AN INVESTIGATION OF THE TWO-WAY RELATIONSHIP BETWEEN COMMODITIES AND THE UK ECONOMY IN AN ENVIRONMENT OF INFLATION TARGETING

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Abstract

This study investigates the sensitivity of the relationship between oil industrial inventories and oil supply at national, international and global levels to developments in monetary policy in the UK. More specifically, it provides evidence for the UK about the two-way relationship between monetary policy and commodity markets in an environment of inflation targeting. The importance of this research can be found in the provision of information which may be beneficial when projecting the economic outlook in general and inflation forecasts in particular. Although the UK operates under an inflation targeting framework, where supply shocks are considered as short-term, but recent movements in commodity markets are found to be more persistent, this study also investigates whether the sensitivity of the UK economy and policy makers to unanticipated movements in commodity prices has changed since the peak in commodity prices in 2008 which is coincident with the start of the financial crisis.

The estimation of VEC models adjusted for the UK, and plotting impulse response functions is used to investigate the dynamic reaction of oil inventories and oil supply at national, international and global levels to the shock in monetary policy. Estimated SVAR models investigate the size of the persistent and transitory effects of different types of oil and food commodity shocks on the UK economy and the reaction of policy makers. Afterwards, the Chow test is used for the identification of potential structural breaks and the investigation of whether the sensitivity of the UK economy to shocks in commodity prices has changed.

The results reveal that an expansionary UK monetary policy leads to a statistically significant decline in the OPEC oil supply while there is a less statistically significant effect on EU oil supply movements. Tight monetary policy is found to have the most significant effect on the UK's industrial oil stocks and EU industrial oil stocks. The results also reveal that the world oil supply, as well as the OPEC oil supply, became less responsive to money supply and more responsive to interest rates after the Bank of England was given an operational independency. The responsiveness of the OECD oil stocks has also become slightly more responsive since the financial crisis. Following an investigation of the transitory and persistent effect of oil and food commodities shocks in relation to the nature of the shocks, the results reveal that shocks in oil prices pass through into the UK's core inflation. It is also found that policy decisions in the UK are more sensitive to the actual shock in food prices than to the primary shock in food demand. The response of headline inflation to oil price shocks is found to be stronger before the oil price peak in 2008 and becomes less responsive afterwards while the response of core inflation to the shock in food prices is stronger after the price peak in 2008.

Acknowledgment

First of all, there is a team of fantastic people behind my journey. Just like the UK economy, I also went through the years of expansion to slow down with forecast of future success (hopefully with only small forecast error). Most importantly, I am very grateful to my mum who supported me the most. She did not only lift me up when I was at my lowest but also listened to me and probably now become an expert in monetary policy. I am very thankful for the advice and expertise of my main supervisor, Dr. Shabbir Dastgir. He has always had plenty of new ideas and suggestions. Also, I would like to thank to my second supervisor, Dr. John Anchor for being a fantastic supervisor and providing the best support. He also helped me to become who I am today. I cannot forget my sister and my friends who have always been there for me and reminded me that life is too short to worry too much. Last, but not least, my very special thanks goes to Dr. Yong Tan for his valuable advice and the time he spent helping me to improve my thesis, and to Dr. Matthew Greenwood-Nimmo who was patient with me and also offered very good suggestions. Many thanks also go to the University of Huddersfield for providing me the opportunity and support I needed through my studies.

Thank you all…

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Chapter 1 Introduction

"It's an interesting time to be an economist. Principles of macroeconomic policy, public finance and financial regulation are going to have to be rewritten for the 21st century."

Robert Skidelsky (2012)

1.1 Introduction

Commodity price fluctuations are considered to be an important source of volatility in many small open economies (Monacelli, 2013). The transmission mechanism and the size of the effect of commodity price fluctuations depend on the way monetary policy is conducted. The recent experience with commodity price shocks has differed from those experienced in the 1970s and 1980s. During the 2000s significant and joint co-movements in commodity prices have been observed. These movements evoked policy makers as well as academics to re-open the discussion on how to react to a commodity price shock, especially in an environment of inflation targeting. In general, transitory shocks are presumed to be a short-term price shocks; thus the reaction of policy makers is not required. Nevertheless, the unprecedented increases in commodity prices during the 2000s, which were assumed to be only transitory, have turned out to be more persistent. The reason why these movements re-opened the discussion on their sources, impact and suitable policy reaction was that even during the peak of the financial crisis in 2008, and during the following period of world recovery, commodity prices still have an increasing trend.

Since the size and persistence of increasing commodity prices has not been as expected, policy makers conducted decisions under the assumption of temporary shocks. Persistent commodity price shocks do not only lead to adjustments in economies, but also to adjustments in policy decisions since considering the environment of inflation targeting and the importance of credibility, relaxed policy towards to inflation pressure from commodity prices may lead to high costs as inflation expectations rise.

Since consumers focus on individual prices rather than price indices, significant changes in food prices or energy prices may be taken as signals of rising inflation and thus affect their inflation expectations. According to Bullard (2011) relative price movements may lead to a significant change in consumers' inflation expectations as they observe food prices while oil prices have an effect on the production and distribution costs. Therefore, increasing food and oil prices may represent challenges for policy makers in terms of anchoring inflation expectations. As pointed out by Bernanke et al. (2004), unanchored inflation expectation can only lead to ineffective monetary policy.

As observed from studies (Lucia and Bartlett, 2014, Timilsina et al., 2011), when investigating the magnitude of the impact of recent commodity price increases, the focus has been on their sources. Although in the history, most of the commodity shocks had been driven by supply disruptions and led to increases in inflation and decreases in output. In contrast, the increases in 2000s have been related to several factors but also to increasing overall world's demand for commodities (Gregorio, 2012).

The implication for policy makers is not so straight forward since, as a study by Kilian (2009) shows, the effect of a commodity price shock depends on the nature of the shock. On the other side of the problem with joint co-movements in commodity prices the interest of economists and academics is towards to the investigation of whether or not rising commodity prices could be a result of higher sensitivity of commodities to easing monetary policy (Reicher and Utlaut, 2013). The evidence of time-varying sensitivity of commodities on developments in monetary policy motivates to investigate this relationship since findings may be beneficial to a better understanding of recent commodity movements as well as the sensitivity of the UK economy to shocks in commodity markets, especially after 2008.

1.2 Rationale for the study

The era of "Great Moderation" brought stabilisation into economies and with relatively stable commodity markets without extreme volatility, as observed in the 1970s and 1980s the attention paid to commodity markets in relation to economies shifted to other fields. With a current smaller share of oil in the economy (compared to the 1970s and 1980s) and well anchored expectations, increases in commodity prices, which were in most cases supply driven shocks during the 1970s and 1980s, led to less attention being paid by policy makers.

However, during the 2000s a joint increases in commodity prices, which reached all-times high in nominal prices and high level in real prices, showed that commodities are not such an out of date topic as had been presumed. The events in commodity prices motivated a new investigation of drivers of these movements due to their unprecedented joint increases as well as to an investigation of their effect on economies after observing inflationary pressures in most of the developed countries. As a result, inflation projections in inflation targeting countries like the UK or EU underestimated inflationary pressures from commodity markets due to insufficient information being provided by futures contracts which are used as a predictor of future commodity price movements and investors' expectations (ECB, 2013). The characteristics of commodity prices, in terms of their sensitivity to drivers, have changed and nowadays, commodity prices became more sensitive to monetary policy in developed countries as never before (Frankel, 2006). The finding in relation to the sensitivity of commodity prices to developments in monetary policy would suggest that there have been a number of studies focusing especially on inflation targeting countries. This, however, does not seem to be the case, as most of the studies focus on the U.S given the importance of the size of the economy and its global position, while an investigation of small open economies has been left behind. The exception can be found in a study by Frankel (2013), who tested the sensitivity of commodity prices to monetary policy in small developed countries such as the UK and found evidence for an existing relationship.

Nevertheless, even though the existence of the sensitivity of world commodity prices to developments in UK monetary policy has been confirmed by Frankel (2013), in contrast to his findings, this study focuses on investigation of the relationship at national, international, as well as global levels. It is the first study of its kind, and follows Frankel's (2006) model with adjustments for the UK economy with an extension to an investigation of the sensitivity of oil supply and oil industrial inventories at national, international as well as global levels. Therefore, the study introduces an assumption that not only the UK's but also the EU oil supply and oil industrial inventories may be sensitive to monetary developments in the UK given the special position of the UK in the EU. In addition, due to an underestimation of inflationary pressures from commodity prices in inflation projections, this study also investigates the sensitivity of UK economy to developments in commodity markets since it has been found that the effect is time-varying (Millard and Shakir, 2013).

Given the importance of the role of anchored inflation expectation in an inflation targeting environment, it is also investigated whether shocks in commodity prices tend to be transitory or persistent to the UK economy and specific attention is paid to the after commodity price peak in 2008 which coincided with the financial crisis. Moreover, as Kilian (2009) showed, the effect of commodity shocks on the economy depends on the nature of the shock. Again, this approach has been mostly investigated for the U.S and the only study which focuses on the effect of oil price shocks in relation to the UK is a study by Millard and Shakir (2013).

Nevertheless, this is the first study of its kind which does not only investigate the effect of the different nature of oil price shocks, but also food price shocks, and measures the size of their persistent and transitory effect on the UK economy.

1.3 Research aim and objectives

The main aim of the research is to investigate the relationship between monetary policy and commodity markets in both directions. Thus the focus is on an evaluation the effect of shocks in UK monetary policy on commodity markets with the following objectives:

1. *To identify and measure the size of the effect of economic and monetary developments in the UK on food prices and crude oil prices.*

This is to be done by adopting a similar approach to econometric modelling as that found in previous studies on this topic, but adjusted for the UK economy. The rationale for this objective can be found in the lack of previous studies of the UK economy. The results obtained from this analysis aim to fill a gap in the evidence of the effect and help to establish an argument for the following investigation. The research hypothesis formulated in relation to this objective is as follow:

H0: Oil prices and Food prices overshoot in response to UK monetary policy

The hypothesis aims to test whether overshooting reaction of commodity prices found as a response to monetary policy in larger economies can be also identified in the case of small-developed country. The assumption here is that the commodity prices overshoot in order to adjust to expansionary monetary policy. The investigation also includes testing the hypothesis whether commodity prices also respond by overshooting to developments in money supply and output. The results confirm the hypothesis of overshooting reaction of oil prices and food prices as a response to movements in UK interest rates while the hypothesis cannot be confirmed in the case of developments in UK money supply and output.

2. *To investigate the channels for the transmission of UK monetary shocks on commodity markets at national, international and global levels.*

This objective aims to explore the most recent understanding of the channels by which monetary policy may impact on commodity markets with implications for the UK. The rationale for this objective is to apply the most recent methods of evaluating the channels and to provide the missing evidence for the effect of UK monetary policy. It also aims to provide the evidence for comparison with larger economies such as the U.S and build an understanding of the position of the UK. The concept developed as a fulfilment of this objective aims to be presented as a contribution to the most recent understanding of the channels, due to the extension of the current concept for investigating the global effect to the concept adjusted for a small open economy and investigation on national, international as well as global levels. The research hypotheses formulated in relation to this objective are as follow:

H0: Restricted UK monetary policy leads to a decrease in oil inventories at different levels.

H0: Expansionary UK monetary policy leads to a decrease in oil supply at different levels.

In relation to the previous objective and findings, these hypotheses are formulated based on theory of storage which states that due to opportunity cost, in an environment of higher interest rates, the opportunity cost of storing the storable commodity is high thus leads to demotivation of storing commodity, particularly oil. As explained by Frankel (2006) the environment of low interest rates, which is investigated by second hypothesis, the opportunity cost of extracting the oil from the ground became higher since the optional investment offers only low return on investment thus a decrease in oil supply may be assumed. The results from testing the hypotheses confirm the assumptions introduced by Frankel (2006) and show that UK monetary policy affects motivation of holding the oil inventories as well as motivation to postpone the extraction of oil due to low interest rates.

3. *To investigate whether commodity markets at different levels shows different levels of sensitivity in respect to the changes in UK monetary policy since adoption of inflation targeting.*

There are three key purposes for this objective. Firstly, evaluating the effect and size of the effect of the shock in monetary policy before and after the change in the monetary policy is assumed to help to better understand the sensitivity of the channels and contribute to the discussion on the importance of a stable policy. Secondly, it contributes to the most complex analysis of the channels that has been undertaken in this area of research so far. Thirdly, from an econometrics point of view, it aims to provide a strong argument for the stability of the model developed. The research hypotheses formulated in relation to this objective are as follow:

H0: The operational independence of the Bank of England led to a stronger sensitivity of oil inventories and oil supply to changes in interest rates.

H0: The unconventional response of monetary policy due to the financial crisis led to a change in the response of oil inventories and oil supply.

The hypotheses aim to test whether structural beak in monetary policy during the examined period also led to a different response of oil inventories and oil supply. As the results show, the operational independence of the Bank of England led to a stronger response of oil inventories at all levels while unconventional response of monetary policy during the financial crisis led to higher sensitivity of oil supply.

The investigation continues to evaluating whether UK monetary policy is sensitive to developments in commodity markets, thus following objectives are formulated:

4. *To investigate whether shocks in oil prices and food prices are transitory or persistent for the UK economy.*

The aim of this objective is to provide an up-to-date evaluation of the importance of crude oil price and food price shocks for the UK economy as the importance of the shocks is proven to be time-dependent. By investigating the actual size of the persistent and transitory effect, this objective aims to help to understand the importance of commodity prices for policy makers in the UK. The research hypotheses formulated in relation to this objective are as follow:

H0: Oil price shocks are more persistent than transitory for the UK economy.

H0: Food price shocks are more persistent than transitory for the UK economy.

The hypotheses are formulated in order to test the actual effect of oil price shocks and food price shocks on the UK economy and investigate the validity of the assumption that the actual shocks became more persistent over the time. The results show that both oil price shocks and food price shocks are tent to be more persistent than transitory for the UK economy during the period from 1992 to 2013.

5. *To investigate whether the persistent and transitory effect differs in respect to the different nature of the oil and food commodities shock and whether the sensitivity of UK's monetary policy differs in respect of the different nature of commodity shocks.*

The investigation is towards to a new concept of understanding the importance of the different nature of the shocks. It has been proven recently that policy makers in larger economies react differently to shocks in commodity markets in light to their nature. This objective aims to contribute to the limited evidence for the UK economy. Since the effect of the different nature of the shock has been investigated only in the case of oil commodities, the extension of this concept to the evaluation of food commodities represents a contribution to knowledge. The investigation aims to provide information on whether there is any implication for policy makers in distinguishing between the effect of shocks in food and oil commodities.

This objective also aims to extend previous studies on this topic by applying a concept of persistent and transitory effects of the shocks. Based on the assumption that policy makers may react differently to the different nature of the commodity shocks in respect to their nature, this objective aims to contribute to providing some evidence for further implication for policy makers. The research hypotheses formulated in relation to this objective are as follow:

H0: The different nature of oil shock and food shock has a different effect on the UK economy.

H0: The different nature of oil shock and food shock may form more persistent effect on the UK economy than the actual price shocks.

These hypotheses aim to test the actual impact of different nature of the shocks in oil and food markets. The assumption here is based on the previous research done by Millard and Shakir (2013) and original contributor on this topic Kilian (2009) who found that investigating a different nature of the shock may provide more beneficial information for policy makers. Also, the second hypothesis extends the research that has been already done and introduces the assumption that there may be differences in the different nature of the shocks which may lead to forming more persistent than transitory effects. The results confirm both hypothesis and contribute to findings introduced by Milard and Shakir (2013).

6. *To investigate whether the sensitivity of UK's monetary policy to commodity prices has changed after the new peak in commodity prices in 2008.*

The motivation for this objective is to investigate whether new peaks in commodity prices motivated policy makers to reconsider the role of commodity price shocks and their impact on the economy. It aims to contribute to a greater understanding of the time-varying impact of commodity shocks. The research hypothesis formulated in relation to this objective is as follow:

H0: The UK economy experienced more persistent effect of the different natured shocks in oil and food markets.

The rationale of hypothesis is based on specific events which happened in 2008. Firstly, there was an unconventional response of monetary policy to the financial crisis, but more importantly for this investigation, commodity prices reached a new peak. Thus the investigation is based on assumption that the peak in commodity prices led to higher sensitivity and more persistent effect on the UK economy. The findings show that after the peak, food prices have more persistent effect on the UK economy, while no change has been found in the case of oil prices. Nevertheless, interest rates are found to be less responsive to more persistent effect which may be due to policy action adopted as a response to consequences of the financial crisis.

1.4 Structure of the thesis

Chapter 2 provides an introduction to the relationship between monetary policy and movements in commodity markets. It discusses the historical movements of commodity prices and time-varying drivers of these movements. In addition, this chapter introduces and discusses the rationale for the investigation and the importance of commodity prices for inflation forecasting and economic outlook projections.

Chapter 3 provides a theoretical background for this study by introducing literature explaining the movements in commodity prices as well as the importance and role of commodity prices for monetary policy. This chapter covers two main areas of interest. The first section follows earlier theories explaining the behaviour of commodity markets that helped to develop recent understanding of unanticipated developments in commodity markets. The second section extends the understanding of the channels on how monetary policy may affect the commodity markets in a reverse relationship. This chapter also introduces a theoretical rationale to the assumptions and econometric models developed in Chapter 5 and Chapter 6.

Chapter 4 explores econometric tools and techniques, and discusses methods that are appropriate, given the nature of the data used for analyses. The methods and techniques of the research are discussed in consideration of the advantages as well as the disadvantages of the econometric tools applied to the data. It also explains the philosophy of econometric modelling approached for estimated models, and continues a discussion on the use of Vector Autoregressive models for investigating the impact of policy actions on macroeconomic variables. In section, steps involved in analyses of time-series with focus on the non-stationary nature of the series are discussed. It also discusses the rationale and a source of data collected and presents a preliminary data analysis by identifying the distribution, seasonality and nature of the time-series in terms of stationarity.

Chapter 5 presents a Vector error correction model, as well as, a Vector autoregressive model, developed in order to contribute to understanding the effect of UK monetary policy on oil supply and oil inventories at national, and international, as well as global levels. The estimation of current models used for analysing the relationship applied to large economies is adjusted and extended to an analysis of monetary policy in a small open economy and its effect on oil supply and oil inventories in the light of the literature (Chapter 3).

Chapter 6 presents the econometric models developed for investigating the response of policy makers to developments in commodity markets. The findings of Vector autoregressive models, developed in this chapter, contribute to a recent understanding of the role of commodity prices as a possible indicator of inflation for a small open country operating under inflation targeting and also contribute to an understanding of the effect of commodity prices on the UK economy.

Chapter 7 discusses the results of the econometric modelling in the light of the literature (Chapter 3) and previous research outlined in Chapter 5. Finally, Chapter 8 provides conclusions and summarizes the most important findings and possible implications for monetary policy, as well as, discussing the contribution of this study in the light of its implications for policy makers. It also addresses the limitations of the research and provides suggestions for further research.

Chapter 2 An overview of historical developments in commodity markets

2.1 Introduction

Over the past decade, commodity prices have experienced stronger upward trends (EIA, 2013c), greater joint movements (Alquist and Coibion, 2013) as well as higher volatility (Cavalcanti et al. 2012). The upward co-movements in commodity prices have been referred to as a result of several driving factors, such as developments in global economic activity, specifically the developments in emerging economies (Dwyer et al. 2011), US nominal exchange rate (Chen et al., 2013), easing monetary policy (Arora and Tanner, 2013), and speculations (Algieri, 2012).

As commodity prices play an important role in different aspects of the economy, which can be applied to both developed and developing countries, such as price inflation (Stockton, 2012), food and energy security (Kirwan and Maye, 2013), and economic and political stability especially in net-importing and net-exporting countries (Gouel, 2013), the events from the last decade increased the concerns of policy makers in countries around the world. For instance, based on long-run elasticity, Baffes and Dennis (2013) evaluated factors contributing to recent rises in food prices and found that the stock-to-use ratios participated by (-0.25 per cent), oil price (0.25 per cent), and the exchange rate (-1.25 per cent).

Therefore, when taking into consideration the events on commodity markets and their importance for policy makers, it is vital to fully understand the drivers behind these movements as well as their impact on the economies. The time-varying nature of commodity price developments since the 1970s discussed in this chapter has significant potential implications for the evaluation of the country's economic outlook. As noted by Gregorio (2012), nowadays, an understanding of developments in commodity prices for formulating the assumptions used for estimating their future developments may be more uncertain than before. It is therefore crucial to conduct an analysis of the recent underlying factors which act or may act as drivers of commodity prices in order to evaluate the implications for medium-term price stability and to approach the appropriate monetary policy response to these changes in commodity prices (ECB, 2013).

The importance of changes in commodity price developments with implications for decisions made by policy makers can be demonstrated on the projection of inflation forecast. The first important implication is that developments in commodity prices are estimated in the projection of future inflation as exogenous variables where they are assumed to be dependent on prices in futures markets (Naifar and Dohaiman, 2013). Thus, the forecast of the price of the commodity in time *t* is estimated from the futures contract with maturity at time *t*, assuming that the futures price is equal to the spot price in time *t* (Gospodinov et al., 2013). Nevertheless, it is possible for the price of the commodity to deviate from the expected spot price at the time *t*, resulting in risk premium (Chevallier, 2013). As noted by Gorton et al., (2013) even though commodity prices have characteristics of financial assets, as further discussed in Chapter 3, they differ in additional costs (which are specific to storable commodities) such as the cost of storage, and convenience yield which represents the benefit of holding inventories (Frankel, 2013).

When commodity prices oscillate around relatively stable or expected levels with only short-term deviations, the convenience yield as well as risk premium are assumed to be larger, thus the forecast error of commodity prices tends to be relatively small (ECB, 2013). However, complications may arise when the developments in commodity prices have a trend, persist longer and are not expected. This situation forms a higher forecast error; since unexpected developments in prices could not have been observed, this consequently leads to the production of an out-dated forecast. For instance, according to Stockton (2012), the performance of the BoE’s forecast for the UK was due to events in the last decade worse than before. As Stockton (2012) further explains, in the UK, the forecast tends to persistently over-estimate the output growth while underestimating Consumer Price Inflation (CPI). Understandably, as inflation targeting country, underestimating CPI may lead to under evaluating the risk of rising inflation which can move above the inflation target and if this situation persists, it may negatively affect the confidence and inflation expectations of consumers.

The explanations of the underestimation of the growth in output are few, such as weaker productivity (Blanchard and Leigh, 2013), pressure on real lower incomes due to the increase in global commodity prices (Saunders, 2013), as well as overall negative developments in most of the countries, which consequently has had an impact on the volumes of net trade (Stockton, 2012). On the other hand, in the case of persistent underestimation of inflation, the forecast error, according to Stockton (2012) has been found in the projection errors of commodity prices in addition the effect of sterling depreciation passed through into consumer prices faster than expected. The same forecast error, due to commodity prices, which contributed significantly to the overall error of inflation projection, can be found in the ECB's economic outlook. The projection underestimated the commodity prices, particularly oil prices in the period between 2007 and 2011 since the developments in oil prices were not anticipated by oil futures (ECB, 2013). As investigated by Cabanillas and Terzi (2012) the forecast errors in 2009 of the European commission's economic projections in the case of GDP, inflation, and investment, were also caused mainly due to events which were not anticipated by commodity futures prices.

It therefore becomes clear that even though policy makers do not set interest rates directly based on commodity prices, as these are exogenous to the economy, the developments in commodity prices are considered in projections of economic outlook which are considered when decision making. Thus, it is important to fully understand the drivers behind these movements as well as their impact on the economy. As noted by ECB (2013) the macroeconomic model for the Eurosystem estimates that a 10 per cent increase in oil prices has an upward impact of 0.5 per cent on Euro area inflation, and a 0.25 per cent downward impact on the output growth of the Euro area. Nevertheless, the impact of movements in commodity prices can be observed in several different channels. Direct effects of inflation can be observed in increases in consumer prices, especially in the case of energy and some food prices such as grains, since these are transmitted directly into consumers' prices for fuel, heating and unprocessed food.

The second round effect of the movements can be observed in the reaction of wages and prices for goods (Gourinchas et al., 2013). This could lead to higher inflation expectations and transform into persistent inflationary pressures which are reflected by core inflation. Due to the different nature of commodity price movements in 2000s, and their stronger growth and joint movements, they are considered as a systematic component of inflation. As a result, in the EU, the share of energy in the consumer price index measured as the Harmonized Index of Consumer Prices (HICP) raised from 8.4 per cent in 2000 to 11 per cent in 2013. Therefore, when the relatively low price elasticity of commodity consumption is considered, it raises the importance of commodity prices for inflation and thus it leads to an increasing relevance for monetary policy too (ECB, 2013).

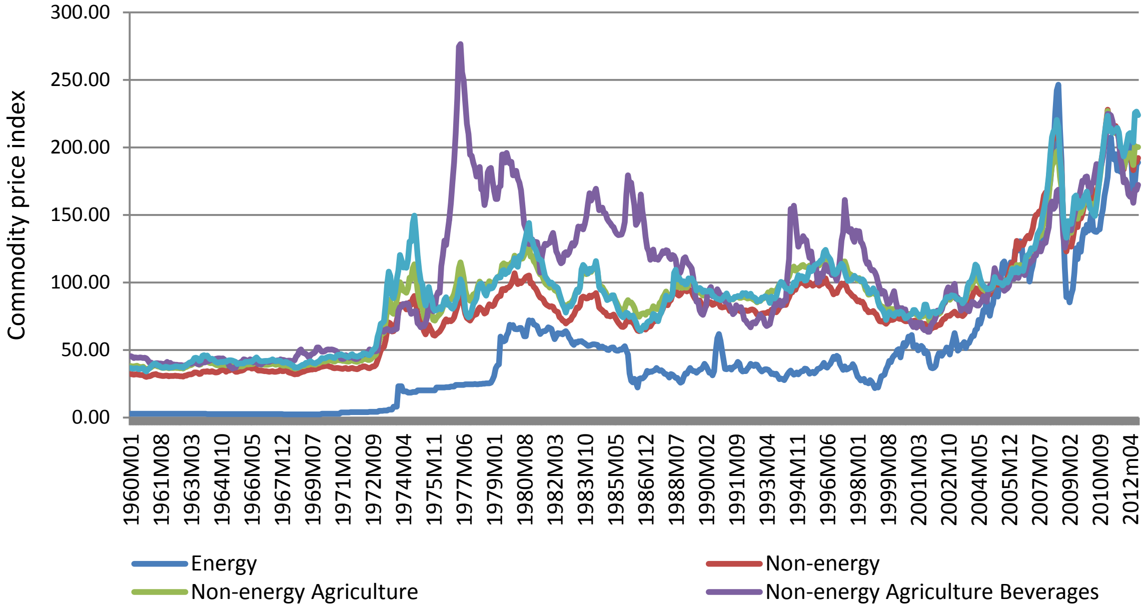
2.2 The relationship between commodity prices and macroeconomic adjustments in developed countries

Until recently, most of the research on commodity prices and their volatility has been the main concern of policy makers in developing or emerging economies, since the swings of commodity prices worsen economic performance in these countries (Alom et al., 2013). However, it should not be forgotten that this impact has spread to developed countries as well. The harmonisation of economic policies, as well as changes in the international economy, caused that the size of the impact on developed countries to be more significant than before (Eickmeier and Pijnenburg, 2013). With changes to the world economy, the commodity market is transforming as well and the commodity sector does not only operate as a transmission mechanism, but also as a major source of instability in the world economy. Therefore, it is assumed that sufficient attention should be paid to these developments in order to investigate the current relationship between commodity prices and monetary policy in developed countries.

2.2.1 The historical evidence of the relationship between commodity prices and economic performance in developed countries

From both an academic and policy perspective it is agreed, that movements in commodity prices may have significant effects on the output and inflation in a country (Murray, 2013). However this statement poses a number of important questions such as: movements in which commodity prices? What is the size of the effects and in which country? The relevance of these issues has increased over the past decade, due to significant increases in the level of commodity prices. According to an individual commodity index measure constructed by the World Bank (2012b), commodity prices more than tripled between 2000 and mid-2012, with the increases being widespread (Figure 2.1). A certain level of decline can be observed in relation to the global economic downturn, but overall commodity prices have rebounded substantially. This general experience stands in contrast to the decline in commodity prices relative to the prices of other goods and services over much of the 20th century.

Figure 2.1: Individual commodity indexes



Source: Adapted data from World Bank (2012b)

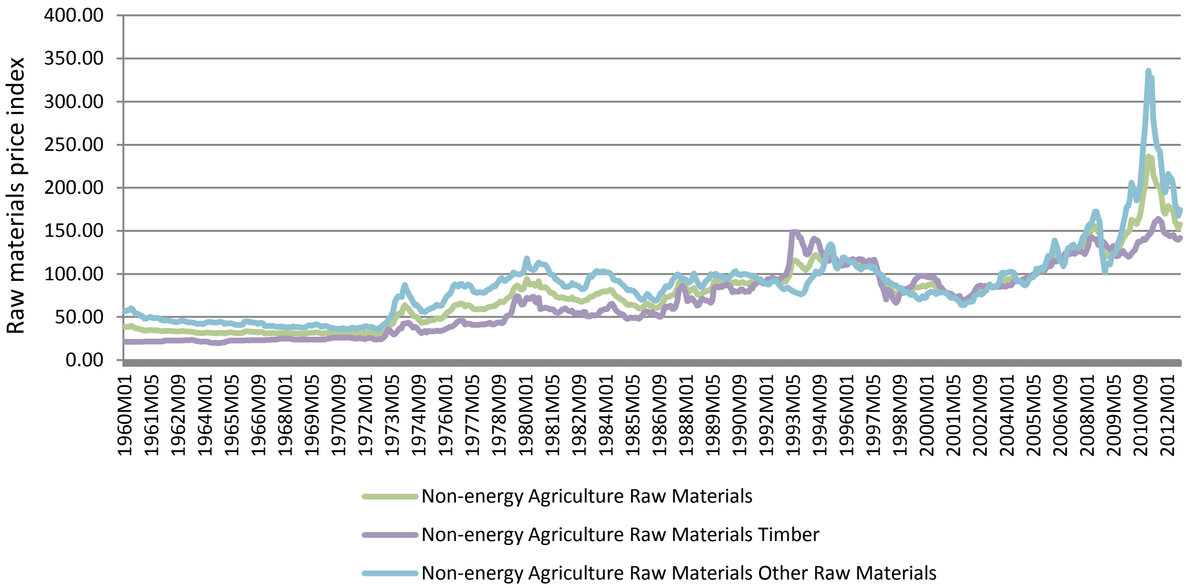
From Figure 2.1 it is clear, that in the 1970s and 1980s commodities tended to move in a different direction, and there was an increased volatility in commodity prices starting in the 1970s comparing to the 1960s. According to Neslin and Shoemaker (1983), the 1970s was a decade of several shocks to world commodity markets, starting with the sharp rise in petroleum prices in 1973–1974, which consequently led to a panic and a continuing general rise in commodity prices, while there was a succession of shortages in some major markets (cereals, sugar, and some vegetable oils in 1974–1975, and coffee in 1977). The situation resulted in significantly higher levels of commodity prices (Nissanke, 2012). While commodity price fluctuations in the 1970s had an upward trend, by contrast, commodity prices in the 1980s, with smaller fluctuations, had a sharp downward trend. Another notable feature of the commodity situation in the 1980s was that the price decline affected all the main commodity groups without exception, especially food, where the downtrend for sugar (with about half the total weighting) was 21 per cent per annum (Jacks, 2013).

Understanding the main causes of the sharp downward trend in real non-oil commodity prices in the 1980s is important, since understanding of what happened in the past helps to establish a credible assessment of the likely future course of commodity prices. A number of studies attempt to explain the volatility of commodity prices over the 1980s. However as already noted, the difficulty is that the dominant influences on commodity prices differ during the years and are also significantly different within commodity groups. In general, the sharp downward trend in commodity prices reflected a simultaneous decline in the growth rate of commodity demand, and the continued expansion in the world commodity supply, together with the influence of monetary factors (United Nations, 2011). Therefore, the decline in commodity prices during 1980s was driven by supply and demand as well as the involvement of policy actions.

2.2.2 The decline of commodity demand in the 1980s

The main issue in the1980s was the slowdown in the GDP growth in OECD countries. While to the late 1970s the industrial production output rose by 3 per cent but declined significantly in the 1980s to only 1.9 per cent (EIA, 2011a). Understandably, it negatively affected commodity demand for all industrial inputs. Moreover, it is necessary to mention that in the 1980s, countries like Germany and the UK were dealing with a high rate of consumer price inflation. In addition, another important issue was the substitution of materials. According to Maizels (1992) the end of the 1970s and beginning of the 1980s is characterized by switching from natural materials such as cotton and wool to synthetics as well as minor metals being replaced by optic fibres, in the food category, sugar was replaced by synthetic sweeteners and high-fructose corn syrup. Simultaneously, there was a decrease in meat and tobacco consumption that consequently led to the decline of food price volatility (Figure 2.3). This substitution effect also caused a long-term continuation of declining consumption of natural raw materials (Figure 2.2).

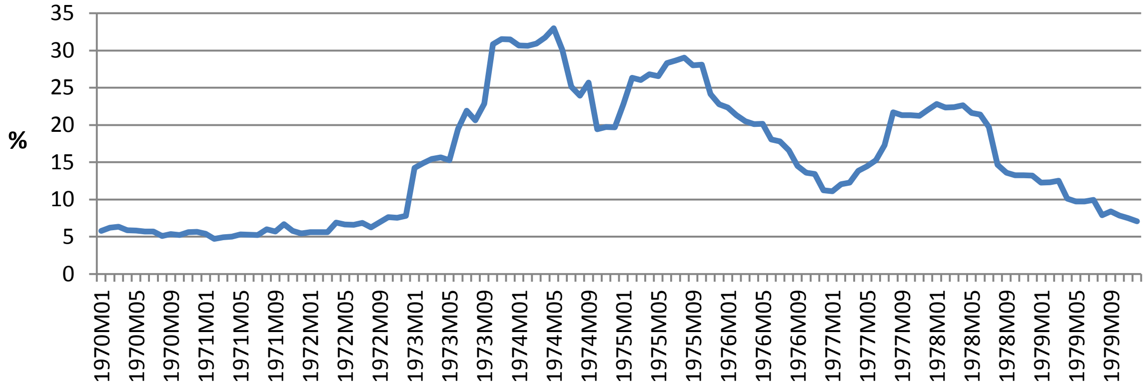
Figure 2.2: Historical development in raw materials price index



Source: Adapted from World Bank database (2012b)

There were several factors affecting commodity prices and the effects of these impulses differed. In general, from the observation of the commodity market in the 1980s, the main factors driving prices were declining demand, excessive supply, and also price instability in developed countries (Dwyer et al. 2011). Although an examination of the historical development in commodity prices gives a general view on price trends, it is important to examine the volatility of commodity prices. Volatility can be used as a month-to-month variation in commodity prices since it measures how much a price changes about its constant long-term level or trend (Anderson et al., 2008). In other words, volatility measures dispersion about a central tendency. However, since the application of a volatility coefficient can be misinterpreted, it should be noted that the volatility coefficient is not a measure of the direction of price changes, but of the dispersion of prices about the mean. The apparent increased volatility of commodity prices in the1970s presented in Figure 2.3 raises questions about the determinants of volatility.

Figure 2.3: Food price volatility in 1970s

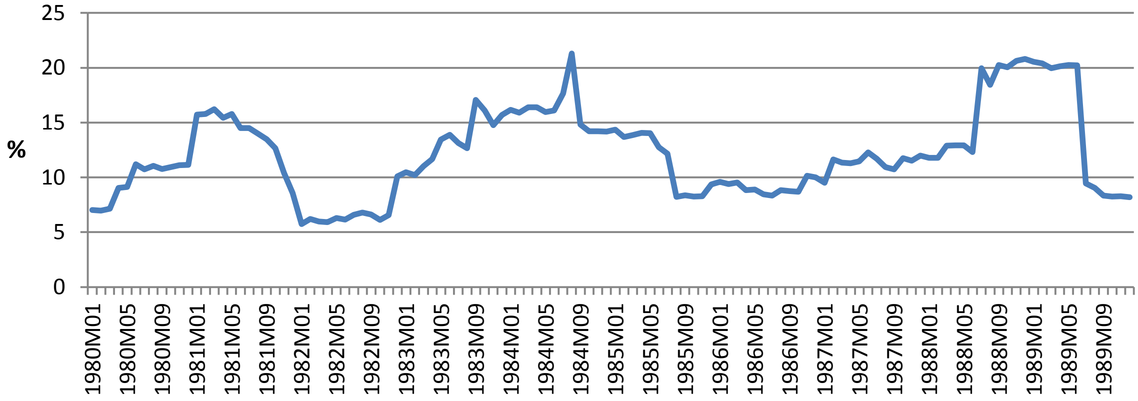


Source: Calculation based on data adapted from the World Bank database (2012a)

Since most of the commodities are considered to have highly inelastic supply and demand curves at least in the short-run, neither supply nor demand initially significantly responds to price changes. Thus any shock to supply or demand will lead to significant changes in commodity prices (Lin, 2011). The dissemination of new information related to fundamentals results in practice adjustment as market participants evaluate the implications of this information. It can be argued that the emergence of a new class of financial traders had transformed the commodity market substantially to a more volatile market (Sockin and Xiong, 2013).

The annualized volatility of food prices during the 1980s is presented in Figure 2.4. Comparing volatility in the 1980s with food price volatility in the 1970s, a sign of stabilization can be observed since the volatility of food prices in the 1970s reached about 30 per cent while in the 1980s it was just about 20 per cent. Therefore compared to the 1970s, food prices in the 1980s had a slightly declining trend and lower volatility. However, except for the decline in demand, and switching from natural resources to *"man made"* materials, there was another factor which is believed to be assigned for lower commodity prices.

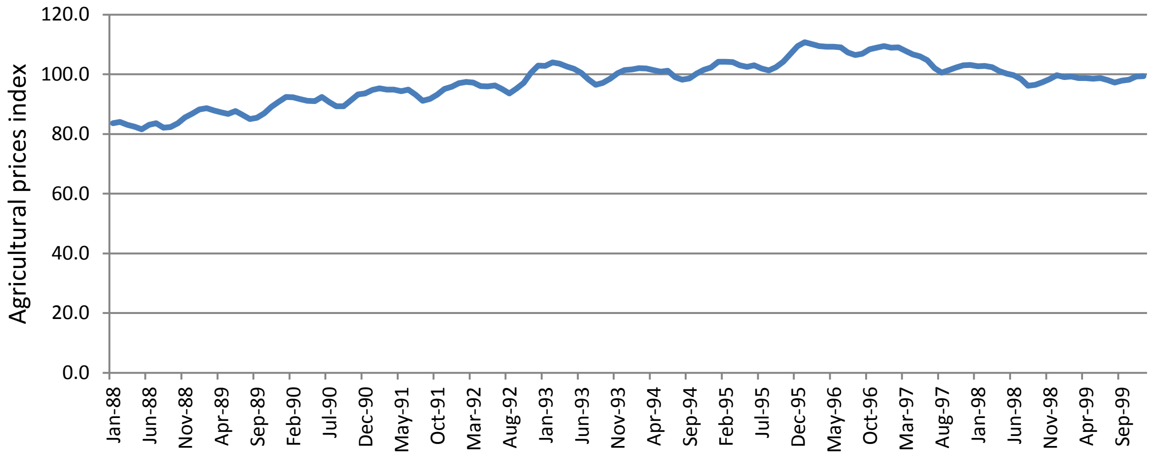
Figure 2.4: Food price volatility in the 1980s



Source: Volatility calculated as annualized volatility of monthly data based on World Bank data (2012a)

The situation was slightly different in the UK agricultural markets. From the late 1970s, UK food inflation began to fall behind general inflation. According to Defra (2010), in the UK, between 1987 and 2006 food prices fell gradually in real terms by over 20 per cent. The drop in food prices in general, can be observed in Figure 2.5 which shows only a very small increase in UK's agricultural price index. However importantly, rising oil prices later did not only affect global commodity prices, they also increased energy costs throughout the domestic food chain. As the research of Defra (2010) shows, a doubling of oil prices in 2008 from $50 to $100/b increased UK consumer food prices by 5-10%. This compared to a relative stable situation on commodity prices worldwide and in the UK during the 1990s represents a significant increase. Thus UK commodity markets went through the period of stabilisation just like the world commodity prices during 1990s (Figure 2.5 and 2.6).

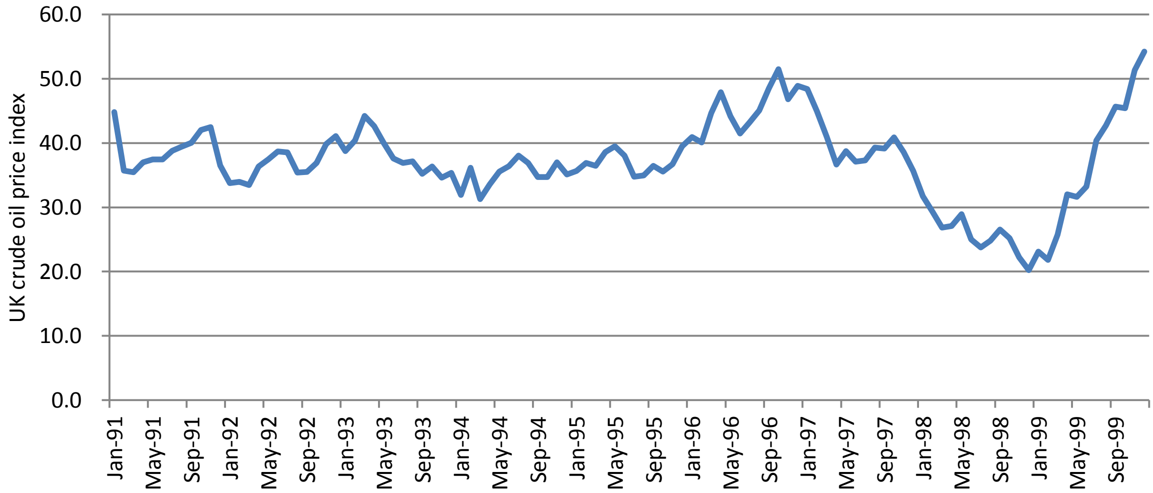
Figure 2.5: UK's Agricultural price index



Source: Data adopted from Defra (2014)

At the start of 1980, the biggest problem facing the UK (and other countries) was cost push inflation. In the late 1970s, UK inflation reached over 20%. This was caused by rising oil prices and wage push inflation. Oil has played a major role in the UK economy during the 1970s and 1980s for two reasons: the price of oil has fluctuated dramatically and, partly in response to higher oil prices, there has been large-scale investment in North Sea oil production, resulting in the UK becoming a major oil-exporting country.

