI.

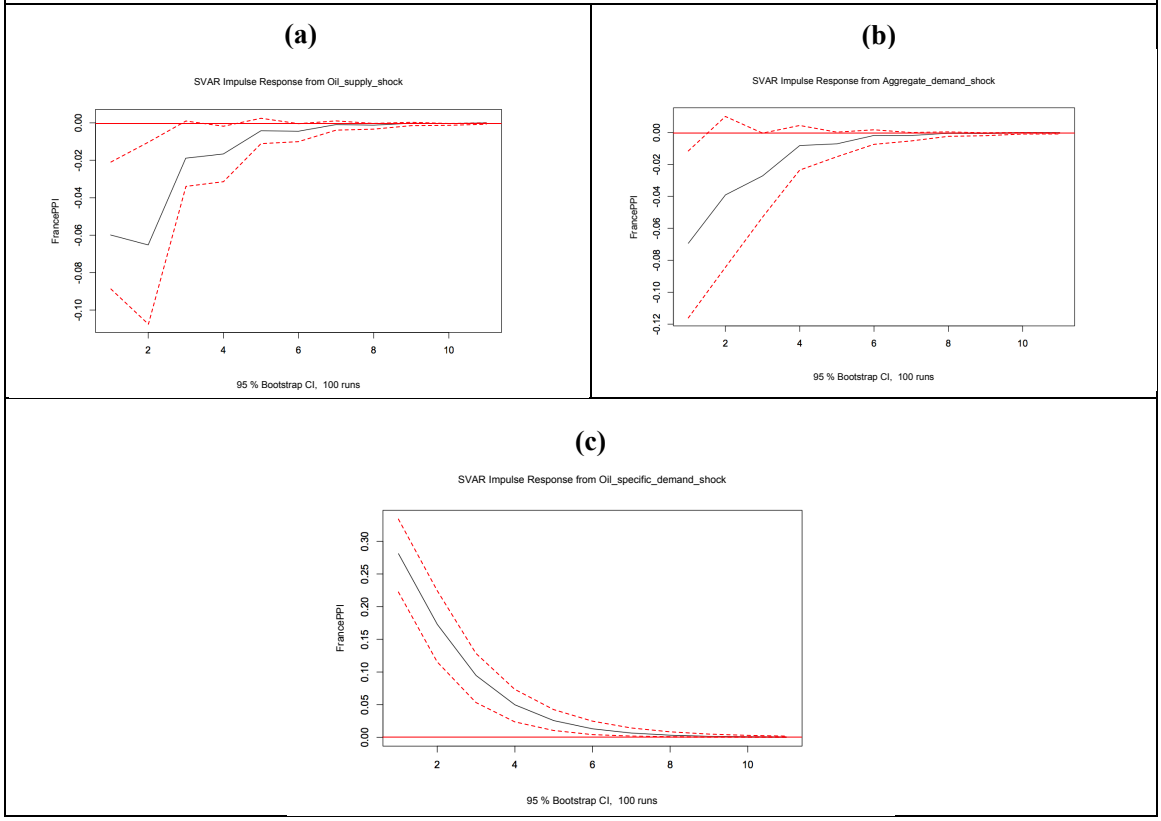
Figure E5.56 – Impulse Response Functions of France PPI with Order 3
(Source: Results obtained by econometric software R, own elaboration.)



* Order of the variables: GBC, WIP, COP and France PPI.

Figure E5.57 – Impulse Response Functions of France PPI with Order 4
(Source: Results obtained by econometric software R, own elaboration.)

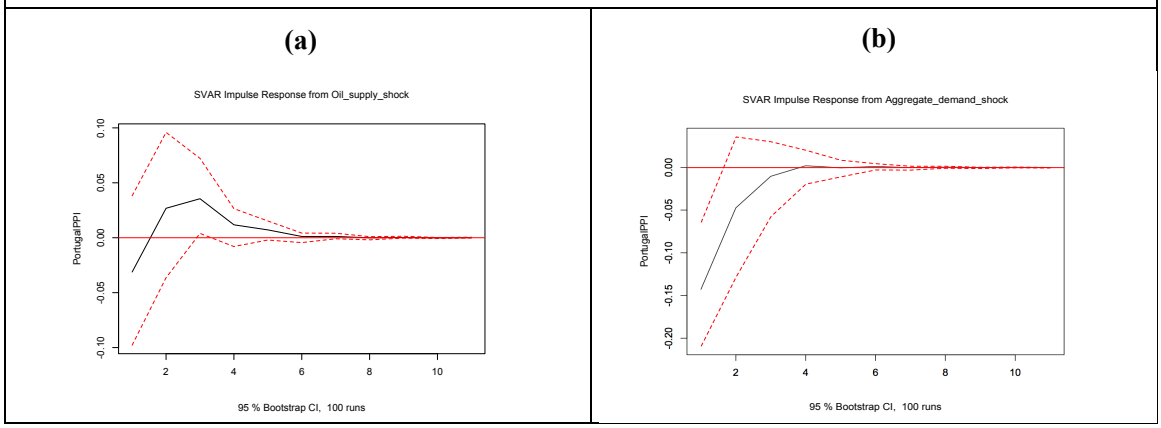
Impulse Response Functions of France PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *



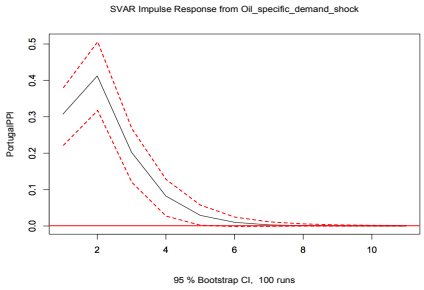
* Order of the variables: GBC, COP, WIP and France PPI.

Figure E5.58 – Impulse Response Functions of France PPI with Order 5 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of Portugal PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *



(c)

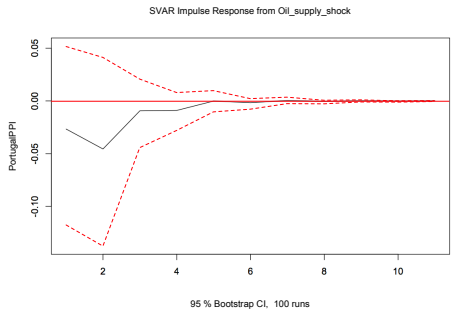


* Order of the variables: COP, GBC, WIP and Portugal PPI.

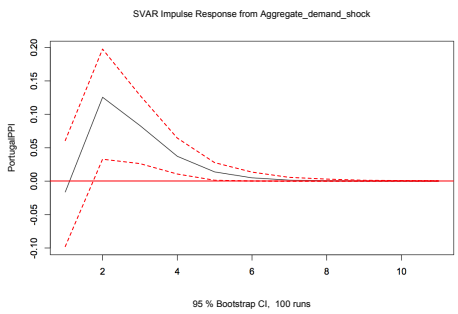
Figure E5.59 – Impulse Response Functions of Portugal PPI with Order 1
(Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of Portugal PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *

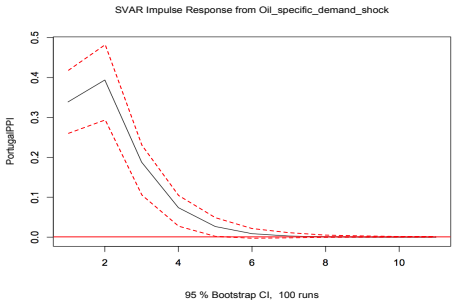
(a)



(b)