Figure 2.6: UK crude oil prices (2005=100)

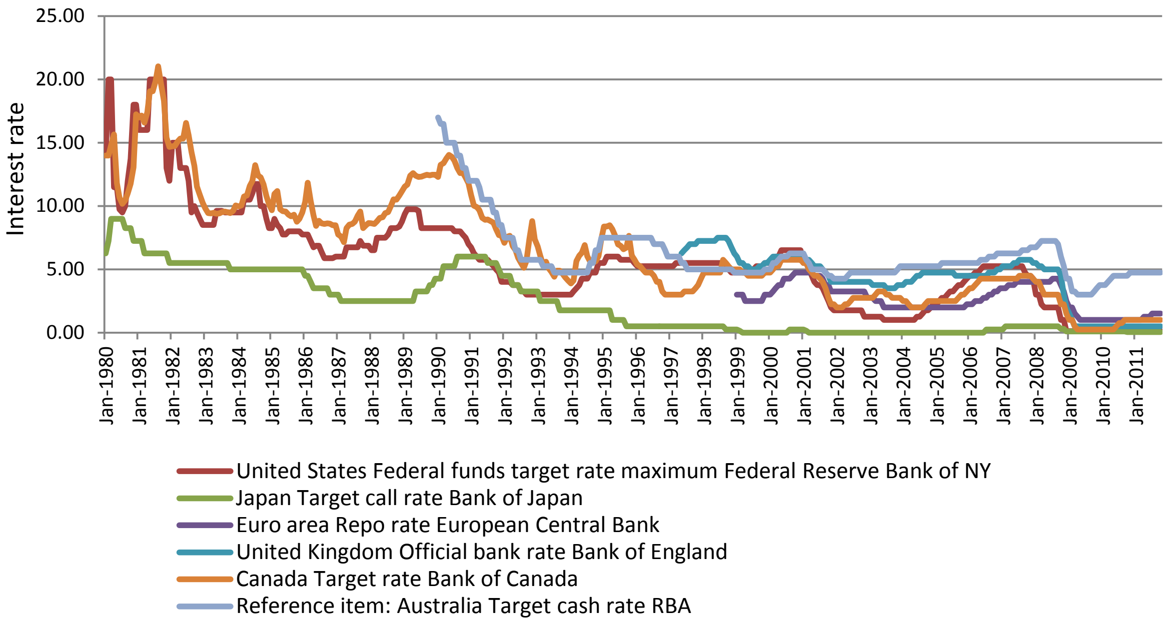


Source: Data adopted from Department of Energy and Climate Change (2014)

As noted earlier, most developed countries such as the UK struggled with controlling the inflation that consequently led to higher interest rates (Figure 2.7). Changes in the volatility of food prices influenced many researchers to investigate whether interest rates could possibly have affected the volatility of food prices, these researchers came to variety of conclusions. While Taylor and Springs (1989) and Tegene (1990) state that there was a direct effect of monetary factors on food prices, Kliesen and Poole (2000) and Shaun (2010) argue that monetary policy can affect food prices only in an indirect way by contributing to low inflation, stable inflation expectations, and low interest rates. In addition to the disagreement on whether the effect of monetary policy on food prices is direct or indirect, other studies show that monetary impacts did not play a dominant role in changes in food price volatility (Isaac and Rapach 1997, Orden 1986, Orden and Fackler, 1989). However, more recent research done by Frankel (2013), and Anzuini et al. (2013) shows that the interest rate can affect commodity prices, especially if market participants expect interest rate shocks or the persistence of interest rate shocks.

In Figure 2.7, a significant change in interest rates since the 1980s in major developed countries can be observed. The most apparent changes came with different monetary regimes, particularly inflation targeting, which was broadly adapted by most of the developed countries in 1990s. The consolidation of interest rates within developed countries brought lower interest rates in 1990s compared to the previous two decades, and could therefore affect the development in commodity prices.

Figure 2.7: Historical development of interest rates in major developed countries

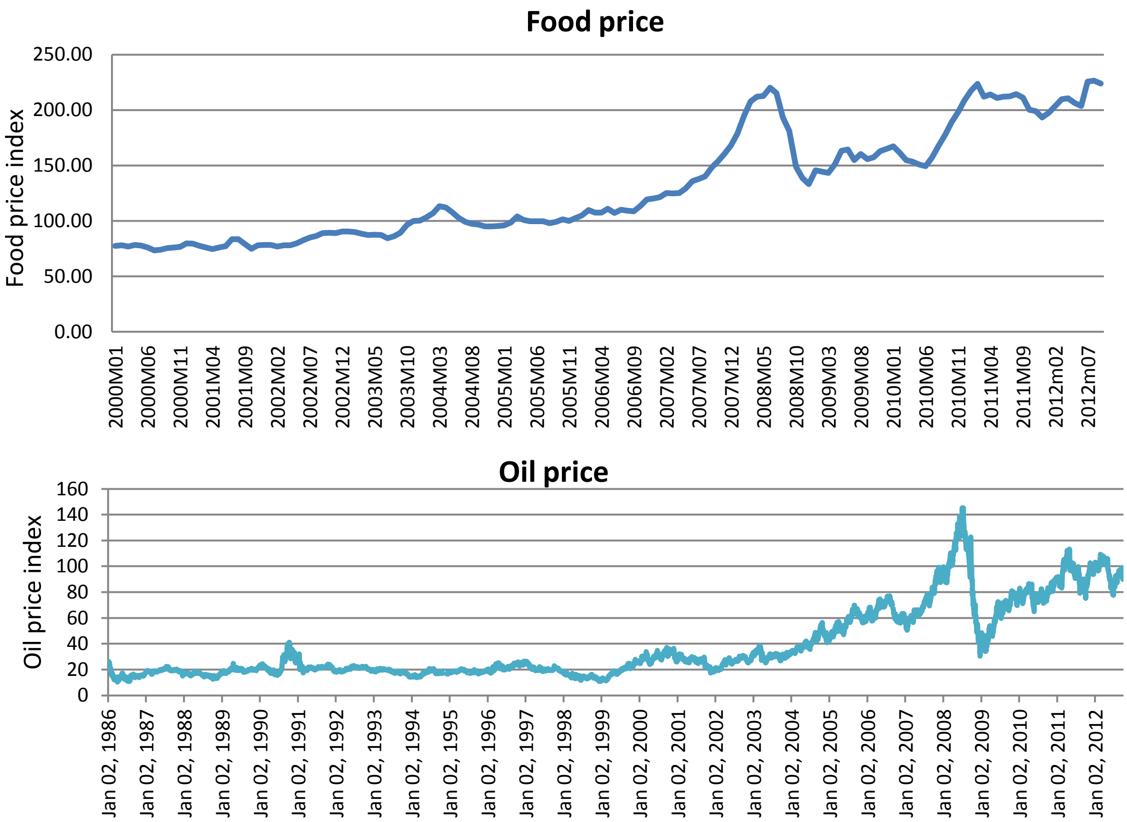


Source: Adapted data from the World Bank (2012b)

2.2.3 Recent commodity price movements

The commodity prices, especially non-fuel commodity groups, have experienced a commodity price boom since 2002. As Figure 2.8 shows, price increases began to escalate in 2006. The food price and oil prices increased further and accelerated in the first half of 2008. This price hike understandably gave rise to a genuine fear of food and fuel crisis due to the characteristic of basic and politically sensitive consumer goods items (Downing and Harker, 2012).

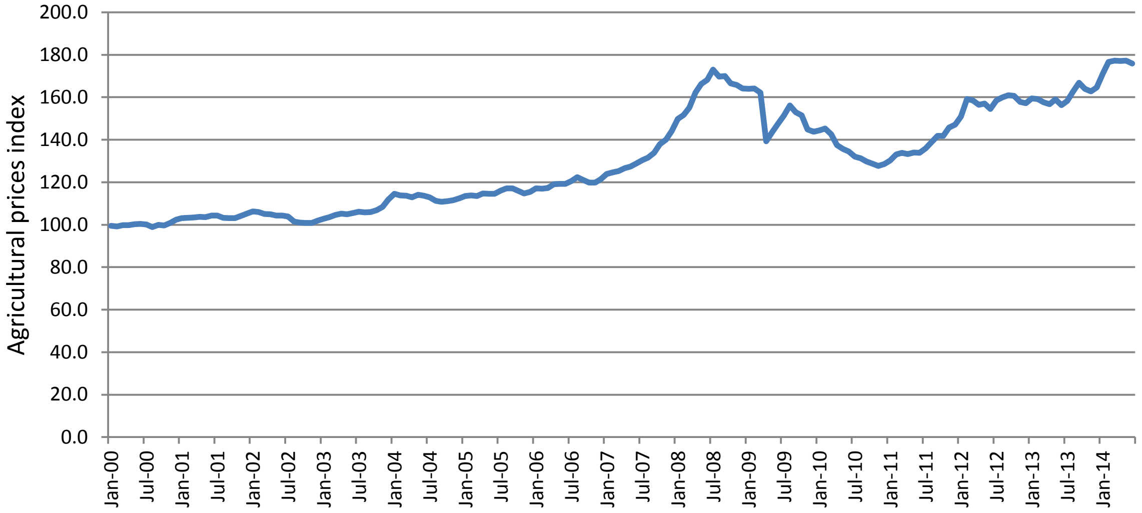
Figure 2.8: Oil price index and Food price index development in 2000s



Source: Adapted data from the World Bank (2012b)

In 2007 and 2008, the combination of rising commodity and energy prices drove up food prices by more than general inflation. In real terms, food and non-alcoholic drinks prices rose by over 12% between August 2007 and December 2008, returning them to the levels of the late 1990s. Real food prices continued to rise in late 2008 and early 2009 because of the inflationary pressure of weaker sterling, which increased prices of tradable commodities such as livestock and fruit. During 2009, retail food inflation began to abate as raw material costs fell and sterling stabilized. By autumn 2009 annual food inflation had fallen below 2% which can be observed by a drop in UK’s Agricultural price index (Figure 2.9).

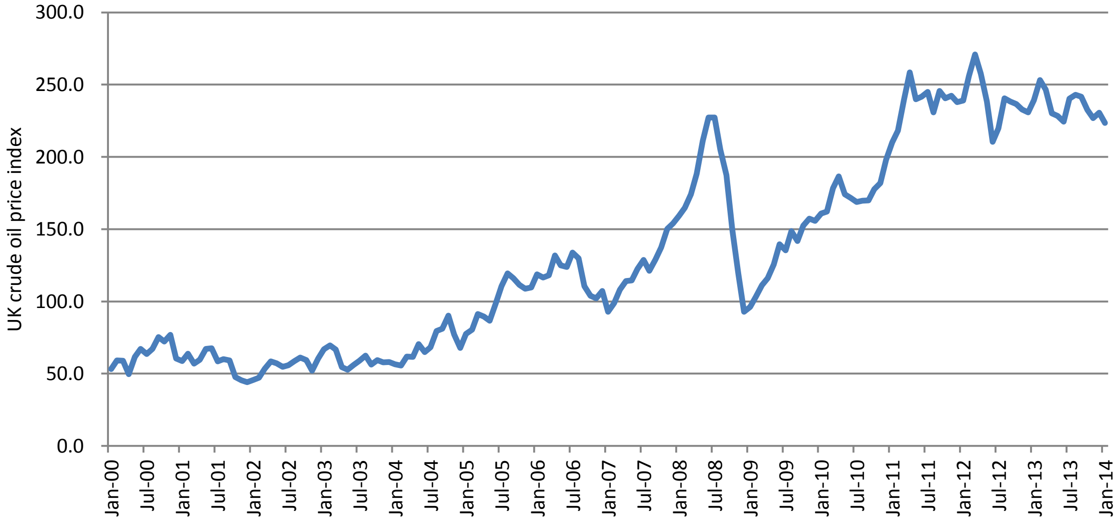
Figure 2.9: UK Agricultural price index



Source: Data adopted from Defra (2014)

Since price changes in foods have a direct impact on affordability the changes in certain types of food raise lead to a substitution effect on alternative foods. Nevertheless in general, rises in food prices will lead to greater pressure on household budgets. Indeed, the percentage spend on food by low income households estimated by Defra (2010) based on average changes in food price inflation since 2007) risen from 15.2% in 2007 to 16.8% in 2009. When compared to households in Europe, UK households devote a low share of their spending to food. In 2005 the average share in the UK was 10% and in the whole of the EU it was 15%.

Figure 2.10: UK crude oil price index (2005=100)

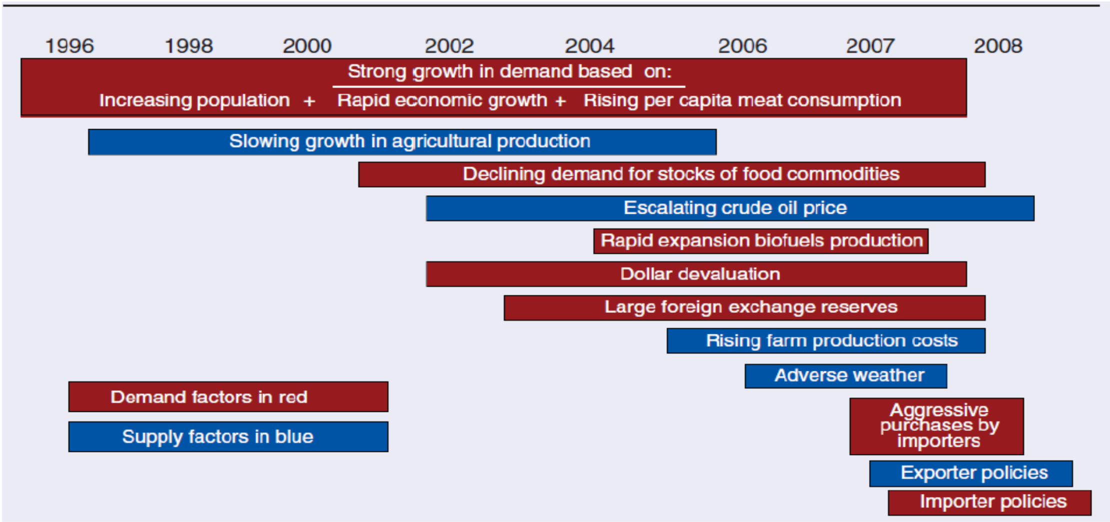


Source: Data adopted from Department of Energy and Climate Change (2014)

The most of the 1990s was characterised by a consistent long term increase that averaged around 2.7 pence per litre each year. Prices increased at a faster rate in late 1999 and 2000 which led to the September 2000 fuel protests when petrol and diesel were an average of 80.2 and 82.3 pence per litre respectively. Prices subsequently fell back to around 75 pence per litre in 2002. Price spikes have tended to be sharper in recent years even though a small decrease in early 2007 can be observable, prices were broadly consistent with the long-term price rises seen in the 1990s. However, early 2008 saw the fastest period of price increases of recent decades and typical retail prices at mid-July 2008 were 119.4 pence per litre for petrol and 132.9 pence per litre for diesel (Figure 2.10). Prices fell back sharply over the second half of 2008, but, apart from summer 2010, have increased in nearly every subsequent month. The mid-May 2011 price of 136.7 pence for a litre of unleaded petrol was the highest cash price ever until the March 2012 figure of 137.9 per litre. Both prices peaked in April 2012 and fell soon afterwards and subsequent increases have been short-lived.

However, not only food and oil prices increased significantly. Minerals, ores and metals increased between 2002-2007 by 261 per cent and all commodities, excluding crude petroleum, increased by 113 per cent (World Bank, 2012b). The generally synchronized price boom indicates that common factors were responsible for the price escalation across primary commodities. As assumed by Nissake (2012) the key factor for price dynamics over the medium term are demand-supply relationships, since the demand e.g. for minerals and metals, is believed to be driven by newly industrialized emerging economies. While there have often been attempts to identify one single factor driving the boom, the evidence suggests that a combination of factors is likely to be more realistic. Robust demand and supply constraints appear to be driving price increases, but financial speculation also appears to be playing a role. Trostle (2008) identified a few factors which according to his assumption led to increases in commodity prices over 2000s (Figure 2.11).

Figure 2.11: Drivers of world commodity prices



Source: Trostle (2008)

Interestingly, as showed in Figure 2.11, Trostle (2008) did not consider the low interest rates of most of the central banks in developed countries as a factor driving commodity prices. In fact the monetary channel is left out. This is in contrast to his previous assumption since he recognizes the possible effect of financial speculation, which can be represented by the inflation hedging position, or in other words, expectations about future price movements, future consumer inflation and consequently the tight or easing monetary policy. Therefore easing monetary policy in the majority of developed countries could assign for higher commodity prices. Nevertheless, there is an ongoing discussion on the effect of monetary policy on world commodity prices, especially considering the recent boom cycle in the commodity market which, cannot be explained entirely by shifts in demand and supply. The excessive volatility is likely to be a reflection of increasing linkages between commodity markets and financial markets. In addition to constantly evolving economic conditions under globalisation, and swings in commodity prices, it is even more important to investigate the effect of commodity prices on consumer price inflation since understanding this relationship is important not only for policy makers. Although empirical evidence introduced in this chapter helps to introduce the topic, in order to answer the two fundamental questions: (i) Are commodity price movements sensitive to easing monetary policy? (ii) What is the role of commodity prices in relation to consumer price inflation and can commodity prices be a useful indicator of future inflation? A theoretical justification is needed. The next chapter therefore discusses the theories developed through the century.

2.3 Summary

This chapter introduced a background to historical movements in commodity prices and attempted to introduce an existing link between commodity prices and monetary policy. A simple correlation coefficient shows that in 1980s food prices moved in the same direction as UK interest rates. As the results show, the relationship broke in the 2000s. However, the continuing simultaneous increase in commodity prices suggests that the factors driving the commodity prices are beyond the traditional supply and demand forces and the relationship between commodity prices and monetary policy in developed countries needs to be further investigated.

Chapter 3 Commodity price movements and their effect on the economy

3.1 Introduction

The purpose of this chapter is to review theories explaining movements in commodity prices as well as the importance and role of commodity prices for monetary policy. This chapter is therefore split into two main areas of interest. The first section follows earlier theories explaining the behaviour of commodity markets that helped to develop more recent understanding of unanticipated developments in commodity markets. The second section extends the understanding of the channels on how monetary policy may affect the commodity markets in the reverse relationship. The theoretical explanation is based on the earliest theories on the transmission of commodity shocks to the economy. This chapter therefore aims to provide a theoretical rationale for the assumptions and econometric models developed later in this thesis.

The discussion of earlier theories on commodity price determination begins in Section 3.2 and continues in Section 3.3 with discussions on the most recent approaches adopted in order to understand commodity movements during 2000s. Section 3.5 is dedicated to the investigation, through the existent literature, of the relationship between monetary policy and commodity markets. The reverse relationship with supportive evidence is discussed in Sections 3.6 and 3.7. Finally, Section 3.8 focuses on the overview of monetary policy in the UK during the era of inflation targeting.

3.2 The impact of monetary policy shocks on commodities

3.2.1 Theory of storable and non-storable commodity price determination

The developments in commodity prices discussed in the previous chapter have encouraged economists to discuss the role of commodity prices in the conduct of monetary policy and the achievement of price stability. However, an important issue which requires more attention when analyzing the commodity prices and their impact on any aspect of the economy is the determination of commodity prices. The key role is played by distinguishing between commodities in terms of their storability since it directly affects how the price is determined.

As outlined by Nissanke (2012), commodities can be split into storable and non-storable commodities. Non-storable commodities refer to a very small group of commodities such as electricity, while storable commodities refer to oil, food and metals. Regarding the flexibility or volatility of stocks, storable commodities can be further distinguished between storable with large stock and limited volatility of stocks (thus the stock cannot jump up or down) such as gold and silver, and storable commodities with possible stock outs thus immediate availability might not be possible (Chevallier and Ielpo, 2013). Examples from this category are agricultural products (at expected harvest) and oil (at expected easing of supply).

In the case of non-storable commodities there is a volatility of stocks, for example electricity and natural gas and also oil, but only if the production is at the storage capacity. With regards to price determinants, the distinction between storable and non-storable commodities is that storable commodities can be acquired at the spot price and stored until the expiration of the futures contract (Turnovsky, 1983). In markets for storable commodities such as oil or food, inventories play a crucial role in price formation (Pindyck, 2001). The price of futures contracts in the case of storable commodities does not usually deviate significantly from spot prices and reflects the spot price and carrying costs. However, in the case of non-storable commodities, future prices can deviate from spot prices significantly mainly due to unexpected changes in supply and demand (Emmons and Yeager, 2002). The problem of the volatility of future prices when applied to monetary policy can be found in a prediction hypothesis.

The bias of a prediction hypothesis is based on how accurately the future prices can be predicted. If the prediction is more likely to be accurate, this can help to understand the current expectations about future price movements, and thus send an earlier signal about expected inflation (Yang et al., 2001). While there is sufficient evidence for price discovery functioning for storable commodities, beginning with Working (1948), non-storable commodities have been a puzzle as more authors pointed at the failure of futures markets in serving the forward pricing role. The weakness of non-storable commodities can be found in the fact that they are non-storable.

The anatomy of the problem has been very well explained by Benth and Brandis (2009). As they pointed out, in the case of a non-storable commodity such as electricity, if a hypothetical future cut in the supply was known information available to all traders, this would not be reflected into today's spot price as it would be in the case of storable commodities. The reason for not incorporating the information about a future supply cut is due to the lack of ability to store the non-storable commodity. The expected cut in production will have a direct impact on forward contracts with delivery during the period of lower production, but due to non-storability, the demand and supply up until today will not reflect the future cut in production. Today's spot price therefore fails to take the forward-looking events into account and the forward price based on information given by today's spot price and will therefore fail to take the forward-looking events into account.

Since the term "commodity" may refer to different kinds of goods, that can differ in terms of production (food commodities), or extraction (oil), also in use as inputs such as oil or final goods for the consumer (food commodities) as well as storability, the behaviour of different commodities understandably requires different theories. As an example, pricing based on the theory of storage, which is popular and has been successfully applied to storable commodities, is not applicable to non-storable commodities (Geman, 2005).

The motivation for focusing primarily on storable commodities, in particular crude oil and food commodities can be found in the higher independence of the UK in the production of non-storable commodities such as electricity, and a higher level of national regulation as well as EU legislation of the price for non-storable commodities. On the other hand, the storable commodities, as explored in the previous section, are volatile due to international impacts on setting the prices. The next part therefore focuses on discussing the most dominating theories of storable commodities and their prices' behaviours.

3.2.2 Theory of storage

The dominant theory about commodity price behaviour is the theory of storage. It explains the relationship between the spot and futures prices in storable commodity markets with a focus on storage costs, the motives of stock holding on the physical market, and the price discovery function of the futures markets. The theory also focuses on the importance of stocks which are only available in the case of storable commodities since in the case of non-storable commodities holding stocks would be very costly. The major contribution to the theory of storage can be found in the work by Working (1949) and was later extended by Williams and Wright (1991). The main contribution of Working (1949), in relation to the theory of storage, is the identification of the problem of inter-temporal price relations which can be interpreted as the relationship between spot price and futures price for the same commodity.

The price relation between the current price of commodity x_t can be explained as the current price $p_t \equiv p_{t-i}$. In other words, the current prices of the storable commodity, for example an agricultural product, is equal to the price of the same agricultural product i months before. Therefore if the price of, for example, the September futures of the agricultural product is quoted in April at a price p_a and the quotation for the same agricultural product in May (p_m) is higher, thus $p_m > p_a$, the ordinary explanation would be that the lower September futures price quoted at p_a was based on future expectations at time *t-i* of an extensive harvest, therefore even if the price between April and September increased, the existing surplus would depress the price by September. Therefore the existing relationship between the current price p_t (which represents the futures price) and price i months before p_{t-i} can be written as $p_t \equiv p_{t-i}$. However, Working (1949) suggested that the theory of inter-temporal price relations needs to be considered. In other words, the prices quoted at p_t for more than one different delivery are not affected by expectations about events which could occur between these two dates. Rather than expectations about future events, in the case of storable commodities it is the storage cost or the cost of carrying the stocks that determines the price. Naturally, the behaviour of storage is related to the motivation behind holding the storage. As outlined by Lautier (2009), in theory, three main categories can be distinguished: speculation purposes, holding inventories to avoid frictions and storage as the insurance against stock-out.

One of the earlier ideas behind holding inventory as an insurance against stock-out is to keep consumers satisfied, by the continuity of the supply. This approach offers a more microeconomic view of the motivation for holding the storage, which is discussed in detail by Brennan (1958). Williams (1986) explains that holding inventories is necessary and can be explained as a backwardation. Thus a response to a variation in the demand, due to time lags, would not be possible otherwise. Nevertheless, even if the backwardation does explain the motivation to hold storage, it certainly does not provide a full explanation since its microeconomic approach is a limitation to the understanding of the commodity movements in a more global context. On the other hand, the speculative motive behind holding the storage offers a more macroeconomic view and has been investigated by a convincing number of authors (Hubbard and Weiner, 1986, Pant et al., 2010, Kilian and Murphy, 2010, Mason, 2012). The speculative motive has been well explained by Routledge et al. (2000) who point out that the main motivation behind holding inventories is the trading profit resulting from present and expected spot prices. This relation has been the subject of a pioneering work by Deaton and Laroque (1992).

The theories on motives behind holding inventories are very similar to motives of holding any type of asset, thus the costs of holding the inventory is necessarily compared to the benefits from it. The role of inventories as frictions was proposed by Brennan (1958) and later extended by Williams (1986) who explained that the main reason behind holding stocks was not the profitability, to keep the stocks, or in order to avoid the cost of delivery, as explained by the theory on holding inventories as an insurance against stock out. As he explains, the main motive behind the friction does not have an exogenous nature but an endogenous nature, thus frictions are internally manipulated in order to influence costs. It is understandable that theories related to the motives of holding the stock are similar in nature to motives of holdings any other assets. Based on the supply and demand theory, low stocks represent a limited supply, therefore in the case of excessive demand or limited supply it will drive the prices up. According to Gilbert (2011), low stocks were one of the major contributors to the 2007-2008 commodity price spikes. He also explains, in the case of food commodities, that high prices in the 2000s were driven by a low level of stock.

However, if it is assumed that the price peaks were driven by low stocks in commodities, since this seems to be a common factor for all of the commodities, it is less likely to be a coincidence. So what is behind the motivation for keeping the commodity inventories low? As explained by Kaldor (1939), the price determination of commodities is more interconnected and one needs to consider not only the direct costs of storage but also the convenience yield. Thus, a yield represents the benefits of using a stored commodity. His proposal motivates a deeper understanding of the theory of storage as a model of a speculator’s behaviour who will engage the commodity transactions based on expectations about future price changes.

Understandably, as with any other asset, if the actual price is below the expected one, since the price is adjusted for storage and costs, it motivates the storing of the commodity (limited supply) and the selling of it at a higher price in the next period. Even if speculative motives seem to dominate, another explanation behind higher commodity prices and the level of inventories could possibly be explained by the characteristics of storable commodities as a necessity, and to introduce the factor of scarcity. The Hotelling rule provides a well established theory applied to agricultural commodities but applicable to oil commodities as well.

3.2.3 The Hotelling rule and the factor of scarcity

Under the assumption of non-renewable resources, the theoretical literature assumes that the prices of these resources should be rising over time to reflect the increasing scarcity. As pointed out by Livernois (2009) the price of marginal cost rises as the demand increase. This represents not only a theoretical but also a conceptual framework for the understanding of long-run developments in non-renewable resources. Nevertheless, this framework was originally proposed by Hotelling (1939). His concept, also known as the Hotelling rule, states that because resources are non-renewable, a higher price is charged in order to reflect the scarcity of the resources. Thus, the decision to extract resources or to keep inventories at a certain levels based on an intertemporal arbitrage unnecessarily leads to movements in prices similar to interest rate changes.

The Hotelling rule was a popular theoretical model of the dynamic behaviour of private markets especially in the early 1970s. However, its ability to explain and predict the actual behaviour of commodity markets still remains an open question (Halvorsen and Smith, 1991). The theoretical model has been criticized for its insufficiency to explain empirical price movements. As Krautkraemer (1998) explains, the Hotelling rule assumes finite resources and thus does not account for technological change or new resources. Nevertheless, the validity of the Hotelling rule has been investigated by many economists with mixed results. Fishelson (1983) tested the Hotelling rule to explain the stability of oil prices during the 1960s and 1970s. His findings reveal that continuity in increases in oil prices are better explained by the technological progress than by scarcity. Gaitan et al. (2006) argue that the limitation of the Hotelling rule can be found in disagreements between the empirical evidence and point at declining commodity prices while the rule predicts exponentially increasing prices. Their findings reveal that the elasticity of substitution in input factors and interest rates play a crucial role in determining the long-run behaviour of prices for non-renewable commodities. Even if the Hotelling rule theoretically explains the problem of non-renewable commodities, the scarcity rents arising from the exhaustibility of commodities such as oil are found to be insignificant. Nevertheless, in addition to the speculative motives related to the theory of storage, the Cobweb model also explains the motives behind holding a certain level of inventories.

3.2.4 The Cobweb model

While the theory of storage assumes price movements to be exogenous and caused by shocks in the supply, the Cobweb model which was firstly introduced by Ezekiel (1938), assumes that price fluctuations are endogenous. In its classical representation, the Cobweb model introduces an equilibrium model describing price fluctuations of a storable commodity. Even if both theories aim to model the behaviour of market participants, the storage model assumes rational expectations, while the Cobweb model is based on naive short-term expectations and the assumption of endogenity which implies that price movements are driven by the behaviour of market participants whose expectations play a crucial role. According to Ezekiel (1938) production decisions are based on the current price, even if the future price is not known. If the current price is low due to naive expectations, production will be reduced and thus the price in the next period will be higher (Mitra and Boussard, 2009). The Cobweb model therefore introduces an economic model to predict the relationship between prices of a particular commodity and the supply and demand forces. The main advantage of the model is that it considers the time lag, as production cannot respond to demand immediately (Hommes, 2013). Chatrath et al. (2002) tested the behaviour of prices for agriculture products and the validity of the Cobweb model under the assumption of a chaotic structure, which to a certain level, can explain naive expectations. They found no evidence for a long-lasting chaotic structure in agricultural products. On the other hand, the study by Mitra and Boussard (2009), who tested the endogenity of shocks in food prices, concluded that models of endogenous price fluctuations are competitive to models of exogenous price fluctuations, but it is not clear which model outperforms the other, since both approaches perform equally.

The dominant theories on storable commodities discussed in this chapter suggest that the prices of storable commodities are dependent on the level of inventories. Understandably, low inventories together with the characteristic of commodities being non-renewable create a certain level of scarcity that stimulates prices. The motivation seems to be for keeping inventories at a low level range, but the speculation motive seems to dominate. Even if the speculative motives are at the centre of attention for many economists, the results are in contrast. While Kilian and Murphy (2012) use the Vector Autoregressive model (VAR) to investigate the relationship between speculative activity and inventory changes, they found no evidence that speculation increased prices. Juvenal and Petrella (2011) also estimated a VAR model, but they concluded that speculation played a significant role in the oil price increases between 2004 and 2008. Hamilton (2009) investigated the possible causes of oil price changes, and concluded that speculation contributed to the price increase in 2008. Contrary to previous results, Smith (2009) did not find any evidence that speculation drew commodity prices between 2004 and 2008. The same has been recently concluded by Byun (2013), who argues that the there is not sufficient evidence for the potential contribution of speculations to the crude oil market.

Although agreement between economists on the role of speculative motives cannot be found, it is assumed that the motivation behind low inventories can be, to a certain level, explained by speculative behaviour. If this assumption applies, then it is necessary to investigate what factors drive the speculative behaviour in the first place. The theoretical model discussed in the next part aims to benefit to the explanation of the motives for keeping the inventories at a low level.

3.2.5 Overshooting theory

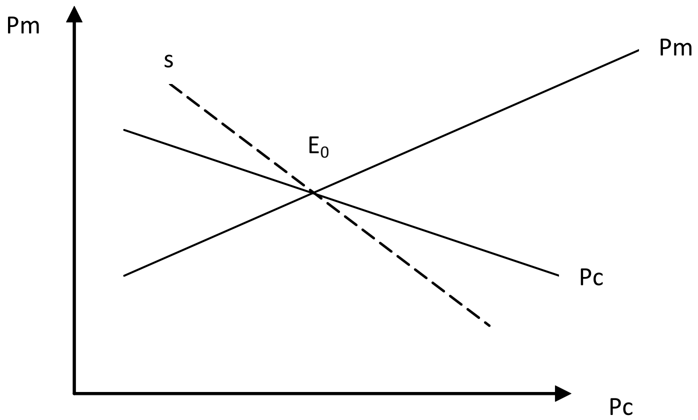
The popular theory of overshooting was firstly introduced by Dornbush (1976) as an explanation of movements in exchange rate. He showed that the overshooting of foreign currency happens when the spot price reacts more than proportionally to an unexpected movement in the money supply, thus it overshoots its long-run equilibrium. After the initial overshoot, the exchange rate should return back to its long-run equilibrium. Since his pioneering work, the overshooting model has been introduced in different variations explaining various assets movements. As an example, Frankel and Rodriguez (1982) introduced the overshooting model for restrictions on capital mobility, and Driskill (1981) investigated the overshooting response in the case of foreign bonds and their substitutability. Papell (1984) introduced the undershooting model for the condition of accommodative monetary policy, which could lead to the underestimation of the spot exchange rate. However, it was Frankel (1986) who introduced the theory of overshooting in the context of commodity prices and monetary policy. Frankel's (1986) original idea was that monetary policy must have an important effect on agricultural commodity prices since even the prices are flexible, while prices of other goods are sticky.

His contribution to the overshooting theory can be found in refusing the original idea of Dornbush (1976), and followers of his theory, that overshooting is predominantly an outcome of the exchange rate. Frankel (1986) built his argument on the assumption that monetary policy has an impact on the real prices of commodities. The rise in inflation led to a shift out of money into commodities. Thus, the increased demand for commodities, in combination with expected increases in inflation, drove the commodity prices. As he further explains, an increase in the nominal interest rate, due to raising inflation, leads to shifts out of commodities. Thus, Frankel (1986) directly applies the overshooting model developed by Dornbush (1976) by the simple substitution of prices of foreign currencies to prices of basic commodities. The assumption of Frankel's (1986) model of overshooting is that a restrictive monetary policy that can be presented as a cut in money supply in the long-run, leads to a drop in commodity prices, while in the short-run there will not be any reaction since commodity prices are assumed to be fixed in the short-run.

The reduction in the money supply understandably leads to an increase in interest rates. The arbitrage condition, which is an unconditional assumption of Frankel's model, holds that commodities are storable, so the rate of return on interest rates cannot be higher than the expected rate of increase in commodity prices and the storage costs discussed in previous section. The commodity prices are expected to overshoot in order to achieve future capital gain that is sufficient to compensate a higher interest rate. A similar approach was developed by Boughton and Branson (1988) as an extension to the original model of Frankel (1986) to capture the relationship between commodity prices and industrial prices. The model therefore presents the theoretical relationship between commodity prices and industrial prices with the role of expectations in commodity price movements due to monetary policy changes. An important condition to the model is the role of financial markets, since commodity prices are determined in spot markets, thus prices are able to react immediately to new information about expected future inflation.

Boughton and Branson (1988) assumed that in the case of unexpected monetary decisions, the commodity prices overshoot and lead industrial prices. Indeed world food prices and crude oil prices often result from adverse supply shocks or large increases in input costs so a supply shock is highly possible. In the model (Figure 3.1), the commodities enter consumer price inflation as final goods, showing the role of commodity prices as a leading indicator of inflationary effects.

Figure 3.1: Commodity prices and manufacturing prices



Source: Adopted from Boughton and Branson (1988)

Where P_m stands for the price of manufacturing goods and P_c for the price of commodities goods, *S* represents the equilibrium in the money market which Frankel (1986) expressed as:

$$m - \alpha Pm - (1 - \alpha)Pc = \emptyset y - \lambda i \qquad (3.1)$$

Where m is the logarithm of nominal money, α represents the share of manufactures in the consumer price inflation, y is real output and i is the official nominal interest rate and includes the relationship between the expected commodity price inflation and interest rate, thus:

$$i = Pc + b \qquad (3.2)$$

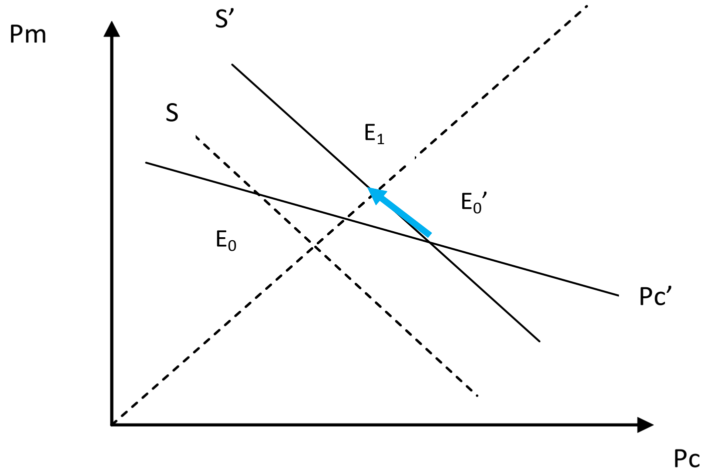
Where b represents the net storage costs and the real return to holding commodities for final use. From Figure 3.1 the relationship between commodity prices and manufacturing prices is inversed. In the equilibrium at E_0, commodity prices are expected to stay at the current level and the interest rate is equal to the real return for holding commodities for final use. A question that arises is: what would be the reaction of commodity and manufacturing prices in the case of a shock? It is necessary to note that the commodity and manufacturing price movements depend on the nature of the shock. According to Boutghton and Branson (1988), in terms of monetary shock in the short-term, it is important to consider the different speed of price adjustment. While industrial prices adjust gradually, so in the short-term the industrial price can be held as a constant, commodity prices are able to react immediately to new information about expected future inflation.

Therefore, in the short-term, due to the faster adjustment of commodity prices, commodity prices (*Pc'*) rise until they overshoot. The point where commodity prices are considered to have overshot is presented in Figure 3.2 as new equilibrium E_0'. Rises in commodity prices until they are considered as overvalued can be explained by the assumption of the model, which assumes a change in the money supply, and therefore a change in the short-term official interest rate.

Keynes (1930) named this condition of the market as the "Gibson paradox" since classical economic theory assumed that the natural or full stock equilibrium rate of interest is fairly stable over time. If this was true, then upward movements of the market rate would have generally produced a gap between the market and natural rates, and this would have generated a deflationary gap between the desired saving and investment rates. Similarly, downward movements in market interest rates produce inflationary pressure (Sargent, 1973). The fact that the theory does not correspond to the pattern implied by these considerations is the Gibson paradox. Keynes (1930) explained it as the relationship between prices and interest rates, and argued that prices tend to rise when the market rate at that time is below the natural rate. In this case the natural interest rate is represented as net storage costs and the real return of holding commodities for final use.

Indeed, the initial increase in commodity prices was driven by a cut in the interest rate as the interest rate is now lower than *b*. Consequently, due to the expectations that commodity prices will fall in the future (so the market is in equilibrium again), the initial price has to rise in order to decline later in the adjusting period. In the long-run, the general price level adjusts to the change in the money supply and commodity prices decline, moving up along the *S* line until the money supply, interest rate, and commodity price create a new long-run equilibrium at E_1 (Figure 3.2).

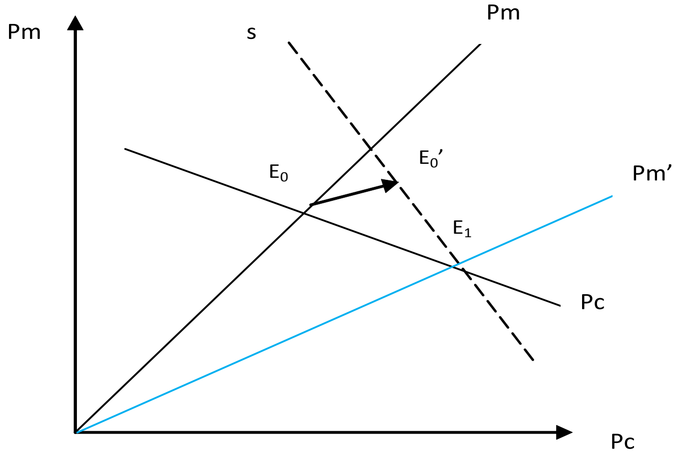
Figure 3.2: Overshooting



Source: Adopted from Boughton and Branson (1988)

As is shown, the monetary shock causes overshooting. Although, as described by Boughton and Branson (1988), in the case of a supply side shock the commodity prices undershoot. Figure 3.3 shows the reaction of commodity prices to a supply side shock assuming that the monetary policy does not react to increases in prices. The black lines represent the original equilibrium in the market, the same as in Figure 3.2. A supply shock raises the equilibrium, thus the original P_m line shifts down along the *Pc* line and creates a new long-run equilibrium in E_1.

Figure 3.3: Supply side shock



Source: Adopted from Boughton and Branson (1988)

Since monetary action is excluded from the model, the commodity price jumps into a new equilibrium at E_0' and continues to rise while industrial prices fall toward the new equilibrium at E_1. Although traditional theories might explain the motivation for holding inventories, they cannot fully explain the situation of the commodity markets during 2000s. Due to the lack in explanation of commodity movements in the 2000s, new approaches for traditional theories and explanations of factors behind the recent increases in commodity prices have been developed.

3.3 Macroeconomic motivation for rises in commodity prices in the 2000s

The theories discussed in previous sections provide a theoretical explanation of storable commodity prices determination. Although, the theoretical models of price behaviour help to understand commodity pricing in a traditional way, they become less explanatory for what has happened in the 2000s. The joint continuing increase in storable commodity prices suggests that prices have been driven not only by the usual forces, but also by factors such as excess liquidity and speculations which are beyond the theory of demand and supply. To support this statement, Graph 4.3 (Chapter 4) shows movements in demand and supply as well as inventories and prices for crude oil.

As can be observed from Graph 4.3, within the year 2007-2008 the OPEC production increased from about 33mb/d to 36mb/d. World demand had been slowing down, but was still increasing compared to previous years. Nevertheless, before 2007 the World demand was higher than the World supply, but lower than the World supply in 2008. According to the basic principle of the demand and supply theory, the crude oil prices should understandably have fallen. However, as can be seen from Graph 4.3, the crude oil price index increased sharply and the same applies to food price index even if the rise was not as sharp as in the case of crude oil. The OPEC spare capacity, which represents the ability to respond to demand and price increases, in 2002 was about 4.08 mb/d at $33.72 per barrel, while in 2009 when the spare capacity was also about 4 mb/d, the price was $69.16 per barrel (EIA, 2013a). Understandably, the contrast between empirical evidence and theoretical assumptions requires attention, and motivated to the introduction of various concepts explaining the gap.

According to Baffes and Haniotis (2010), the dominant driver of commodity prices, especially food commodities, is a stronger link between energy and non-energy commodity prices while excessive demand from emerging economies is less likely to push food prices. They also reject the hypothesis that food prices have been significantly driven by bio fuels. On the other hand Gilbert (2010) argues that the main drivers in 2007-2008 were monetary factors that through index-based investment in agricultural futures markets generated food price rises. In addition, Carter et al. (2011) identified the core increases in food commodity prices in supply and demand shocks, which together with low inventories, and easing monetary policy pushed food prices up. Belke et al. (2013), found that food prices are cointegrated with global liquidity, thus they significantly adjust to movements in global liquidity suggesting that excess liquidity caused by easing monetary policy in most of the developed countries was one of the drivers. Interesting results have been presented by Ratti and Vespignani (2013) who argue that oil prices and global oil production have been significantly driven by the BRIC countries' liquidity. However, several authors e.g. Kilian and Murphy (2010), Hamilton (2013) see low interest rates and a large flow of investments in commodity futures markets as the main drivers. In addition, a study by Wang and Chueh (2013) shows that lower interest rates set by the Federal Reserve Board (FED) lead to higher expectations about the future oil demand, due to the price fluctuations of crude oil.