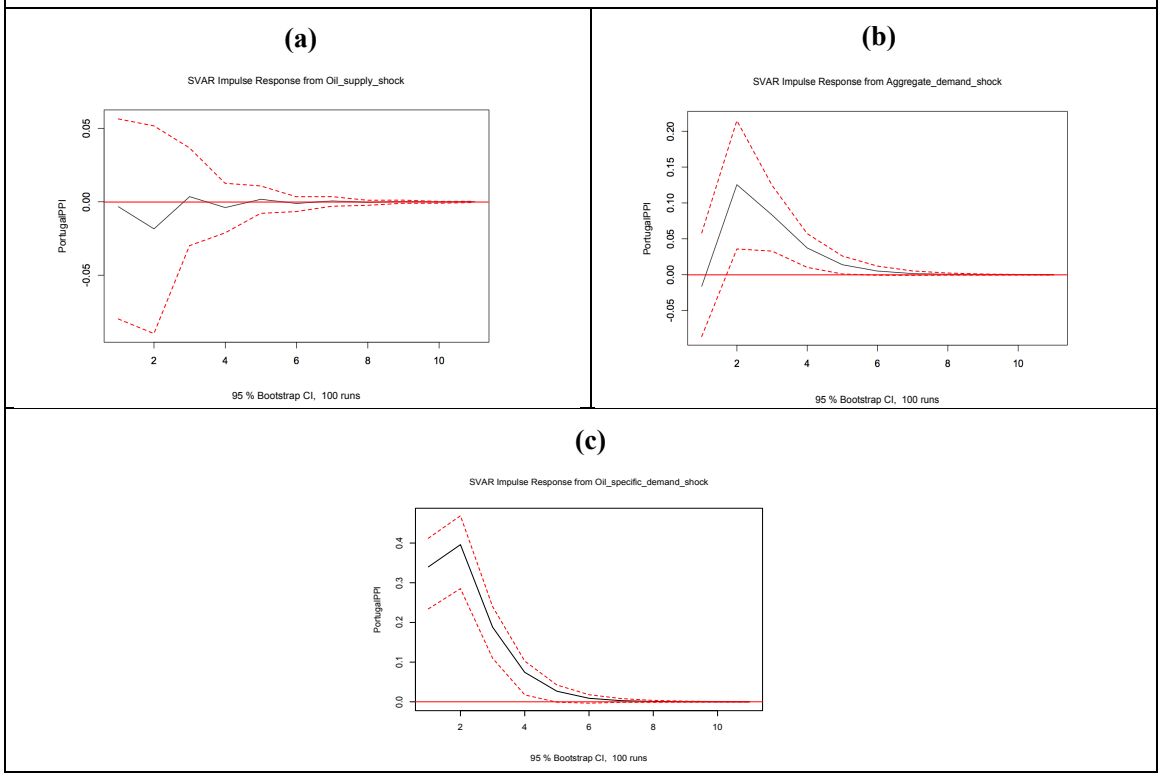
(c)



* Order of the variables: WIP, COP, GBC and Portugal PPI.

Figure E5.60 – Impulse Response Functions of Portugal PPI with Order 2
(Source: Results obtained by econometric software R, own elaboration.)

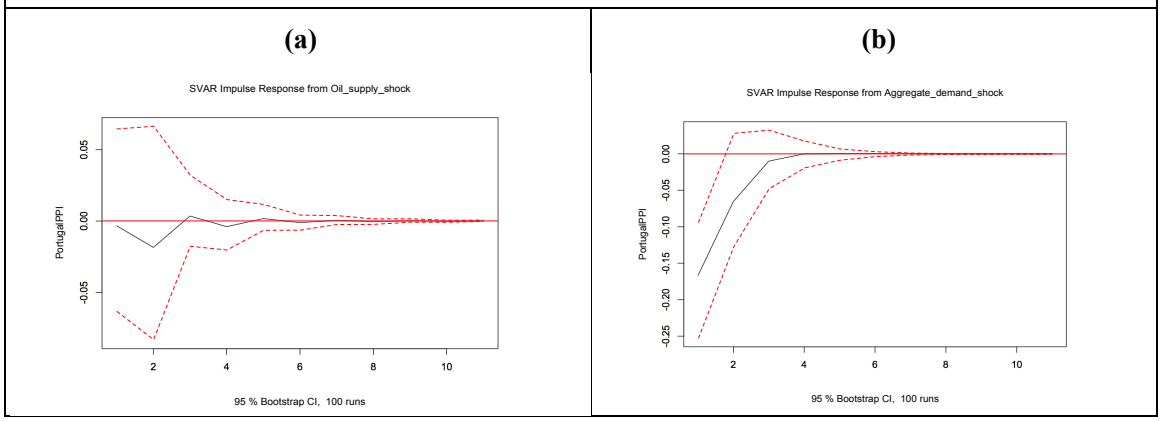
Impulse Response Functions of Portugal PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *

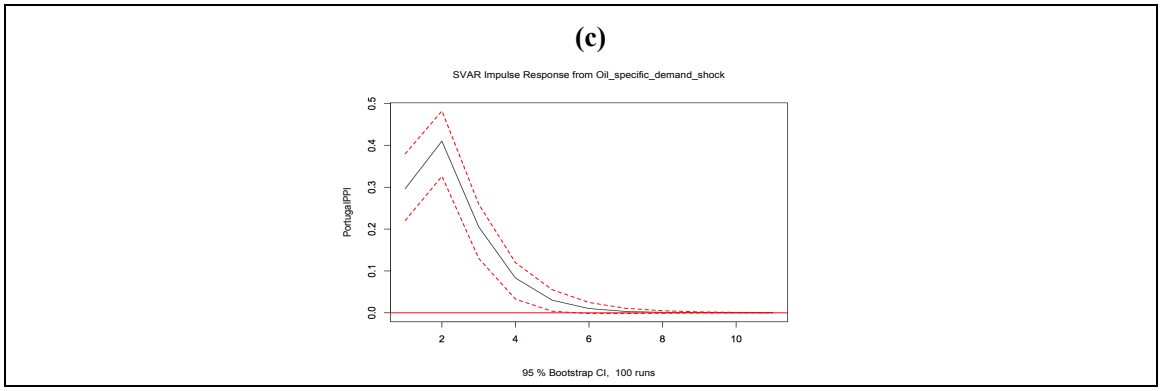


* Order of the variables: WIP, GBC, COP and Portugal PPI.

Figure E5.61 – Impulse Response Functions of Portugal PPI with Order 3 (Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of Portugal PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *

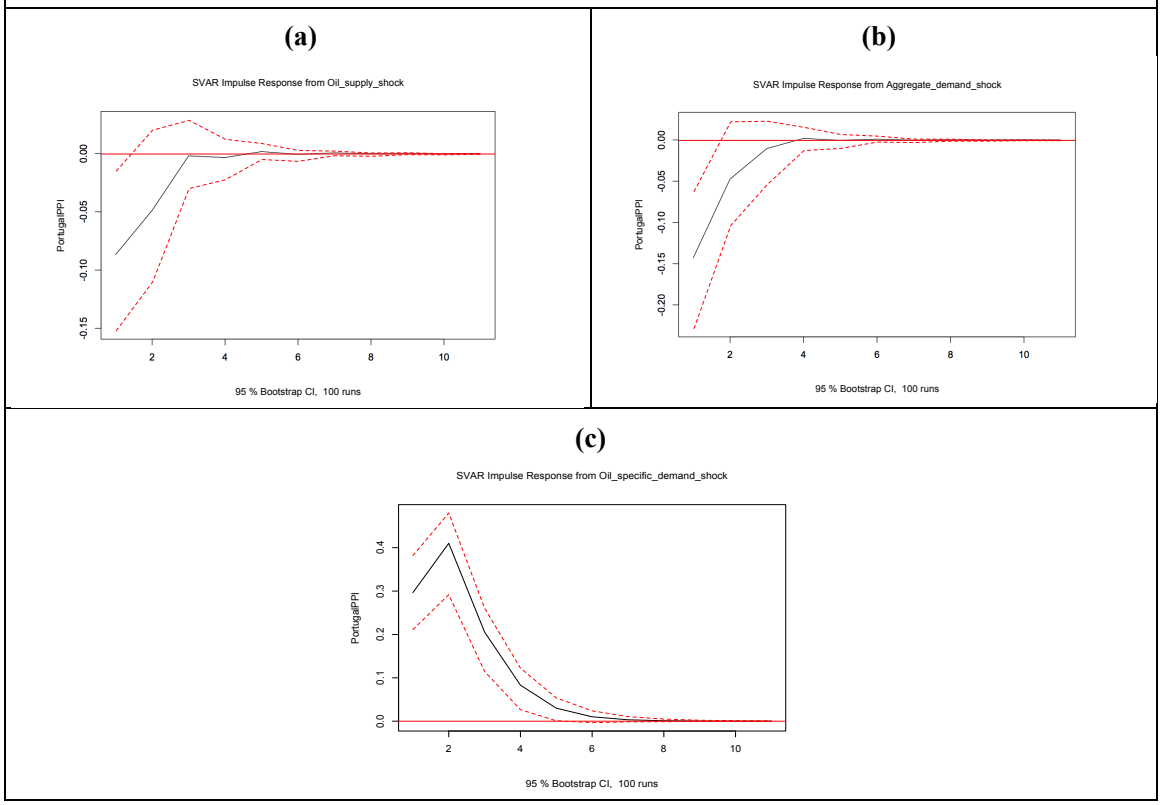




* Order of the variables: GBC, WIP, COP and Portugal PPI.

Figure E5.62 – Impulse Response Functions of Portugal PPI with Order 4
(Source: Results obtained by econometric software R, own elaboration.)

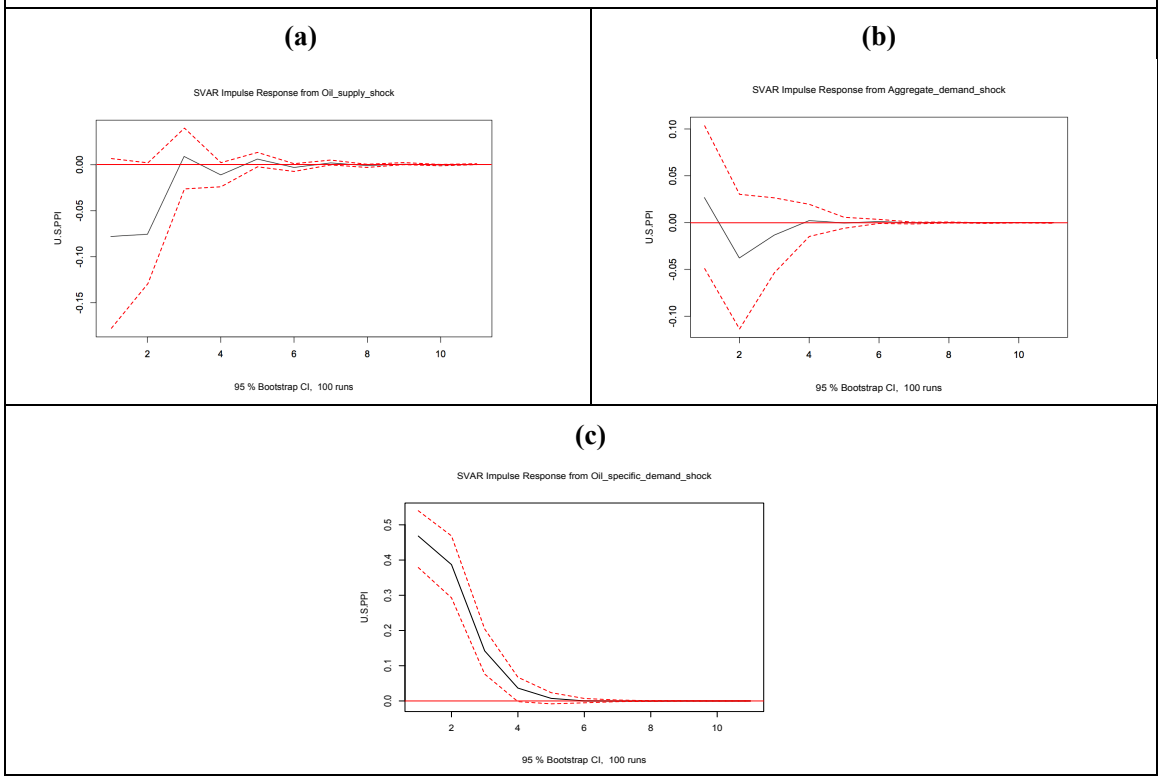
Impulse Response Functions of Portugal PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *



* Order of the variables: GBC, COP, WIP and Portugal PPI.

Figure E5.63 – Impulse Response Functions of Portugal PPI with Order 5
(Source: Results obtained by econometric software R, own elaboration.)

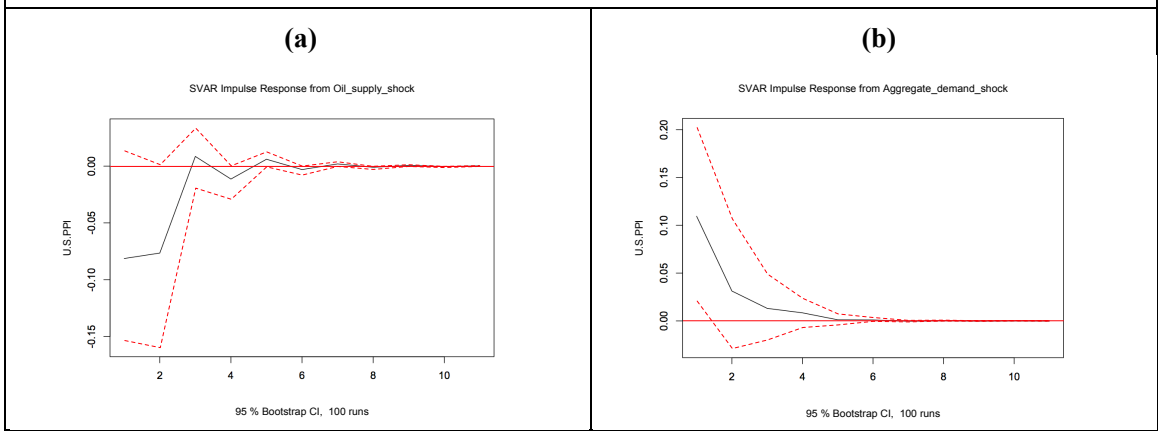
Impulse Response Functions of U.S. PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *



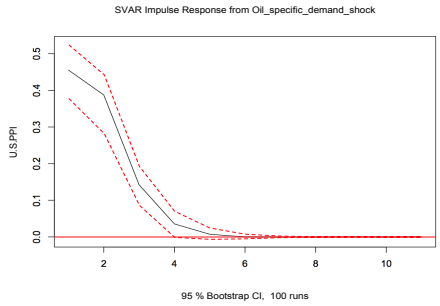
* Order of the variables: COP, GBC, WIP and U.S. PPI.

Figure E5.64 – Impulse Response Functions of U.S. PPI with Order 1
(Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of U.S. PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *



(c)

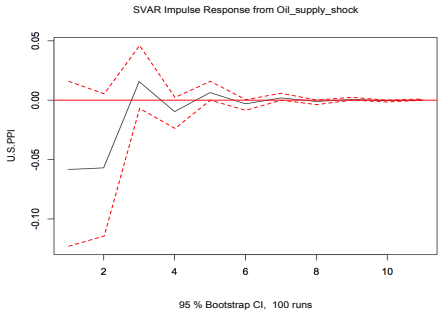


* Order of the variables: WIP, COP, GBC and U.S. PPI.

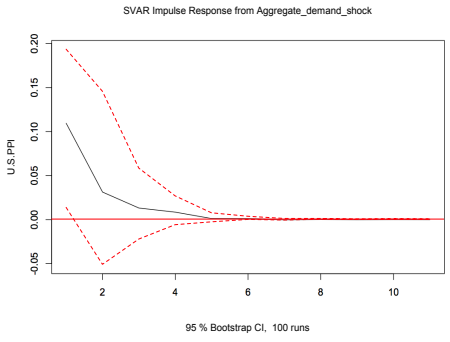
Figure E5.65 – Impulse Response Functions of U.S. PPI with Order 2
(Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of U.S. PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *

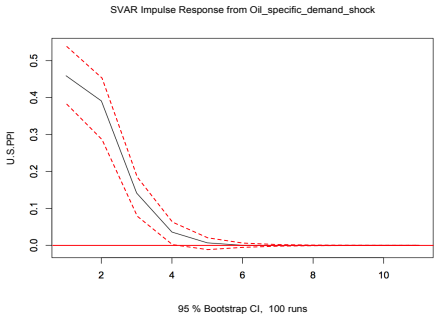
(a)



(b)