Different concepts explaining the behaviour of commodity prices have been introduced and indeed the number of studies is extensive, thus the three broad sources of commodity prices increases in the 2000s can be identified. Firstly, the increasing global growth in demand which is mostly referred to as being due to increasing demand from emerging economies. Secondly, since commodities are also a form of asset, speculation motives cannot be overlooked. Lastly, the role of expansionary monetary policy with a focus on developed countries. The following sections are therefore dedicated to a discussion on all three possible drivers of commodity prices in the 2000s supported by empirical evidence.

3.3.1 Global demand growth

Taking the theory of supply and demand into consideration, it is understandable that increases in demand for commodities, assuming the low elasticity of the supply, raise the price of commodities. The growth in global demand for commodities is believed to be driven by developing economies, especially BRIC countries. In recent years, BRIC countries that comprised of Brazil, the Russian Federation, India and China have experienced significant increases in real income as well as liquidity. It is believed that increases in their liquidity may cause significant as well as persistent increases in oil prices, oil production and aggregate demand. The effect of unanticipated increases in the BRIC countries' liquidity on oil prices has been investigated by Ratti and Vespignani (2013a). Their results show that developments in China and India are the main drivers of the effect of BRIC countries' liquidity which consequently led to rises in oil prices. Also, the results show that the effect of BRIC countries on oil prices is stronger than the effect of developments in liquidity in Japan, the U.S. and the Eurozone.

A study by Ratti and Vespignani (2013b) shows that the impact of movements in China's money supply on the real price of crude oil is statistically significant, arguing that the rise in China's real M2 was one of the significant drivers of real oil prices in 2009. Erten and Ocampo (2013) tested whether the situation of commodity markets during the 2000s could be a result of super cycles. The super cycles of commodity prices were first introduced by Schumpeter (1939) who focused on commodity prices, industrial production, and interest rates, during the 1800s and the 1900s and found persistent long-term waves lasting for 40-60 years. However, he refuses exogenous reasons such as wars or gold production and argues that super waves are a result of technological changes and the accumulation of capital. Thus Erten and Ocampo (2013) investigated whether the unprecedented rises in commodity prices during the 2000s were a result of such a super wave due to the technological boom in developing countries such as China and accumulated capital from developed countries. Their findings reveal the existence of a super wave during the period of the 2000s for both agricultural and oil commodities. Nevertheless, if current developments in commodity markets are truly a case of a super wave, then the commodity prices can be expected to be high as long as developing countries keep up the increasing production, despite slow growth in developed countries and the accumulation of the capital from developed countries continues.

Other evidence shows, that in the case of food commodities, during the last decade, in most years, utilisation has been exceeding production. Even if supply has had an increasing trend in order to meet rising demand, due to weather conditions there was a significant cut in stocks in harvests in 2000, 2002, 2003 and also later in 2006 (FAO, 2008). Extremely low stocks were one of the main drivers of food prices after 2006. Also, according to FAO (2013) the situation is still worrying. The world cereal stocks declined in 2013 compared to 2012, and the most significant cut in stocks has been found in developed countries. Another factor behind the rise in prices was the policy initiatives in the EU as well as in the U.S, promoting the use of bio fuels that should support energy self-sufficiency. Thus increases in demand, together with the above mentioned reductions in supply, led to the reduction of stocks to very low levels (Trostle, 2008).

According to Harrison (2009) not only has demand for bio fuels increased the price of corn, the increase is also linked to a rise in the price of oil. Collins (2008) estimated that from 2006 to 2008, the 60 per cent increase in maize prices was caused by an increase in maize used in ethanol. Rosegrant, et al. (2008) also investigated the effect of bio fuel and found that the increase in bio fuel production during the period of 2000 to 2007 increased cereal prices by 30 per cent. Mitchell (2009) has also examined the factors behind the rapid increase in internationally traded food prices since 2002 and estimated the contribution of various factors. The main ones that have been identified as important are: the increased production of bio fuels, the depreciation of the U.S dollar, and increases in the cost of food production due to higher energy prices. Based on his analysis, he identified significant increases in bio fuel production in the U.S and the EU as the main contributor to the increases in wheat and maize stocks. The large production of bio fuels is also responsible for speculative activities and export bans since they pushed food commodity prices up (Mitchell, 2009). Trostle (2008) also supports the assumption of export bans driving food commodity prices however he explains export bans as a policy response to increases in prices rather than speculative motives. The most recent study by Zilberman et al. (2013) also does not provide evidence for bio fuels being a driver of food prices. As their results show, an important role is played by inventories since their inclusion into the estimation of the impact of economic growth on food prices improves the forecast error by 12 per cent.

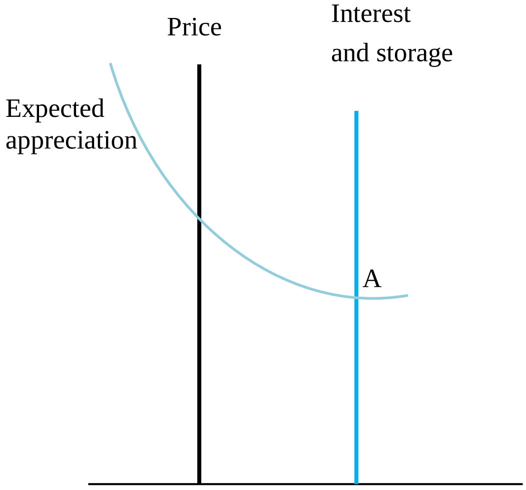
In particular, Zilberman et al.'s (2013) findings reveal that U.S bio fuels production contributed up to 25 per cent of the increase in the price of corn between 2001–2007 and contributed to 7–8 percent of the increase in the price of soybeans, while the increase in the Gross National Product (GNP) in developing countries was associated with an up to 38 per cent rise in the price of corn, a 30–31 per cent increase in the price of rice, and a 24–40 percent increase in the price of wheat.

3.3.2 Financial speculations

The role of commodities has significantly changed over time. Their importance increased in the 2000s when many banks and investment banks showed an increasing interest in commodities trading (Irwin and Sanders, 2012). Naturally, commodity trading and inflation hedging is believed to be an important source of profit, attracting many other investors to enter the commodity markets (Miffre and Brooks, 2013). The combination of forces is often referred to as a driver of increased interest in commodities and their prices. Crawford et al. (2013) tested the hypothesis that commodities can be used as a form of hedging against inflation. The investigation of the spot prices of 45 commodities during the last 53 years reveals that inflation hedging with commodities is costly and too risky. Crawford et al. (2013) also argued that due to timing risks, it is very difficult to construct a basket of commodities which would protect against inflation.

However, the financial market, particularly the increased interest of investors and financial intermediaries, have also participated in remarkable movements in commodity prices, mainly in the second half of the 2000s (Pirrong, 2012). Zhang (2013) states that internationally, crude oil prices experienced several speculative bubbles driven by the investment funds. The sequence of assumptions behind this theory as presented by Fattouh et al. (2012) is that the entry of financial investors into the oil futures market was significant. Their demand for long positions led to increases in the oil futures prices. Understandably, higher oil futures prices send a signal about rising expectations about spot prices and thus drove the demand for oil inventories. As a consequence, the higher demand for oil inventory drives the real spot price of oil and therefore the real price of gasoline. The Nobel Prize winner Krugman (2008) explains the speculation through the downward-sloping relationship between the current price of oil and the expected change in prices as showed in Figure 3.4.

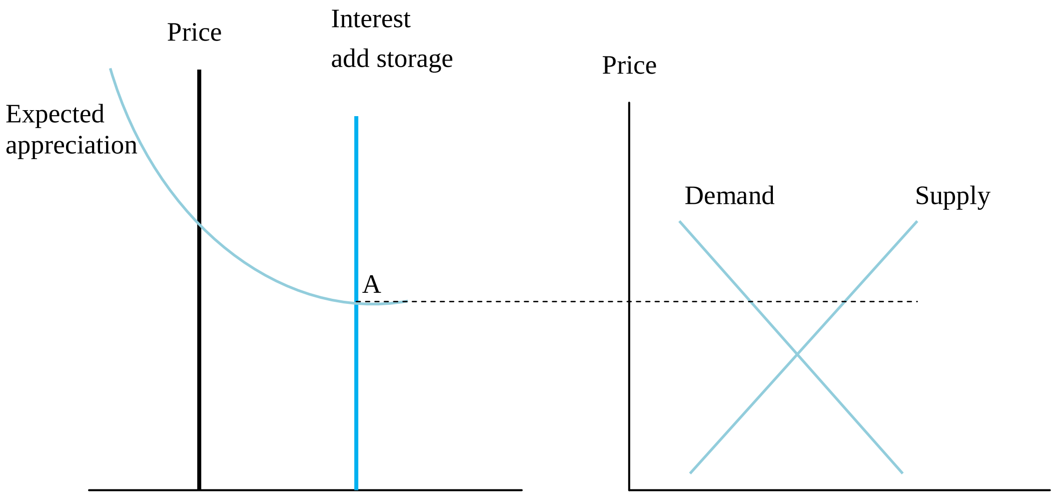
Figure 3.4: Relationship between the spot price and expected change in price



Source: Adapted from Krugman (2008)

The downward-sloping relation is based on the simple assumption that investors believe that the price of the commodity in the next period (e.g. the next year) will be p_{t+1} without taking into consideration the current spot price p_t. Thus the change in the expected rate of the oil price can be written as $(p_{t+1} - p_t)/p_t$. In Figure 3.4, the cost of holding the commodity (assuming oil) is consistent with the assumption presented by Kaldor (1939) in relation to the theory of storage discussed in Section 3.2.2. The cost of holding the commodity therefore consists of the direct costs of storage and also the convenience yield, thus yield, which represents the benefits of using the stored commodity, is presented by Krugman as an interest foregone from holding physical inventories. Krugman (2008) suggests that the situation when speculative expectations determine the spot price in point *A* is possible, but only under circumstances as presented in Figure 3.5.

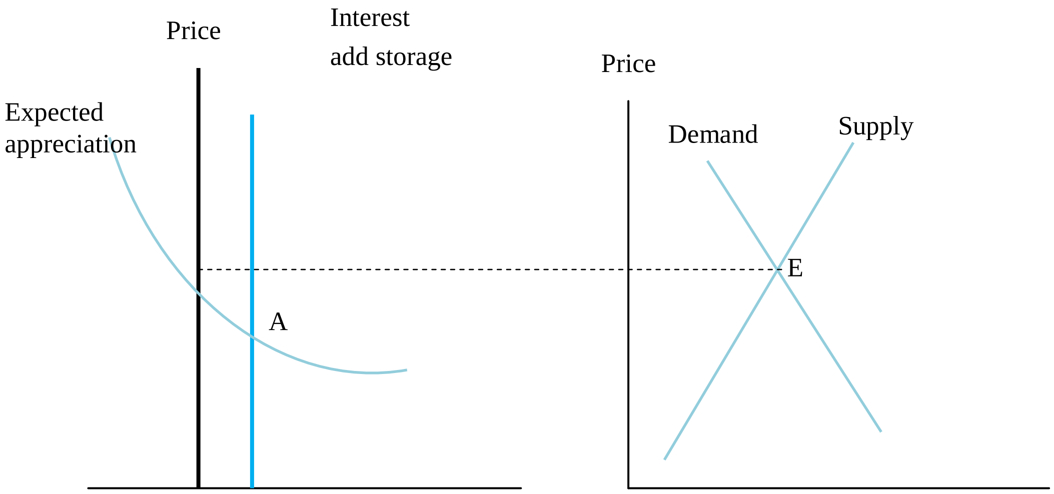
Figure 3.5: Speculation motives of storage



Source: Adapted from Krugman (2008)

Figure 3.5 shows the relationship between spot prices and expectations about movements in price, together with a simple demand and supply for crude oil. The broken line represents the spot price. In the short-term the quantity of oil produced (supply) exceeds the quantity consumed (demand), however it is assumed that speculators are motivated to buy the excess supply and store it, based on an earlier assumption of future spot price being higher. In other words, future price is determined by current spot prices. Even this is not so unlikely, Krugman (2008) highlights that this equilibrium can arise only if the future price is sufficiently above the spot price thus it is worth keeping storage. Otherwise, an accumulation of inventories due to speculation motives will not take a place. This case is presented in Figure 3.6.

Figure 3.6: Absence of speculation



Source: Adapted from Krugman (2008)

The spot price (broken line) is determined by supply and demand. However, in this case the inventories are not growing due to backwardation, as explained by Williams (1986), thus the situation when the futures price is lower than the future spot price or due to the fact that the motivation for storage is weak and simply not profitable. Here, Krugman (2008) makes his main point arguing that there is a lack of empirical evidence of the significant accumulation of crude oil inventories or a sign of speculative demand. Therefore his argument is that the missing evidence of substantial increases in physical commodity inventories proves the absence of speculative activity. His explanation supports the critics of the Master hypothesis. The Master hypothesis assumes a strong buying pressure from index investors that leads to the creation of a bubble in commodity futures prices. The bubble passes-through the spot prices through the arbitrage link between futures and spot prices as explained earlier (Irwin, 2013). The hypothesis is used to explain the argument that commodity index investors were one of the principal drivers of spikes in food commodity prices in the 2000s. However, the hypothesis has been rejected as an explanation of recent peaks in commodity markets by a number of economists (Sanders and Irwin, 2010, Wright, 2011).

Also, in addition to Krugman (2008), defining this behaviour of investors as speculation could be controversial. As argued by Buyuksahin and Harris (2011) excessive speculation is difficult to determine; in addition, there is nothing excessive about the behaviour of investors and hedge funds. Nevertheless, Knittel and Pindyck (2013) show that although it is not possible to rule out that speculation had any effect on oil prices in the 2000s, it is possible to rule out that speculation motives are explanatory for the sharp changes in crude oil prices since 2004. On the other hand, Shi and Arora's (2012) and also results of a study by Phillips and Yu (2011) and Gilbert (2010) reveal that a bubble in oil prices existed for a short period in 2008 and was a result of speculative motives.

Fratzscher et al. (2013) has examined the relationship between oil prices, the U.S dollar and asset prices causality between the U.S dollar and oil prices since the early 2000s. They found that oil prices as well as the U.S dollar are significantly affected by changes in the equity market, returns and risk. However, this response of oil prices is documented only after 2001. The explanation of a significant link between oil and other assets could be found in, as previously mentioned, the increased use of crude oil as a financial asset. Kilian and Murphy (2013) develop a structural model of the global market for crude oil to investigate the speculative demand for oil as well as shocks to demand. They found that the speculative component presented as a movement in oil inventories during 2003–2008 explains the oil price surge. However, an important driver was also the unexpected increases in world oil demand resulting from the global business cycle. An interesting conclusion presented by Kilian and Murphy (2013) is that the additional regulation of the oil market could not prevent the oil price rises in the 2000s. Also, Creti et al. (2013) investigated the assumption of speculation motives driving commodity prices in the 2000s, and found that the correlation between 25 commodities and stock markets became stronger as commodities became more volatile especially during the years 2007-2008. They do not reject the hypothesis that speculation led to rises in oil prices as well as prices for coffee and cocoa. Also Kilian and Lee (2013) found evidence of speculative demand raising the price in mid-2008 by between $5 and $14, although they found no evidence of speculative demand pressures between early 2003 and early 2008.

This finding also supports the argument of Kilian and Murphy (2013) that the higher regulation of oil derivatives markets cannot lead to lowering the real price of oil in the physical market. Nevertheless, it can be assumed that the acceptance of commodity derivatives as a financial asset, and inexpensive access in combination with low interest rates that created excess liquidity in financial markets, caused returns in other financial markets to be lower. Commodities such as oil or food could be considered as a hedge against inflation risk arising from expansionary policy and a weak U.S dollar. Therefore, the assumption here is that expansionary monetary policy in developed countries led to excess global liquidity which consequently passed-through in the form of investments into commodity markets. The discussion on the relation between monetary policy and commodity prices therefore continues in the next section.

3.3.3 Expansionary monetary policy

The low interest rates supported by most of the central banks in developed countries resulted in excess liquidity which consequently passed-through into commodity markets (Baffes and Haniotis, 2010). A vast literature, as well as empirical evidence, can be found on the effect of monetary policy changes on variables such as interest rates (Kuttner, 2001, Landier et al. 2013), exchange rates (Fatum and Scholnick, 2008), stock returns (Bernanke and Kuttner, 2005) or market bubbles (Fischbacher et al., 2013). There is limited research on the response of individual commodity prices to monetary policy shocks.

As pointed out by Gospodinov and Jamali (2013), given the increasingly important role of commodity prices for aggregate inflation and output, asset allocation, and investor sentiment, more attention should be paid to the effect of monetary policy on commodity prices. Arseneau and Leduc (2013) investigated the impact of monetary policy on commodity prices through the level of storage and found that the endogenous movement in interest rates jeopardized the effects on commodity prices through the storage. Also, Rosa (2013) provides the evidence that monetary policy impacts commodity prices. His investigation however focuses on the responses of traders to announcements about monetary policy decisions, the state of the macroeconomy and news about inventories holdings. Rosa (2013) found supportive evidence that commodity prices strongly respond to announcements of changes in interest rates as well as announcements about the state of oil inventories. Nevertheless, the identification of the effect of monetary policy shocks on commodity prices is not an easy task; due to heterogeneity within individual commodities, the sign and the magnitude of the response may be very different. Also it is necessary to take into consideration the volatility of commodity prices, which is higher than the volatility of interest rates and possibly higher than stock prices. Nevertheless, the identification of the contribution of monetary policy shocks to the volatility in commodity prices may contribute to the understanding of the transmission of shocks to the interest of policy makers as well as investors.

The main contributor Frankel (2006) explained the link between monetary policy and commodity prices. His assumptions are not a novelty in the literature since they originate partially from the work of Hotelling (1939) and Working (1949), but mainly from Dornbusch (1976) as discussed earlier. Frankel (1986) suggests a theoretical model where he assumes that tight monetary policy leads to raises in the real interest rate, whether via a raise in the nominal interest rate, a fall in expected inflation, or both. As a result, the real commodity prices fall until they are considered as undervalued, thus, there is an expectation of future appreciation (in line with the additional advantages of holding inventories) that is sufficient to offset the higher interest rate (as well as other costs of carrying inventories which can be expressed as storage costs plus any risk premium).

Consequently, when an expected return is in balance there is still the motivation to hold the inventories even if the carrying cost is higher. In the long-run, the general price level adjusts to the change in the money supply. As a result, the real money supply, real interest rate, and real commodity prices are assumed to return to where they originated from. The key role is played by the levels of inventories, or in other words, storage. As explained by Frankel (2006), it is necessary to include the role of interest rates as a response of monetary policy; therefore the real interest rate represents the opportunity cost of oil extraction and storage.

Understandably, a lower real interest rate leads to a reduction in production and increased storage while a contractionary monetary policy, reflected in a higher real interest rate, has the opposite effect.

As proposed by Frankel (2006), high interest rates can lead to a reduction in the demand for storable commodities, or may increase the supply, which consequently reduces the market price of commodities. He therefore assumes a causal link from interest rate to commodity prices. On the empirical side, Frankel (2007) investigated whether the loose monetary policy of the FED does explain the negative relationship between commodity prices and interest rates, thus confirming a significant relationship. He also found an inverse relationship between the real interest rate and oil price. Interestingly, Alquist et al. (2011) reject the hypothesis of the relationship between the real interest rate and oil price. However, it should be noted that controversial results on the relationship between monetary policy and commodity prices are not due to weak significance, but due to a different period being considered. The relationship tends to be insignificant for the period after the1980s, while it has been confirmed that oil prices responded inversely in the 2000s.

A more recent study by Akram (2009) is one of the examples. His investigation of the relationship confirms that commodity prices generally, and oil prices in particular, increase with negative movements in U.S real interest rates. Moreover his results show that the forecast error variance of commodity prices is, to a significant proportion, caused by movements in interest rates. These results have also been confirmed by Anzuini et al. (2012) who investigated the effect of monetary policy on commodity prices and concluded that expansionary monetary policy led to a modest increase in commodity prices. A different perspective on the relationship between monetary policy and commodity prices has been introduced by Belke et al. (2013), who concluded that the recent overshooting of commodity prices can be explained by different price elasticity.

Wang and Chueh (2013) investigated the relationship between interest rate and gold prices as well as oil prices. While they found a negative influence of interest rates on future gold prices, a positive relationship was identified in relation to future crude oil prices. They also found out that in the long-run interest rates pass through into the international crude oil prices through influence on the U.S dollar.

The expansionary monetary policy of the FED, expressed as a lower interest rate, drives market expectations for changes in oil demand that result in the fluctuation of oil prices. Also, they found a certain level of speculation; since cuts in interest rates lead to expectations about the depreciation of the U.S dollar, thus investors prefer to move the capital to commodities, preferably gold. Probably the most interesting findings have been presented by Arora and Tanner (2013) who found that the broken inverse relationship between interest rates and oil prices has been re-established again through the period of the mid 2000s. Their findings show that the oil price consistently falls with unexpected rises in short-term interest rates. From their results, a few important points can be made. Firstly, the oil price responds to short-term U.S interest rates as well as international interest rates, which underlines the importance of storage, and secondly, oil prices became also more responsive to long-term interest rates compared to previous decades.

Studies on food prices in relation to monetary policy are limited compared to studies on oil prices. One of the earlier studies presented by Schuh (1974) shows that movements in interest rates do impact agricultural markets. Schuh (1974) found that the levels of agricultural prices respond proportionally to changes in the level of money supply in the long-run and that the neutrality of money applies in the short-run. As he later explains, agriculture is a competitive sector in which prices tend to be more flexible than in other sectors. As a result, expansionary monetary policy stimulates the agricultural sector, because farm prices can be expected to increase faster than prices of other commodities. Bordo (1980) argues that agricultural commodities tend to be more highly standardised and therefore exhibit lower transaction costs than manufactured goods.

Due to short-term contracts, which are characteristic of the agricultural sector, a faster response to monetary shocks can be expected. Also, Tweeten (1980) introduced the argument that food price shocks accommodated by expansionary monetary policy can cause inflation. Thus, even though various explanations on recent movements in commodity prices can be identified, neither agreement within literature nor empirical evidence can be found, due to the number of factors influencing commodity markets. Nevertheless, the effect of monetary policy and low interest rates becomes a centre of interest of economists due to the fact that several developed countries are set for long slow growth and a low interest rate.

3.4 Summary

The first part of the literature review discussed the main theories developed to explain the price determination of commodities with respect to their storable or non-storable nature. Although, the theory of storage, Hotelling rule and Cobweb model introduce earlier economists' understanding of the motives of holding inventories, thus explaining price determination through scarcity and speculation, they cannot fully explain the recent movements in commodity prices. As Skidelsky (2012) stated: *" [The] principles of macroeconomic policy…are going to have to be rewritten for the 21st century."* His statement is also applicable to commodity markets and commodity price determination. Thus, the most recent thoughts, and theoretical as well as empirical explanations of recent unusual movements in commodity prices have also been discussed in this chapter. Nevertheless, it is important to note that the novelty in understanding commodity price determination and the introduction the role of the monetary policy in recent studies still needs to be examined.

3.5 The macroeconomic and monetary effects of commodity price shocks

3.5.1 Introduction

As noted earlier, there was a significant joint co-movement and rise in commodity prices during the 2000s. This significant rise in commodity prices, particularly in food and energy prices, has posed complex challenges for monetary policy in terms of forecasting and anchoring inflation expectations. Thus, this section of the literature review discusses the role of commodity price shocks in monetary policy and focuses on the recent developments in commodity markets as well as in monetary policy.

In the previous part, the theoretical justification of the possible endogeneity of food price and oil price shocks has been discussed. The endogeneity, which is understood as the impact of monetary policy on commodity price determination, plays an important role since it introduces an argument that commodity prices are not only affected by forces that are exogenous, such as political reasons in the Middle East, or an excessive rise in demand from emerging economies but also by monetary policy in developed countries (Barsky and Kilian, 2004). While Hamilton (2003) shows that commodity price shocks, specifically oil price shocks, are exogenous to the U.S economy, Kilian (2008) criticizes his findings due to the nature of the instruments used in his analysis. On the other hand, Kilian's (2008) VAR model shows that US monetary policy does affect movements in commodity prices, specifically oil prices which prove the endogenous relationship between oil prices and economic variables. In respect to this finding, Kilian (2009) later investigates how oil price shocks, which are endogenous, transmit into the U.S economy. Although, the endogeneity has been proven in relation to the U.S economy, it should be noted that the generalizing of his findings to all economies could be misleading. Since only very few studies focus on the effect of commodity prices on the UK economy (e.g. Jonson, 1976; Chowdhury et al., 2006; Surrey, 2009), this chapter focuses on the transmission channel of how commodity prices can affect economic activity in the UK. Thus, after the identification of the endogenous and exogenous nature of commodity price shocks discussed in the previous section, it is necessary to understand the transmission of the shocks into the economy. It should be noted that scarcity, which, as discussed in Section 3.2.3, drives the commodity prices, it also affects the behaviour of consumers and is consequently reflected in production as well as inflation. One of the possible channels is through investments made by companies.

Although, higher oil prices may lower companies' profits and lead to the reduction of new capital purchased, in the case of a permanent increase in commodity prices (as observed in recent years) investments in more energy-efficient capital may be expected (Drakos and Konstantinou, 2013). On the other hand, if consumers expect the increase in commodity prices to be short-term, it can lead to cuts in their savings or extra borrowings which consequently cause a decrease in the real balance followed by an increase in the price level (Cologni and Manera, 2008). It must not be forgotten that economic activity can be influenced by the income transfer from oil importing to oil exporting countries. From this point of view, it is interesting to investigate the effect on the UK, since the position of the UK as an oil exporter (discussed in more detail in Chapter 6) has changed over the last 20 years. Nevertheless, as a result, in the long-term a negative impact on the consumers' demand for goods in an oil importing country can be expected. The main argument here, which is also observable from the commodity peaks in the past, is that higher commodity prices (especially crude oil as a direct input in production) lead to economic slowdown and also cause inflation (Misati et al., 2013).

Although, this has a direct effect on inflation, the changes in behaviour of economic agents count for second round or indirect effects on inflation. While higher prices of inputs can be passed on in higher consumer prices, as a response to the higher costs of living there may be pressure to increase wages. Thus a negative effect on households can lead to a decrease in consumption and therefore lower output. Another possible negative impact on households can be found in lags of companies' responses to higher input prices. In the long-term, companies can find a more cost effective way, change the technology, or find a substitute, but in the short-term, adjustments are not possible which can lead to an increase in unemployment (Pindyck and Rotemberg, 1983). As will later be discussed in more detail, the last argument may have an important implication for the UK, since interest rates are assumed to be held at the present historical lowest levels until a further rise in employment (Carney, 2013). In relation to the objectives of monetary policy to promote high employment and price stability, the response of policy makers may be difficult due to both the recessionary, as well as the inflationary, effects of commodity price increases.

If price stability is the main concern, then the reaction of policy makers should be on the initial impact of the shock to the inflation rate, since the increase in the interest rate should stabilize the headline (and core) inflation, however, for the price of a lower demand (Arora et al., 2013). Under the assumption of lags in the response of prices to changes in unemployment, the increase in interest rates may lead to significant increases in unemployment. On the other hand, when priority is given to output or unemployment, the reaction of policy makers should be to avoid the reduction in demand by implementing an expansionary policy. Nevertheless, it is necessary to consider that policy decisions are affected by different factors, thus the reaction of policy makers to shocks in commodity prices understandably depends on the balance between higher unemployment and a higher inflation rate. Another factor that highlights the importance of understanding the size of the effect of commodity price shocks on inflation and output, and whether the shocks are transitory or persistent, can be found in information they provide.

If the effects are found to be significant for inflation, then commodity prices can be used as an indicator of future inflation. Naturally, in this case commodity prices would provide valuable information for policy makers in inflation targeting regimes. Even if in inflation targeting countries priority is placed on the inflation rate, when placing higher importance on output (as further expected in the UK) an understanding of the size of the effect also plays an important role. Starting with earlier economists' views on the impact of commodity prices on the economy, and continuing to new developments in research done on this topic, the following sections provide an insight into the relationship whose importance may be assumed to rise in recent years.

3.5.2 Direct commodity price effects

The theory of a direct commodity price effect on consumer price inflation offers theoretical support for the view that commodity price inflation can be used as an indicator for future consumer price developments. Since most commodity prices are determined in auction markets (Boughton and Branson, 1991), they are therefore assumed to respond quickly to changes in supply and demand (as discussed in Section 3.2.5). Moreover, since they include the expectations of investors about future price and inflation, commodities futures may be also used for inflation hedging (Ewing and Malik, 2013).

Thus, on the one hand commodity prices reflect aggregate supply and demand in the economy, since increases in aggregate demand are expected to be reflected onto higher price inflation, thus an increase in commodity prices reflects the increase in aggregate demand. On the other hand commodity prices have a forward-looking element since commodity stocks are traded in future markets thus are sensitive to expectations about future economic conditions. This supports the previous assumption that an increase in aggregate demand is already reflected in the present commodity prices. Therefore, under the assumption that markets are perfectly efficient and expectations are rational, an increase in expectations about inflation is immediately reflected in higher commodity prices. In this case, the increase in commodity price would provide useful information about future consumer prices. However, the weakness of this argument can be found in forming rational expectations and efficient markets. Also, it is necessary to point out the characteristic of commodity prices in terms of supply and demand.

The commodity market is very specific and stands outside of traditional factors which affect demand and supply. As mentioned in previous sections, an important role is played by specific factors such as climate, and also political factors. These specifics represent the weakness of commodity prices acting as an indicator of inflation. Nevertheless, it may not be forgotten that commodity prices enter as costs in output prices or in manufacturing costs, therefore it can be argued that commodity price movements in time t have a direct cost effect on movements in the consumer price index in time $t+1$.

According to Labys and Maizels (1990) it is important to distinguish between the hypothesis that commodity price levels can be useful as an indicator of consumer price level and the hypothesis that commodity price inflation can act as an indicator of future consumer price inflation. Their argument is that commodity price levels can act as an indicator of future consumer price level only if a relationship between the levels of the two price series does not depend on economic factors and adjustments in the economic factors. This can be viewed as inapplicable since nowadays the interconnection of economies and markets is remarkable. Therefore if these conditions were applied, it would mean that the commodity price level is not affected either by economic or monetary adjustments and price level only reflects the market's demand and supply. This would be a limitation to the assumption that it is possible for commodity prices to act as an indicator of general price development.

Therefore, the direct price hypothesis applies the forward-looking element in commodity prices, which enables them to react quickly to changes in supply and demand. It can be assumed that present commodity prices already include information or expectations about future demand and supply, and therefore can be used as an indicator of future consumer price inflation (Celasun et al., 2012). This theory was empirically tested by Bosworth and Lawrence (1982) as well as Nordhaus and Showen (1977) who, based on an input-output model, concluded that a significant part of the increase in the general price index could be accounted for by increases in commodity prices. Even the theory of direct commodity price effect explains how the forward-looking nature of commodity prices effect consumer price inflation, though the most important drawback is the assumption of perfect markets. Nevertheless it provides a base for theoretical explanation and rationale of why commodity prices can be used as an indicator of future inflation.

3.5.3 Kaldor's indirect commodity price effect

In the previous section the direct price effect of commodity prices presume that commodity prices are unaffected by economic adjustments; this represents a significant limitation of this theory. However Kaldor (1976) had a different assumption. In his view, an increase in commodity prices has a significant inflationary effect on industrial prices, since the higher prices of basic materials are passed through different channels into unit labour costs and understandably into final product prices.

According to Kaldor's (1976) assumption, in order to demonstrate the indirect effect of commodity prices, it is necessary to distinguish between the "primary sector" of the world economy, the “secondary" and " tertiary" sectors. While inflationary pressures are not expected to arise from the tertiary sector, both the industrial sector and the primary sector can become sources of inflation, however of a different character, differing both in the nature of the causal mechanism, and in the general economic consequences. In the primary production, the market price is given to the individual producer or consumer, and prices move in direct response to market pressures in the classical manner and act as signals for the adjustment of production and consumption in the future. In industry, the adjustment of production to changes of demand takes place independently of price changes, through a stock-adjustment mechanism, industrial prices (in contrast to the prices of primary products) are not acting as a market cleaner. The asymmetry can be according to Kaldor's assumption explained by the fact that while commodity prices are demand-determined, industrial prices are cost-determined, and because of that the rise in commodity prices has a very powerful inflationary effect operating on the cost side thus the rise in the price of basic materials and fuels is passed through the various stages of production into the final price with an exaggerated effect.

As a consequence, inflation has a deflationary effect on the effective demand for industrial goods in real terms, since the rise in the profits of producers in the primary sector is higher than their expenditure which can be observed from the accumulation of financial assets by the oil producers. The accumulation of financial assets is also resulting from the fiscal and monetary policies in the industrial countries which are likely to react to the domestic inflation and lead to reduction of consumer demand and industrial investment. As a result, the increase in commodity prices may also lead to a wage – price spiral inflation and restrict industrial activity. The main point that Kaldor (1976) made is that volatility of commodity prices is mainly due to inflationary expectations. In the absence of a stable monetary policy which could act as a hedge against inflation, the recovered demand will have a speculation effect in commodity prices which in consequence will lead to an increase in unemployment and lower effectiveness in using resources.

Kaldor's (1976) assumption is based on the reaction of monetary and fiscal policy in developed countries, since the deflationary effect of commodity price inflation on demand for industrial goods is caused by a restrictive policy in order to avoid the acceleration of domestic inflation. However, a certain degree of caution should be taken when applying Kaldor's theory of indirect effect, since his hypothesis does not reflect the crucial development in monetary policy in developed countries. While in 1970s and 1980s most of the developed countries moved from a fixed to a floating exchange rate, and the period until 1990s can be taken as *"looking for the right way to go,"* nowadays developed countries approach inflation targeting. Kaldor (1976) assumed that the rise of commodity prices above a certain level would lead to a restrictive policy (monetary or fiscal) in developed countries in order to avoid the inflationary pressure on domestic inflation.

However, it can be assumed that this action of policy makers is not so straightforward in inflation targeting countries such the UK, since the central bank targets consumer price inflation and strictly does not react to external developments in prices if the commodity price fluctuations are only temporally (Frankel, 2012). However, according to Bosworth and Lawrence (1982) when policy makers are interested in the "balance" between consumer price inflation and unemployment, a shock to commodity prices is accommodated into the decisions of policy makers through an expansion of the money supply. Their argument has a rationale in the assumption that if policy is more inflation orientated, in the event of a positive exogenous shock to commodity prices, a significant rise in unemployment is required in order to avoid accelerating consumer price inflation. Indeed the study by Labys and Maizels (1990) that tested Kaldor's indirect commodity price effect shows a strong correlation between primary commodity prices and domestic consumer prices as well as unemployment, and shows that increases in unemployment in developed countries are underlined by commodity prices. The most important conclusion derived from their findings is that developed countries in the 1970s and 1980s did make monetary policy adjustments to a certain level as a response to commodity price swings by cutting interest rates and increasing the money supply.

However, what Bosworth and Lawrence (1982) did not consider is that not only movements in commodity prices can have an effect on fiscal or monetary policy in developed countries but the relationship can also be the other way round, thus there is a possibility for the shocks being endogenous.

3.6 Empirical evidence on commodity prices as an inflation indicator

In the past decades, the UK as well as other countries experienced the unreliability of several approaches to monetary policy making. After decades of inflation instability (further discussed in Section 3.7), nowadays it is recognized that levels of nominal and real interest rates, real economic variables such as employment, economic growth or narrow monetary aggregates as the sole guides may not be such a reliable target for monetary policy. As history shows, the right target and policy tools are the first steps to stable inflation, but an important ingredient in any policy making is without any doubt forecasting inflation and projecting the economic outlook. Therefore, it is crucial to search for the right type of indicators to be used for formulating policy decisions (Frankel, 2012).

It is believed that financial market indicators, due to their forward-looking nature, can be useful indicators of future inflation, particularly the exchange rate, bond prices and commodity prices (Angell, 1992). The reasons why commodity prices may be useful indicators for monetary policy are excessive. As previously mentioned, the forward-looking nature incorporates agents' anticipations of fundamental market forces as well as anticipations of both policy change and movements in general prices. Thus it can be assumed that commodity prices incorporate expectations about future movements in prices. As also mentioned in previous sections, since they enter the production process at an early stage, movements in commodity prices can lead to movements in consumer price indices thus can also be useful for monetary policy.

It is important to mention the flexibility of commodity prices, which is higher than other prices therefore they can signalize the changes in policy and thus have the potential to be a good inflation indicator. From the forecasting point of view, commodity prices have an advantage compared to indicators such as the Gross Domestic Product (GDP) or other output and income statistics, since they are observed at frequent intervals and are not the subject of later adjustments or revisions. However, more importantly, commodity prices together with exchange rate movements can help central banks to distinguish between the domestic or global nature of inflation and thus send a signal to policy makers as to whether the monetary policy needs to be tight or easing (Frankel and Saravelos, 2012). This is possible since the depreciation of domestic currency against a selection of other currencies, while commodity prices are weak, sends a signal to easing domestic monetary policy relative to foreign monetary policy (Brayton et al., 1997).

Despite these advantages of commodity prices, and also their potential for being a good inflation indicator, and the general agreement between economists of the importance of inflation forecasting for policy makers, there is an extensive debate on the relevance of commodity prices as a leading indicator for inflation. The theoretical justifications for using commodity price inflation to predict future consumer price inflation can be found in the way that commodities are purchased. As explained in the previous section, commodities are purchased in spot markets and their prices are therefore flexible in contrast to final goods prices which are more likely to be sticky.

In the case of a macroeconomic shock, commodity prices will be affected contemporaneously and affect consumer prices only with a lag (Gregorio, 2012). A number of studies refuse commodity prices as useful inflation indicators (e.g. Garner, 1995, Bloomberg and Harris, 1995). Garner (1995) concludes that there is a decline in usefully explaining inflation using several leading indicators, specifically after the year 1983. Similar results are found in a study by Bloomberg and Harris (1995) who investigated the same period. It should be noted that the evidence of commodity prices being useful inflation indicators is related to the period analysed as well as the country. While in the 1970s and 1980s most of the literature is supportive in terms of the role of commodity prices as inflation indicators, since the mid-1980s and the 1990s the results differ.

For example Boughton and Branson (1988) claimed that commodity prices might serve as a useful leading indicator of inflation in developed countries as shock in prices can occur in the market for certain commodities such as food or oil. As these commodities are important for the domestic production of final goods, higher prices will be passed through to final goods prices. Indeed, it could be argued that it is necessary to consider the stickiness of prices of final goods therefore the increases in prices of final goods will be slower. However, according to Boughton and Branson (1988) commodity prices are determined in relatively flexible auction markets and as a result tended to respond quite quickly to disturbances, especially monetary ones. On the other hand, Moutos and Vines (1992) found the tendency for movements in commodity prices to affect movements in consumer prices, but the results were confirmed only when using an effective exchange rate rather than domestic currency.

Furlong (1989) used a VAR model for testing the usefulness of commodity prices as an inflation indicator for the U.S during the years 1965-1987, with the inclusion of quarterly data on monetary aggregate, commodity price index, consumer price index and an indicator of the strength of economic activities relative to the potential, and found that commodity prices provide useful information for policy makers and also tend to improve the inflation forecast. As study by Cody and Mills (1991), that follows Furlong’s (1989) study, also finds that the use of commodity prices in formulating monetary policy would improve the performance of the U.S economy.

On the other hand, although Blomberg and Harris (1995) find that the commodity price index performed well in predicting inflation in the 1970s and the early 1980s in the U.S, they find no evidence for the predictive power of commodity prices after the early 1980s. As they explain, the change came mainly due to the declining importance of commodities as a source of exogenous shocks to the economy. Later, Furlong and Ingenito (1996) came to the same conclusion; they found that commodity prices were a strong leading indicator of inflation only during the 1970s and mid 1980s. However nowadays, an empirical link between commodity prices and consumer prices can be difficult to detect as higher commodity prices may not be passed fully to the consumers of final goods due to the competition from free trade. The reason why the relevance of commodity prices in inflation forecasting is still open, is that if consumer price inflation is subject to several offsetting shocks at the same time, the unconditional covariance between consumer prices and commodity prices may be small or insignificant.

A more recent study on the forecasting ability of commodity prices was investigated by Sims (1992), by the inclusion of a commodity price index in a VAR model. His findings show that the consecutive rise in the price level and short-term interest rate were the result of an endogenous policy response to higher than expected inflation, and proposed including a commodity price index in the inflation forecast. Since Sims's study, the commodity price index has been extensively used in numerous VAR models in order to develop a deeper understanding of the behaviour of monetary policy e.g. Bernanke and Mihov (1998). A more recent study by Hansen (2001) shows that the inclusion of the commodity price index in the inflation forecast by adding certain commodity price indices to a VAR forecasting model reduces the forecast error of consumer price inflation by 35 per cent per year. An interesting study by Blomberg and Harris (1995) indicates that commodity and producer price indices performed well in forecasting inflation in the 1970s and the early 1980s however, they lost the prediction ability after the mid-1980s due to the absence of significant food and oil price shocks.

Their results explain why Boughton and Branson (1991) could not identify a long-term relationship between commodity prices and consumer prices. These results were confirmed by Furlong and Ingenito (1996) who indicated that the ability of a non-oil commodity price index to Granger cause Consumer Price Inflation (CPI) loses its power of prediction in the mid-1980s. From the results of studies in the 1970s and 1980s it can be assumed that the relationship between commodity price indexes broke due to the lower volatility of commodity prices, together with developments in commodity markets and switching to different materials. The results from studies also suggest that the effect of commodity prices and their role as an inflation indicator is time-varying.

As pointed out by Browne and Cronin (2007), due to developments in commodity prices during the 2000s, the role of commodity prices has been brought back to the discussion especially in relation to developed countries and the potential inflationary pressures of commodity prices. As an example, Awokuse and Yang (2003) investigated the changes in the role of commodity prices as an indicator of inflation during the longer period of 1975-2001 and concluded that commodity prices still provided useful information about the future inflation rate.

Contrary to the above mentioned studies, Steindel et al. (2000) came to a different conclusion when instead of adding the commodity price indices and comparing the outcome with the prediction without commodity prices; the authors added a series of individual indicators of future inflation, such as exchange rates, interest rates and unemployment to a VAR model for more complex comparison. Over the period 1975 – 1998, their results demonstrated that including certain commodity price indices (e.g. gold index, oil price index) outperformed the autoregression model more often than other indicators. Another study by Stock and Watson (1999) over the period 1971 – 1984, indicated that forecasting models, with the inclusion of the commodity price index, increased the accuracy of a forecast for the change in monthly consumer price inflation relative to an autoregressive benchmark by 21 per cent. While this literature constitutes an important indication of the role of commodity prices in consumer price inflation, these studies focus on consumer price inflation in the U.S over the period of 1980s, when the ability of commodity price indices as a predictor of future inflation weakened. While most of the studies focussed on the U.S, the evidence for different countries also shows that commodity prices may provide useful information about future inflation, and also, that the effect of commodity price shocks on economies differs significantly depending on the driver of the price shock. Baumeister et al. (2010) and Peersman and Robays (2012) used the decomposition approach for cross-country data and came to the conclusion that the impact of oil price shocks on developed countries varies and strongly depends on the driver of the price movement.

Hamori (2007) also used a VAR model to investigate the role of commodity prices for Japan during the policy of a zero interest rate. Although, his results supported the evidence of the importance of commodity prices as an inflation indicator, this has been confirmed only for the period before the zero interest rate policy was introduced. His findings are interesting as the correlation coefficient calculated in Chapter 2 (Table 2.1) shows no correlation between Japan's interest rate and food prices during the 1980s and 1990s while positive correlation has been found in 2000s. Nevertheless, the coefficient calculated for the oil prices and Japan's interest rate (Table 2.2) shows a weak but positive correlation in the 1990s and a higher positive correlation in the 2000s. Since Hamori (2007) focuses on oil commodities and does not find evidence for oil prices during 2000s, an extension to this study could be an investigation on the role of food commodities as an inflation indicator. Although as Hamori (2007) explains, the results are understandable since during the zero interest rate policy, monetary policy did not respond to the movements in commodity prices due to strong deflationary pressures presented during this period.

Bloch et al. (2007) investigated the impact of commodity prices on industrial goods in commodity exporting countries, particularly Australia and Canada and concluded that commodity prices have a positive impact on aggregate price level. However, their study does not encounter the effect on inflation. Hasan and Salim (2011) investigated the role of commodity prices in predicting key variables such as inflation, unemployment and the official interest rate in Australia concluding that commodity prices are determinants of monetary policy.

For the UK, a limited number of similar studies can be found however, the focus is on determinants of increasing retail food prices in the UK, rather than the ability of commodity prices to predict future inflation. Hendry (2001) modelled UK inflation over the period of 1875 – 1991 with the additional inclusion of commodity prices, in order to investigate whether they accounted for higher inflation. However, the limitation of his study is in the missing commodity price data during the analyzed period, therefore Hendry (2001) had to use an interpolation of the data over each period. Even this is a standard statistical procedure for dealing with missing data, though according to Asteriou and Hall (2011) it may not capture the trend of the data. Thus, the use of data interpolation might also contribute to Hendry's conclusion that commodity prices do not explain UK's inflation shocks. Harrison et al. (2011) investigated the impact of persistent energy prices shocks on the UK economy and concluded that the response of the UK's economy to oil price shocks is sensitive to changes in nominal rigidities and the response of policy makers.

The most recent study by Millard and Shakir (2013) investigates whether the impact of oil price movements differs in relation to the different nature of the shock, particularly shocks driven by oil supply and oil demand. Their findings confirm that the source of the shock directly affects the size and nature of the impact on the UK economy. While oil supply shocks lead to negative impacts on output and higher inflation, the impact of oil demand shocks is largely positive. Their findings also reveal that the impact of oil shocks has changed over time. While the impact was statistically of low significance after the 1980s, confirming Hendry's (2001) findings, the impact has been found to be increasing since 2004.

The lack of literature on the ability of commodity prices to improve the inflation forecast in the UK might be explained in the flow of inflation targeting. Monetary policy should respond if there is inflation, i.e. if there is a sustained increase in the general price level. However, it can be argued that high commodity prices often result from adverse supply shocks or large increases in input costs and it is not the intention of policy makers to react to short-term shocks since the conventional wisdom is that if inflation expectations are well anchored, monetary policy does not need to react to supply shocks (Coletti et al., 2012). This is based on the assumption that supply shocks are purely temporary. However, this assumption does not always hold. Supply shocks are often structural and lead to a permanent upward shift in prices. Substantial increases in commodity prices have now being recognized and the argument that commodity prices are not a reliable indicator of inflation due to temporally short-term shocks may not hold anymore.

3.7 Transmission of commodity shocks to the economy

Given the importance played by commodities in the economy, a significant number of studies have been introduced to investigate the causal relationship between commodity prices and macroeconomic variables, such as output and unemployment as well as monetary variables such as inflation rate. However, economists have not come to an agreement regarding the magnitude and significance of the effect of commodity price shocks on the economy and monetary policy. Several reasons for disagreement between economists can be found. Firstly, in recent studies authors use more sophisticated econometrics models which outperform traditional models. For example Bessler (1984) investigated the relationship based on the standard Granger causality tests performed on macroeconomic, monetary and price variables. Nowadays, due to the weaknesses of Granger causality tests (discussed in more details in Chapter 4) authors prefer more advanced econometric tools. As also shown by Toda and Phillips (1993) the Granger causality test may lead to misleading results when there are stochastic trends and cointegration in the system of variables. Later studies e.g. Marquis and Cunningham (1990), Cody and Mills (1991) and Hua (1998) consider the non-stationarity of variables and conduct vector error correction models to capture the short-term as well as the long-term relationship.

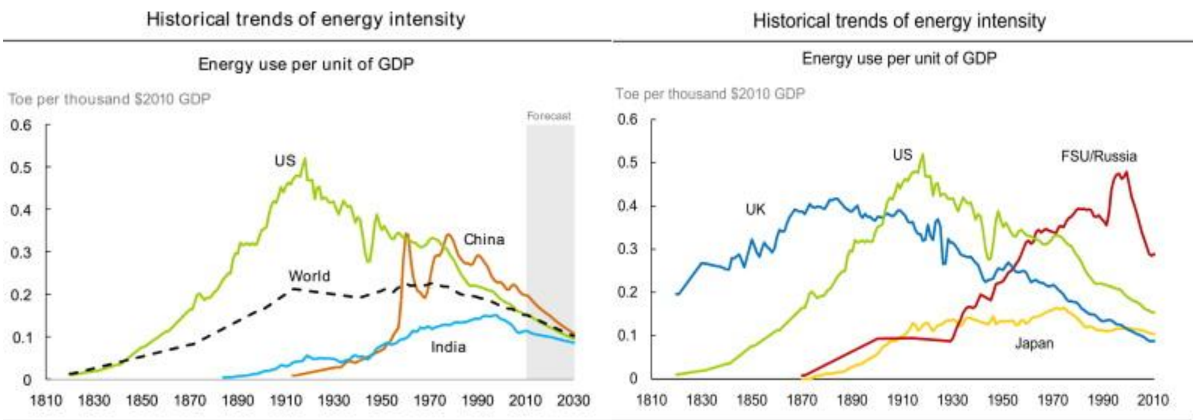
As mentioned earlier in this section, results also differ when different countries are analyzed. Secondly, the significance of the effect directly depends on the period analyzed. As discussed in the previous section, while in the 1970s till the mid-1980s a strong link between commodity prices and inflation was found, this effect dies after. In addition to the period analyzed, as will be discussed later in Chapter 6, a number of studies can be found where authors did not consider potential structural breaks during the period analyzed. This specifically applies to studies trying to explain the relationship during a longer period. Last but not least, is that results also vary due to different variables used for modelling the impact. If the above mentioned factors are considered, when investigating the specific effect commodity price shocks on the UK economy, it is necessary to understand how the shocks can be passed into the economy. A theoretical explanation on how commodity price shocks can be transmitted into the economy as presented by Barsky and Kilian (2004) can be interpreted as follows.

If the output is assumed to be a function of the imported commodity, labour, and capital services Y= Q[C, L, I] the magnitude of the shock in commodity price on output (ceteris paribus) will be small. If the usage of the commodity is reduced by 10 per cent, the output will be reduced by a percentage corresponding to the cost share of the commodity (Barsky and Kilian, 2004). This argument is not a novelty and has been already investigated by Rotemberg and Woodford (1996) for oil prices, who found that a 10 per cent increase in oil prices lead to less than 0.5 per cent reduction in the U.S output. The argument of Bratsky and Kilian (2004) is based on the assumption that the elasticity of substitution in the case of oil is less than unity, suggesting that the impact on output will be small. However, in the case of food prices, the elasticity of the substitution is higher, thus understandably the actual drop in output could possibly also be higher.

The corresponding effect of an oil price shock on value added, in contrast, is less clear. Nevertheless, when a real output is considered by implementing the domestic value-added, the output can be written as a function Y = Q[V(K, L), O], where V(K, L) is domestic value-added, Rotemberg and Woodford (1996) state that when perfect competition is assumed, the direct effect of a commodity price shock on value added cannot be identified, since changes in the quantity of the commodity do not shift the demand curve for labour and capital. However, as presented by Kilian and Bratsky (2004) when imperfect competition is assumed, an increase in commodity price can lead to a reduction in demand due to firms applying the mark-up to all costs as in this case capital, labour and commodity used for production. As mentioned earlier in this section, higher oil prices may lower companies' profits and lead to a reduction of new capital purchased, in the case of a permanent increase (as observed in recent years) investments in more energy-efficient capital can be expected (Cologni and Manera, 2008).

The assumption of Cologni and Manera (2008) is mostly based on the general assumption that the peak in energy prices in the 1970s led to a reduction in energy-intensive capital. However, this assumption was investigated earlier by Hulten et al. (1989) who tested the hypothesis that the shift from energy-intensive capital to less intensive capital would be reflected in the lower prices of used equipment. Nevertheless, the hypothesis was rejected as the results showed that after 1973 not only did the price of used equipment not decrease, but in some cases the price of energy-intensive equipment increased.

Figure 3.7 Historical trends in energy intensity



Source: Rühl et al. (2012)

The study on the decomposition of the trend in energy intensity by Rühl et al. (2012) (Figure 3.7) shows a decreasing trend over the last two decades and the projection of a continuing decreasing trend. If one considers that energy intensity is decreasing, based on the assumption of the demand-supply theory, energy prices should be decreasing too. However, as mentioned before, energy prices have a rising trend and new peaks were reached in the 2000s thus production costs stayed higher even though the energy intensity decreased.

As mentioned earlier economic activity can be influenced by income transfer from commodity importing to commodity exporting countries. In the case of developed countries this channel is mostly applicable to oil export and import. However, as estimated by Olson (1988) the total wealth transfer from industrialized countries such as the UK to oil producing countries does not tend to be significant. His results show that extra import costs accounts for only 1 per cent of the output in the case of the U.S.

Another explanation of how commodity price shocks can affect the economy is through the response from economic agents and the impact on unemployment proposed by Hamilton (1988). As he explains, when applied to oil prices, a shock leads to a reduction in the demand for energy-intensive goods. In the longer-term this shift in demand leads to reallocation of labour in sectors. However, as argued by Bratsky and Kilian (2004) the shifts of labour could be costly, which may consequently lead to a reduction of labour. Also, as they argue, the assumption does not always hold, since while the oil price peak in the early 1980s led to a significant rise in unemployment, the later shock in 1986 did not prove to have any impact on unemployment.

The different magnitude of effect on unemployment as well as output has been discussed by Bernanke (1983) who explains that it is necessary to account for lags in the reactions of firms and consider the expectations on whether the increase in prices are persistent or only transitory. Understandably, the shifts in labour and postponing the investments of a firm are more likely appear if the increase in commodity prices is expected to be persistent, while transitory shocks may be absorbed by inventories or reflected in higher costs. This argument raises the importance of examining the magnitude and significance of the effect of commodity price shocks in terms of their persistence.

3.7.1 Impact of commodity prices on economic growth and inflation

Theoretical contributions on the relationship between commodity prices and output have changed over time, and there is not an agreement on whether commodity prices do have an effect on output or what the size of the effect is. Kliesen (2008) investigates the effect of oil prices and concludes that the price elasticity of the demand for oil is low in the short-term due to lags in the consumption patterns of firms and consumers, thus he assumes there will only be a small effect from oil price shocks on output in the short-term. However, as already mentioned in the previous section, a negative demand shock may lead to the reallocation of labour in production of energy intensive goods. Since reallocation of labour may be costly, the impact on the economy is assumed to be significant even if the oil share of the GDP is low. Although Rotemberg and Woodford (1996) explain that the negative impact on output is caused by monopolistic producers who increase their mark-ups during oil price shocks, Finn's (2000) findings show that oil price shocks lead to sharp and simultaneous declines in energy use as well as capital utilization with significant effects on output. Jimenez and Sanchez (2005) identify that commodity prices, particularly oil prices, affect the output through cost adjustments and also interact with the impact through a negative demand shock. Also considerable attention has been paid to the correlation between oil prices and real output, with special interest being paid to the effect on industrialized countries. A number of authors e.g. Hamilton (1983), Mork (1989), Guo and Kliesen (2005) focussed on the effect of oil price shocks on a country's output and found that lower output growth can be expected due to rising production costs.

Commodity price shocks may therefore impact the economic growth in the long-term. According to Hansen (2001), oil prices shocks in 1970s caused a slowdown in productivity. Aghion and Banerjee (2005) also investigated the impact of commodity prices on productivity and output and concluded that countries that specialize in the exporting of raw commodities have to face more significant macroeconomic volatility than countries exporting manufactured products. As they further discuss, macroeconomic volatility may negatively affect savings, investments of economic agents, as well as the long-term economic performance of the country.

Other authors, e.g. Blattman et al. (2007) and Loayza et al. (2007) studied the economic volatility of commodity prices and also concluded that the volatility of commodity prices has a negative impact on growth in the long-run. On the other hand, an earlier study by Olson (1988) shows that there is not significant evidence to conclude that oil price shocks in the 1970s explain the slowdown in production. Olson (1988) explains the slowdown in the U.S economy after the oil price shocks in 1970s as a result of the effect of substitution. Similar results were found by Burbidge and Harrison (1984) who examined the impact of oil price shocks on the economic performance of the U.S, U.K., Japan, Canada and Germany. Although, their results show that during the early 1970s the cuts in oil supply caused by an oil embargo explained a significant part of the fluctuations in industrial production, there is no evidence for a relationship between oil prices and industrial production in late 1970s and early 1980s. In addition to Burbidge and Harrison's (1984) results, a study by Mork at al. (1994) of six industrialized countries (France, Canada, UK, Norway, Germany and Japan) found significant differences between the impacts within the countries. They concluded that the size of the impact of oil price shocks on output is directly related to the level of a country's dependency on oil imports. Nevertheless, their findings reveal that the output growth of the above mentioned industrialized countries had been asymmetrically and negatively affected by oil prices in 1990s. As study by Roeger (2005) shows, over three years, the effects of a 50 per cent increase in oil prices on output growth slowed down from -0.5 per cent to -2.3 per cent. More recently DePratto et al. (2009) investigated whether oil price changes are transmitted into the UK and Canadian economies through temporary demand and supply channels by affecting the output gap, or through persistent supply side effects thus affecting the trend growth during the period of 1971-2008.

From their findings it can be concluded that the main effect is through the supply side while the demand side effect is not significant. Most importantly, oil price shocks temporarily affect the output gap but in the long-term they translate into a permanent reduction in potential as well as actual output. Theories that can explain how commodity prices may lead to a recession still do not explain the presence of stagflation, which was caused by oil prices in the 1970s. Thus, it is necessary to discuss another role of commodity price shocks in explaining inflation (Rotemberg and Woodford, 1996). Although the existing literature has investigated the effect of commodity price shocks on aggregate output, limited attention has been paid to the notion that commodity price shocks may also be inflationary.

Barsky and Kilian (2002) extend the above mentioned work of Rotemberg and Woodford (1996) by examining the inflationary effect of oil prices, and concluded that an oil price shock is indeed unambiguously inflationary for the price of gross output. Therefore, from their results a shock in oil prices should be followed by a decrease in industrial production and a rise in inflation. Although, the reaction of policy makers to a shock in commodity prices is relative to the size of the shock and the persistence as well as the nature of the shock, a key role is the played by the policy framework used by the central bank. In order to understand the reaction of policy makers, the next section therefore discusses the evolvement in UK monetary policy during the last 21 years.

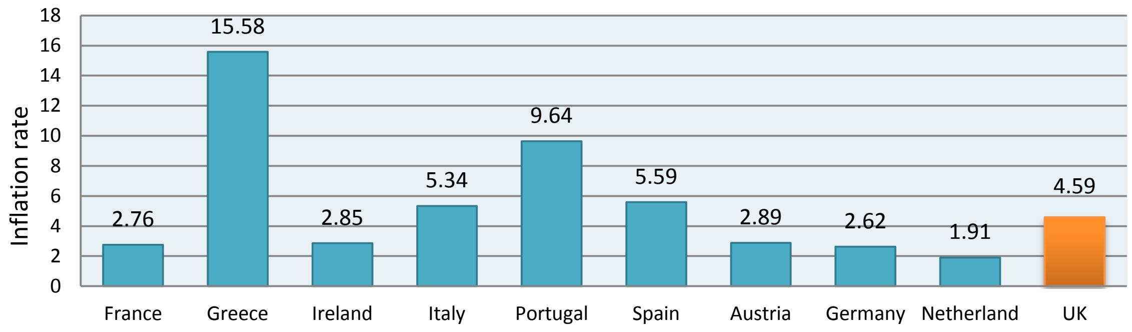
3.8 Monetary policy in the UK

Monetary policy has been always conducted in undertrained environment. Unexpected macroeconomic shocks and errors in estimated channels of policy transmission monetary led to challenges in policy design (Asso and Leeson, 2012). The following section discusses some of the key events in the UK's history and its experience with different monetary regimes in the last 21 years with a focus on fundamental changes in monetary policy related to understanding the importance of right target and right policy tool. Through the history, since the gold standard, the UK experienced a variety of monetary policies from the fixed exchange rate to targeting money aggregates until the most recent framework also known as inflation targeting. Switching from one regime to another was mostly characterized by worsening one or in some cases a few of the key indicators such as unemployment, inflation rate, GDP growth or exchange rate and put the country into long time run for economic stabilization. Understanding the developments in the UK monetary policy is important for analyzing the relationship between commodity prices and monetary policy in both ways. Also historical view helps to identify possible structural breaks during the period of interest. The discussion starts in 1992 and through the last 21 years introduces the most important events in the history of UK's monetary policy.

3.8.1 The beginning of a new consensus in the UK (1992-1997)

After the failure of the exchange rate mechanism in early 1992, the UK stayed in front of a difficult task which required an immediate action. As a resolution to the situation, the Chancellor Norman Lamont introduced five alternative policies– cutting the interest rates and sustains the parity, devaluation within the ERM, German realignment and leaving the ERM, cutting the interest rates or the last one leaving the ERM and setting interest rates according to domestic indicators (Lamont, 1993). In 1992, after the UK left ERM, the UK's Government declared the longer-term objective formulated as *"price stability"*, or in other words the defeat of inflation on a lasting basis. However, the exact explanation of what exactly this formulation of low inflation means was not specified as the objective was to hold the inflation on a permanently as low rate as the best of the other countries in the Europe. In fact, the UK aimed to achieve the same inflation level as Germany. However, this objective was not achieved (Figure 3.8) even it was assumed by the government that lower inflation of 2 per cent in 1996-1997 could be achieved by inflation measured by the GDP deflator, the same measurement as used in Germany.

Figure 3.8: Annualized inflation rate (1987-1994)



Source: Adapted data from HM Treasury (1992a)

Neither different measurement did not have expected effect therefore the objective of holding the inflation on a permanently as low rate as the best of the other countries in the Europe was not achievable. In his letter from 24 September 1992 the Chancellor Norman Lamont (HM Treasury, 1992b) explains that the forecast shows that inflation in the UK should match inflation in Germany during the years 1993-1995, and suggested holding inflation in the range of 3-4 per cent over the next two years. However, he also points out that a significant tightening of policy will be necessary in order to match inflation in Germany. This was the beginning of a new policy approach, based on a revolutionary framework of conducting the policy as a systematic response to incoming information about economic conditions introduced by Taylor (1993), nowadays known as the Taylor rule. The Taylor rule suggests that policy makers should set the nominal interest rate as a function of deviations of inflation from target and deviations of the level of real output from its trend (Kahn, 2012).

The original Taylor rule can be written as:

$$R_t = (r^*+\pi^*) + 1.5(p_t - \pi^*) + 0.5(y_t - y_t^*) \qquad (3.3)$$

Where Rt is the nominal interest rate, p_t represents the inflation rate and $(y - y^*)$ is the deviation of the output from its trend level, thus the output gap, π^* is the target inflation and r^* represents the real interest rate. Nevertheless, even though the purpose of the Taylor rule was to describe the setting of monetary policy in the U.S and it fits the data empirically, it says only little about what information policymakers actually respond and how they make decisions (ECB, 2011). According to Belke and Klosen (2011) policy decisions cannot be made solely on inflation and output, but the policy needs to be conduct using additional information such money growth, asset prices as well as commodity prices.

At the meeting on the new monetary framework on 2 October 1992 (HM Treasury, 1992b), one of the main concerns discussed was the improvement of credibility of policy. Inflation target was suggested to be from 0 to 4 per cent because of the previous errors and variations in the forecast. However, the Chancellor Norman Lamont strongly refused including zero inflation into the objective as he hoped to move away from zero inflation before sterling's membership of the ERM had been suspended as it seemed to be unachievable (HM Treasury 1992a). Therefore, a target at a range of 0-4 per cent as the upper end of the range was refused as according to Chancellor Lamont did not reflect an ambitious performance. A few of days after the meeting, in 8 October 1992, the Chancellor Norman Lamont sent a letter to the Chairman John Watts in order to set out the Government's policy as it required an immediate action. In his letter he states that the Britain can rejoin ERM under the condition that current turbulence in the foreign exchange markets ends and more importantly when German and UK monetary policy will be *"in line"* (Lamont, 1992).

"*In the Government's view these conditions are unlikely to be satisfied soon therefore we need to establish a framework for monetary policy to replace that hitherto provided by the ERM."*

The Chancellor Norman Lamont

Even the Chancellor showed his averse to range of 0-4 per cent, in the letter from 5th October 1992 to the Chairman John Watts he stated the objective of keeping inflation rate within a range of 1-4 per cent with an aim to be in the lower part of the range. In this letter, the Chancellor also clearly presents that the UK suffers from price stability for more than a generation and in order to achieve a price stability he suggests to measure inflation by the change in retail prices excluding mortgage interest payments and express an aim at a long term rate of inflation of 2 per cent or less (HM Treasury, 1992b). As stated in the letter from 1 October 1992 to the Chairmen that individual variable has to be target as targeting more than one measure will reduce credibility and even GDP deflator seems to be a better indicator of inflation than RPI, he argues that RPI has fallen more than the GDP deflator over the past years. On the other hand he points out that none of the indicators is ideal as according to Norman such an indicator does not exist and needs to be created (HM Treasury, 1992a).

It should be noted that the Taylor rule does not dominate in the policy framework of the BoE however plays a background role (Nelson and Nikolov, 2004). Nevertheless, expectations were high as taking the control over inflation seemed to be an illusion more than a reality when considering that the UK did not experience stable inflation over a generation before inflation targeting. The fear of losing the credibility achieved by joining ERM shifted into reality however, it was only an immediate effect and lost credibility was according to Chancellor's speech to the European Policy Forum in 29 July 1993 again achieved by the announcement of a new monetary policy framework and including inflation target of 1-4 per cent (Lamont, 1993). As a result of the ERM membership the retail price inflation dropped from 11 per cent to 4 per cent, interest rates were cut from 15 to 10 per cent and trade deficit with European countries had fallen from 11 billion GBP in 1990 to 2 billion GBP in 1991 (Lamont, 1993). In the speech from 29 July 1993 the chancellor evaluated situation one year later after leaving the ERM as previous forecast about dramatic economic consequences of leaving the ERM showed wrong and the UK was enjoying low interest rates and inflation, improved competitiveness and an economic recovery, however the unemployment was still higher.

3.8.2 The Bank of England's operating independence and pre-crisis period (1997 - 2007)

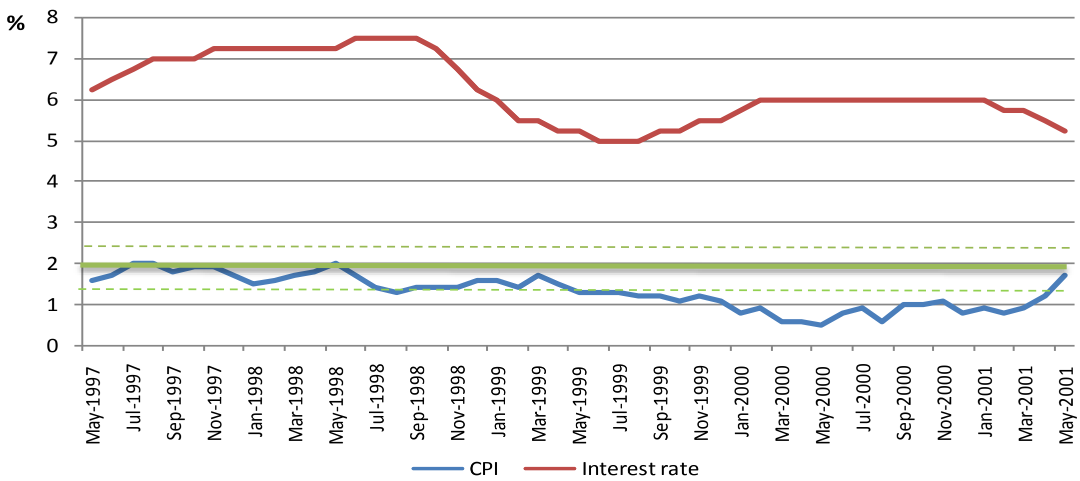
The period after the Government's official announcement of inflation targeting had been, when compared to previous monetary policies, successful (Ginindza and Maasoumi, 2013). However, indeed, had some key drawbacks. The most significant among these was the suspicion that interest rate decisions, taken by the finance minister after consultation with the Bank of England Governor, reflected political considerations rather than economic environment or signals from forecast. According to Malikane and Mokoka (2012) found that the UK experienced lack of the credibility during the 1990s, but improvements can be found during the late 1990s and beginning of 2000s.

Understandably, this could cause complications with anchoring inflation expectations or, even worse, send mixed signals. Therefore, in order to achieve the credibility and transparency of monetary policy, the new government announced in May 1997 that the Bank of England would therefore have operational independence for the conduct of monetary policy. While the objectives of policy remained a matter for the government to determine, responsibility for interest rate decisions moved to the Bank's new Monetary Policy Committee (MPC).

It is convenient to point out that not only operational independence signed up for changes since 1997, but also the inflation target. Later in the 1990s, the UK switched from previously targeting RPIX to targeting CPI. Fundamental difference is that RPIX included effects of commodity price shocks, including oil price shocks (Bernanke et al., 2001).

As shown in Figure 3.9, since the operational independence of the Bank of England, inflation rate had been most of the time within the band (upper and lower green broken line) and close to the target (full green line). Indeed this period was characterized as a success of inflation targeting, since the stability of inflation rate significantly increased not only in the UK but also in other inflation targeting countries (Mishkin and Posen, 1997). However, Friedman (2004) as well as Ball and Sheridan (2004) argue that most central banks, not only inflation targeting countries, experienced lower inflation rate during this period. One explanation for this is that the widespread adoption of IT happened to coincide with a period of historically low inflation and output volatility, also known as a period of the "Great Moderation" and mild macroeconomic shocks (Kuttner and Posen, 2012). Therefore the main argument of the critique is that inflation targeting had not been tested by a situation involving trade-offs between low inflation and stable output.

Figure 3.9: Inflation rate and interest rate – pre crisis period



Source: Adapted data from ONS (2013a)

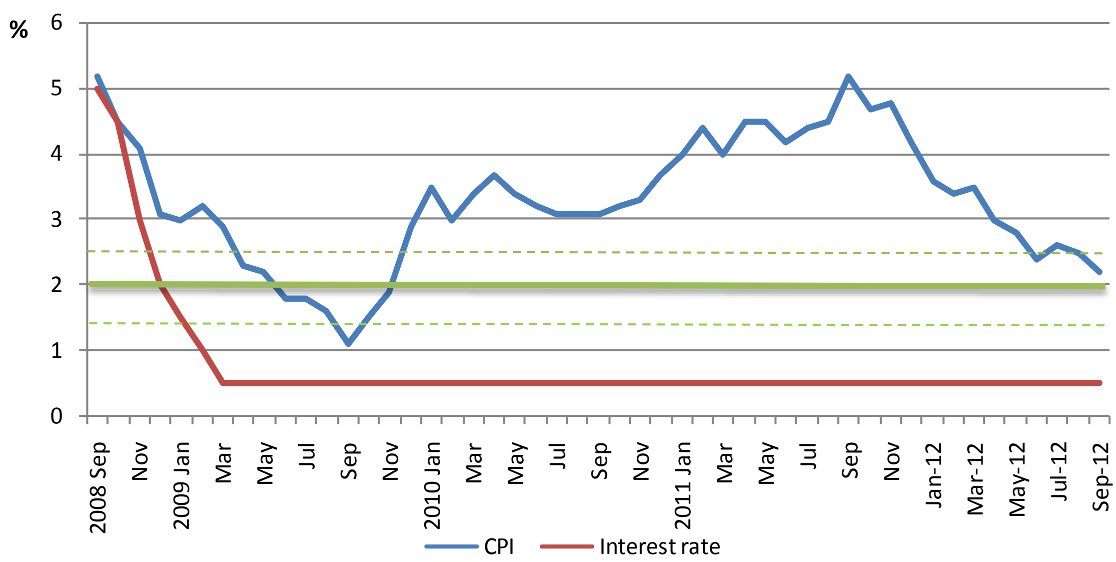
However, it should be noted that during this time, the global economy was not affected by any large shocks, what indeed helped policy makers not only in the UK, but also in other countries keep stable inflation rate (Figure 3.9) after all it was the credibility and transparency which helped to anchor expectation and kept inflation low (Malikane and Mokoka, 2012). Indeed, the size of negative effect of crisis or global imbalances to an open economy is bigger than the size of a positive effect of stable global economy. Since it is difficult to find a consensus on this period, the opponents and proponents of inflation targeting agree that the new framework helped to achieve credibility and transparency of policy and more importantly, it helped to anchor the inflation expectation better than any previous policy.

3.8.3 Inflation targeting in the UK during the financial crisis (2008-2012)

After years of apparent success, inflation targeting has come under increasing critique for its inability to prevent countries against recession and depression during the global financial crisis of 2008. Opponents of inflation targeting argue that financial crisis became a real test for new framework showing the power of its drawbacks and too much of confidence in its flexibility to allow central banks to pursue countercyclical monetary policy while maintaining medium and long term price stability (Svensson, 1997 and Svensson, 1999, Bernanke et al., 2001).

Indeed, this period has been a difficult task for policy makers in the UK and also elsewhere. As Figure 3.10 shows, inflation rate most of the time missed the target and moved above the upper board of 2.5 per cent. The official interest rates dropped to the lowest in the UK history while inflation rate rose up to its highest rate since 1992 (Figure 3.10). Understandably accelerating inflation became the core of the opponent's critique such DeGrauwe (2006) who argued that inflation targeting "has failed" as a strategy or more recently Woodford (2012) who propose that financial crisis also resulted from inflation targeting.

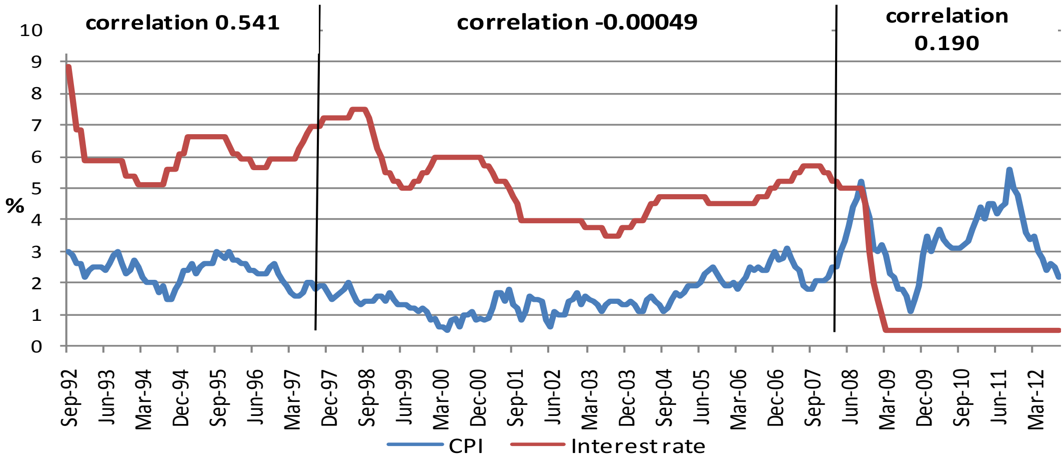
Figure 3.10: Inflation rate and interest rate during the financial crisis



Source: Adapted data from ONS (2013a)

Therefore, in addition to the discussion, Figure 3.11 shows the development of interest rates and inflation rate in the UK since adoption of inflation targeting. Period is split into three periods. First period represents beginning of inflation targeting in the UK. Looking at the strength of the relationship between interest rates and inflation during the first period calculated as a correlation coefficient it can be observed (Figure 3.11) that there was a moderate positive relationship (0.541).

Figure 3.11: Correlation between inflation and interest rates



Source: Calculation base on adapted data from BoE (2012b)

Nevertheless, although any conclusion about credibility of the UK government during the period of its responsibility for meeting the inflation target can be made, comparing the period of government's responsibility for meeting the target and period of the BoE's operational independence and interesting results can be observed. The correlation coefficient for the period 1997–2008 thus, since the BoE's operational independence, shows a weak negative relationship. In other words it suggests that during 1997 – 2007, the interest rates and inflation rate had been moving opposite direction. However more importantly, since the coefficient is very close to zero it suggests that the relationship is very weak. This could be explained by Kuttner and Posen (2012) who argue that low inflation rate was achieved due to global great moderation and mild macroeconomic shocks. Indeed, the weakness of correlation coefficient enables to conclude whether movements of inflation rate were driven by policy decisions about interest rates or moderate stability in the global economy. However interestingly, from the beginning of financial crisis until now the correlation coefficient shows positive relationship again more interestingly it has higher value (0.19) that in previous period (-0.00049). Even strong expansionary policy during financial crisis led to the cuts in interest rates from 5 per cent to 0.5 per cent, due to panic in banking sector, the transmission mechanism was not able to pass though the effect of low interest rate. Moreover, due to the risk of deflation in 2009, stagnating production and rising unemployment, the interest rate stayed at 0.5 per cent the lowest level in the UK's history. Since the beginning of inflation targeting in the UK, the only period when correlation coefficient shows at least moderate relationship between inflation rate and interest rate is the early beginning of inflation targeting.

3.8.4 State-contingent forward guidance and 7 per cent threshold (August 2013-)

The policy of low interest rates however, did not stimulate the economy as assumed and the BoE had to approach unconventional policy of quantitative easing. From the first authorised assets purchase in March 2009 until now, the total assets purchases of £375 billion has been made. Nevertheless, even though as shown by Nelson (2013), asset purchases have prevented expectations of deflation and thereby helped to avoid the fall in output during the recession, by stimulating the real aggregate demand in 2010 and thus output growth.

However, it has been six years since the financial crisis started and the recovery of the UK economy from the financial crisis is slower than expected (Osborne, 2013). Slow recovery is mostly driven by a significant output gap which is clearly evident in the high rate of unemployment. As shown by Seim and Zetterberg (2013) even though inflation targeting helped to anchor the inflation expectation and lower the inflation rate and real wages are on average higher in inflation targeting countries, no evidence can be found on the effect of inflation targeting on unemployment. This finding may explain why the central banks decided to approach forward guidance to stimulate the economy. The unemployment rate in August 2013 stayed unchanged from January 2013 at 7.8 per cent of the economically active population which is 0.2 per cent less than in the previous year (ONS, 2013b). In order to avoid expectations about further tightening in interest rate, an explicit state-contingent forward guidance has been introduced. This guidance is tied to the outlook of monetary policy to economic conditions in the case of the UK it is the unemployment rate.

The nature of forward guidance is still the subject of continuing debate. According to Krugman (1999) and Eggertsson and Woodford (2003) policy makers need to encounter the zero lower bound which, on the policy rate, can stimulate current aggregate demand by stating to keep the rate at zero longer than required by economic conditions and thereby create an economic boom in the future. The state-contingent guidance therefore aims to provide a clear statement on how and why the Committee will respond to unanticipated developments, and to keep expectations anchored. Issing (2013) argues that a credible forward guidance, and anchoring the expectations, cannot be effective when announcing a fixed number for a policy rate. According to Issing (2013) the central bank should provide a strategy which allows the public a kind of ex-ante understanding of policy decisions, but by announcing a specific interest rate, for an extended period of time may be understood as an unconditional commitment, thus any change may be taken as a surprise with potential of causing the turbulences in the market an put the credibility of the central bank under the risk. Woodford (2013) investigated the effect of forward guidance in Canada after adopting this approach in 2009 and found that interest-rate expectations has been changed by explicit forward guidance.

Nevertheless, one of the disadvantages of state-contingent guidance compared to others forward guidance can be found in lower effect on opinions formed by economic agents about the future outlook of the economy. Also the complication of misleading expectation may arise since only a few broader economic indicators are linked to the path of the monetary policy. Thus it is necessary for policy makers to be extremely clear about the actions taken (Bank of England, 2013). Although state-contingent forward guidance represents a novelty in the UK monetary policy, the first use of forward guidance was by the Bank of Japan in 1999. In contrast to the Bank of England, the Bank of Japan used an open-ended guidance which provides only qualitative information about the future path of monetary policy, alongside with a broad indication of the circumstances under which the central bank expected the stance of policy to change. Nevertheless, the state-contingent guidance has been firstly used by the Federal Reserve in 2012.

It applied that in the case of unemployment oscillating at the levels higher than 6.5 per cent, the Federal Funds rate will be hold at an exceptionally low level. In the UK, the main aim is to support the economic growth however, without putting the price stability as well as financial stability into the risk. Although the expected annual growth in two years is estimated to be about 2.4 per cent and GDP is not expected to retain to its levels before the financial crisis in the following year, due to the current margin of spare capacity a sustained period of growth higher than pre-crisis period will be needed (Carney, 2013). Therefore, the focus on monetary policy will be in supporting the period of growth by not considering the increase in interest rate, which is currently at its historical lowest level of 0.5 per cent, through next three years until the unemployment rate does not fall below 7 per cent. However, even if the rate of unemployment will be below 7 per cent, the interest rate may still be kept at its lowest level depends on economic conditions since the consistency with primary objective of price stability must be kept. As mentioned, the forward guidance in its different forms has been already applied in several countries. The effectiveness or benefits of adopting forward guidance are not straightforward since only limited evidence exists. A very few studies have focused on the effect of forward guidance on stabilizing the economy and none has been done on the effectiveness of state-contingent forward guidance since it has been only introduced in the U.S in December 2012.

Although the introduction of a state-contingent forward guidance is assumed to be a good stimulus for the economy it also has a few drawbacks. The success of forward guidance will also depend on the exogenous shocks to the economy and reaction of policy makers. As discussed in Section 3.7, the commodity price shock may lead to reallocation of the labour which may be costly thus can lead to reduction of labour (Bratsky and Kilian, 2004), but these shocks also negatively affect output of the country. As shown by DePratto et al. (2009) the oil price shocks temporarily affect the output gap however in the long-term they may translate into a permanent reduction in potential and actual output. If the commodity price shocks are more persistent, they can also transform into core inflation and raise inflation expectations. If so, the potential success of forward guidance may be lower than expected as policy makers would have to respond to the inflationary pressures.

According to Bodenstain et al. (2012), forward guidance can be successful only if short-term interest rate is kept at rate lower than it otherwise would in the future so the inflation rate arises higher than the target. Therefore, in order to keep expectations anchored the central banks may increase interest rates before the guidance is fulfilled (Klaus and Billi, 2007). As stated by Reifschneider and Roberts (2006) the expectations channel is very important for optimal forward guidance policy. If the understanding of intention of policy makers by public is low, state-contingent forward guidance may not be successful. Also as Bodenstein et al. (2012) show the zero nominal interest rates lead to the problem of rate time-inconsistency. As their assume, a promise to keep the nominal interest rate low for longer than it otherwise would, raise inflation expectations and stimulate the current output. However, if the low interest rates are kept after the economy emerged from recession the announcements are not considered as credible thus forward guidance does not work and economy experience even deeper recession than it otherwise would.

Their findings show that the Federal Reserve as well as the Swedish Riksbank experience low credibility of in the aftermath of the 2008 economic crisis. Similarly, Svensson (2009) shows that the expectations on interest rates to rise before the previously announced date by the central bank and caused complications in economy's recovery from the recession and also show the imperfection of credibility. Therefore, the success of this new path for monetary policy in the UK will depend on how well are the expectations anchored. Although, as discussed in previous section on the impact of monetary policy on commodity prices, low interest rates may also cause raises in commodity prices, there is also a possibility that exogenous shocks (such as commodity prices) can lead to increases in inflation rate to the level when the BoE will have to raise interest rate before promised time period.

3.9 Summary

While the first section of this chapter discusses the theoretical explanation of commodity prices movements with emphasis on the effect of monetary policy, second part focused on the reverse relationship. The role of commodity prices as a good indicator of future inflation has changed over the last few decades. Although, the evidence is supportive for the period in the 1970s and 1980s, due to changes in global economies the role of commodity prices as an inflation indicator weaken in the 1980s onwards. Nowadays, their role has been re-called by many economists as it is believed that due to developments in commodity markets, also developed countries became more sensitive to changes in commodity prices thus commodity prices may provide important information for policy makers.

Chapter 4 Methodology

4.1 Introduction

As Stock and Watson (2011:7) stated: *"If economic theory is to be a useful tool for policymaking, it must be quantifiable."* This chapter is therefore dedicated to the conceptual framework of applied econometric and practical elements of this research. It discusses the complexity of bridging the gap between theories introduced in the previous chapter and data used for testing the assumptions. However, this chapter also discusses methodological issues from insufficient data that may arise to gain reliable evidence for or against a hypothesis or theory.

In order to successfully achieve the aim and objectives stated in Chapter 1, this chapter explores econometric tools and techniques in more details, and discusses methods that are appropriate given the nature of the data. The methods and techniques of the research are discussed in consideration of the advantages as well as the disadvantages of the econometrics tools applied to the data that has been collected. The chapter is organized as follows: Section 4.2 explains the philosophy of econometric modelling approached for estimated models, and continues in discussion on the use of vector autoregressive models for investigating the impact of policy actions on macroeconomic variables in Section 4.3. Section 4.4 identifies the steps involved in analysis of time-series with focus on the non-stationary nature of the series. Section 4.5 introduces the vector autoregression model for stationary time-series in its general form and critically discusses its usefulness for modelling on how economy reacts to different policy shocks. Section 4.6 extends the discussion on non-stationarity of time-series in relation to vector autoregression model and its application on non-stationary data and offers a bias for introducing the vector error-correction model in Section 4.7. Section 4.8 critically discusses the techniques for evaluation of the results from vector autoregression model and vector error-correction model. Section 4.9 is dedicated to discussion on different techniques that can be used for forecasting from vector autoregression model and vector error-correction model. Section 4.10 discusses in details the rationale and source of data collected. Section 4.11 presents a preliminary data analysis by identifying the distribution, seasonality and nature of the time-series in terms of stationarity. This section is crucial for further estimation of models in Chapter 5 and Chapter 6. Finally, Section 4.12 summarizes the main findings in terms of appropriate methods that will be approach as well as data analysis.