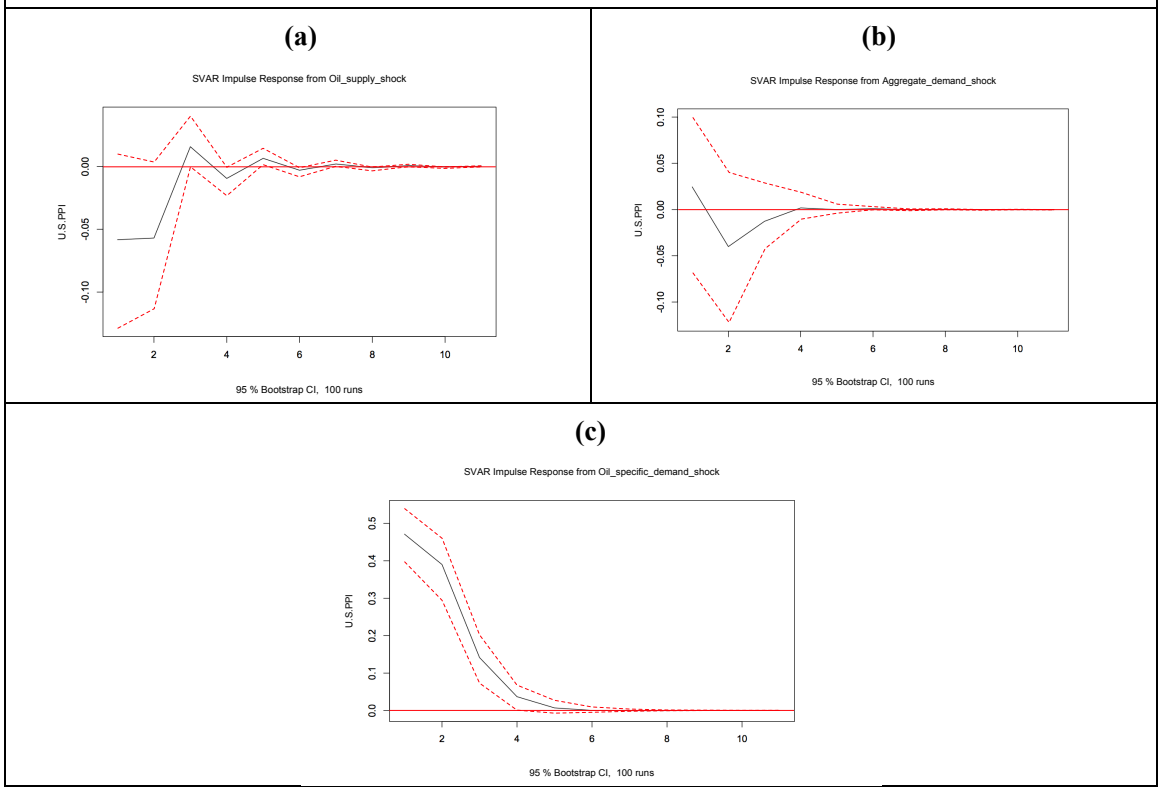
(c)



* Order of the variables: WIP, GBC, COP and U.S. PPI.

Figure E5.66 – Impulse Response Functions of U.S. PPI with Order 3
(Source: Results obtained by econometric software R, own elaboration.)

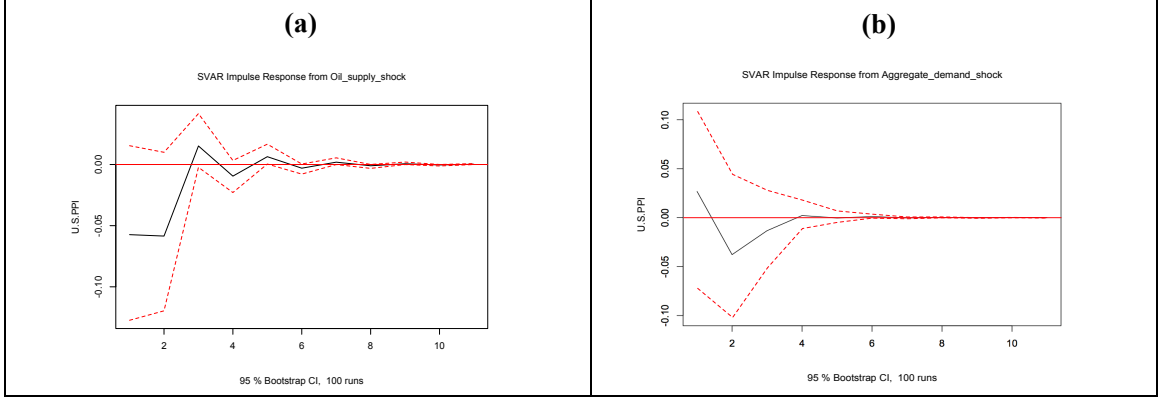
Impulse Response Functions of U.S. PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *



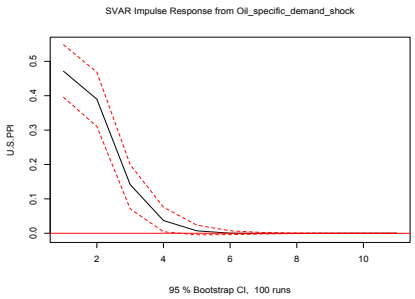
* Order of the variables: GBC, WIP, COP and U.S. PPI.

Figure E5.67 – Impulse Response Functions of U.S. PPI with Order 4
(Source: Results obtained by econometric software R, own elaboration.)

Impulse Response Functions of U.S. PPI to Oil Supply (a), Aggregate Demand (b) and Oil-Specific Demand Shocks (c) *



(c)



* Order of the variables: GBC, COP, WIP and U.S. PPI.

Figure E5.68 – Impulse Response Functions of U.S. PPI with Order 5
(Source: Results obtained by econometric software R, own elaboration.)