4.2 Philosophy of econometric modelling

As stated by Hoover (2012:14), *"The methodology of econometrics is not the study of particular econometric techniques, but a meta-study of how econometrics contributes to economic science. As such it is part of the philosophy of science."*

Since the earliest ideas of the greatest philosophers of the economy, the economic ontology has focused on the identification of the factors that make things happen and also on how these changes in economy can be explained. Hume (1739) set the instrumental agenda for practical causal analysis by introducing his explanation of causal relationships. If *A* causes *B* then the analysis must be focused on key features of causality. As Hume (1739) explains, the analysis must consider the asymmetry of the relationship since *A* precedes the movement of *B* but *B* does not necessary cause *A*. Also, as he explains, it is necessary to distinguish between accidental correlations and causes. It is in the human nature to see connections in relationships based on logic or experience, but this cannot be taken for granted as according to Hume it is a habit of mind without any warrant (Hume, 1739).

However, the idea of causal interface was further developed in the 20th century, by applying statistical techniques such as multiple correlation as well as regression. Unlike correlation, regression has a natural direction which should respect the direction of causation. Nevertheless, there is a problem of identification of the causality direction in natural causal direction. The problem of identification of the causality direction was later partially solved by Cowles Commission[1] by searching for additional causal determinants in the relationship (Morgan, 1990). Nevertheless, after the econometric work of the Cowles Commission, two different approaches which look at the problem of causality can be distinguished. The process analysis approach, introduced by Wold (1939), follows Hume's argument on the asymmetry of the causality. This approach became an essential to the analysis of time-series, Granger causality, and Vector Autoregression (VAR) models. While the process analysis approach does not distinguish endogenous and exogenous variables, the second approach relates the causality to the properties of the structural econometric models and distinguishes the endogenous and exogenous variables (Hoover, 2004).

[1] The Cowles program, as a part of the research foundation, aimed to investigate how to combine economic theory and statistical methods with observed data in order to estimate a system of simultaneous equations that could describe how the economy works. The aim was to learn how economic policy could improve the performance of the economy (Christ, 1994).

The *a priori* approach (applied by the Cowles Commission) identifies assumptions based on the economic theory, which was later criticized by Sims (1980) for applying identifying assumptions which are not credible, and because the structural equations were in principle not identifiable.

In the flow of Hume's opinion on the human understanding of causality, the intention of Sims (1980) was therefore to find out how different shocks affect the rest of the variables in the system without imposing theoretical restrictions. Although the VAR technique introduced by Sims (1980) is efficient in summarizing the statistical properties of economic time series, the critique can be found in the reliability of its policy evaluation. It was estimated that the VAR model in its reduced form could not be used for policy evaluation since it does not provide information about causal relations (Leamer, 1985). As a result of this critique, Sims (1982) introduced Structural Vector Autoregressions (SVARs) and Choleski decomposition to impose restrictions on variables. The SVAR models therefore represent a move from the inferentially based VAR model to the *a priori* approach applied by the Cowles Commission. Since the introduction of SVARs, the literature in this chapter is dedicated to the identification of structural economic shocks by applying the Cowles Commission's methodology and an *a priori* approach, thus the restrictions are derived from theory or institutional knowledge.

4.3 Application of autoregressive models to monetary policy

Vector Autoregressive (VAR) models are nowadays considered as very useful for the empirical analysis of monetary policy issues. The main advantage of VAR models can be found in avoiding the need for a complete specification of a structural model of the economy (Kilian, 2001). Traditional structural models focus on identifying the impact of policy actions on macroeconomic variables in a way that will achieve the desired target for a particular macroeconomic variable under the assumption of policy decisions being exogenous. The VAR approach takes into consideration the endogenous response of policy actions to the economy as shown by Leeper (1997). Therefore the main aim of VAR models is to provide empirical evidence of the response of macroeconomic variables to monetary policy shocks without theoretical restrictions in order to enable the potential endogenous behaviour of policy instruments (Favero, 2001). The focus of VAR models on how the central banks should react to movements in macroeconomic variables, rather than investigating the optimal response of policy makers to developments in macroeconomic variables in order to achieve the target, is a response to Lucas' (1976) critique of traditional models. Another critique introduced by Lucas (1976) is that given the importance of coefficient identification, the model of transmission mechanism should only be estimated on a single monetary regime, and the forecast should not be out of the sample, otherwise the model is not valid and different parameterizations are required. A general response of macroeconomic variables to the contractionary monetary policy was introduced by Christiano et al. (1996) who conclude that the evidence of the response is in contrast to the traditional model of real business cycles, and more in line with alternative interpretations of the transmission mechanism based on the model of sticky prices introduced by Goodfriend and King (1997). According to their study the initial response of price level to contractionary monetary policy shock is small, while interest rates respond by initially increasing, and in the case of the output, the initial reaction falls with a zero long-run effect. Nevertheless, even if VAR models overcome Lucas' critique, a problem may arise in the fundamental identification of the model.

The complication is in distinguishing endogenous actions, and thus the policy actions and exogenous policy actions in order to obtain reliable information on the monetary transmission mechanism. The identification of monetary policy shock has therefore been at the centre of the VAR literature, particularly its direct and indirect effects (Gordon and Leeper, 1994). After identification of the monetary rule, and solving the problems with endogenous policy actions, the VAR model has the ability to provide beneficial information about deviations from the rule. Giving the importance of this advantage, significant attention has been given to monetary shocks; identification issues have also been investigated in relation to the commodity markets which are believed to have an effect on economy, as well as on monetary policy actions.

The empirical literature on the relationship between commodity prices and monetary policy is varied. While in studies such as Hooker (2002), LeBlanc and Chinn (2004) and Chen (2009) the focus is primarily on inflation with the implementation of augmented Phillips curve frameworks to estimate the pass-through effect from oil prices into general prices, other studies adopt the estimated vector autoregression model (Hamilton, 1983, Edelstein and Kilian, 2009). Nevertheless, other studies, with the application of multivariate VAR models, focus on the relationship between commodity prices and nominal variables in order to evaluate the different effects of commodity price shocks on nominal economic variables such as GDP growth or inflation within a few countries (Blanchard and Galí, 2008, Gregorio et al., 2007). The results show that VAR models are beneficial in explaining the effects of commodity prices on inflation in more details and conclude that the effect of commodity prices differs through the time.

For instance Gregorio et al. (2007), by using a multivariate VAR model, investigated the impact of different factors on commodity prices and found out that the most significant factor driving commodity prices is world demand. While Gregorio et al. (2007) investigated the drivers of commodity prices, Clark and Terry (2010) estimated Bayesian VAR, thus VAR which allows that both coefficient drift and stochastic volatility helps to investigate the pass through channel from commodity price inflation to core inflation. However, whether the traditional model or VAR method is applied, parameters identification seems to be critical in both cases thus the problem is discussed in more details in the next part.

4.3.1 Problem of model parameters identification

The common feature of all empirical macroeconomic models when estimating the structural parameters is the identification problem (Faust, 1998).

Let:

$$\Gamma \ln(Y_t) = \beta \ln(X_t) + \epsilon_t \qquad (4.1)$$

represent the structure of economy, where Y_t represents the natural logarithm (n x 1) vector of the endogenous variables, X_t stands for the natural logarithm of exogenous and lagged endogenous variables and ϵ_t is the matrix of structural innovations. Parameters of interest are represented by coefficients Γ and β and cannot be directly estimated. According to Gottshalk (2001) the identification problem is likely to arise, since the sampling information is not sufficient. Since there is an infinite set of different values for coefficients Γ and β with the same probability distribution for observed data, it is not possible to identify the true values for Γ and β, thus these parameters stay unidentified and further identification restrictions need to be applied.

The problem of unidentified parameters can be demonstrated with the reduced form of Equation 4.1 which can be written as (Hamilton, 1994):

$$Y_t = BX_t + u_t \qquad (4.2)$$

Where B is $\Gamma^{-1}B$ and $u_t = \Gamma^{-1}e_t$

By multiplying Equation 4.1 by a full rank matrix Q a new model is estimated:

$$Q\Gamma(Y_t) = Q\beta(X_t) + Q\epsilon_t \qquad (4.3)$$

The reduced form of Equation 4.3 can be written in a form which is identical to Equation 4.2 and implies that both models are observationally equivalent (Bagliano and Favero, 1998). The equality in observation of both models therefore represents the identification problem and supports imposing identifying restrictions.

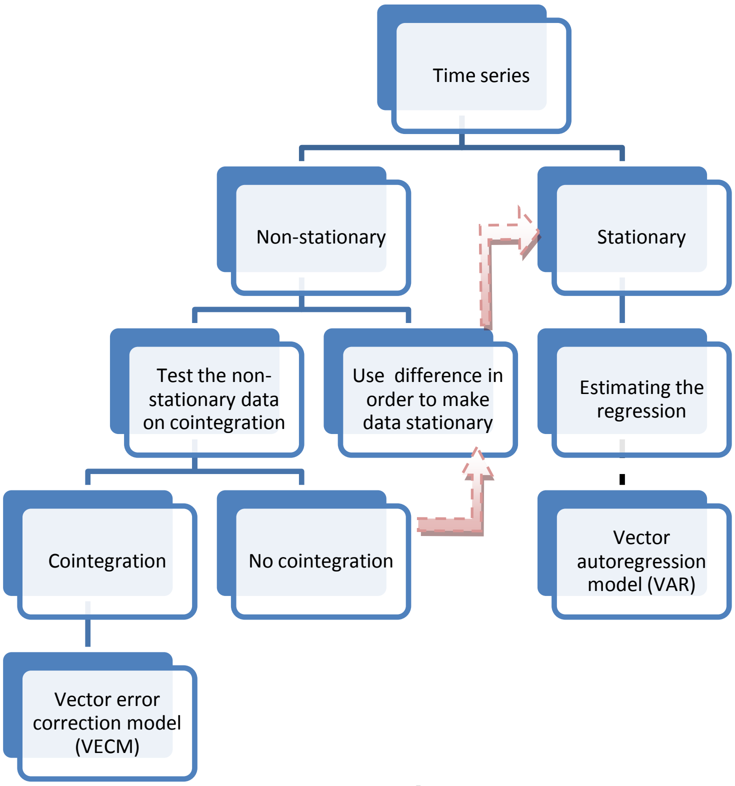
Understanding the necessity of parameter identification is the first step, however, even more challenging is to decide what restrictions should be imposed, especially in the traditional dynamic simultaneous equation approach (King, 2000). As will be discussed further in this chapter, VAR models, particularly SVAR models, are preferred, for the sake of their relative simplicity in comparison to traditional models when it comes to imposing restrictions on parameters. However, before estimating any models, a conventional procedure is to investigate the nature of the data collected for model estimation. The next part of this chapter is therefore dedicated to the discussion on how the nature of data relates to the choice of model estimation.

4.4 Estimating a model from time-series data

For testing the theoretical justification of the two-way relationship between monetary policy and commodities introduced in Chapter 3, a dataset of time-series will be used. Time-series can be defined as a set of "*well defined and ordered sequence of values of variables repeatedly and consistently measured over the time*" (Wooldridge, 2008:26).

An important feature of time-series data can be found in the difficulty of analysis, as they are found to be dependent across time. The main characteristic of time-series is that in most of the cases the series significantly relates to historical developments (e.g. GDP). This leads to the necessity of modifications and embellishments to standard econometric techniques commonly used in econometrics (Asteriou and Hall, 2011). Therefore, to specify econometric models for time-series data, adjustments to account for the dependent nature of economic time-series need to be employed. The demonstration of steps that need to be employed before estimating models from time-series data is presented in Figure 4.1.

Figure 4.1: The steps involved in time-series analysis



Source: Author

As Figure 4.1 shows, the first step includes the unit root testing which based on the results leads to estimating two different models. If the time-series is found to be stationary, then the VAR model can be approached. However, if the series is found to be non-stationary, then it is necessary to continue in testing whether stationarity of series can be achieved at the first difference. From the test, following results can be obtained:

1. Series is stationary at first or *n* difference – the next step is to test for cointegration (long-term relationship between variables). Based on the results from the test of cointegration:

    a. There is no cointegration – use difference to transform non-stationary series into stationary and continue in estimating VAR model.

    b. There is one or more cointegrating equations – use series in their non-stationary form and continue in estimating VEC model.

2. If the series cannot achieve stationarity at first or *n* difference, then it is necessary to continue in testing for cointegration and continue as explained above. However, in this case if series cannot achieve stationarity and no cointegration relation is found, it is

necessary to return to data set and reconsider the use of chosen time-series. The rest of this chapter is dedicated to the justification of methods and econometrics tools used for model estimation.

4.4.1 Stationarity and Non-stationarity of time-series

During the last decade significant attention has been paid to find the best way to characterize or model the dynamic properties of economic time-series. As outlined by Culver and Pappel (1997) the dominant topic in time-series econometrics and the issue in empirical macroeconomics is the distinction between unit root and stationary processes. Stationary time-series can be characterized as series whose statistical properties such as mean, variance, and autocorrelation are all constant over time (Fuller, 2009).

Therefore the series is believed to be stationary (at least in weak sense) if:

- E(y_t) is constant
- Var (y_t) is constant
- Cor ($y_{t,}y_{t-n}$) = y_k thus it changes as y_k changes

However, since not all series can be found to be stationary, most statistical forecasting methods are based on the assumption that the time-series can be return to stationarity by using specific mathematical operations (Asteriou and Hall, 2011). In stationary series the shocks are temporary and their effects will be eliminated as the series revert to their long-run mean values. In contrast to stationary series, non-stationary time-series necessarily contain permanent components. Thus, a serious and very common problem of forecasting macroeconomic time-series is that they are often trended or affected by persistent innovations to the process, in other words, they are non-stationary (Brooks, 2008). Moreover, the use of non-stationary data can lead to spurious regressions. If standard regression techniques are applied to non-stationary data then as a result, the standard Ordinary Last Squared (OLS) regression procedures could easily lead to incorrect conclusions. The end result could be a regression with significant coefficient estimates and a high but valueless R^2 (Brockwell and Davis, 2009). Such a model would be termed as a spurious regression. In other words, since this model requires time-series data when the dependent variable is the interest rate followed by explanatory variables such as inflation rate and commodity prices, which are in most of the cases non-stationary, the problem of spurious regression might be highly possible. A consequence of overlooking the problem of spurious regression could be arriving at wrong conclusions and having misleading results of estimation. This gives a rise to one of the main reasons for taking the logarithm of data before subjecting it to formal econometric analysis. Taking the logarithm of a series, which exhibits an average growth rate, will turn the time-series into the series following a linear trend and is integrated (Mahadeva and Robinson, 2004):

$$y_t = \beta y_{t-1} \quad (4.2)$$

$$\log(y_t) = \log(\beta) + \log(y_{t-1}) \quad (4.3)$$

Therefore the lagged dependent variable has a unit coefficient, which in each period increases by an absolute amount equal to $\log(\beta)$.

As discussed previously, due to the characteristics of time-series, the non-stationarity is often presented; therefore the first step should include the identification of whether the time-series is stationary or non-stationary. Non-stationarity can be characterised in two ways, by the random walk model with drift:

$$y_t = \mu + y_{t-1} + u_t \quad (4.4)$$

Random walk is non-stationary because even its mean is constant, it grows linearly in time therefore it is difficult to predict variance of y_t since Var(y_t)=∞. The second model to characterize non-stationarity is the deterministic trend process:

$$y_t = \alpha + \beta_t + u_t \quad (4.5)$$

The deterministic trend process is non-stationary because it changes over time and u_t (white noise) has no memory of the past (Chatfield, 2004).

An effective and generally used method for testing non-stationarity is a unit root test. If the time-series is stationary, then it is acceptable to continue in estimating regression as shown in Figure 4.1 however, if not, the non-stationarity of time-series cannot be ignored. To get round the problem of non-stationary series, it is common to test whether series are stationary in levels or differences (Clements and Hendry, 1998). The unit root test is one of the tests of stationarity. The pioneering work on testing for a unit root in time-series was done by Dickey and Fuller (1979), where the basic objective of the test is to examine the null hypothesis that $\emptyset = 1$ (thus the series contains a unit root and is non-stationary) in an autoregressive (AR) equation of the form:

$$y_t = \emptyset y_{t-1} + u_t \qquad (4.6)$$

against the one-sided alternative $\emptyset < 1$. Therefore the hypotheses of interest are H_0: Series contains a unit root versus H_1: series is stationary.

A more convenient version of the test can be obtained by subtracting y_{t-1} from both sides of the equation:

$$y_t - y_{t-1} = (\emptyset - 1)y_{t-1} + u_t$$

$$\Delta y_t = (\emptyset - 1)y_{t-1} + u_t$$

$$\Delta y_t = \gamma y_{t-1} + u_t \qquad (4.7)$$

Where $\gamma = (\emptyset - 1)$.

There are three types of equations in the Dickey-Fuller test (or Augumented D-F) also known as the τ-test awhich can be conducted allowing for an intercept, intercept and deterministic trend or neither:

Without intercept or trend: $\Delta y_t = \emptyset y_{t-1} + u_t$, E($y_t$)=0 the assumption is that the series fluctuate around a flat line which is equal to zero.

Intercept: $\Delta y_t = \alpha_0 + \gamma y_{t-1} + u_t$,E($y_t$)= u_t the assumption is that series fluctuate around a flat line which is not equal to zero.

Intercept and trend: $\Delta y_t = \alpha_0 + \alpha_1 t + \gamma y_{t-1} + u_t$, E($y_t$) $= \alpha + \beta t$ the assumption is that the series fluctuate around a flat line which is not equal to zero and has a trend.

However, the D-F test does not take into account possible autocorrelation in the error process u_t. Present autocorrelation in u_t can also cause inefficiency of the OLS estimates (Cochrane, 1991). There are two main drawbacks of the D-F test. First, the test is only valid if u_t is white noise. In particular, u_t will be autocorrelated if there is autocorrelation in the dependent variable of the regression Δy_t. Due to this limitation the power of the D-F test is, according to Cook (2004), only 25 per cent. In other words in the D-F test the possibility for misinterpretation of unit root results is 75 per cent.

A more comprehensive theory of unit root and non-stationarity has been developed by Phillips and Perron (1988) who incorporated an automatic correction to the D-F procedure to allow for autocorrelated residuals. However, the most important criticism of the original Dickey-Fuller and Phillips-Perron-type tests is that their power is low if the process is stationary but with a root close to the non-stationary boundary. The tests are poor at deciding especially with small sample sizes, as the null hypothesis can be either rejected or not rejected. A failure to reject the null hypothesis could occur either because the null hypothesis was correct or due to insufficient information in the sample to enable rejection (Zhang, 2008).

Therefore Dickey and Fuller (1981) developed the Augmented Dickey-Fuller (ADF) test which approximates the autocorrelation based on the following regression model:

$$\Delta y_t = \alpha_0 + \alpha_1 t + \gamma y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + u_t \quad (4.7)$$

This model is augmented and the solution to serial correlation is to include k –number of lags for Δy_{t-i}. Number of lags is crucial as including too many lags can increase the error in the forecasts or estimation results. However, including too few could leave out relevant information. Information criterion procedures can help to sort out the problem with an appropriate number of lags. Three commonly used information criterions are: Schwarz's Bayesian information criterion (SBIC), the Akaike' information criterion (AIC), and the Hannan and Quinn information criterion (HQIC) (Ivanov and Kilian, 2001).

If there is an unknown trend status, or the information that a trend exists is used, then SIC and AIC always perform better than the two simulated hypothesis testing strategies. In case of monthly data, the Akaike information criterion (AIC) is preferred since it performs better in smaller samples with higher frequency (Hacker, 2010).

As already noted, not all time-series data can be found to be stationary. Since there are two characterisations of non-stationarity, the random walk with drift and the trend-stationary process (Equation 4.4 and Equation 4.5), they also require different treatments to induce stationarity. To achieve stationarity in the random walk with drift it is necessary to subtract y_{t-1} from both sides:

$$y_t - y_{t-1} = \mu + u_t \quad (4.8)$$

$$\Delta y_t = \mu + u_t \quad (4.9)$$

Equation 4.8 shows the induction of stationarity by differencing. Equation 4.10 represents deterministic non-stationarity, therefore stationarity is achieved by detrending (Clements and Hendry, 1995). If it is assumed that all time-series data are stationary or stationarity can be achieved by detrending, the natural procedure is to continue by estimating the Vector Autoregressive model (VAR) or its structural form (SVAR). The next part is therefore dedicated to the introduction of autoregression modelling.

4.5 Vector autoregression model (VAR) and Structural VAR

If time-series are I(0), as shown in Figure 4.1, a vector autoregression model (VAR) can be estimated. As already noted, the main purpose of VAR models is that they are useful for forecasting systems of interrelated stationary time-series data and for analyzing the dynamic impact of random disturbances on the system of variables. This applies even if the VAR models do not represent the truth in economics, but are nevertheless useful for gaining understanding in the interactions between variables, by providing relevant descriptions of the data.

The basic form of a *p*-th order bivariate VAR model is shown in Equation 4.10 and Equation 4.11 which may be also estimated using standard OLS regression techniques (Wooldbridge, 2008).

Following Sims (1980) let us assume:

$$y_t = \beta_{10} - \beta_{12}x_t + \gamma_{11}y_{t-1} + \ldots + \gamma_{12}x_{t-1} + u_{yt} \qquad (4.10)$$

$$x_t = \beta_{20} - \beta_{21}y_t + \gamma_{21}y_{t-1} + \gamma_{22}x_{t-1} + u_{xt} \qquad (4.11)$$

Where y_t as well as x_t must be stationary, u_{yt} and u_{xt} are uncorrelated white-noise error terms. Equations 4.10 and 4.11 therefore represent the first order VAR model since the longest lag length is equal to unity in its non-reduced form where y_t has a contemporaneous impact on x_t and the reverse relationship is valid too.

In its matrix form Equation 4.10 and Equation 4.11 can be written as:

$$\underbrace{\begin{bmatrix} 1 & \beta_{12} \\ \beta_{21} & 1 \end{bmatrix}}_{B} \underbrace{\begin{bmatrix} y_t \\ x_t \end{bmatrix}}_{z_t} = \underbrace{\begin{bmatrix} \beta_{10} \\ \beta_{20} \end{bmatrix}}_{\Gamma_0} + \underbrace{\begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix}}_{\Gamma_1} \begin{bmatrix} y_{t-1} \\ x_{t-1} \end{bmatrix} + \underbrace{\begin{bmatrix} u_{yt} \\ u_{xt} \end{bmatrix}}_{u_t} \qquad (4.12)$$

Thus:

$$Bz_t = \Gamma_0 + \Gamma_1 z_{t-1} + u_t \qquad (4.13)$$

The reduced (standard) form of VAR model is achieved by multiplying both sides of the Equation 4.13 by B^{-1} :

$$z_t = A_0 + A_1 z_{t-1} + e_t \qquad (4.14)$$

Therefore the VAR model can be written in the form:

$$y_t = y_0 + \alpha_{11}x_{t-1} + \cdots + \alpha_{p1}x_{t-p} + \ldots + \alpha_{11}y_{t-1} + \cdots \alpha_{p1}y_{t-p} + e_{1t} \qquad (4.15)$$

$$x_t = x_0 + \alpha_{12}x_{t-1} + \cdots + \alpha_{p2}x_{t-p} + \ldots + \alpha_{12}y_{t-1} + \cdots \alpha_{p2}y_{t-p} + e_{2t} \qquad (4.16)$$

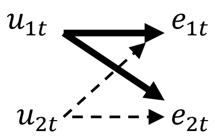
The system of Equations 4.15 and 4.16 represent the VAR model where e_{1t} and e_{2t} are composites of the two shocks.

When estimated in this form, the VAR model has a good potential to provide empirical evidence on the response of economic variables to monetary policy shocks (Christiano et al., 1996).

4.5.1 VAR critique

It is convenient to note that every model has some limitations, but an important question is whether the advantages of the model overcome its limitations. VAR models are usually preferable due to the flexibility in formulating data without restrictions on the dynamic relations between variables approached by economic theory, as well as in testing economically meaningful hypothesis. In comparison with univariate time-series models there is no need to specify exogenous and endogenous variables since all variables in VAR models are endogenous. Also the value of a variable can be dependent on more than its own lags (Brooks, 2008). Nevertheless the most appreciated advantage of VAR models compared to traditional models is their simplicity and better forecast results. As showed by Sims (1980) and McNees (1986), VAR models produced more accurate forecasts for variables than large-scale structural models. On the other hand, the main critique of VAR models is based on the difficulty of interpreting the coefficients. The interpretation problem arises due to the lack of restrictions on parameters causing the causality to float in both directions (Figure 4.2).

Figure 4.2: The identification problem of VAR models



Source: Author

Therefore, the shock in the system can affect both the variables. The difficulty of interpreting coefficients leads to using VAR models in their reduced form (Equation 4.14) which allows for testing the formation of expectations (Strongin, 1995).

The most common approach for overcoming the problem of interpreting coefficients is to use an impulse response function (discussed later in Section 4.7.4) which examines the response of variables to the shock. The complication in this case is how to define the shock (Asteriou and Hall, 2007). However, impulse responses which are driven from VAR in their reduced form lack the structure to be easily interpreted. To overcome this problem, Sims (1980) proposed a transformation by triangulating the system which enables the interpretation of the system. A different and popular approach for dealing with the problem of interpreting VARs is to develop a structural vector autoregression (SVARs) which introduces 'theoretical' restrictions to identify underlying shocks.

4.5.2 Structural vector autoregression model (SVAR)

As noted before, the VAR models are usually used for forecasting and perform well in investigating the effects of shocks on a system of variables. The interpretation of estimated results from an unrestricted VAR model (Equation 4.15 and Equation 4.16) is not an easy task. The output of an unrestricted VAR cannot provide information about how the economy reacts to different shocks. Thus, to investigate the effect of shocks on a system of variables it is necessary to impose restrictions on the model. The need for restrictions led to the development of structural vector autoregression models SVARs. However, an important implication in SVAR models is that only restrictions common to a variety of theoretical models can be applied (Bank of England, 1999). The advantage of SVAR models over VAR models or traditional models is that the focus is on obtaining information about the shocks' driving movements in the endogenous variable and the identification of the effect of these shocks on movements between these endogenous variables.

SVAR models become especially beneficial when the different effects of structural shocks need to be examined. Bernanke (1986) introduced an identification scheme for SVAR models which is widely used nowadays. The approach is based on imposing n(n-1)/2 zero restrictions on the matrix where *n* is a number of variables in the SVAR model. Blanchard and Quah (1989) suggest imposing zero restrictions on levels only on the long-run effects of structural shocks in endogenous variables.

Assume the three variable SVAR model from Equation 4.14 and Equation 4.15. The zero restrictions on matrix will, according to Blanchard and Quah (1989), have a form:

$$\begin{bmatrix} e_t \\ e_z \\ e_y \end{bmatrix} = \begin{bmatrix} 1 & \alpha_{12} & 0 \\ \alpha_{21} & 1 & \alpha_{23} \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_t \\ u_z \\ u_y \end{bmatrix} \quad (4.17)$$

However, this approach is based on the assumption of a non-stationarity series I(1) with no cointegrated relationships. Nevertheless, not all series are stationary and cointegration cannot always be rejected, therefore King et al. (1991) suggest taking into account any cointegrating relationships in the system method by estimating the VAR model in its error correction form. The identification of structural parameters requires restrictions on the elements of *A* and *B* matrixes. The SVAR model can be identified either by imposing restrictions that economic variables do not react to monetary variables simultaneously but this is not rejected to be the other way round. Or alternatively, by imposing restrictions on variables that represent monetary policy in order to reflect operational procedure. In case of monthly data, these restrictions can either be driven from the theory or based on institutional analysis. Once the monetary policy is identified, a VAR model helps to identify the deviations from the policy rule, thus it is possible to detect the response of macroeconomic variables to the shock in monetary policy (Bagliano and Favero, 1998).

4.5.3 SVAR critique

However, there are several potential problems with SVARs. First, as Blanchard and Quah (1989) recognised, the economy may be hit by higher number of shocks than identified in the SVAR system. SVARs will therefore produce reliable results only if the most important types of shock are identified in the system. This could be overcome, but not completely avoided, by imposing restrictions which are widely accepted in the theory. Another limitation of SVAR models is that due to the exact identification of the system, not all tests usually applied to VAR models can be implemented. The Granger causality test can be an example since it does not provide any information about contemporaneous causality. SVAR models as well as VAR models are particularly useful when the determinants of endogenous variable movements are unobservable. However, there are situations when the advantages of traditional modelling overcome the advantages of SVAR models, especially in the case of identifying restrictions which can be inappropriate, unrealistic or insufficient. Moreover, though VAR and SVAR models have been used widely to examine the reaction of monetary policy to defined shocks, they are difficult to use for particular policy analysis such as estimating Taylor rules. The choice of using autoregressive models must therefore be determined case by case (Bank of England, 1999).

4.6 Dealing with non-stationarity

As discussed in Section 4.3.1, non-stationarity in time-series can be common, especially in the case of economic series such as output or inflation. When ignored, the standard OLS regression procedures estimated from non-stationary time-series produce an irrelevant outcome without any value. However, as Hendry and Juselius (2000) showed, non-stationary data integrated once can be brought back to stationarity by a linear transformation of differencing $x_t - x_{t-1} = \Delta x_t$. Non-stationary data brought back to their stationary form can then be used for estimating models from I(0), thus stationary data. However, there is a possibility that variables which are found to be individually non-stationary I(1) together determine stationary relations I(0). This relationship is also known as a long-run equilibrium or cointegrated relation since these non-stationary variables act as attractors and converge whenever they move away from each other (Banerjee et al., 1993).

By the definition: *"Time-series Y_t and X_t are said to be cointegrated of order d, b where* $d \geq b \geq 0$ *written as Y_t, $X_t \sim CI(d, b)$, if both series are integrated of order d, and there exists a linear combination of these variables, say $\beta_1 Y_t + \beta_2 X_t$ which is integrated of order d-b. The vector $\{\beta_1, \beta_2\}$ is called the cointegrating vector"* (Katos et al., 2000:296). In other words cointegration therefore indicates whether the long-term relationship between variables exists.

The concept of dealing with non-stationary data and cointegration was first introduced by Granger (1981), and later improved by Engle and Granger (1987). Although, the Engle-Granger approach (EG) tests for the existence of cointegrating (long-run equilibrium) relationships, it is designed only for a single equation with two variables, thus there is the possibility for only one cointegrating relationship in the model. Nevertheless, if a model with more than two variables is considered, thus n > 2, the assumption of the existence only one cointegrating relationship can be misleading since possibly there might be more than one cointegrating relation. A model with more than two variables therefore cannot be resolved by the EG single-equation approach. As a solution to multivariate models, Johansen (1991) developed an approach which takes into account the possibility of multivariate models. Johansen's approach for multiple equations can be applied as an alternative to the EG approach. This approach therefore assumes a multivariate error-correction model with at least three variables (Y_t, Z_t, W_t), where all can be endogenous, using matrix notation for $Z_t = [Y_t, Z_t, W_t]$ can be written in the form (Asteriou and Hall, 2011):

$$Z_t = A_1 Z_{t-1} + A_2 Z_{t-2} + \cdots A_k Z_{t-k} + u_t \qquad (4.18)$$

And can also be written as a vector error-correction model (VECM):

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \Gamma_2 \Delta Z_{t-2} + \cdots \Gamma_{k-1} \Delta Z_{t-k-1} + \Pi \mathrm{Z}_{t-1} + u_t \qquad (4.19)$$

Where $\Gamma_i = (I - A_1 - A_2 - \cdots - A_k)(i = 1,2, \dots, k-1)$ and$\Pi = -(I - A_1 - A_2 - \cdots - A_k)$. The matrix Π contains information regarding the long-run relationships.

Converting the equation into a matrix form:

$$\begin{pmatrix} \Delta Y_t \\ \Delta X_t \\ \Delta W_t \end{pmatrix} = \Gamma_1 \begin{pmatrix} \Delta Y_{t-1} \\ \Delta X_{t-1} \\ \Delta W_{t-1} \end{pmatrix} + \Pi \begin{pmatrix} Y_{t-1} \\ X_{t-1} \\ W_{t-1} \end{pmatrix} + e_t \qquad (4.20)$$

And can be formed into the model for two cointegrating vectors:

$$\Pi_1 Z_{t-1} = \alpha_{11}(\beta_{11} Y_{t-1} + \beta_{21} X_{t-1} + \beta_{31} W_{t-1}) + \alpha_{12}(\beta_{12} Y_{t-1} + \beta_{22} X_{t-1} + \beta_{32} W_{t-1})$$

Where ΠZ_{t-1} can form two different scenarios. First, when there are no linear relationships among Z_t thus Π matrix is zero $\begin{pmatrix} 0 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 0 \end{pmatrix}$ so there is no long-run relationship. In this case it is necessary to take differences of non-stationary data and proceed to estimating the VAR model as showed in Figure 4.1. Nevertheless, when there is *n-1* cointegrating relationships of $\beta' Z_{t-1} \sim I(0)$ (*n* is the number of variables in the system) there are also *r* linearly independent stationary combinations in Z_t. In this case, processing to VAR estimation could lead to misinterpreting results. The way of overcoming problem with non-stationary cointegrated series is estimating an error correction model (Engle and Granger, 1987).

4.7 Vector error-correction model (VEC)

As Figure 4.1 shows, if cointegration, and thus long-run equilibrium, between variables exists, the next steps involves estimating the Vector Error Correction Model (VECM).

If the series is not covariance stationary, but first-difference stationary, thus the level of a time-series is not stationary, but its first difference is, the first difference stationary processes are also known as integrated processes of order 1, or I(1) processes. Thus, any VAR can be rewritten as a VECM. In other words if X_t and Y_t are cointegrated, the relationship with an error correction model (ECM) specification can be expressed as (Hatanka, 1996):

$$\Delta Y_t = a_0 + b_1 \Delta X_t - \pi \hat{u}_{t-1} + e_t \tag{4.21}$$

This specification has a natural advantage compared to the VAR model which could be estimated from stationary data since it includes the short-run and long-run information. In the model specification, b_1 represents the impact multiplier, thus the short-run effect measures the immediate impact of a change in X_t on a change in Y_t. Therefore, when using ECM it is also possible to identify what is the short-term impact of a change in the independent variables specified in the model on a change in the UK inflation. Moreover $\hat{u}_{t-1}$ includes the long-run response while π is the adjustment effect which shows how much of the disequilibrium is corrected (Enders, 2003). It could be argued that the problem of spurious regression discussed in the previous section of this chapter could arise due to using non-stationary data, however, in the equation all variables are stationary. Thus the change in X and Y is stationary as they are assumed to be *I(1)* variables (thus the stationarity can be achieved with first difference) and the residual, by the assumption of cointegration, is stationary as well (Harvey, 1990).

The main advantage of a VEC model can be found in a very good economic implication of results from measuring the correction from disequilibrium. The problem of spurious regression discussed earlier in this chapter is resolved by using VEC since models are formulated in terms of first differences.

4.8 Diagnostic of VAR and VEC models

One of the core advantages of using autoregressive models which made them so popular is their simplicity of use. Autoregressive models have been intensively and successfully used for driving the information about the effects of policy shocks on economic variables as well as for evaluating economic theory models (Christiano et al. 1999). Due to their use for policy analysis and its structure and causality, a few core tools such as the Granger-causality test, Impulse response function and Variance decompositions have been developed in order to improve the interpretation of results and overcome a few of the critiques discussed earlier in this chapter.

Nevertheless, the essence of the above mentioned tests is an appropriate selection of the lag order. While the selection of a small order of lags can lead to overlooking important dynamics of the economic variables, the inclusion of too many lags limits the efficiency of estimation which can translate into coefficient standard errors as well as large coefficient bands for impulse response estimation. Both cases therefore produce invalid and unreliable information (Nielsen, 2011). The next part is therefore dedicated to a discussion on lag selection, and flows into a discussion of the main econometrics tools widely used for evaluating autoregressive models.

4.8.1 Lag structure

As previously noted, an important aspect of VAR models in terms of their specification is the determination of the lag order.

Assume a VAR model from a stationary series:

$$y_t = v + \sum_{j=1}^{p} Z_j y_{t-j} + u_t \qquad (4.22)$$

With constant parameters of (v, $Z_1, Z_2, \ldots\ldots, Z_p$) and $u_t \sim iid\ N[0, \sum]$ the lag order *(p)* is unknown and thus must be selected. If p is misspecified it can lead to estimating a model with the wrong zero restriction or an inefficient model resulting from over parameterization (Gredenhoff and Karlsson, 1999).

The lag length selection therefore affects the validity of the output. A significant number of works have shown the effect of wrong lag length selection. For instance, the study of Lütkepohl (1993) shows that selecting a higher order lag length than the true one leads to an increase in the mean square forecast errors of the VAR. On the other hand, underestimating consequently generates autocorrelated errors (problems with autocorrelation will be discussed in the next part). If the lag length differs from the true length, core tools such as impulse response function or variance decomposition are proved to be inconsistent (Braun and Mittnik, 1993). Moreover, other authors, for example Johansen (1991) or Gonzalo (1994), show that the lag length selected for a VAR model affect the selection of cointegration relations in a VEC model. In addition, a study by Boswijk and Franses (1992) as well as Cheung and Lai (1993) shows that the lag length does matter when testing for cointegration. They found that overestimation of lag length led to a loss of power of VAR model. DeSerres and Guay (1995) found that a structural VAR model with a shorter lag length can lead to significant estimating errors of the permanent as well as transitory components in the model. Hafer and Sheehan (1989) found evidence that the validity and accuracy of the forecast from VAR models directly depended on the selection of lag length.

The lag length can be selected by using information criteria. The most popular are the Akaike Information Criteria (AIC), Schwartz Information Criteria (SIC) and Hannan and Quinn (HQ) Information Criteria.

The AIC was firstly introduced by Akaike (1969) and is formulated as:

$$AIC(p) = ln\left|\widehat{\Sigma_{\mathrm{p}}}\right| + \frac{2k^2p}{T} \qquad (4.23)$$

Where T represents the number of observations, k the dimension of the time-series, p is the estimated number of lags and $\left|\widehat{\Sigma_{\mathrm{p}}}\right|$ is the estimated white noise covariance matrix. However, as shown by Shibata (1976) the AIC criterion can overestimate the true lag order. Therefore, other information criteria can be considered such as HQ or SIC criteria. The SIC criterion firstly introduced by Schwartz (1978) can be written in the form:

$$SIC(p) = ln\left|\widehat{\Sigma_{\mathrm{p}}}\right| + \frac{k^2p\ lnT}{T} \qquad (4.24)$$

The HQ criterion was introduced by Hannan and Quinn (1979) and has the form:

$$HQ(p) = ln\left|\widehat{\Sigma_{\mathrm{p}}}\right| + \frac{2pk^2 ln\ lnT}{T} \qquad (4.25)$$

The test of criterions performed by Lütkepohl (1985) shows that in general, SIC outperforms HQ for any T, if $T \geq 8$, AIC outperforms SIC, however, if $T \geq 16$ HQ tends to be the most restrictive criterion. Lütkepohl (1985) concludes that in general, the SIC and HQ criterions are more likely to underestimate the lag length while AIC is more likely to overestimate the lag length. Koehler and Murphree (1988) compared the effectivity of AIC and SIC on a model of monthly time-series and found that the difference in results given by AIC and SIC is about 27 per cent and they concluded that models with lag lengths estimated by SIC have better forecast accuracy. A more recent study by Liew (2004) shows that AIC is superior to other criterions when the sample consists of a smaller number of observations, since AIC minimizes the chance of underestimating the lag length. As mentioned earlier, underestimating the lag length can cause problems with autocorrelation. Since autocorrelation is a serious problem, the next part is dedicated to its discussion.

4.8.2 Autocorrelation

As discussed in the previous section, one of the consequences of underestimated lag length is autocorrelation. Autocorrelation can be defined as "*the correlation of a time-series x_t to its own past x_{t-n} and future x_{t+n} values*" (Chatfield, 2004:26). It therefore refers to the correlation between variables of a series in time. It becomes natural that an important condition for obtaining valuable results of the estimated parameters is that error terms are white noise. In other words, the presence of autocorrelation can be rejected. The pioneering work on diagnostic testing was introduced by Durbin and Watson (1951). The Durbin-Watson (DW) test is valid under the assumptions that regression models include a constant, only the serial correlation of the first order is presented, and there are no lagged dependent variables as explanatory variables. The DW tests the null hypothesis H_0 that the errors are uncorrelated against the alternative hypothesis H_1 that the errors are AR (1) and can be calculated as:

$$d = \frac{\sum_{t=2}^{n}(\hat{u}_t - \hat{u}_{t-1})^2}{\sum_{t=1}^{n}\hat{u}_t^2} \qquad (4.26)$$

If the DW test statistic is close to 2, it can be assumed that the presence of serial correlation can be rejected. Even though the DW test is popular and widely used it has several drawbacks.

A number of authors have investigated the power of the DW test and found that there is a significant possibility that the test will not reject the null hypothesis of no autocorrelation even if the neighboured disturbances are perfectly correlated (King, 1985). Also, Zeisel (1989) showed that the DW test has limited power when used for a model with an intercept.

On the other hand, as argued by Wan et al. (2007) the DW test is not as powerless as it is presented, since their findings show that the limitations of the power of the DW test might be caused by the misspecification of a linear model. Nevertheless, the main drawback of the DW test is its invalidity to provide reliable results if serial correlation is of a higher order (Asteriou and Hall, 2008).

To overcome the limitations of the DW test, Breusch (1978) and Godfrey (1978) introduced a Lagrange multiplier (LM) test which is a more general test for r^{th} order autocorrelation:

Assume the model:

$$u_t = p_1 u_{t-1} + p_2 u_{t-2} + \cdots + p_r u_{t-r} + v_t \qquad (4.27)$$

$$v_t \sim N(0, \sigma_v^2)$$

The null and alternative hypotheses for the LM test are:

$$H_0: p_1 = 0, p_2 = 0 \ldots p_r = 0$$

$$H_1: p_1 \neq 0, p_2 \neq 0 \ldots p_r \neq 0$$

As showed by Hatemi (2004) the performance and order of autocorrelation of the LM test is satisfactory when used in a different sample size. Since the autocorrelation is usually a product of model misspecification, a common solution to this problem is to change the specification of the model and thus relationship between dependent and independent variables. Nevertheless, in some cases the introduction of more lagged values can be also helpful.

4.8.3 Causality test

The existence of a relationship between two variables understandably leads to an investigation of the direction of this relationship. The earliest method of quantifying the causal effect from time-series is the Granger causality test, which was introduced by Granger (1969). The causality tests are widely used in empirical economic research due to their ability to predict the causality. Granger (1969) developed a simple test following the argument that if y_1 causes y_2, lags of y_1 should be significant in the equation for y_2 thus unidirectional causality exists from y_1 to y_2. If any sets of lags are statistically significant in the equation for the other variable, then y_1 and y_2 are independent.

The causality between two variables is understood as when the current value of one variable is correlated to the past values of others. As discussed in the literature, the theory of direct commodity price effect assumes that commodity prices have a forward-looking element, thus the current commodity price reflects the expectations about future prices. These expectations are, according to the theory of direct effect discussed in Chapter 3, based on demand and supply, without any effect from monetary policy. On the relationship from commodity prices to monetary policy, the Kaldor indirect effect (Chapter 3) suggests that monetary and fiscal policy in the case of inflationary pressures driven by commodity prices leads to restrictive policies, therefore monetary policy does react to movements in commodity prices. The disagreement within the theories can therefore be tested by the Granger causality test (in the UK conditions) and can be used to develop an understanding of whether the easing UK monetary policy does affect movements in commodities, particularly crude oil prices and food price indexes. A causality test can be used for testing the theory of the relationship between commodity prices and UK economic variables.

The Granger causality test can be used as an addition to the preliminary test of the existence of the relationship between commodity prices and interest rates in the UK, calculated as a correlation coefficient (Chapter 2, Table 2.1 and Table 2.2) which, as discussed previously, has a weak explanatory function and cannot explain the direction of the relationship. Granger causality must not be understood as causation in the classical philosophical sense. Nevertheless as argued by Geweke (1984), compared to contemporaneous correlation, it does demonstrate the likelihood of causation (in the case of its presence) more forcefully.

The Granger causality test requires both variables y_t and x_t to be stationary or transformed to stationary by taking logarithm or first differences so the causality is preserved (Pierce and Haugh, 1977). However, as argued by Roberts and Nord (1985), when time-series after logarithmic transformation were used, no causality could be found, but in the case of untransformed time-series a significant causality could be found. The explanation of the different results can be found in the meaning of a logarithmic transformation which reduces the heteroskedasticity of series while increasing their stationarity (Stern, 2011).

Even if the Granger causality test is mostly used in the case of stationary variables, it can be also used in the same way in case of non-stationary cointegrated variables where the only difference is that the first step is the estimation of y_t and x_t as a VEC model (Brooks, 2008):

$$y_t = a_1 + \sum_{i=1}^{n} \beta_i X_{t-i} + \sum_{j=1}^{m} \gamma_j y_{t-j} + e_{1t}$$

$$x_t = a_2 + \sum_{i=1}^{n} \theta_i X_{t-i} + \sum_{j=1}^{m} \delta_j y_{t-j} + e_{2t} \quad (4.28)$$

Where e_{xt} and e_{yt} are uncorrelated white-noise error terms. Then:

- The lagged *x* may be statistically different from zero as a group and the lagged y terms in the second equation are not statistically different from zero thus x_t causes y_t.
- The lagged *y* may be statistically different from zero as a group and the lagged x terms may not be statistically different from zero. In this case y_t causes x_t.
- Both *x* and *y* are statistically different from zero in both equations so that there is a bi-directional causality.
- Both *x* and *y* terms are not statistically different from zero in both equations so that x_t is independent of y_t.

Despite of the ability of the Granger causality test to provide an overview of the relationship between time-series, it is convenient here to mention its main drawback. Even if the Granger causality test is a necessary and sufficient condition for optimal forecasts it is at the same time not a sufficient condition for economic policy. Therefore, the Granger causality test is useful but indeed not a sufficient condition for predicting and controlling the processes influenced by policy interventions (Varcelli, 1991). Indeed, this limitation needs to be considered when evaluating the results of Granger causality test. The criticism of the idea of the Granger causality can be found in contemporaneous correlation. Two variables can be autoregressive, and thus well predicted by them, therefore the innovations in the model will be highly correlated. This can lead to rejecting a null hypothesis of non-causality even if the past values of the variables are not predictive of each other (Brant and Williams, 2007). Another weakness of the Granger causality test is its sensitivity to lag length. If an estimated VAR model has too many lags, it will result in inefficiency; however, the results of the Granger test fail to reject the null hypothesis. On the other hand, if too few lags are included, it results in finding causality when it may not be present. Another issue with the Granger causality test presented by Drobny (1988) is that none of the variables can be unit root or contain a stochastic trend; otherwise coefficients will be incorrectly statistically significant. Even if the

Granger causality is often criticized, and the power or validity of its results is questioned, Cuthbertson et al. (1992) argue that the multivariate Granger causality test is one of the few useful applications of VAR models, and thus it can help to avoid spurious correlation. Given the criticism of the Granger causality test, results should be therefore considered with caution and significant attention should be paid to already discuss lag length selection.

4.8.4 Impulse response function

As discussed in the critique of VAR models, it is usually difficult to directly interpret the coefficients of an estimated VAR model. The impulse response function (IRF) is therefore often computed in order to study the interrelationships within the variables of a system (Griffiths and Lutkepohl, 1990). An impulse response function is taken as an essential tool in empirical causal analysis and policy effectiveness analysis, since it measures the time profile of the effect of a shock on the behaviour of a series and can be applied on a VAR model, when estimated from stationary data, as well as VEC model. However, the impulse response function modelled from the structural VAR approach for analyzing the monetary transmission mechanism is often criticized due to its assumption of a certain level of random behaviour from central banks (Bernanke and Mihov, 1998). Thus, the assumption of random behaviour in policy makers' decisions must be taken with caution. Despite this assumption, SVAR models can still be used for tracing monetary shocks, since SVAR models trace the dynamics of the model thus, the shocks do not have to be large or persistent. Whether a VAR model, SVAR model or VEC model is used, the economic interpretation of monetary policy shocks is not straightforward or clear. Since monetary policy shocks can be generated from imperfect information that the central banks have about the current state of economy and the importance of output and inflation are relatively different in terms of moderating fluctuations, a certain level of random behaviour can be traced (Bernanke and Mihov, 1998). The random process and its fluctuations enable investigating the effect of monetary policy shocks on economic variables.

Since the impulse response function measures the time profile of the effect of a shock on the behaviour of a series, it can also be used for testing the reaction of consumer price inflation to a simulated shock to commodity prices in order to understand the relationship between variables. The analysis is carried out with regard to shocks of time-series rather than the series themselves. As noted, an impulse response function can be used in VAR, SVAR and VEC models with a similar technique but different results (Bisgaard and Kulahci, 2011).

While IRFs from a stationary VAR expire over time, IRFs from a cointegrating VEC model do not always expire. Since each variable in a stationary VAR has a time invariant mean, and limits it causes, so that the effect of a shock to any one of the explanatory variables must expire in time so that the dependant variable can revert to its mean. However, if IRF is applied to time-series I(1), therefore the series is non-stationary but stationary in the first difference, in a cointegrating VEC model the effects of shocks will not expire over time. This is due to long-term equilibrium defined in the VEC model (Kennedy, 2003). In respect to the nature of series, there is an option for either a traditional impulse response or a generalized impulse response function. The generalized IRF is used, according to Koop et al. (1996), if treatment of the future is dealt with by using the expectation operator conditioned on only the history and/or shock. The impulse response constructed this way is therefore an average of what might happen given what happened in the present and past. However, a generalized impulse response function is strictly applicable only to stochastic time-series where shocks have a well defined meaning. Due to the volatility of commodity prices as explanatory variables, series can be assumed to be deterministic; therefore a traditional impulse response would be more relevant. The traditional IRS answers the question of what is the effect of a shock of size δ at time *t* on the series at time $t+n$ under the condition of ceteris paribus.

The traditional impulse function can be expressed as the difference between the two different realizations of Y_{t+n}, where one realizations assumes time-series being hit by only one shock between *t* and $t+n$ while the other realizations assumes the time-series is not hit by any shock between *t* and $t+n$ therefore (Brooks, 2008):

$$l_y(n, \delta, \omega_{t-1}) = E[Y_{t+n} | V_t = \delta, V_{t+1} = 0, \dots V_{t+n} = 0, \omega_{t-1}] - E[Y_{t+n} | V_t = 0, V_{t+1} = 0, \dots Vt+n=0, \omega t-1 \tag{4.29}$$

The impulse response function, whether applied to the VAR or VEC model, will therefore help to answer the question of what happens to consumer price inflation if there is a one unit shock to world food price, crude oil price and other series.

4.8.4.1 Variance decomposition

Another econometric tool in the VAR analysis for assessing the driving forces of cyclical fluctuations is variance decomposition. As explained by Seymen (2008), it gives the proportion of movements in the dependent variables that are due to their own shocks, versus shocks to the other variables. Indeed a shock to one of the variables will directly affect that variable; however, it will also affect other variables in the system through the dynamic structure of the VAR. Therefore, variance decompositions determine how much of the forecast error variance of a given variable is explained by innovations to each explanatory variable. Usually, it can be observed that own series shocks explain most of the forecast error variance of the series in a VAR (Asteriou and Hall, 2011). Therefore, variance decomposition function can be also presented as a demonstration of the forecast error variance and it also refers to the breakdown of the forecast error variance for a specific time horizon and is able to indicate which variables have short-term and long-term impacts on another variable of interest. In other words, it provides valuable information on what percentage of the fluctuation in a time-series is attributable to other variables at select time horizons.

4.9 Forecasting

As discussed in Section 4.3, the important advantage of VAR models compared to traditional models is the accuracy of the forecast. This part is therefore dedicated to important choices that have to be made when forecasting from VAR/VEC models. Even if forecasting from VAR or VEC models should provide comparable results, while forecasting from a VAR model can be straightforward, a VEC model requires the development of an appropriate model first. In both cases it is convenience to choose whether the final forecast model is deterministic or stochastic and whether to prefer an in-sample or out-of-sample forecast.

4.9.1 Deterministic vs. stochastic models

The main purpose of every model is to present a simplified description on how a theory fits empirically. It is a well known dilemma for any researcher working with time-series to choose between models with deterministic or stochastic trends. The most common approach is using a deterministic trend, thus models are based on adding a time trend with a constant level or in other words, autoregressive models (Rao, 2007). However, as argued by Harvey (1997), a deterministic linear trend is too restrictive and proposes that time-series should include a stochastic trend which is slowly evolving. The models suggested by Harvey (1997) are known as structural time-series models.

The argument in favour of stochastic models is that if the influence of several unknown factors is sizable, then the exact prediction is not possible, however it is more likely to predict within a known confidence interval. Such an estimated model can be defined as a stochastic or probabilistic process. The stochastic model can be used for time-series where many variables act independently to influence the economy, thus there is a certain level of random effect. However at the same time, there is evidence of a relationship between these variables (Koopman et al., 2006). Contrary to a stochastic model which assumes random walk, a deterministic model assumes that the model variables are fixed. Therefore the outcome of the model is certain, that consequently leads to the main difference between these two models: in a stochastic model some parameters or elements of the model are sampled from a probability distribution (Startz, 2009). Instead of dealing with only one possible reality of how the process evolves over time, stochastic models can capture the indeterminacy in its future evolutions described by probability distributions. In contrast to a stochastic model, where the prediction of future system states is necessarily uncertain if the inputs are random, the deterministic model provides a qualified statement. Therefore, it can be assumed that the deterministic model is limited to providing predictions for the decision making process by policy makers as it cannot quantitatively address the risks and uncertainties. Based on the characteristics of stochastic and deterministic models, stochastic models are usually used for exploring inflation dynamics. Kapetanios and Yates (2011) used a deterministic model for analyzing the inflation dynamics in the UK and the U.S in order to examine the temporary increase in the volatility and persistence of inflation. Even if they had applied the deterministic trend to a VAR model for inflation, the deterministic model would not have fit the data appropriately. This gives support to Harvey's (1997) argument that deterministic trends can be only used for a short-term period. Nevertheless, the any decision about whether it is more appropriate to use a deterministic or a stochastic model needs to be based on the nature of data.

4.9.2 In-sample vs. out-of-sample forecast

Commonly, in empirical work, there is a problem of assessing the predictability of one time-series providing information about another time-series. Predictability tests can be constructed either as an in-sample fit or out-of-sample fit. Even the in-sample tests tend to more often reject the null hypothesis of no predictability than out-of-sample, and also, significant in-sample evidence of predictability does not mean significant out-of-sample predictability. Out-of-sample forecast, also called an ex-ante, can be understood as the following:

Assume that N_t represents the time-series from N_{t-j} to N_t. Out-of-sample forecasting therefore means fitting a model to N_t data to make projections for N_{t+j}. The problem with an out-of-sample forecast is effectively explained by Chatfield (2000). One of the difficulties is checking for the relevance of a model, since future observations are not available at the time of the forecast. Another option for forecasting is an in-sample forecast which uses N_t time-series to fit the model to the data and then estimate the series again to see whether it fits well. It is convenient to note that an in-sample forecast is argued to have weak forecasting power since the prediction errors are simply residuals that yield no information on the predictive accuracy of the procedure. Inoue and Kilian (2003) argue that in-sample forecasts are not necessarily an indication of unreliability. Their analysis shows that results of in-sample tests of predictability are more likely to be more credible than results from out-of-sample analyses. However, according to Elliot et al. (2006) it is more appropriate to use real-time out-of-sample data rather than an in-sample forecast. Nevertheless, the method that compromises both seems to be the most effective.

Steindel et al. (2000) suggest estimating so called simulated out-of-sample forecasts. The estimation is done by splitting the sample into two and using the first half of the sample to fit model to the data. The second half of the sample is then used to test how good the forecast is. This procedure is designed to reproduce the reality of having data only up to the starting point of forecast. Thus the advantage of an out-of-sample model can be seen in the comparison of the forecast result with the actual data. Therefore, based on the results of an error forecast it is possible to choose the most appropriate model, the model with lowest forecast error.

4.10 Data description

The monthly data used for modelling the relationship between monetary policy and commodities (particularly crude oil and food commodities) covers the sample period from September 1992 to September 2013. The preference of monthly data is motivated by the fact that in the case of annual frequency not all important questions can be addressed in a satisfactory manner since the sample covers 21 years. Even if quarterly data could be used to understand the economic impact of many important events, it is preferable to have data available at a higher frequency that are reliable and consistent. Most of the economic variables are available at a monthly frequency, thus providing more information. The sample period was selected carefully in respect to the developments in monetary policy in the UK introduced in Section 3.8. The sample starts with the UK adoption of inflation targeting as a new monetary policy framework. Inflation targeting has been successful for more than 20 years and even though vast criticisms can be found, one cannot ignore that inflation targeting has helped to stabilize inflation not only in the UK but also in other countries where inflation targeting was adopted as well. Since 1992, the monetary policy has not changed in the sense of target and objectives, which has created good conditions for applying VAR models, especially given the importance of Lucas' critique discussed earlier in Section 4.3. Nevertheless, it is still possible to encounter the problem of changes in the monetary policy that could appear due to the financial crisis in 2008. The potential breaks in monetary policy will therefore also be taken into consideration. In addition, the period of the last 21 years is also interesting from the perspective of developments in commodity markets, as discussed in Chapter 2.

Following Anzuini et al. (2012) the movements of storable commodity prices are captured by using the crude oil price index and the food price index. In contrast to their study, the data on the overall commodity index are not included, as this index has not been proved to be a good source of information needed for evaluating the impact of a monetary policy shock (Ahmed et al., 2004). The Brent (US$) spot price, collected from the International Energy Statistic (IEA, 2013) is used as a proxy for world oil price. It is expressed as a simple average of three spot prices; Dated Brent, West Texas Intermediate and the Dubai Fateh. Monthly data on world oil production and world oil demand are also obtained from the IEA (2013) International Energy Statistic. As a proxy for world food price, the food price index from the Food and Agricultural Organization of the United Nations (FAO, 2013) is used, as it represents an average of five commodity group price indices weighted with the average export shares of each of the groups. As a proxy for world food supply, the Net Food Index is used. The Net Food Index is published by the World Bank and covers food crops containing nutrients and crops considered as edible with the exclusion of coffee and tea due to their zero nutrition value (World Bank, 2012b). Food demand is calculated based on yearly data from the FAO on the world consumption of more than one hundred agricultural products which are grouped into 21 groups (cereals, starchy roots, sugar crops, sugar and sweeteners, pulses, tree nuts, oil crops, vegetable oils, vegetables, fruits - excluding wine, stimulants, spices, alcoholic beverages, meat, offal, animal fats, eggs, milk - excluding butter, fish, seafood, aquatic products and other). Since the rest of the data are monthly frequency, the transformation of this series cannot be avoided. Therefore the annual data on production and consumption have been converted in Eviews to monthly series. In order to transform the nominal oil and food price to real price US CPI deflator is used (Millard and Shakir, 2013). Using the average year 2000 as a base in the following way:

Nom.oil (food) price*(deflator/avg 2000deflator) (4.30)

The easing monetary policy, or in other words for measuring the impact of liquidity measured as a money supply, is represented by monetary aggregate M4, collected from the Bank of England's official online database. Monetary aggregate M4 was first introduced in 1987 and includes: the UK private sector's holdings of Sterling notes and coin, Sterling deposits (including certificates of deposit) with banks in the UK, Building society shares, deposits, and Sterling certificates of deposit (Bank of England, 2012a). Since 1987, M4 has not been re-defined or changed in contrast to other monetary aggregates, thus it secures the consistency and accuracy of the information required by the model. The inclusion of the money supply serves the investigation of the indirect channel of how monetary policy shocks can affect commodity prices. As already noted, the aim is to investigate the indirect effect, since the direct effect of monetary policy shocks, for instance easing policy, can be described by stock accumulation or financial flows, the existing literature on indirect channels seems to be limited, especially in the case of the UK. To investigate the indirect channel, the nominal interest rate, which is the official tool of the Bank of England (BoE), has been collected from the official BoE online database. Moreover the 3-months Treasury Bills rate has been collected as well. The importance of the inclusion of interest rates has been well explained by Frankel (2007) who states that low interest rates consequently lead not only to a reduction of the opportunity costs from carrying inventories, but also speculative positions, which consequently, through arbitrage, increases pressure on spot prices and understandably on futures as well.

Therefore the inclusion of two different measurements of interest rates is assumed to provide sufficient information for testing the indirect channel. Moreover, the indirect channel, as stated by Barsky and Kilian (2004), represents the transition through expectations about growth and inflation. To measure the transition through growth, data about the Industrial Production Index (IPI) has been collected from the Office for National Statistics' (ONS, 2013c) official database since data about the Gross Domestic Product (GDP) or unemployment are announced quarterly or yearly and therefore are not consistent with the frequency of model dataset. The rationale for using the Industrial production index (IPI) can be also found in the nature of the indicator which is one of the most important short-term statistics indicators. IPI is used to identify turning points in the economic development at an early stage and to assess the future development of the GDP, thus it is available on a monthly basis in a detailed activity breakdown and with a short delay (1 month and 10 days) (OECD, 2003). The industrial production index is an essential economic indicator used to monitor and steer economic and monetary policies. ONS (2013c) explains the usefulness of industrial production index as:

“The monthly United Kingdom (UK) Index of Production provides a timely indicator of growth in the output of production industries at constant prices. It is a key economic indicator and one of the earliest short-term measures of economic activity and shares exactly the same industry coverage as the corresponding quarterly series within UK Gross Domestic Product (GDP).”

According to Dedola and Lippi (2005), the industrial production index can be used as a representative variable for evaluating the UK’s transmission mechanism as well as the effect of monetary policy on economic variables. Headline Consumer Price Inflation (CPI) represents the expectations about inflation channels and data has been collected from the ONS official database. The preference of using CPI as a measure of inflation rather than Retail Price Inflation (RPI) has been made based on the inflation target which measures the headline inflation as CPI. While the inclusion of CPI serves to investigate the transitory effect of commodity shock, the effect on core inflation is also investigated as the persistent effect on inflation. The economic argument for investigating the effect on core inflation is that CPI is likely to be subject to disruptions in supply. Thus, there is high potential for volatility in CPI due to substantial movements in commodity prices. The rationale behind using core inflation together with headline inflation is that the inclusion of core inflation is assumed to provide a better picture of the existing underlying inflation pressures from commodities. It is also assumed to help policy makers to make more accurate judgements on the effect of commodities on the state as well as the prospects of inflation (Hogan et al., 2001, Brischetto and Richards, 2006).

There are three different methods of measuring the core inflation: standard core measures, trimmed means and volatility weighting. The method used for measuring the UK core inflation follows standard core measures which exclude food and energy. The study by Bakhshi and Yates (1999) on optimal trimmed means for the UK shows that the optimal trim that best approximates the benchmark inflation rate is not robust as an estimator of core inflation. Also as argued by Cogley (2002) and Bilke and Stracca (2007) the volatility weighting method does not provide sufficient information about core inflation as also, it is not always found to be significant in predicting the future headline inflation in all of the countries. Even if measuring the core inflation by excluding the food and energy has been criticized by

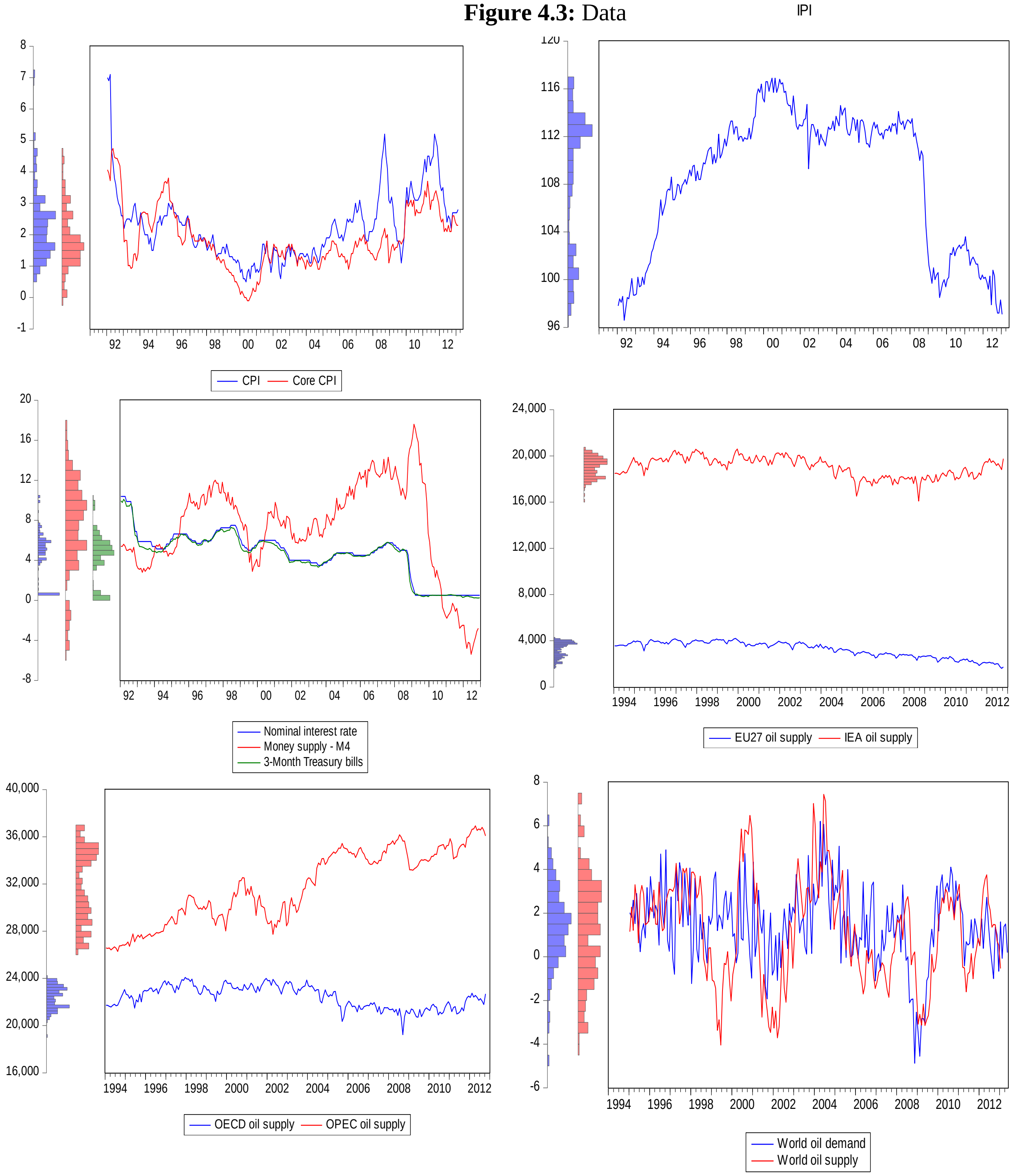
Catão and Chang (2010) the critique is related to its use as a policy target, not to investigate the persistent effect of commodities shocks. Thus the monthly data on core inflation are collected from the Organisation for Economic Co-operation and Development (OECD) official database. A similar approach to estimating the core inflation for the UK by using the data of the OECD has been applied by Mills (2013).

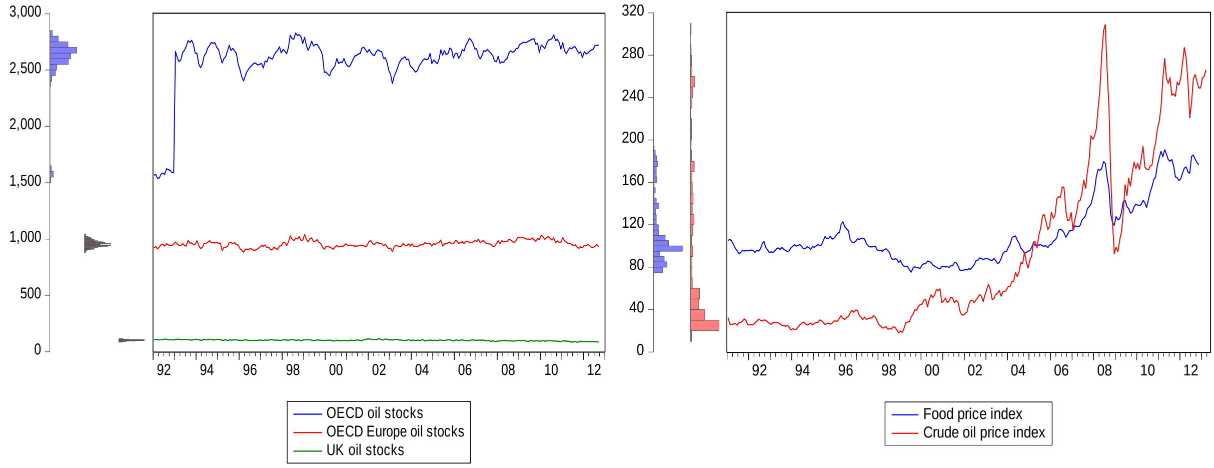
To investigate the effect of monetary policy on commodity markets through inventory channels at national, international and global levels, the following monthly variables are considered: UK industry oil stocks (Department of Energy & Climate Change, 2013), OECD Europe oil industry stocks and OECD oil industry stocks (IEA, 2013). To investigate the effect of monetary policy on commodity markets through supply channels at the national, international and global levels, the following monthly variables are considered: IEA oil supply and EU27 (IEA, 2013) oil supply for the national level, OPEC oil supply (EIA, 2013) for the international level and the World oil supply (EIA, 2013) at a global level. The logarithm of all time-series data are taken as showed in Equation 4.3 (except for the nominal interest rate and 3-months Treasury Bills) to avoid the problem of heteroskedasticity. Finally, the EViews 7 software is used in all the steps included in the econometric analysis. The analysed period includes 509 observations and is considered as a period with a sufficient number of data to obtain reasonably accurate estimates.

4.11 Preliminary data analysis

The preliminary data analysis is important in order to understand the nature of time-series. The following Figure 4.3 shows raw data presented by a line graph. During the examined period (1992-2013), the commodity prices (crude oil and food prices) show a slowly increasing trend since 2001 which accelerates in the middle of 2008, and shows a significantly volatile trend prior to the financial crisis in 2008. What is interesting, are the noticeable co-movements of both commodities mainly after the financial crisis. It is interesting that even though the global output growth declined (United Nations, 2013) and decline is observable in developments in world oil demand and supply, OPEC supply, OECD supply, IEA supply and EU27 supply declined (Figure 4.3), commodity prices reached the new peak. The development in commodity price movements under these circumstances suggests that the prices were not driven by excessive demand. There are parallel movements of the official interest rate and the slightly lower 3-months Treasury bills. Two significant cuts of interest rate can be observed, the first was in 1992 after the UK left the ERM and the second in the middle of 2008 due to the financial crisis. The upper left graph shows movements of headline CPI and core inflation. Similarly, a sharp decrease in the money supply shows the impending of economic prosperity by the financial crisis in 2008, augmented by movements of headline inflation away from the inflation target.

Figure 4.3: Data

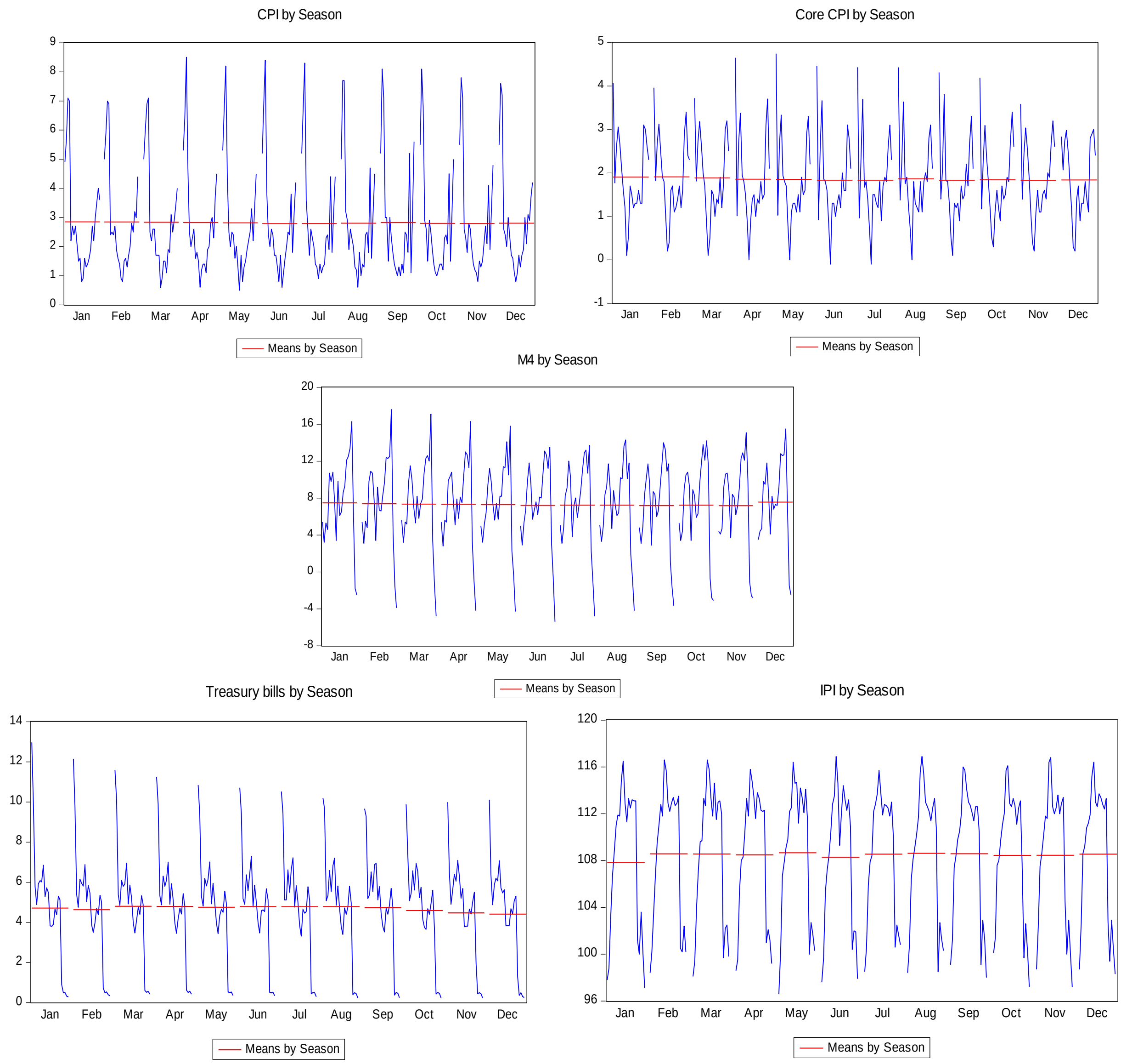




The oil stocks also experienced drop which is not, due to the scale, as obvious as the decline in the supply. From the observation, it becomes more obvious that the rising trend of crude oil price and food price might be jeopardized by events discussed in Chapter 2. Moreover, in both cases the histogram (vertical axis) is right-skewed. The right-skewed histogram shows asymmetrical distribution since a natural limit prevents outcomes on one side. In this case, the asymmetrical distribution causes data to have an upper bound rather than a lower bound. In other words, the asymmetry of distribution is caused by upper trended data. The same applies to consumer price inflation (CPI) and core inflation. However, a different type of asymmetry is shown by the IPI. The bimodal histogram suggests that the IPI has two peaks. Due to the asymmetric distribution of time-series, it is not suggested to use the mean as a good estimate of the inflation or commodity prices. Nevertheless, world oil demand as well as world oil supply show nearly normal distribution. In order to choose the right technique for data analysis, it is necessary to investigate whether data contains seasonality.

Figure 4.4 shows economic variables and their seasonal cycles. It is observed that the time-series are likely to have seasonal cycles and consistent trends. Seasonality usually causes series to be non-stationary because the average values at some particular times within the seasonal span (months in this case) may be different than the average values at other times. It is convenient to note that most of the economic data are characterized by seasonality (Jaditz, 1994). The seasonality in economic data can be described as noise in the signal which prevents the identification of important features of the economy. Therefore, in other words, seasonality being present in the time-series could lead an inability to identify the relationship between dependent and independent variables.

Figure 4.4: Seasonality of time series



As Figure 4.4 shows, the seasonality is present in all variables, therefore for empirical analysis; all the variables are transformed into logarithms and seasonally adjusted using the U.S. Census Bureau's X-12-ARIMA procedure[2] excepting data on the Industrial production index and monetary aggregate M4 since these are published as seasonally adjusted data. The basic analysis of data gives a broad picture of the time-series characteristic. The identification of seasonality in data series leads to a suspicion of non-stationarity of data which needs to be tested. As discussed in Section 4.4.1 there are a few methods used for seasonal time-series analysis to test for unit root. Table 4.1 presents the results of the unit root test at the levels and

[2] X-12-ARIMA procedure is "*seasonal adjustment software developed by the United States Census Bureau. It incorporates regression techniques and also ARIMA modelling to improve estimation of the different time series components*" (Census, 2012).

first difference respectively. The ADF test indicates that all the variables, except world oil demand and OECD oil stocks, are non-stationary but stationary at first difference.

Table 4.1: Unit root test

Unit – root test Augmented Dickey – Fuller test statistic							
	Constant	Constant & linear trend	1st difference – constant	1st difference - constant & linear trend	**1% level**	**5% level**	**10% level**
Log(cpi_sa)	-1.013300	*-1.739891*	-6.690310	**-7.102834**	-3.458845	-2.874397	-2.573472
Log(core_cpi)	0.853773	*0.852788*	-18.58129	**-18.61212**	-3.460453	-2.874679	-2.573850
i_nominal	-0.445352	*-2.720112*	-5.597178	**-4.175763**	-3.457630	-2.873440	-2.573187
treasury_bills	-0.334459	*-2.755731*	-6.176795	**-7.736806**	-3.457286	-2.873289	-2.573106
Log(ipi)	-2.412476	*-3.654175*	-2.125636	**-6.496156**	-3.530030	-2.904848	-2.589907
Log(food_sa)	0.361560	*-0.954825*	-5.859941	**-6.445054**	-3.458594	-2.873863	-2.573413
Log(oil_sa)	-0.085450	*-3.795739*	-6.304711	**-6.860906**	-3.458719	-2.873918	-2.573443
Log(m4)	-1.525382	*-0.966095*	-3.651686	**-5.424275**	-3.462412	-2.875538	-2.574309
Log(ipi)	-2.412476	*-3.654175*	-2.125636	**-6.496156**	-3.530030	-2.904848	-2.589907
Log(world_oil_demand)	-5.125811	-5.023553	-	-	-3.484198	-2.885051	-2.579386
Log(world_oil_supplyint)	-3.643669	*-3.868326*	-14.66942	**-14.63464**	-3.460739	-2.874804	-2.573917
Log(EU27_oil_supply)	3.538031	*-1.284560*	-5.924735	**-11.69431**	-3.461030	-2.874932	-2.573985
Log(IEA_oil_supply)	-2.394367	*-4.007077*	-9.248709	**-9.225327**	-3.459627	-2.874317	-2.573656
Log(OECD_oil_stock)	-5.394183	-5.167311	-	-	-3.456950	-2.873142	-2.573028
Log(OECD_oil_supply)	-3.159529	*-3.986591*	-13.40896	**-13.38301**	-3.459362	-2.874200	-2.573594
Log(OECDEU_oil_stocks)	-3.425464	*-3.445776*	-15.54606	**-15.53600**	-3.456840	-2.873093	-2.573002
Log(OPEC_oil_supply)	-1.477814	*-3.109219*	-15.42459	**-15.39686**	-3.459362	-2.874200	-2.573594

Log(UK_oil_stocks)	-1.836493	*-3.696650*	-18.38442	**-18.37252**	-3.456840	-2.873093	-2.573002
Log(world_supply)	-1.305025	*-3.268094*	-12.96910	**-12.98011**	-3.459362	-2.874200	-2.573594
Log(food_production_sa)	-1.005130	*-1.578840*	-9.174219	**-9.198456**	-3.514426	-2.898145	-2.586351
Log(food_demand_sa)	-1.931683	*-1.665715*	-7.992721	**-8.253856**	-3.552666	-2.914517	-2.595033

*MacKinnon (1996) one sided p-values >0.05

The computed ADF test-statistic is higher than the critical values at 1%, 5% and 10% in most of the cases (numbers in italic) thus the H0 hypothesis cannot be rejected. It means that the time series have an unit root problem. However, when first difference of series is taken, the ADF test-statistic is smaller than the critical values (in bold), therefore we can reject H0 thus series do not have an unit root problem and are stationary at 1%, 5% and 10% significant level. From the results of unit root tests it can therefore be concluded that none of the variables are collectively non-stationary in levels form however as time-series achieved stationarity in the first difference. The exception is found in the case of world oil demand and world oil supply where the series seems to be stationary. The rest of the series is non-stationary (containing a unit root), implying that the mean of the series or its variance will change over time. Alternatively, a series with a coefficient smaller than one has a fixed mean and variance. It can be said that the degree of persistence also impacts series predictability. As outlined by Culvel and Papell (1997), series with a coefficient lower than one also show stable forecast intervals, while series with a coefficient of one show forecast intervals that expand over time, thus they are impossible to predict since the probability of an increase at any given time is as likely as a decrease. The question of series persistence plays a crucial role and has practical implications for the policy makers since non-stationary series are as likely to decline sharply as increase which could lead to complications in forecasting. The non-stationarity of the inflation rate which is in this case represented as headline inflation but also as core inflation therefore has an important implication. The non-stationarity of inflation implies that any shock to inflation has a permanent effect, supporting the rationale of the assumption of the persistent effect of commodity shocks (Barsky and Kilian, 2004). As outlined by Baillie et al. (1996) inflation has not always been non-stationary and its stationarity goes back to the 1960s. The implication of non-stationary inflation can be found in economic models especially those investigating the relationship between nominal and real interest rates. As outlined by Culvel and Papell (1997), one of the main areas affected by the non-stationarity of inflation is the construction and evaluation of monetary policy rules. If it is assumed that UK inflation is non-stationary, it thus exhibits the property of long memory, the role of analysing the effect of shocks in commodities on the economy takes an important place.

The non-stationarity also indicates that there is a possibility of existing cointegration between time-series. Therefore a stable equilibrium relationship in the long-run between inflation and each time-series might be assumed (Charemza and Deadman, 1997). This is presented in Table 4.1 after the preliminary analysis of time-series which clearly shows that stationarity can be achieved at the first difference.

4.12 Summary

This chapter discussed the main methods used in the analysis of time-series. The main approach followed is SVAR modelling with the identification of structural economic shocks applying an *a priori* approach, thus the restrictions are derived from theory or institutional knowledge. Econometrics tools such as the Granger causality test, impulse response and variance decomposition will be used for evaluating the SVAR and/or VECM models. The dataset consist of 21 monthly variables covering the period of 1992 to 2013.

Most of the time-series are found to be non-stationary, which motivates further investigation of cointegrating relationships. Given the importance to a possible long-term relationship between monetary policy and commodities, in the following step the presence of possible cointegration is investigated. However, in order to test the cointegration it is necessary to estimate the VAR model first where the preliminary step is to estimate the right length of lag as discussed in Section 4.5. The lag selection will be estimated individually for each of the models developed in Chapter 5 and Chapter 6.

Chapter 5 Investigation of the relationship between the easing UK monetary policy and the sensitivity of commodity markets

5.1 Introduction

The theoretical framework for the models introduced in this chapter is derived from the theories introduced in the first section of Chapter 3. The findings driven from econometric models developed in this chapter aim to contribute to recent understandings of commodity price movements and also contribute to understanding the effect of UK monetary policy on commodity prices. As a reminder, the main aim of this chapter is to evaluate the sensitivity of commodity prices on shocks in the UK monetary policy. Objectives to achieve this aim are formulated as follows:

- *To identify and measure the size and the effect of economic and monetary developments in the UK on food prices and crude oil prices.*

- *To investigate the channels for the transmission of the UK monetary shocks on commodity markets at national, international and global levels.*

- *To investigate whether sensitivity of commodity markets at different levels differs in respect to the changes in UK monetary policy during 2000s.*

The next section therefore provides a deeper insight into the problem and continues with Section 5.3 which focuses on the data analysis necessary for the selection of appropriate econometric model. Section 5.4 introduces an econometric model which is later estimated in Section 5.5. Sections 5.6 and Section 5.7 discuss the results from the models and finally, Section 5.8 summarizes the main findings.

5.2 Monetary policy shocks and commodity prices

As discussed in Chapter 2, the decades of stability of commodity prices were interrupted in the 2000s. Since then, unprecedented volatility and new price peaks have opened a lively discussion on the factors driving the commodity prices. The explanation is not straightforward since higher commodity prices coincided with lower interest rates in most of the developed countries as well as a continued devaluation of the U.S dollar. Therefore, the factors contributing to rises in commodity prices are matters of controversy. As discussed in Chapter 3, several explanations of the volatility of commodity prices have been developed recently. This section discusses the proposed explanations from Chapter 3 in more detail with focus on models developed to investigate the effect of monetary policy on commodity prices. Trostle (2008) identified a number of reasons for rising commodity prices, with the main ones being excess demand, expansion of bio-fuels and devaluation of the U.S dollar. Similarly, Akram (2009) and Kilian (2009) state that increased demand from emerging economies has contributed substantially to the growth in commodity prices. However the spill-over effect should also be considered. High crude oil prices are assumed to contribute through cost-push effects to rises in other commodities, or contribute to shifts in demand for agricultural commodities, particularly bio-fuels, as a substitute for crude oil. Krichene (2007) and Taylor (2009) see expansionary monetary, policy particularly low interest rates and the devaluation of the U.S dollar, as main contributors to increases in commodity prices. Frankel (2013), by using survey data as well as option data to measure the speculation, has identified that economic activity, easing monetary policy and speculations have subscribed for changes in inventories which along with other drivers consequently pushed the commodity prices up. However, even though his findings are interesting, as he admitted in his model, Frankel (2013) did not consider nonlinearity in the effects of growth of inventories as well as the possible non-stationarity of series and also in his study, the investigation for possible long-term relationship has not been approached. The model might therefore suffer from spurious regression and autocorrelation which, as discussed in Chapter 4 (Section 4.8.2), may lead to invalid results.

In addition to previous findings, Baffes and Haniotis (2010) argue that in many countries fiscal expansion and easing monetary policy created an environment that favoured high commodity prices. Important contributing factors include low past investments in extractive commodities, inclusion of commodities into the portfolio of investment funds as well as geopolitical concerns in energy markets. Several supportive studies on the role of speculative activity and high commodity prices can be found (Pyndick and Rotemberg, 1990 and Nikos, 2008). Gilbert (2007) refused the impact of speculations in case of the prices of metals but found the evidence for soybeans. Understandably, all of the above mentioned factors have the ability to drive commodity prices, however one should consider the size of the effect and the possible combination of more factors, rather than a few. Although there are many reasons behind the increases in commodity prices, this chapter focuses on the monetary policy channel outlined by Working (1949) and later adopted by Frankel (2006). Frankel (2006) distinguishes between channels as to how monetary policy can affect commodity prices. Specifically, it is possible to distinguish between the inventory channel, supply channel and speculation channel. This chapter focuses on the first two types.

As discussed in Chapter 3, the inventory channel has a rationale in the theory of storage which explains increases in commodity prices when interest rates are set too low. The effect of low interest rates can be also explained by the theory of overshooting. Loose monetary policy leads to rises in commodity prices until these prices are considered as overvalued. This is the point at which there is a future expectation of depreciation which is sufficient to compensate for the lower interest rate. Even though Frankel (2006) made an important contribution to the knowledge about the relationship between monetary policy and movements in commodities, his analysis has often been criticised due to the disadvantages of using linear bivariate regression models estimated by OLS, which do not enable the investigation of the dynamic interactions between variables. In contrast to Frankel's (2006) study, Arora and Tanner (2013) use the VAR framework to generate the response of oil prices to the U.S interest rates during the period from 1975-2012. Their results confirm Frankel's (2006) results and show the inverse short-term relationship confirming that this represents a monetary policy channel; therefore, the U.S monetary actions may have direct impacts on the oil prices. Their results are certainly interesting, and encourage a discussion on the relative importance of this channel for monetary policy changes as well as for oil price variation.

However, the drawback of their study can be found in the period analysed. During the last 37 years, the U.S monetary policy went though important changes which should be considered. Most recently the financial crisis, which has affected policy makers' decisions significantly. Therefore, an extension to their study could be looking at the break-even points and investigating whether the changes in monetary policy also led to changes in the sensitivity of the commodity prices. Similarly, a study by Anzuini et al. (2012) focuses on the U.S as one of the largest oil consuming economies in the world and analyzing the period from 1970 to 2009 without taking into consideration the changes in monetary policy during such a long period. Krichene (2007) used the VAR model to formulate a short-run model with the implication of the effect monetary policy has in order to analyze the world oil and gas market. His results support the assumption of the importance of monetary policy, and conclude that incorporating interest rates and exchange rates in the model can help to forecast of oil and gas prices. Nevertheless, in his model, Krichne (2007) set the period of 1970 to 2006 and uses annual data, which limits the sample to minimum observation. This will understandably also limit the value of the model. Similarly to previous studies, Krichene (2007) also did not consider the possibility of structural breaks in his model. The importance of investigating for structural breaks can be explained in two ways. Firstly, if there is a structural break (e.g. a change in monetary policy) a SVAR model cannot be applied for the whole sample (see Lucas' critique in Section 4.3). The second point that needs to be made is that in the case of the existence of a structural break, the effect of monetary policy before and after the change may differ. Thus by ignoring the possibility of structural breaks, important information may be overlooked. Thus any conclusion from the model may be considered as incomplete or misleading. The recent study by Arora and Tanner (2013) investigates the response of oil prices to interest rates with a focus on the U.S. Their results also confirm that since 2000s the relationship has changed and oil prices became more responsive to changes in monetary policy underlying the importance of storage.

As presented in previously mentioned studies the main focus is on U.S monetary policy and its effect on world commodity markets, or alternatively, the effect of developments in global economy on world commodity markets. Without doubt this approach may uncover some important information, none of the studies considered the impact of monetary policy on commodity markets at different levels in respect to the national level, international level in line with the global level. Moreover, even the main focus is on the U.S with the exception of a few studies on other countries, there is a lack of empirical evidence in the case of the UK.

From the discussion in Chapter 3 on movements in commodity prices, the assumption of the relationship between monetary policy and commodity prices which this chapter aims to investigate can be stated as the following. Following the assumption of Frankel (1986), the response of commodity prices to changes in economic conditions, or more precisely monetary conditions, is quicker than in the case of consumer prices since they are more flexible. Also, as noted before, commodities are auction-based thus there is little friction in price adjustments as the participants are assumed to have more balanced information as well as resources than consumers. This gives a rationale to the assumption of quick reactions to changes in monetary conditions (Browne and Cronin, 2010). Thus consumer goods are assumed to respond slowly and gradually to monetary decisions, but also to adjust fully in the long-term due to price stickiness and frictions in the labour and goods markets. Following the assumption of

Boutghton and Branson (1988), commodity prices are expected to respond to changes in monetary conditions by compensating in the short-run, but may then overshoot their new long-run equilibrium. Since 1988, similar studies have been done for other countries and none of the recent ones have focussed on the UK, this chapter aims to investigate the validity of Frankel's (2006) assumption of different channels with a focus on the UK monetary policy. In addition, it extends Frankel's study to become one which can distinguish between impacts on different levels.

Therefore the aim of this chapter is to investigate the effects of UK monetary policy shocks on commodity prices through inventory channels at national, international and global levels. Considered variables for this investigation are UK industrial oil stocks, OECD Europe oil industry stocks and OECD oil stocks. The assumption behind the distinguishing between inventory stages is based on the size of the economy and possible differentiation of importance. A model which distinguishes between the impacts of the shock is assumed to contribute to a better understanding of a link between UK monetary policy and sensitivity of commodity markets at different levels.

A similar approach is applied to supply channels. While Anzuini et al. (2012) examine the effect on world supply, the model introduced in this chapter does not only investigate the impact on the world supply but it also considers the country's aggregation. Therefore when investigating the supply channel, the model examines the effect of a monetary policy shock on World supply, EU27 supply, IEA supply, OECD supply and OPEC supply (detailed description of data can be found in Chapter 4, Section 4.10).

The majority of studies focus on the transmission mechanism from U.S monetary policy to commodity prices given the importance of the size of the U.S economy and its international position. This chapter introduces and investigates the validity of the argument on a small open economy and its possible impact on developments on commodity markets at different levels. Even if there is the rational assumption of a smaller size effect of UK monetary policy compared to the effect of the U.S monetary policy, the cumulative effect needs to be considered as well. Therefore, this chapter brings a view from a different perspective by measuring the actual contribution of expansionary UK monetary policy to developments in commodity prices (thus a possible endogenous relationship) which consequently (through shocks in commodity prices) may affect the UK economy by causing imbalances in prices and price inflation further investigated in Chapter 6.

5.3 Empirical Strategy

5.3.1 Lag length estimation

As discussed in the methodology (Chapter 4), the correct lag length estimation is essential for VAR models, thus before progressing to further analysis, Table 5.1 shows the lag length criteria selected by information criteria discussed in Section 4.8.1. Although results of several information criteria are presented, the criteria considered for lag selection is AIC based on Liew (2004) and Hacker (2010) who found that AIC is superior to other criterions especially when higher frequency data are used.

Table 5.1: VAR lag length selection

VAR Lag Order Selection Criteria

Endogenous variables: DLOGCPI_SA DLOGFOOD_SA DLOGOIL_SA DLOGIPI DLOGM4 DTREASURY_BILLS DI_NOMINAL

Exogenous variables: C

Sample: 1992M08 2013M09

Lag	LogL	LR	FPE	AIC	SC	HQ
0	406.0054	NA	4.22e-14	-10.93165	-10.71202*	-10.84413
1	450.6460	79.49706	4.78e-14	-10.81222	-9.055155	-10.11200
2	989.5692	75.00308*	9.27e-15*	-16.17998*	-3.660892	-11.19091*
3	541.6613	73.37011	6.59e-14	-10.62086	-5.788930	-8.695251
4	575.0662	40.26897	1.22e-13	-10.19360	-3.824236	-7.655296
5	637.3537	63.14073	1.18e-13	-10.55764	-2.650845	-7.406643
6	710.1491	59.83182	1.08e-13	-11.20956	-1.765341	-7.445879
7	818.4684	68.25601	5.39e-14	-12.83475	-1.853097	-8.458373
8	489.1513	61.18651	6.61e-14	-10.52469	-7.230197	-9.211780

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

As shown in Table 5.1, AIC criterion as well as other criterions (except of SIC) suggests 2 lag as an optimal lag length. According to Schwartz information criterion, the optimal lag length is 0. However, as discussed in methodology chapter, given the nature of data used for analysis and the size of the sample, AIC outperforms SIC. Therefore, in following sections, the length of 2 lags will be used in order to avoid underestimation of lag length which could lead to misspecification of the model.

5.3.2 Do commodity prices overshoot in response to UK monetary policy?

Before estimating the SVAR model, the Granger causality test is used in order to investigate the direction of the relationship. The results of the Granger causality test (Appendix A) show that the null hypothesis of *"DI_nominal does not Granger Cause Dlogfood_sa"* cannot be rejected (p >0.05) suggesting that current food prices are not correlated to the past values of nominal interest rates. Also the results show that current food prices are not correlated to the past values of money supply, IPI or 3-months Treasury bills. Clearly, the Granger causality test does not identify the relationship between food prices and developments in the UK economy since food prices are not found to be related to developments in the UK economy. Money supply also seems to be irrelevant for oil prices, since the null hypothesis of *"DLOGM4 does not Granger Cause Dlogoil_sa"* cannot be rejected (p >0.05). Nevertheless, in contrast to food prices, the null hypothesis *"DlogIPI does not Granger Cause DLOGOIL_SA"* can be rejected (p< 0.05) suggesting that current oil prices are correlated to the past values of the UK's industrial production. This result may not be expected as the size of the UK oil demand is possibly not as important as in other countries such as China. This may be explained by the specific position of the UK in the oil market. As an oil importer as well as exporter, the position of the UK may not give clear results and further investigation is needed. Another interesting result is that the null hypothesis *"Dtreasury_bills does not Granger Cause DLOGOIL_SA"* can be rejected confirming the assumption that the monetary policy in the UK might have an impact on developments on commodity markets, particularly the oil market. It is interesting that current values of oil prices are correlated to the past values of 3-months Treasury bill while stay uncorrelated to nominal interest rates.

Nevertheless, even if the results of the Granger causality test are interesting, as discussed in Chapter 4 (Section 4.8.3), the power of this test is debatable and results must be interpreted with caution. Thus, rather than taking these results as final, the next part breaks down the investigation of the relationship between monetary policy in the UK and commodity prices into fewer channels, discussed in Section 5.2. The main motivation for the investigation of different channels is to develop an understanding on sensitivity of commodity prices to developments in the UK monetary policy.

5.3.3 An investigation on the presence of a long-run relationship

As pointed out by Granger (1986), in the long-run, certain pairs of economic variables such as interest rates, commodities or income expenditure do not tend to diverge from each other to a significant extent. Although, they can diverge from each other in the short-run, market forces or government interventions will bring them together again. To investigate the validity of this argument a test for possible long-run relationships is undertaken. The results from the unit root test in Table 4.1 (Chapter 4) show, most of the data are I(1) thus as shown in Figure 4.1 (Chapter 4) the next step is to test for cointegration, or in other words, long-run relationships. Frankel (2013) already pointed out the importance of testing for non-stationarity in his study of the role of monetary policy on commodity markets. The Johansen cointegration test discussed in Section 4.6 is applied since the intention is to estimate a multivariable model (n=7). According to the Parantula (1989) principle when testing for cointegration, it is suggested that one should test for cointegration using each type of test and then, based on one's preferred criteria, choose one. Table 5.3 presents the results from the Johansen test for cointegration where number of lags is based on AIC (Table 5.1).

Table 5.2: Johansen cointegration test

Sample: 1992M08 2013M09
Included observations: 100
Series: LOGM4 LOGIPI LOGCPI_SA I_NOMINAL_SA TREASURY_BILLS_SA LOGOIL_SA LOGFOOD_SA
Lags interval: 1 to 2

Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	1	2	1	1
Max-Eig	1	2	2	1	1

*Critical values based on MacKinnon-Haug-Michelis (1999)

As noted in the methodology chapter, the first and the last type of data trend are not common. Also it is assumed that variables follow linear trend, and therefore the forth option is chosen. The Trace statistics as well as Max-Eigenvalue found one cointegrated relationship at p=0.05. The results provide motivation for using a VEC model as discussed in Chapter 4 (Section 4.6.). It is worth pointing out that options one and five from the Johansen test are usually implausible, while the first option suggests that the VAR model, as well as the cointegration equation, has no trend or intercept thus has a zero mean. The last option assumes the VAR model has a non-zero mean, and a linear trend as well as a quadratic trend with the cointegrating equation having an intercept and trend. In respect of the characteristics of time-series, it is not assumed that data have quadratic trends. Since the choice of option should be made based on economic theory, and the nature of the time-series, the assumption here is that both cointegrating equations as well as the VAR model, have a non-zero mean and a linear trend.

5.4 Model

The modelling strategy (introduced later in this chapter) can be split into two. The first part of the modelling strategy used for analyzing the impact of monetary policy on commodity prices, can be found in the works of Akram (2009), Anzuini et al. (2012) and Arora and Tanner (2012). This approach follows the VAR method which treats all the core variables symmetrically without distinction between endogenous and exogenous variables. It is convenient to note that after the standard model introduced by the above mentioned authors is estimated, the following section will introduce an extended model discussed in more detail in Section 5.7. The applicability of the VAR (VEC) model strategy can be acceptable in large open economies and since these studies focus on the U.S monetary policy, results from the VAR model can be reliable. However, it can be argued that this method may not be efficient in the models of small open economies, such as the UK, where the aim is to develop models that are influenced by the core variables however they themselves have little feedback into the core variables (Garratt et al., 2006). More precisely, commodity prices such as oil prices and food prices can be treated as exogenous to the domestic economy since their prices are set outside the UK economy. Therefore, it can be assumed that the decisions of small open economies, such as the UK economy, do not influence the rest of the world significantly; thus international events can be determined as exogenous. However, it might be also argued that there are occasions when movements in macroeconomic variables in the UK might provide important contemporaneous indicators of movements in commodity price indicators, therefore variables can be treated as endogenous. The same approach was applied by Reicher and Utlaut (2010) as well as Kilian (2008) who argue that both theory, as well as their results, indicates that oil prices should be treated as endogenous. Nevertheless, in contrast to these studies, Blanchard and Galí (2008) estimate oil prices as exogenous to the economy. In relation to the model developed in this chapter, the assumption of endogenous commodity prices is essential since the main aim is to investigate the impact of developments in the UK monetary policy in line with the investigation of the sensitivity of commodity prices to the UK monetary policy.

Apart from the existence of a cointegrating relationship, another argument for preferring to use the VEC model in this study is the higher precision of the estimators of impulse responses from a structural VEC model when compared to a VAR model (see Section 4.8.4 for discussion). For instance, studies by Jang and Ogaki (2003), Cologni and Manera (2008), Kaabia et al. (2002) show that relevance of results from VEC models impulse response estimates are especially higher when evaluating monetary policy than in the case of a VAR model. Contrary to VEC model, VAR model can lead to an exploding impulse response even if the impulse response is not exploding. An important advantage of VEC model over VAR model is the possibility of imposing long-run restrictions as well as short-run restrictions in order to identify shocks. From the preliminary data analysis this investigation adopts the standard notation as x_t is a $n \times 1$ vector of non-stationary variables which are, from the results of the Johansen test, assumed to be cointegrated, r is the number of cointegrating vectors, k is the number of common trends ($k = n \in r$) and the data generating process is also assumed to be VAR (p) where p is the lag length selected by the Aike Information Criterion and L is the lag operator.

5.4.1 Error correction model

As discussed in the methodology (Chapter 4, section 4.7), when series are cointegrated the system has a reduced rank and there are cointegrating relationships, it is necessary to estimate an error correction model. The results of the Johansen test in the previous part identified one cointegrating vector. Therefore an error correction model (ECM) can be estimated under the assumption that x_t has a finite order with unrestricted VAR representation:

$$\Delta Y_t = a_0 + b_1 \Delta X_t - \pi \hat{u}_{t-1} + e_t \qquad (5.1)$$

5.4.2 Long-run restrictions

As Δx_t is assumed to be stationary, the representation can be written as:

$$\Delta x_t = \delta + C(L)\epsilon_t \qquad (5.2)$$

Where $\delta = C(1)\mu, C(L) = I_n + \sum_{i=1}^{\infty} \Gamma_i L^i$ and v_t is a vector of structural disturbances with variance Σ_v and mean zero with long-run restrictions imposed on the structural form (Blanchard and Quah, 1989). When cointegrated variables have a reduced rank r, it can be assumed there exist $k = n - r$ common trends. Therefore common trends can be generated by permanent shocks thus by decomposition of v_t into v_t^k, v_t^r (Stock and Watson, 1988). Where

v_t^k is a k dimensional vector of permanent shock and v_t^r is an r dimensional vector of transitory shock. The decomposition requires $\Gamma(1) = [A\ 0]$, A is $n \times k$ matrix and 0 is $n \times r$ matrix with the long-run effects of permanent shocks and transitory shocks. Therefore the application of long-run restrictions when n = 7 and k = 1[3] the long-run effects A have a structure:

$$x_t = \begin{bmatrix} x_t^1 \\ x_t^2 \\ x_t^3 \\ x_t^4 \\ x_t^5 \\ x_t^6 \\ x_t^7 \end{bmatrix}, v_t^k = \begin{bmatrix} v_t^1 \\ v_t^2 \\ v_t^3 \\ v_t^4 \\ v_t^5 \end{bmatrix}, A = \begin{bmatrix} 1\,0\,0\,0\,0\,0\,0 \\ x\,1\,0\,0\,0\,0\,0 \\ x\,x\,1\,0\,0\,0\,0 \\ x\,x\,x\,1\,0\,0\,0 \\ x\,x\,x\,x\,1\,0\,0 \\ x\,x\,x\,x\,x\,1\,0 \\ x\,x\,x\,x\,x\,x\,1 \end{bmatrix} \quad (5.3)$$

Where x represents unrestricted parameters. These long-run restrictions imply that a permanent shock in v_t^2 has no long-run effects on variable x_t^1, a permanent shock in v_t^3 has no long-run effects on variable x_t^1 and x_t^2, and a permanent shock in v_t^4 has no long-run effects on variable x_t^1, x_t^2 and x_t^3.

For the investigation of the impulse responses of macroeconomic variables to one permanent shock *n – 1* a long-run restriction is sufficient to identify the last permanent shock in its matrix form:

$$A = \hat{A}\Pi = \hat{A}\begin{bmatrix} 1 & \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} & \alpha_{16} & 0 \\ \alpha_{21} & 1 & \alpha_{23} & \alpha_{24} & \alpha_{25} & \alpha_{26} & 0 \\ \alpha_{31} & \alpha_{32} & 1 & \alpha_{34} & \alpha_{35} & \alpha_{36} & 0 \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & 1 & \alpha_{45} & \alpha_{46} & 0 \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & 1 & \alpha_{56} & 0 \\ \alpha_{61} & \alpha_{62} & \alpha_{63} & \alpha_{64} & \alpha_{65} & 1 & 0 \\ \alpha_{71} & \alpha_{72} & \alpha_{73} & \alpha_{74} & \alpha_{75} & \alpha_{76} & 1 \end{bmatrix} \quad (5.4)$$

Where $A = \hat{A}\Pi$ is an orthogonalizing condition of a permanent shock, as proposed by Sims (1980).

5.5 Estimation of the model

Consider the seven-variable model with a number of long-run restrictions as defined in the previous section. Therefore let x_t be M4 (money supply), IPI (output), CPI (price level), i_{nom}

[3] n= number of variables, k=number of lags selected by AIC is VAR=2 for VEC = 1.

(official interest rate), Treasury_bills (3-months Treasury bills), Oil (oil price index), Food (food price index). Therefore, the monetary cycle and changes in monetary policy are captured by M4, CPI, I_nom and Treasury_bills while the state of economy is expressed by the industrial production. The last two variables represent the development of commodity markets.

The following equations summarize the identifying restrictions (the restrictions on the contemporaneous structural parameters α_{xy}). All restrictions are expressed as zero (exclusion) restrictions.

$$\begin{bmatrix} x_t^{m4} \\ x_t^{ipi} \\ x_t^{cpi} \\ x_t^{i_{nom}} \\ x_t^{treasury} \\ x_t^{oil} \\ x_t^{food} \end{bmatrix} = \begin{bmatrix} 1 & \alpha_{12} & \alpha_{13} & \alpha_{14} & 0 & 0 & 0 \\ 0 & 1 & \alpha_{23} & \alpha_{24} & \alpha_{25} & \alpha_{26} & \alpha_{27} \\ 0 & \alpha_{32} & 1 & \alpha_{34} & \alpha_{35} & 0 & 0 \\ 0 & \alpha_{42} & \alpha_{43} & 1 & 0 & 0 & 0 \\ 0 & \alpha_{52} & \alpha_{53} & 0 & 1 & 0 & 0 \\ \alpha_{61} & \alpha_{62} & \alpha_{63} & \alpha_{64} & \alpha_{65} & 1 & 0 \\ \alpha_{71} & \alpha_{72} & \alpha_{73} & \alpha_{74} & \alpha_{75} & 0 & 1 \end{bmatrix} \qquad (5.5)$$

Where x_t^{m4}, x_t^{ipi}, x_t^{cpi}, $x_t^{i_{nom}}$, $x_t^{treasury}$, x_t^{oil} and x_t^{food} are structural disturbances, therefore money supply shocks, output shocks, inflation shocks, interest rates shocks and the last two variables represent commodity price shocks. The shocks are in terms of innovations, and due to the monthly frequency of data, they are not very restrictive. The first equation in the system is the money supply modelled on the assumption of the long-run neutrality of money. As discussed in Chapter 3 (Section 3.3.3) Schuh (1974) found that the levels of agricultural prices respond proportionally to changes in the level of money supply in the long-run, while the neutrality of money applies in the short-run. Therefore, the money supply in the long-run is assumed to affect only the nominal variable. Here the assumptions are that an increase in money supply leads to a proportional increase in industrial production and inflation, as well as an increase in the nominal interest rate. The long-run neutrality of money (LRN) hypothesis assumes that an expansionary monetary policy may be helpful for the economy in times of recession, and helps the economy to return faster to its long-run equilibrium. However, this does not lead to a sustainably higher output. This assumption is set in respect to the unconventional policy (quantitative easing) approached in order to increase the confidence and stimulate demand. Malliaropulos (1995) investigated the validity of the neutrality of money in the UK and concludes that money is found to be neutral in the long-run with respect to real GDP. However, in the short-term and medium-term permanent positive shocks to the money supply seem to be positively correlated with the real GDP and negatively correlated with real equity prices. King and Watson (1997) tested the long-run neutrality of money using the VAR method. They found that signs of the estimated effect of money growth on output depended on the particular identifying assumption used, but nominal interest rates were found to move less than one-for-one with inflation in the long-run.

The second equation models industrial production, which in the long-run is affected by inflation and monetary policy decisions as well as developments in commodity markets. While in the short-run the assumption of sticky prices would hold (Goodfriend and King, 1997), in the long-run it can be assumed that industrial production is affected by developments in commodity markets particularly oil and food markets. The third equation in the system represents the hypothesis of real activity responses to price and financial signals. Therefore, inflation is modelled as a response to the output as well as to the monetary policy decisions. Equations four and five are modelled as monetary policy reactions to output and inflation, and therefore as a reaction to the development in the economy. However, based on the literature on inflation targeting and the practice of policy makers, it is assumed that interest rates are not affected by developments in commodity prices since, as assumed, policy makers do not react to supply shocks as these are taken as short-term (see discussion in Section 3.8). This is understandable since as Hamilton (2009) noted, the short-term shocks in commodity prices are driven by speculations. It is notable that speculations cannot drive prices for decades. Nevertheless, the last two equations in the system modelled commodity prices in an arbitrage equation. These two equations are assumed to be contemporaneously affected by changes in all variables in the system, except for the effect of oil prices on food prices and food prices on oil prices. Despite of Gilbert's (2010) findings that oil prices are one of the drivers of food prices, Baumeister and Kilian (2013) did not find supportive evidence for this argument and also from the results, the hypothesis of *"Food prices does not Granger Cause Oil prices"* (Table 5.2) can be rejected thus, this relationship is excluded from the analysis. The rationale behind separating the possible effect within commodities is the motivation to investigate and measure whether shocks in the UK economy affect commodity markets and do not account for other possible drivers. The unrestricted relationship enables analyzing the effect of easing monetary policy in the UK, on the sensitivity of food and oil prices, and on the investigation for a potential pass-through effect.

5.6 Empirical results

5.6.1 Long-run neutral money restrictions

Firstly, this section examines the response of commodity prices to money supply. The rationale is based on an assumption that the financial crisis had, at the beginning, caused a significant decrease in money supply followed by quantitative easing adopted by the BoE. So it may be interesting to investigate whether the shock in money supply, which resulted from unconventional policy, has an impact on oil and food prices. Even though it could be assumed that money supply in the UK might not be a significant variable affecting commodity prices, however in the long-term, the stability of the money supply might play more important role. Moreover, even if money is neutral in the long-run, commodity price overshooting can still have significant impact in the short-run.

Table 5.3: VEC with neutral money restrictions

Vector Error Correction Estimates
Cointegration Restrictions: B(1,1)=1,B(1,5)=0, B(1,6)=0, B(1,7)=0
Restrictions identify all cointegrating vectors
LR test for binding restrictions (rank = 1):
Chi-square(3) 6.144909
Probability 0.104769

LOGM4(-1)	LOGIPI(-1)	LOGCPI_SA(-1)	I_NOMINAL_SA(-1)	TREASURY_BILLS_SA(-1)	LOGOIL_SA(-1)	LOGFOOD_SA(-1)	C
1.000000	1.502463 (0.19898) [7.55096]	1.266468 (0.36192) [3.49931]	0.294859 (0.12921) [2.28208]	0.000000	0.000000	0.000000	-5.953754

Standard errors in ( ) & t-statistics in [ ]

Error Correction:	D(LOGM4)	D(LOGIPI)	D(LOGCPI_SA)	D(I_NOMINAL_SA)	D(TREASURY_BILLS_SA)	D(LOGOIL_SA)	D(LOGFOOD_SA)
CointEq1	-0.029018	-0.488639	-0.006230	0.010243	0.012788	-0.000408	-0.001157
	(0.01688)	(0.07764)	(0.01618)	(0.02293)	(0.01848)	(0.00781)	(0.00298)

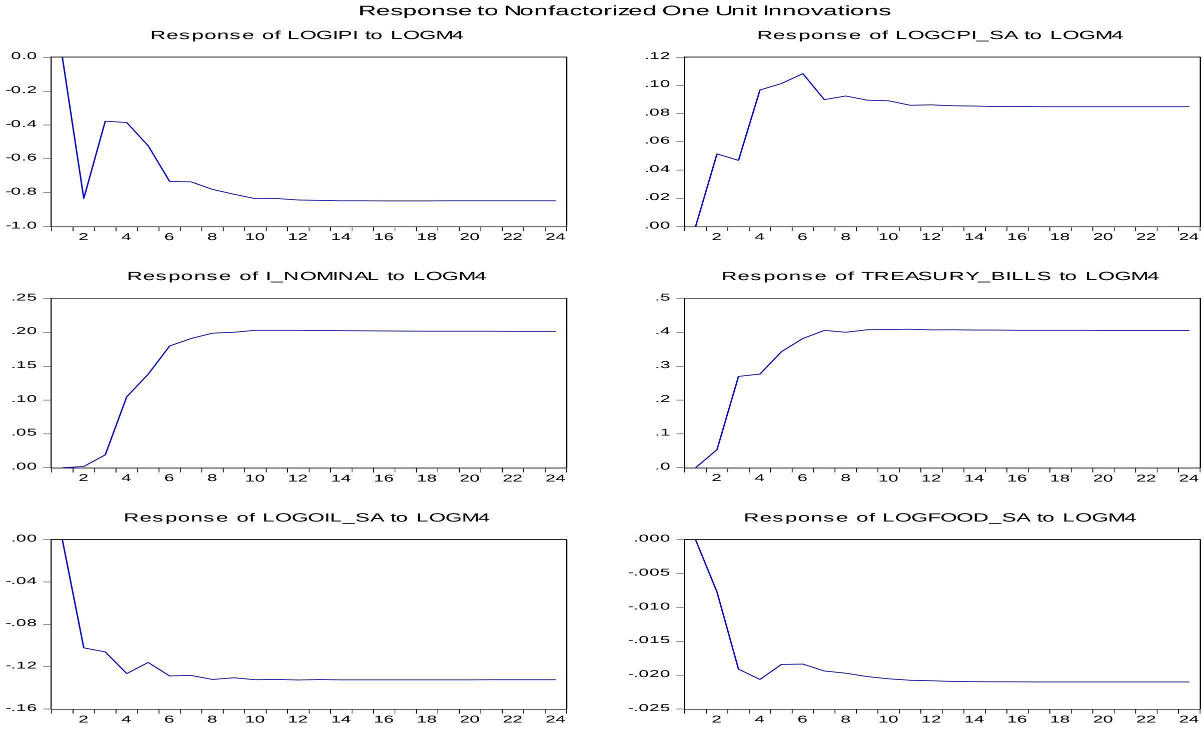
	[-1.71860]	[-6.29348]	[-0.38508]	[0.44667]	[0.69203]	[-0.05233]	[-0.38864]

The long-term money supply equation for the UK is modelled based on an assumption of the neutrality of money; therefore the money supply does not react to developments in commodity markets. Therefore money supply is assumed to affect only nominal variables.

From the cointegrating equation of error correction model in lower part of Table 5.4, the results show that if money supply shifts above its long-run equilibrium, inflation rate decreases in the next period. The same reaction can be observed in the case of short-term interest rates and industrial production which measures the output.

The hypothesis that money is neutral in the long–run cannot be rejected at the 5 per cent significance level with a probability 0.104769. Similar results were obtained by King and Watson (1997) who used a sample of 40 years of quarterly observations. They concluded that the data contained little evidence for the long-run neutrality of money. As presented by Johansen (2002) the long-run coefficients in a cointegrating relationship represent elasticity if variables are expressed in logarithms. Since time-series are transformed in logarithms, the interpretation of results can be as following. The results of a long-term relationships show that a 1 per cent increase in the money supply in the long-run leads to an increase of output (Table 5.4), measured as industrial production, by 1.5 per cent and inflation by 1.26 per cent followed by a 0.30 per cent increase in interest rates. The sign of the coefficients measuring the long-run impact of money supply are as expected. The responses of variables to the money supply shock defined as a nonfactorized one unit increase in M4 are presented in Figure 5.1., where the horizontal axis shows months after the initial shock.

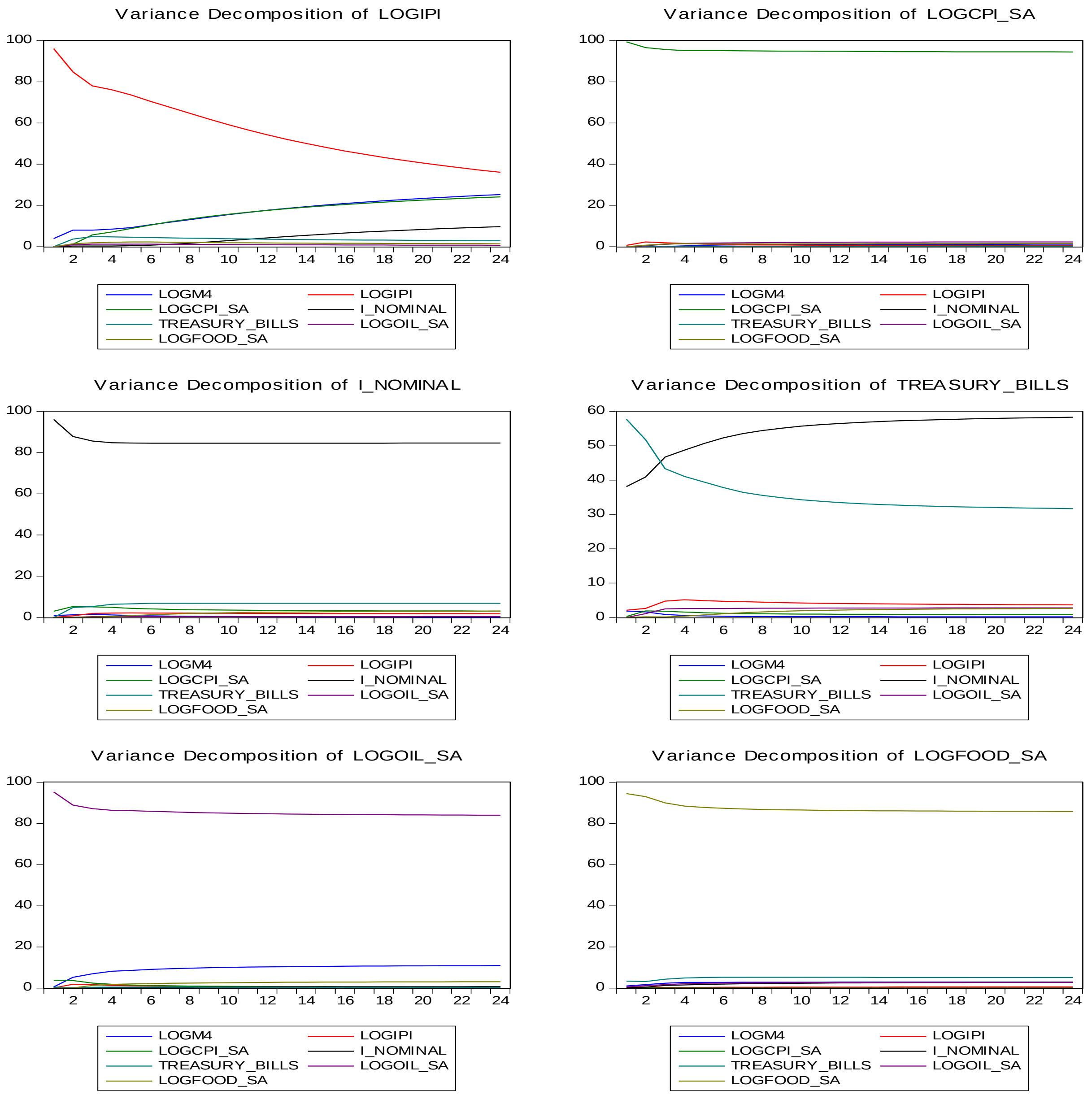
Figure 5.1: Impulse response functions to a nonfactorized one unit innovation



The response of monetary policy to the money supply shock has an expected sign. A magnitude of the 1 per cent increase in money supply leads to a 0.20 per cent increase in the nominal interest rate and 0.4 per cent in the 3-months Treasury Bills. According to ECB (2011) if monetary developments deviate from the economic determinants as a result of a shift in money supply that could be represented as an unexpected shock in money supply, this leads to an adjustment of monetary policy, thus in this case it leads to a response in interest rates.

Even if the effect is not strong however, it peaks soon in the first year after the shock. As suggested from the results of the Granger causality test, the effect on oil prices and food prices is insignificant. The CPI responds by sharper acceleration. A sharp acceleration after the shock can be interpreted as an increase driven by the short-term inflation expectations, which however without any other shock in the following year, starts oscillating back to its long-run level assuming that inflation expectations are well anchored. The response of oil and food prices is found to be insignificant and downward sloping.

Figure 5.2: Variance decomposition of the money supply shock



The report of the forecast error variance decomposition is reported in Figure 5.2. The horizontal axis shows the period at which forecast errors are calculated. In this case it is 24 months. In the case of industrial production, the money supply explains a forecast error variance increasingly over the time, reaching nearly 30 per cent in the second year. Consumer price inflation explains also nearly 30 per cent of forecast error. Although, money supply shocks are the major sources of industrial production fluctuations in the UK, they do not seem to contribute to increases in food prices and explain only 10 per cent variations in the oil prices.

5.6.2 Long-run restrictions on output development

The hypothesis investigated is based on an assumption that industrial production does not affect money supply in the long-run however, does have an impact on the rest of the variables. The hypothesis cannot be rejected at the 5 per cent significance level with probability 0.7. In Table 5.5 the results show that a 1 per cent increase in output, in a short-run, leads to an increase of oil prices by 0.25 per cent while a more sensitive response is showed by food prices 1.24 per cent.

Table 5.4: Long-run restrictions on output development

Vector Error Correction Estimates
Restrictions identify all cointegrating vectors
Cointegration Restrictions: B(1,1)=0,B(1,2)=1
LR test for binding restrictions (rank = 1):
Chi-square(3) 0.115632
Probability 0.7

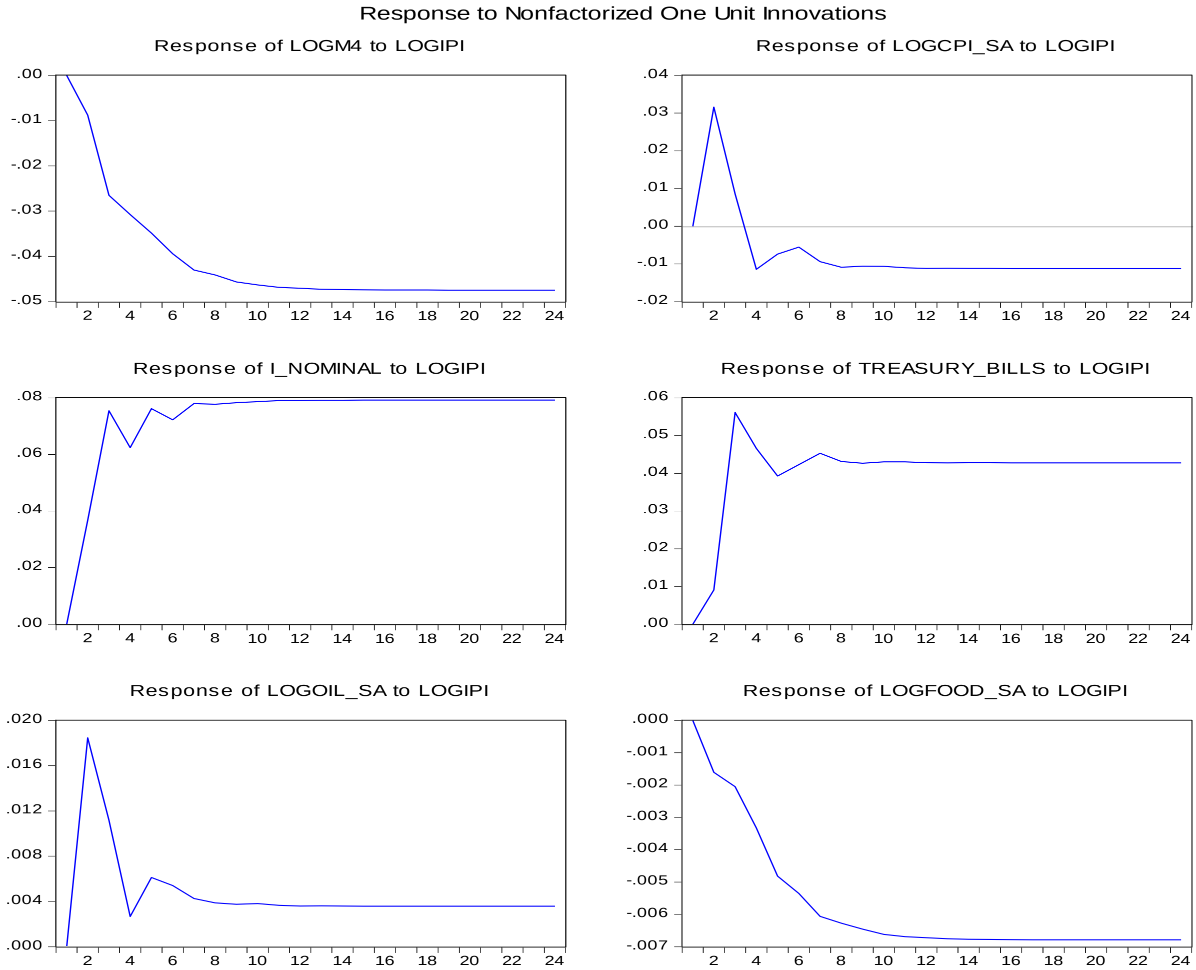
LOGM4(-1)	LOGIPI(-1)	LOGCPI_SA(-1)	LOGI_NOMINAL_SA(-1)	LOGTREASURY_BILLS_SA(-1)	LOGOIL_SA(-1)	LOGFOOD_SA(-1)	C
0.000000	1.000000	0.831878 (0.49303) [1.68729]	-1.144066 (0.52247) [-2.18974]	1.616784 (0.51955) [3.11189]	0.245211 (0.49094) [0.49947]	1.243359 (1.48270) [0.83858]	-10.56408

Standard errors in ( ) & t-statistics in [ ]

Error Correction:	D(LOGM4)	D(LOGIPI)	D(LOGCPI_SA)	D(LOGI_NOMINAL_SA)	D(LOGTREASURY_BILLS_SA)	D(LOGOIL_SA)	D(LOGFOOD_SA)
CointEq1	-0.036873	-0.651719	-0.003766	0.037413	0.010484	0.000535	-0.002631
	(0.02134)	(0.09548)	(0.02046)	(0.02873)	(0.02340)	(0.00987)	(0.00375)
	[-1.72799]	[-6.82536]	[-0.18406]	[1.30204]	[0.44809]	[0.05422]	[-0.70080]

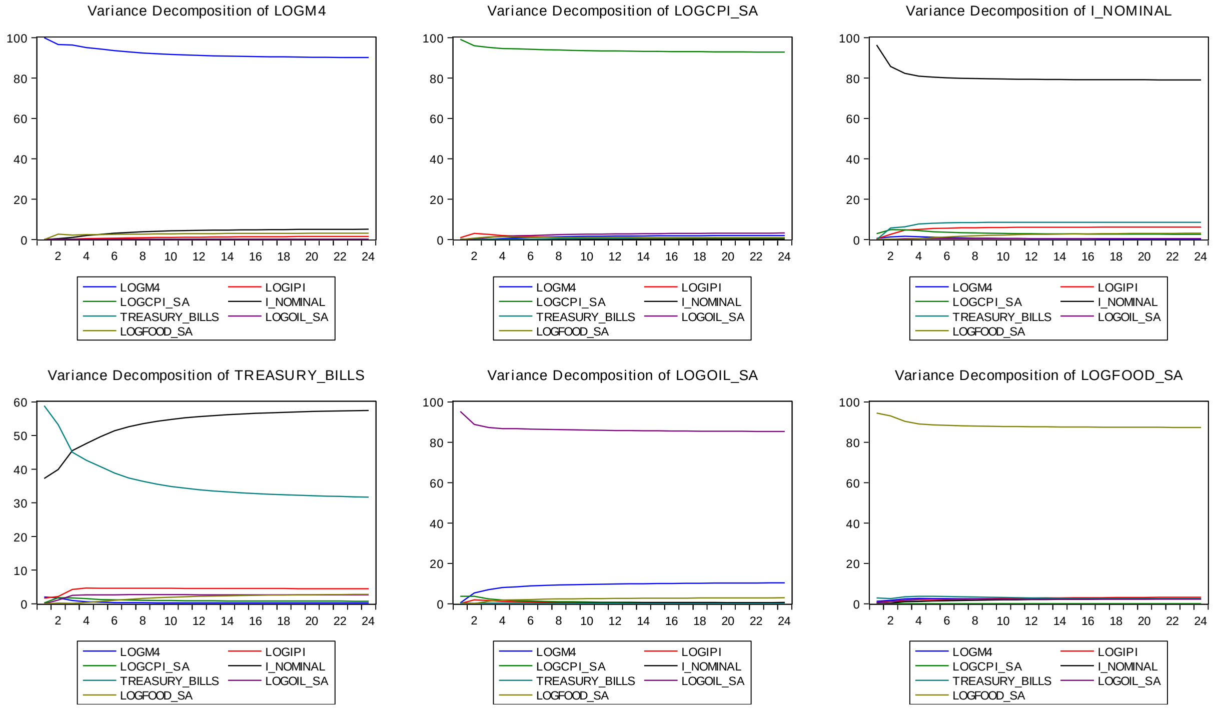
From Figure 5.3 it can be observed that an industrial production shock has a long lasting negative effect on the money supply. As in the previous case, the first few months after the shock, inflation seems to be driven by inflation expectations which lead to a slight acceleration in inflation followed by its return to a level slightly higher than the long-term equilibrium. The monetary policy response to a shock in industrial production has a positive, slightly increasing response. Interestingly, the 3-months Treasury bills seem to react to the shock with a 1 month lag compared to the nominal interest rate.

Figure 5.3: Impulse response function



However, the response of commodity prices confirms the assumption that even if the UK became a net-oil importing country, it would not have a significant effect on world oil prices since the size of oil consumption, when compared to other large economies, is modest. For instance, the study of Roache (2012) shows a nearly 3 per cent increase in crude oil prices as a response to a positive, 1 per cent shock in China's economic activity. In contrast to China, these results show that a positive shock to the UK's industrial production can cause a short-term small rise in oil prices as a response of supply to the higher demand. However, in the long-run the oil prices oscillate back to equilibrium since even though a 1 per cent increase in industrial production may have an important impact on the UK economy, in the world context this increase is statistically insignificant, thus the response of oil prices is weak in the short-term as well. If it is considered that a 1 per cent increase in global output (measured as industrial production) leads to a rise in oil prices of about 9 per cent (Helbling, 2012) the results for the UK seem to be accurate. To support the argument, Kilian (2009) also found that a 1 per cent shock to the global aggregate demand led to an increase in the real price of oil of about 1 per cent after 12 months. Therefore, the effect of the UK's industrial production shock on oil prices can be taken as reasonable. Similarly, the effect on food prices is small. A decrease in food prices may be explained by a higher demand for oil due to higher industrial production that consequently leads to a lower demand for food products (see Chapter 3). However, the effect is again very small and statistically not significant. Food prices respond by only a 0.016 per cent decrease to a 1 per cent positive shock to the industrial production. Therefore, taking into consideration the size of the change and its impact it can be concluded that the shock to the UK's output measured as industrial production does not play an important role in terms of food and oil price determination.

Figure 5.4: Variance decomposition



The report of the forecast error variance decomposition is reported in Figure 5.4. In this case, none of the variables seem to explain commodity prices except of money supply which explains 8 per cent variation of the oil prices.

5.6.3 Monetary policy shock

For evaluating of the response of commodity prices to expansionary monetary policy in the UK one should remember that the monetary policy is considered under the assumption of inflation targeting, where the official interest rate is set in respect to the headline inflation and output (in this case measured as industrial production) is also considered, with restrictions on commodity prices. Therefore the assumption is that the official interest rate does not react to developments in commodity prices. The focus is on the identification of to what extent low real interest rates in the UK account for sensitivity of commodity prices and whether commodity prices tend to display overshooting behaviour in response to the UK's interest rate changes. The hypothesis is based on Frankel's (2007) assumption that low interest rates lead to a reduction in the opportunity costs of carrying inventories followed by increases in demand for commodities. Since the hypothesis is that lower interest rates also lead to an upward pressure on futures prices as well as on spot prices through arbitrage. By reducing the cost of speculative positions a model of expansionary monetary policy is tested. However, in contrast to the study of Anzuini et al. (2012) who apply a (nominal) Federal Fund rate to their analysis of the effect of monetary policy shock on commodity prices, Frankel (2006) suggests using real interest rates. His argument is that the impact of real interest rates might not be as critical as gross world product, but even if it does have a lower level of importance it is often neglected.

Furthermore the quantitative effect of monetary policy is estimated by modelling the shocks to the official nominal rates (expansionary monetary policy) and comparing with the effect of the shock on 3-months Treasury bills. A similar study supporting Frankel's argument has been done for the U.S by Akram (2009). His results show that commodity prices increase in response to lower real interest rates. Moreover, Akram's (2009) findings confirm that commodity prices, specifically oil prices and prices of industrial raw materials tend to display overshooting behaviour in response to such interest rate shocks, while food prices and metal prices tend to respond gradually. The results (presented in Table 5.6) show the response of inflation and industrial production to expansionary policy with the expected signs. From the lower part of Table 5.6, if short-term interest rate (i_nominal) shifts below its long-run equilibrium, inflation rate increase in the next period as well as industrial production and money supply.

Table 5.5: Monetary policy shock (i_nominal)

Vector Error Correction Estimates
Cointegration Restrictions: B(1,1)=0, B(1,4)=-1, B(1,5)=0, B(1,6)=0, B(1,7)=0
LR test for binding restrictions (rank = 1):
Chi-square(3) 12.53335
Probability 0.013796

LOGM4(-1)	**LOGIPI(-1)**	**LOGCPI_SA(-1)**	**LOGI_NOMINAL_SA(-1)**	**LOGTREASURY_BILLS_SA(-1)**	**LOGOIL_SA(-1)**	**LOGFOOD_SA(-1)**	**C**
0.000000	2.013606 (0.29028) [-6.93667]	2.866329 (0.53294) [-5.37834]	-1.000000	0.000000	0.000000	0.000000	10.71315

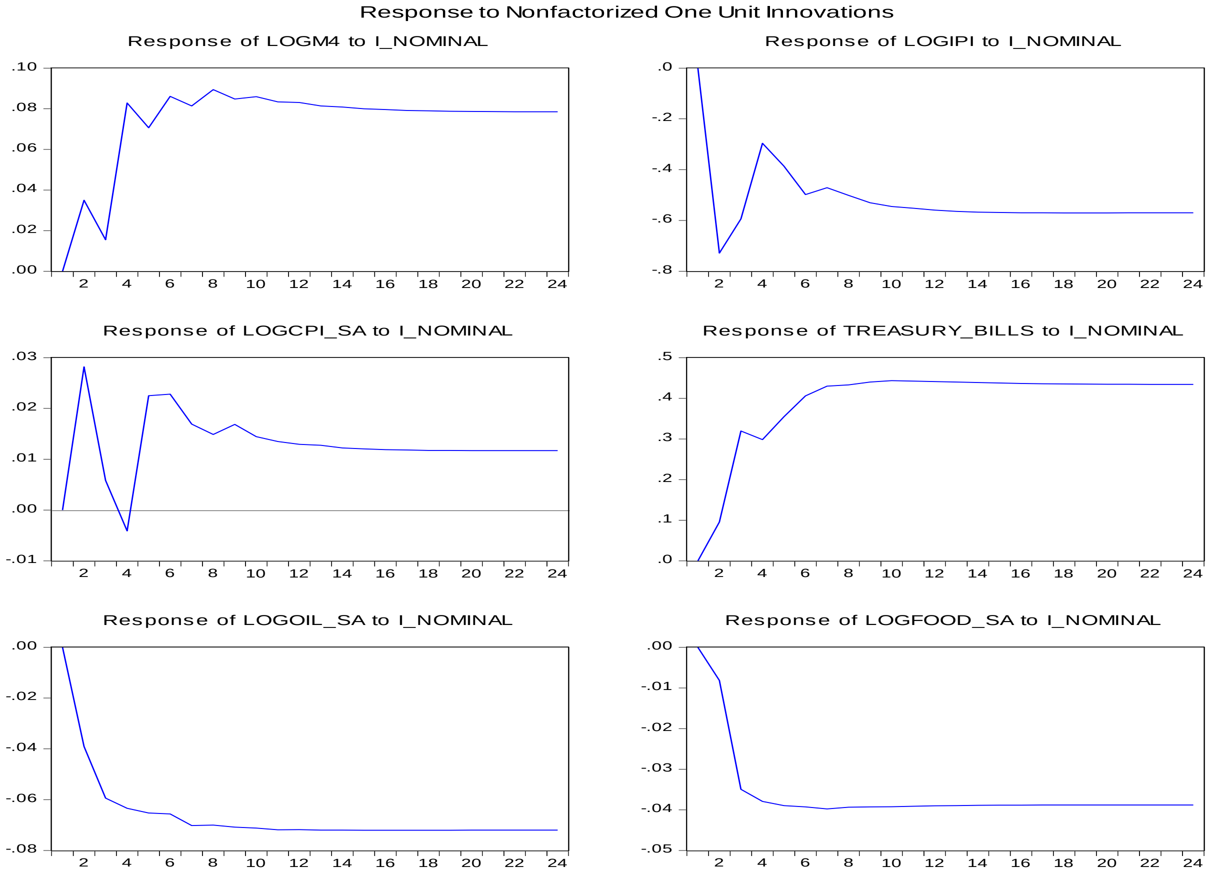
Standard errors in ( ) & t-statistics in [ ]

Error Correction:	**D(LOGM4)**	**D(LOGIPI)**	**D(LOGCPI_SA)**	**D(LOGI_NOMINAL_SA)**	**D(LOGTREASURY_BILLS_SA)**	**D(LOGOIL_SA)**	**D(LOGFOOD_SA)**
CointEq1	0.017182	0.307235	0.006350	0.004222	0.001707	0.001816	-0.001166
	(0.01102)	(0.05130)	(0.01051)	(0.01493)	(0.01206)	(0.00508)	(0.00193)
	[1.55926]	[5.98903]	[0.60408]	[0.28278]	[0.14159]	[0.35778]	[-0.60310]

The impulse response functions presented in Figure 5.5 show that the money supply seems to respond to the 1 per cent cut in interest rates significantly by a proportional rise in the first 4 months with an increase by 3 per cent in the long-term. The response of inflation to a 1 per cent cut in the nominal interest rate is not as strong as the money supply, but is persistent. Nevertheless, the reaction of inflation to easing monetary policy is in contrast to stylized macro models which suggest that prices should increase following a surprise decrease in interest rates (Rusnak et al., 2013). The opposite reaction of prices to the shock in monetary policy is according to Sims (1992) often referred as *"price puzzle"* resulting from either model misspecification (Bernanke et al., 2005) or developments in the economy (Rabanal, 2007). However, results of Rusnak et al. (2013) release that the puzzle is created due to the omission of commodity prices, which in this model are restricted to zero.

There is a sharp increase in the first months with peaks of 0.03 per cent. An increase is assumed to be driven by expectations, however in the long-term the shock is persistent and leads to a 0.02 per cent increase in consumer prices. In the case of commodity prices the results of response functions reject Frankel's (2006) assumption in the UK's conditions. The long-term impact of the nominal interest rate shock on the oil prices reported in Figure 5.5 is relatively small since a unit shock leads to a reduction in oil prices by 0.06 per cent. However, the shock is persistent since the response function does not reach a stable level prior to a 24-month forecast horizon.

Figure 5.5: Response to the nominal interest rate shock



Similarly to the oil prices, food prices also respond to the nominal interest rate shock with a negative drop without reaching a stable level prior to a 24-month forecast horizon. Therefore the theory of overshooting does not apply. However, when estimating the model with 3-months Treasury bills, the response seems to differ. The response of CPI and IPI has the expected positive sign of a 0.57 per cent increase in CPI and a 0.022 per cent increase in IPI in the case of a 1 per cent cut in the 3-months Treasury bills (Table 5.7). Interestingly, CPI as well as IPI seems to be more sensitive to cuts in official interest rates than 3-months Treasury bills as the response is slightly higher.

Table 5.6: Monetary policy shock (3-months Treasury Bills)

Vector Error Correction Estimates
Cointegration Restrictions: B(1,1)=0, B(1,4)=0, B(1,5)=-1, B(1,6)=0, B(1,7)=0
Restrictions identify all cointegrating vectors
LR test for binding restrictions (rank = 1):
Chi-square(3) 7.736341
Probability 0.101728

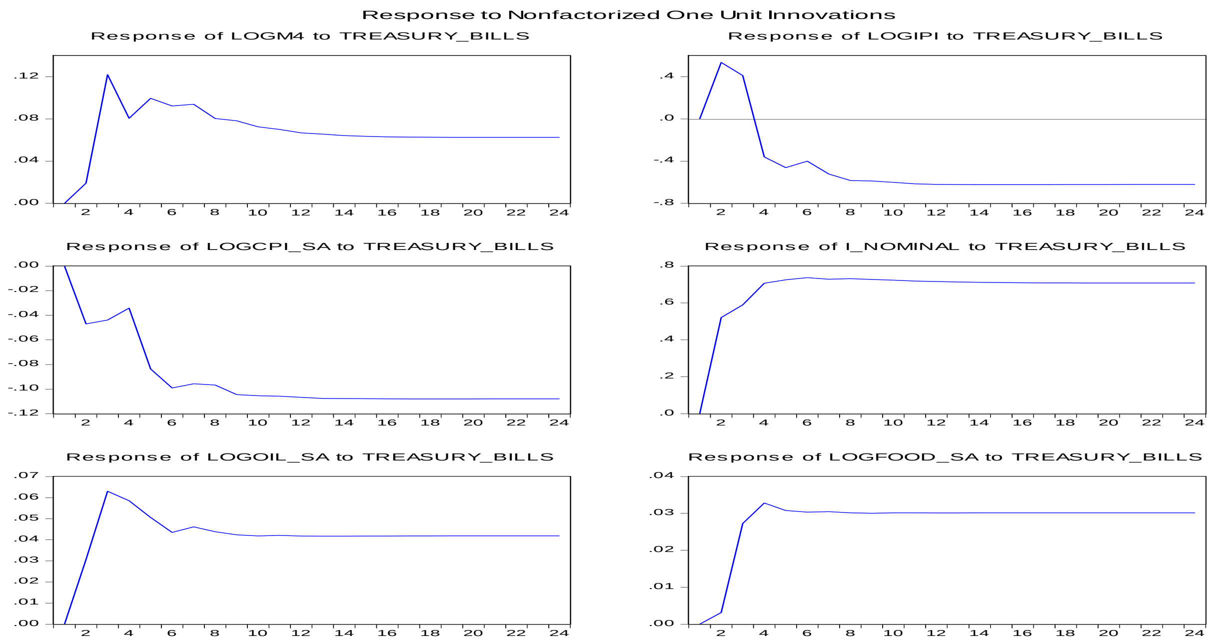
LOGM4(-1)	LOGIPI(-1)	LOGCPI_SA(-1)	LOGI_NOMINAL_SA(-1)	LOGTREASURY_BILLS_SA(-1)	LOGOIL_SA(-1)	LOGFOOD_SA(-1)	C
0.000000	1.942386 (0.25970) [7.47923]	2.666748 (0.47680) [5.59305]	0.000000	-1.000000	0.000000	0.000000	-10.11982

Standard errors in ( ) & t-statistics in [ ]

Error Correction:	D(LOGM4)	D(LOGIPI)	D(LOGCPI_SA)	D(LOGI_NOMINAL_SA)	D(LOGTREASURY_BILLS_SA)	D(LOGOIL_SA)	D(LOGFOOD_SA)
CointEq1	-0.018525	-0.339630	-0.006954	0.002258	-0.000381	-0.001657	0.000334
	(0.01152)	(0.05235)	(0.01100)	(0.01563)	(0.01262)	(0.00531)	(0.00203)
	[-1.60776]	[-6.48798]	[-0.63218]	[0.14440]	[-0.03023]	[-0.31180]	[0.16478]

From the response function (Figure 5.6) money supply respond similarly to the shock in 3-months Treasury bills as to a shock to the nominal interest rates, but the response is slightly postponed by a month. Interestingly, IPI seems to be sensitive to the 1 per cent cut in 3-months Treasury bills since it responds with a sharp increase in the first few months and slowly decreases in the long-term. While the theory of overshooting can be rejected in the first case, from the plot of the impulse response function of commodity prices, the overshooting can be observed in the case of oil prices as well as food prices.

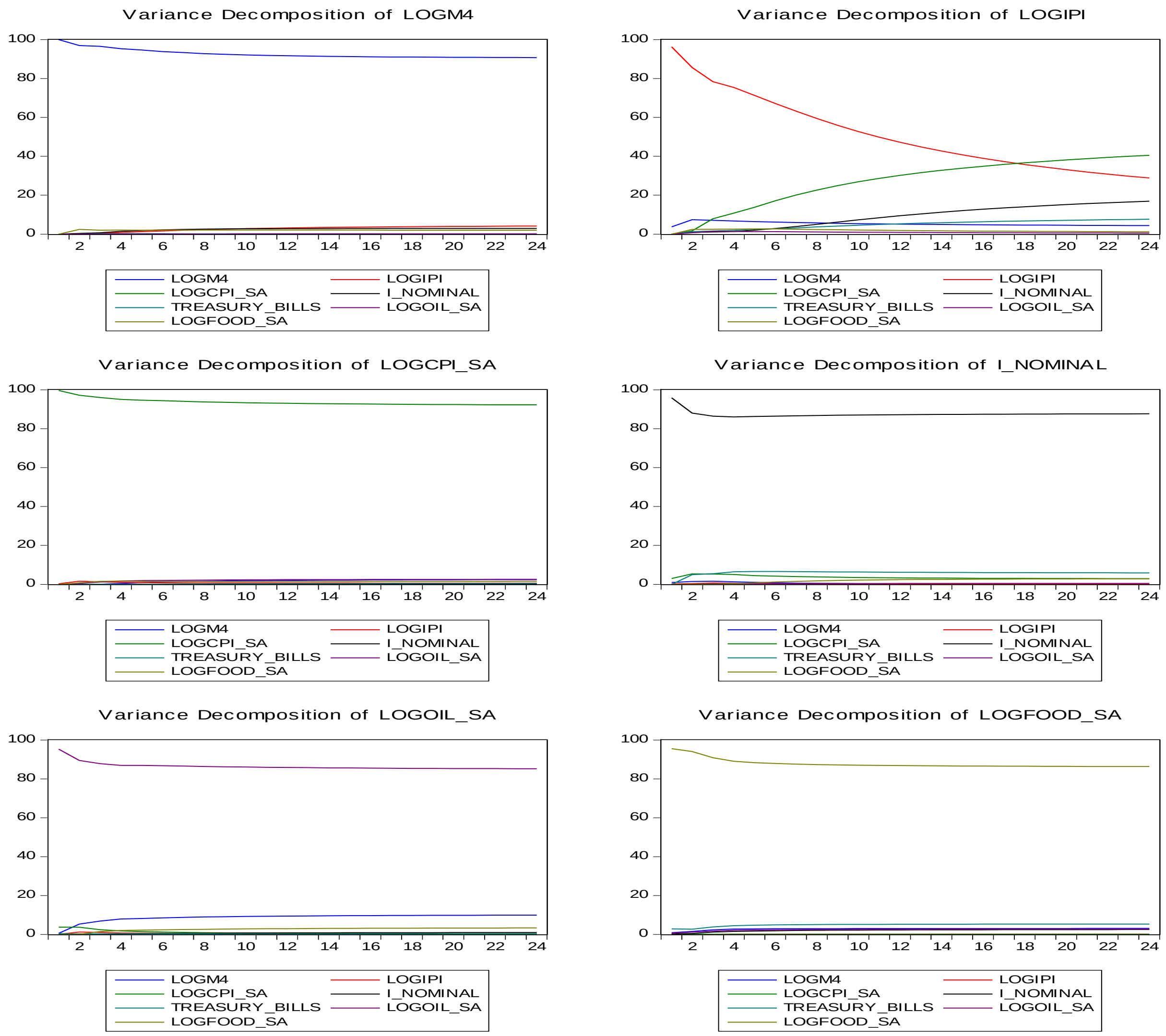
Figure 5.6: Response to the shock in 3-months Treasury Bills



A monetary expansion through lower 3-months Treasury bills rate generates an increase in both oil and food prices. The impact on oil is sharp, peaking 3 months after the shock and decreasing afterwards with oscillation close to the long-term equilibrium. Nevertheless, the effect does not vanish even after two years. Contrary to oil prices, the effect on food prices is not as strong and sharp however, it also peaks in the first half of the year after the shock. Interestingly, the effect vanishes after 18 months when the price returns back to the equilibrium. When evaluating the significance of the commodity price response the country's specifics need to be taken into account. As mentioned at the beginning, there is a rational assumption that the size of the effect of UK monetary policy might be smaller than in the case of the U.S. While results from this study show that a 1 per cent cut in the UK interest rate leads to a more than 0.6 per cent increase in oil prices and 0.3 per cent increase in food prices, the results of Anzuini et al. (2012) show a 3 per cent increase in oil prices, and around 4 per cent increase in food prices as a response to a 1 per cent cut in FED. Even if the response to the UK monetary policy is smaller, considering the position of the UK and the size of economy, results can be considered as notable. Given the considerable significance of UK monetary shocks, it may be interesting to investigate the size of the relative contribution of the shock to overall commodity price fluctuations. This may be done using the forecast error variance decomposition which measures the percentage share of the forecast error variance due to a specific shock at a particular time horizon.

The report of the forecast error variance decomposition is reported in Figure 5.7. Nominal interest rates and inflation explain about 40 per cent of the forecast error of industrial production, but none of the variables seem to provide notable explanation of movements in commodity prices.

Figure 5.7: Forecast error variance decomposition



The results show that in the short-term, movements in food prices may be, to a certain level, explained by the 3-monts Treasury Bills rate supporting the assumption set by Frankel (2007). Nevertheless, the response is low suggesting that the effect of UK monetary policy on potential variations in oil prices is limited (up to 10 per cent) thus not as significant as in the case of larger economies. However, in the long-term, food prices significantly responded to UK inflation as well as to the official interest rate.

5.7 Transmission channels

In the previous part, the estimated model followed the work of Akram (2009), Anzuini et al. (2012) and Arora and Tenner (2012) with adjustments for the variables to UK conditions. Thus, it has been investigated whether monetary policy or developments in the UK industry effect movements in oil prices and food prices. The actual effect has been measured by estimating the money supply shock, output shocks, and inflation shocks as well as interest rates shocks with interesting results. As it was assumed that a positive shock to industrial production could drive the oil prices up, nevertheless the size of the effect was small and only short-term with a peak in the second month after the shock. Understandably, expansion in industrial production leads to decreases in the UK's demand for agricultural products which may consequently drive food prices down. However, as in the case of oil prices, the size of the effect is very small. Therefore the results show that increased production does not affect world commodity prices significantly, therefore considering the size of the UK economy the demand channel in respect to these results will not be considered in this part. However, when investigating the pure monetary channel (interest rates), the results provide a few interesting conclusions. Firstly, commodity prices seem to be more sensitive to 3-month Treasury bills rather than official interest rates. Secondly, the theory of overshooting seems to be working only when using the 3-month Treasury bills. Also, overshooting is more significant in the case of oil prices rather than food prices even though the size of the effect is not much stronger. Interestingly, the effect of the UK money supply shock has a stronger impact on commodity than actual increase in production, leading to the assumption that monetary policy may have a higher importance than an actual state of the UK economy.

Even if the results confirmed an impact of the monetary policy shocks on commodity prices, it would be interesting to investigate the actual channel through which the effect is taking place. Understandably, indirect impacts through expectations of inflation and growth do not seem to be significant. However based on the results, direct channels such as the inventory channel, supply channel or financial channel can be considered (Frankel, 2007). The relevance of these channels has been investigated by Anzuini et al. (2012) as well as Vansteenkiste (2011) and others with mixed results. However, the research is mostly focused on the U.S monetary policy rather than small open economies, including the UK. Therefore, this section investigates possible channels of how the UK monetary policy may affect commodity prices, particularly oil prices, since the size of the effect seems to be more significant than in the case of food prices. The identification of monetary policy shock follows

Kim (2000) since his identification of monetary policy shock for G7 countries has been widely accepted and its reliability has been positively tested by other economists (e.g. Peersman and Robays, 2012 and Sousa and Zaghini, 2007). However, in contrast to Kim (2000), instead of using the call money rate, based on the results in the previous part, this model uses 3-months Treasury bills and the money supply in the UK is not expressed by M1, as Kim suggested, but M4 since M4 is officially taken as a money supply. Another difference can be found in the identification of the effect of monetary policy shock on commodity prices which Kim (2000) expressed as the impact on the world export commodity price index. The argument against using the world export commodity price index is based on the low relevance in channel specification. Contrary to Kim (2000), Anzuini et al. (2012) used U.S industry stocks for the inventory channel, and world oil production for the supply channel. Even if their data seem to be more appropriate for the identification of the inventory and supply channel, a misspecification can be found as well. The argument is that while their examination of the inventory channel is at the national level, the supply channel is investigated at the global level, thus a certain level of inconsistency can be found. Although, the model developed in the following section uses Kim's (2000) identification of the monetary policy effect, the data used are adjusted to the UK country specification and extends Anzuini et al's. (2012) model by adding consistency in the data.

The aim of this section is to investigate the effect of monetary policy shocks on commodity prices through the inventory channel at the national, international and world levels. The assumption behind the distinguishing of inventory stages is based on the size of the economy and possible differentiation of importance. A model which distinguishes between the national, international and global impact of a shock is assumed to contribute to a better understanding of the UK position since the results might not be significant in terms of world impact, but might be significant for Europe.

A similar approach is applied to the supply channel. While Anzuini et al. (2012) examine the affect on the world supply, the model introduced in this section does not only investigate the impact on the world supply, but also considers the aggregation of countries. Therefore when investigating the supply channel, the model examines the effect of a monetary policy shock on the world supply, EU27 supply, IEA supply, OEDC supply and OPEC supply. These possible transmission channels have not been, to the best of the author's knowledge, investigated so far.

5.7.1 Model specification

As discussed in the Chapter 4 (Section 4.3), VAR models are usually used for forecasting. However they are also widely used by central banks to investigate the effects of shocks on a system of variables. This, however, requires the imposing of restrictions on the models (Bank of England, 1999). The formula for identifying restrictions is restricted to those common to a variety of theoretical models (as discussed in Chapter 4, Sections 4.5.1 and 4.5.2). The selection of using VAR model estimation is based on Johansen cointegration results (Appendix B).

Taking into consideration the advantage of using SVAR models in obtaining information about the shocks driving movements in the endogenous variables which are afterwards used to make inferences about the co-movements between variables, the effect of a monetary policy shock on the inventory channel and the supply channel, a five–variable SVAR model is developed where the fifth variable represents an inconsistent variable in respect to measurement. The effects of these five shocks on system variables are evaluated to determine which are statistically significant and how long they remain significant. The structural VAR representation is:

$$A_0 X_t = \alpha + \sum_{i=1}^{p} A_j x_{t-j} + e_t \qquad (5.6)$$

Where p is the lag order, and e_t denotes the vector of serially uncorrelated structural innovations. The reduced-form VAR representation is:

$$x_t = A_0^{-1}\alpha + \sum_{i=1}^{p} A_0^{-1} A_i X_{t-1} + e_t \qquad (5.7)$$

If A_0^{-1} is known, the dynamic structure represented by the structural VAR model could be calculated from the reduced-form VAR coefficients, and the structural shocks e_t can be derived from the estimated residuals $e_t = A_0 e_t$. Coefficients in A_0^{-1} are unknown, so the identification of structural parameters is achieved by imposing theoretical restrictions to reduce the number of unknown structural parameters to be less than or equal to the number of estimated parameters in the VAR residual variance–covariance matrix. When applied to the model developed in this section, the data vectors are logs of monthly data on 3-months Treasury bill, M4, CPI, IP, and X_{oil}, are defined as follows: M4 is the money supply, CPI is the consumer price index, IPI is industrial production index, and X_{oil} represents oil industrial inventories $\{UK_{stock}, OECD_{stock}, OECDEU_{stock}\}$ in the inventory channel and

$\{world_{supply}, EU27_{supply}, IEA_{supply}, OECD_{supply}, OPEC_{supply}\}$ in the oil supply channel. It is convenient to note that the nominal interest rate (i_nom) is excluded from this model due to the low significance found in the previous section. Moreover, as found in Figure 5.2, the decomposition of 3-months Treasury bills shows that movements in 3-months Treasury bills are well explained by movements in nominal interest rates. The same is applied to food commodities as the effect of monetary policy is more significant in the case of oil prices.

The following equations represent identifying restrictions. All restrictions are zero (exclusion) restrictions.

$$\begin{bmatrix} e_{MS} \\ e_{treasury} \\ e_{CPI} \\ e_{ipi} \\ e_{oil} \end{bmatrix} = \begin{bmatrix} 1 & \alpha_{12} & 0 & 0 & \alpha_{15} \\ \alpha_{21} & 1 & \alpha_{23} & \alpha_{24} & 0 \\ 0 & 0 & 1 & \alpha_{34} & 0 \\ 0 & 0 & 0 & 1 & 0 \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & 1 \end{bmatrix} \begin{bmatrix} u_{MS} \\ u_{treasury} \\ u_{CPI} \\ u_{ipi} \\ u_{oil} \end{bmatrix} \quad (5.8)$$

Here e_{MS}, $e_{treasury}$, e_{CPI}, e_{ipi} and e_{oil} are the structural disturbances and u_{MS}, $u_{treasury}$, u_{CPI}, u_{ipi} and u_{oil} are the residuals representing the unexpected movements of each variable by construction. The recursive structure of the structural VAR model is achieved by assuming that not all variables respond to shocks contemporaneously. The money supply equation is assumed to be a reaction function of the Bank of England which sets the interest rate (or money) after observing the current value of money (or interest rate) and the oil supply/oil stocks. However it does not consider the current value of output and price levels. According to Kim (2000) this assumption is valid since there is an information delay in the case of output and price levels, while commodity information and money supply information are published monthly. The interest rate, money and commodities are assumed not to affect real activities contemporaneously while in the commodity equation (supply/inventory) all variables are assumed to have contemporaneous effects. It is convenient to note that based on the discussion in Section 4.8.2 (Chapter 4), the presence of autocorrelation has been tested too. The results of the autocorrelation test can be found in Appendix C.

5.7.2 Granger causality test

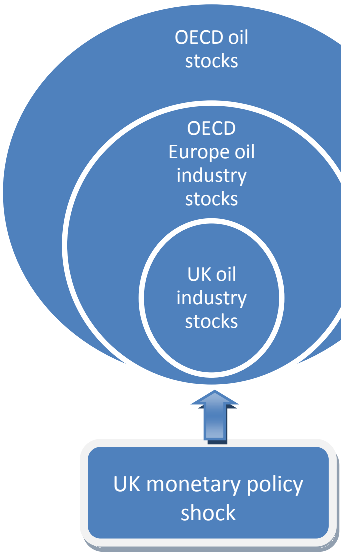
Before progressing to the model estimation, the Granger causality test (Table 5.8) shows some interesting results. For the sake of the space only selected hypothesis are presented in Appendix D. As the results show, the null hypothesis *DTREASURY_BILLS does not Granger Cause DLOGWORLD_SUPPLY* can be rejected ($p<0.05$) suggesting that the current world oil supply is correlated to the past values of UK 3-months Treasury Bills. The same applies to the current values of the UK oil stock and OPEC oil supply. As results show, the relationship between 3-months Treasury bills and world supply works both ways since the null hypothesis of "DLOGWORLD_SUPPLY does not Granger Cause TREASURY_BILLS can be also rejected ($p<0.05$). Nevertheless, this relationship will be investigated in Chapter 6.

Interestingly, the current values of the IEA oil supply are not correlated to past values of UK interest rates. Some expected findings can be driven from the results too. The null hypothesis of "*DLOGOECD_OIL_SUPPLY does not Granger Cause DLOGWORLD_SUPPLY"* can also be rejected. The current values of the UK oil stock, OECD oil supply and IEA oil supply are correlated to past values of the EU27 oil supply. As can be observed from the results, 3-months Treasury bills represents the only variable out of four core variables that affect oil supply or oil stock. This result supports the assumption of the important role played by UK monetary policy. Therefore, the next section breaks down the investigation of different transmission channels and focuses on investigation of the sensitivity and reaction of oil inventories and oil supply at different levels to the shocks in UK monetary policy.

5.7.3 Data

Even if the estimated model is a five-variable SVAR, since the developed model investigates two different channels at the national, international and global levels (Figure 5.8) overall there are twelve variables. The core four economic variables such as CPI, M4, 3-months Treasury bills and IPI have been discussed in Section 5.5. New variables introduced to the model on investigation of the pass-through effect of monetary policy can be split into two groups. The inventory channel includes monthly data during the period of 1992-2013 published by EIA (2013) in billions on UK oil industry stocks, OECD Europe oil industry stocks and OECD oil industry stocks. The information about oil stocks excludes those in the hold of government, since governmental oil stocks are assumed to be affected by other variables rather than monetary policy which is out of the scope of this thesis. Therefore the inventory channel is investigated exclusively at the industry level. The inclusion of UK oil industry stocks as the fifth variable in the model enables the investigation of the behaviour of the industry within an unrestricted relationship. Therefore the direct effect of monetary policy shock on oil industry stocks at a national level can be examined. As already discussed in the model specification, the condition for a SVAR model is imposing restrictions which should be theoretically widely accepted. Since the part of the model which represents monetary policy shock follows (to a certain level) Kim's (2000) model, the inventory channel as well as the supply channel introduced in this chapter can be presented as a novelty to the recent knowledge on the studies on this topic by introducing an extension of the model.

Figure 5.8: Inventory channel



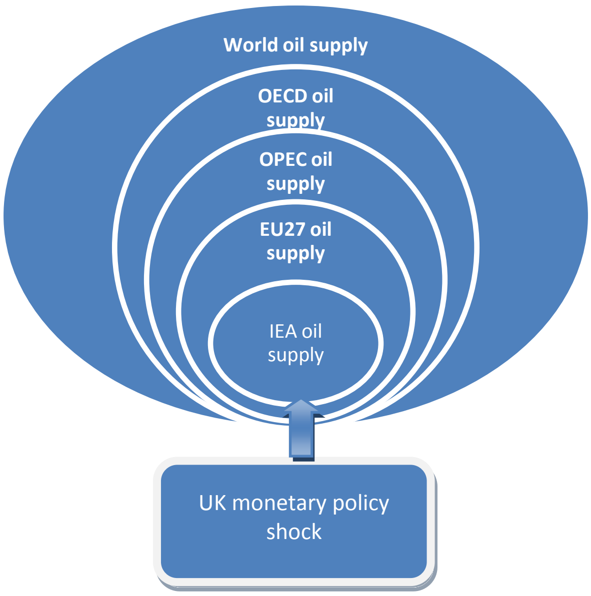
Source: Author

If it is assumed that the theory of storage considers only the effect on world inventories then it would mean that the theory does not apply to smaller countries whose loose monetary policy does not affect world inventories. Nevertheless, there is the possibility of overlooking the effect on national inventories or on members' countries from the same international organisation. Therefore, the theory of storage is tested by a model developed in this chapter. In other words, by examining the sensitivity of oil inventories and oil supply reacts to the shocks in the UK monetary policy, not only at the national level but also within Europe and the world, this model does not only contribute to filling the empirical gap on the effect of UK monetary policy, but also contributes to the knowledge of a well known theory by introducing an extension of the transmission mechanism model.

In the case of the oil supply channel, additional five variables with a monthly frequency $(world_{supply}, EU27_{supply}, IEA_{supply}, OECD_{supply}, OPEC_{supply})$ are added to the core four economic variables. The assumption posted by Frankel (2008) is that lower interest rates increase demand and decrease supply. Since the oil supply tries to hold prices up there will be a decrease in the supply which can be tested at different levels. Since the UK became a net-oil importing country in 1999, an investigation at a purely national level would not contribute to the understanding of the transmission mechanism. More meaningful is the inclusion of the International Energy Agency (IEA) oil supply since it provides information about 28 European countries which are oil net-importers.

For investigating the impact of a UK monetary policy shock at the European level, the EU27 oil supply should provide sufficient information. The rationale behind using data on the EU27 oil supply is that the UK has a very unique position within the Europe union. The decisions taken by policy makers can, but do not necessary have to, follow those taken by the European Central Bank. Therefore it can be assumed that the effect of policy action may have a stronger affect at the European level rather than the global level. The estimation of the effect of monetary policy at different levels (Figure 5.9) may be also beneficial in providing more information when projecting the economic outlook for policy makers in the EU.

Figure 5.9: Supply channel



Source: Author

Nevertheless, to establish more complex empirical evidence, the analysis also focuses on the effect on oil supply from OPEC countries since they represent the main oil producers. Even if the effect on world oil supply is not assumed to be significant in the case of the UK, for comparison with other studies the global effect is still considered as there is not sufficient evidence supporting or rejecting this assumption.

5.7.4 SVAR inventory channel

As discussed in Chapter 3 (Section 3.2.5), holding oil inventories has a cost not only in terms of the fee due to the owner of the storage facilities, but also because of the opportunity cost of using money to buy oil which goes into storage and is not immediately burnt instead of investing the amount needed at the risk-free rate. Understandably, this cost will be lower in an environment of low interest rates and higher in an environment of higher interest rates (Frankel, 2006). Therefore, while expansionary monetary policy may generate the incentives to accumulate inventories, thereby increasing the demand for oil as well as its price, tight monetary policy will lead to giving up inventories due to more attractive investments. To test whether this channel appears to be at work, the model introduced in following part measures the impact of the monetary policy shock on oil inventories.

Following the approach described in Figure 5.8 the first estimated SVAR model investigates the impact of monetary policy shock on the oil industry inventories at the national level. The upper part of the structural VAR model presented in Table 5.9 shows the matrix form and the bottom part estimates coefficients with standard errors. Low standard errors for estimated coefficients suggest that identifying restrictions are correct. The estimated coefficients C1, C7 and C8 are not explanatory variables applying that the money supply (expressed as M4 = C1) is not an explanatory variable for movements in 3-months Treasury bills. Also, the coefficient of industrial production does not seem to be an explanatory variable neither for 3-months Treasury bills nor for the CPI. Nevertheless, the money supply, as well as interest rates and inflation are explanatory variables for UK oil industry inventories. Positive values of the estimated coefficients of C2, C4 and C9 imply that the UK oil industry inventories increase after observing unexpected increases in interest rates or industrial production and money supply. On the other hand, a negative value of inflation implies that after observing a rise in inflation, oil stocks are cut down.

Table 5.7: UK oil industry inventories

Structural VAR Estimates
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

	Coefficient	Std. Error	z-Statistic	Prob.

C(1)	0.268680	0.194436	1.381842	0.1670
C(2)	0.901628	0.290161	3.107340	0.0019
C(3)	3.047053	0.145585	20.92967	0.0000
C(4)	3.145565	0.253163	12.42503	0.0000
C(5)	0.092947	0.021420	4.339161	0.0000
C(6)	-0.211134	0.034405	-6.136824	0.0000
C(7)	0.045695	0.023332	1.958474	0.0502
C(8)	-0.015285	0.099504	-0.153616	0.8779
C(9)	0.089228	0.040312	2.213459	0.0269
C(10)	0.657689	0.129967	5.060413	0.0000
Log likelihood	-374.8930			
LR test for over-identification:				
Chi-square(5)	1636.716		Probability	0.0000

Interestingly, higher values for coefficients have been estimated for money supply and interest rates, while a lower value for industrial production suggests lower importance. From the results, the value for estimated coefficient C2 is positive (0.9016) suggesting that the UK oil inventories accumulate after observing an increase in interest rates. This is in contrast to the assumption of the theory of storage.

Results become even more interesting when comparing at the national, international and global levels. In Table 5.10, the results for the OECD Europe inventory channel also show that money supply and interest rates (C2 and C4) play important role, nevertheless, slightly lower values of their coefficients suggest a still significant but lower importance compared to the national level. Again, the positive value of estimated coefficient C2 suggests the accumulation of OECD Europe oil inventories after observing an increase in interest rates. While in the previous case industrial production in the UK was an explanatory variable for the UK industry oil stock, in the case of European oil inventories the coefficient of UK industrial production (C9) is not found to be explanatory variable since p(0.1701) > 0.05. Although OECD Europe oil industry inventories are not found to be explanatory for M4, but interestingly while in the previous case C7 (oil inventories) were not explanatory to 3-months Treasury bills, in this case it seems to be explanatory since C7(0.0448)<0.05. Nevertheless, it is convenient to note that the value (0.0448) is close to 0.05 thus the result must be taken with caution. Also the results from Table 5.10 reveal that 3-months Treasury bills are not explanatory to OECD Europe oil industry inventories.

Table 5.8: OECD Europe industrial oil inventory

Structural VAR Estimates
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.268261	0.193026	1.389765	0.1646
C(2)	0.866241	0.256588	3.375995	0.0007
C(3)	3.048970	0.146714	20.78170	0.0000
C(4)	3.000006	0.235928	12.71577	0.0000
C(5)	0.104580	0.022785	4.589954	0.0000
C(6)	-0.227600	0.032518	-6.999113	0.0000
C(7)	0.050256	0.025048	2.006338	0.0448
C(8)	-0.003812	0.099504	-0.038309	0.9694
C(9)	0.054366	0.039627	1.371929	0.1701
C(10)	0.704983	0.115899	6.082738	0.0000
Log likelihood	-342.8394			
LR test for over-identification:				
Chi-square(5)	1639.281		Probability	0.0000

While in the previous two models the estimated coefficients have low standard errors and are significant, in the case of a more global context (Table 5.11) the importance of previous coefficients is questionable. Interestingly, the money supply with standard error 0.62 does not seem to be an explanatory variable for movements in OECD oil inventories, since the p-value (0.3261) for C2 >0.05, while coefficient of interest rates (C4) is explanatory, but its negative value suggests cuts in OECD oil inventories after observing an increase in interest rates, confirming the assumptions of theory of storage. In the previous cases, an opposite reaction of oil inventories could be observed. In a more global context, the reaction of oil inventories differs and confirms the assumption formulated earlier, that the investigation on different levels is important. The only coefficient with significantly low standard error and sufficient significance is price inflation (C6 with $p<0.05$).

Positive value of estimated coefficient C6 (0.3309) suggests an accumulation of oil inventories within OECD countries after observing an acceleration in UK inflation. Given the importance of inflation targeting in the UK, a rise in inflation under the assumption of anchored expectations understandably leads to the formulation of expectations about the reaction of the BoE. The oil inventories are therefore accumulated after observing a rise in inflation due to an expected rise in interest rates, which may further lead to a higher opportunity cost. It is convenient to note that even the UK interest rates are also found to be an explanatory variable for movements in OECD oil inventories and the negative values confirms Frankel's (2006) assumptions with the value of the coefficient (-1.839) lower (but still significant) than in the previous two models.

Table 5.9: OECD industrial oil inventory

Structural VAR Estimates
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

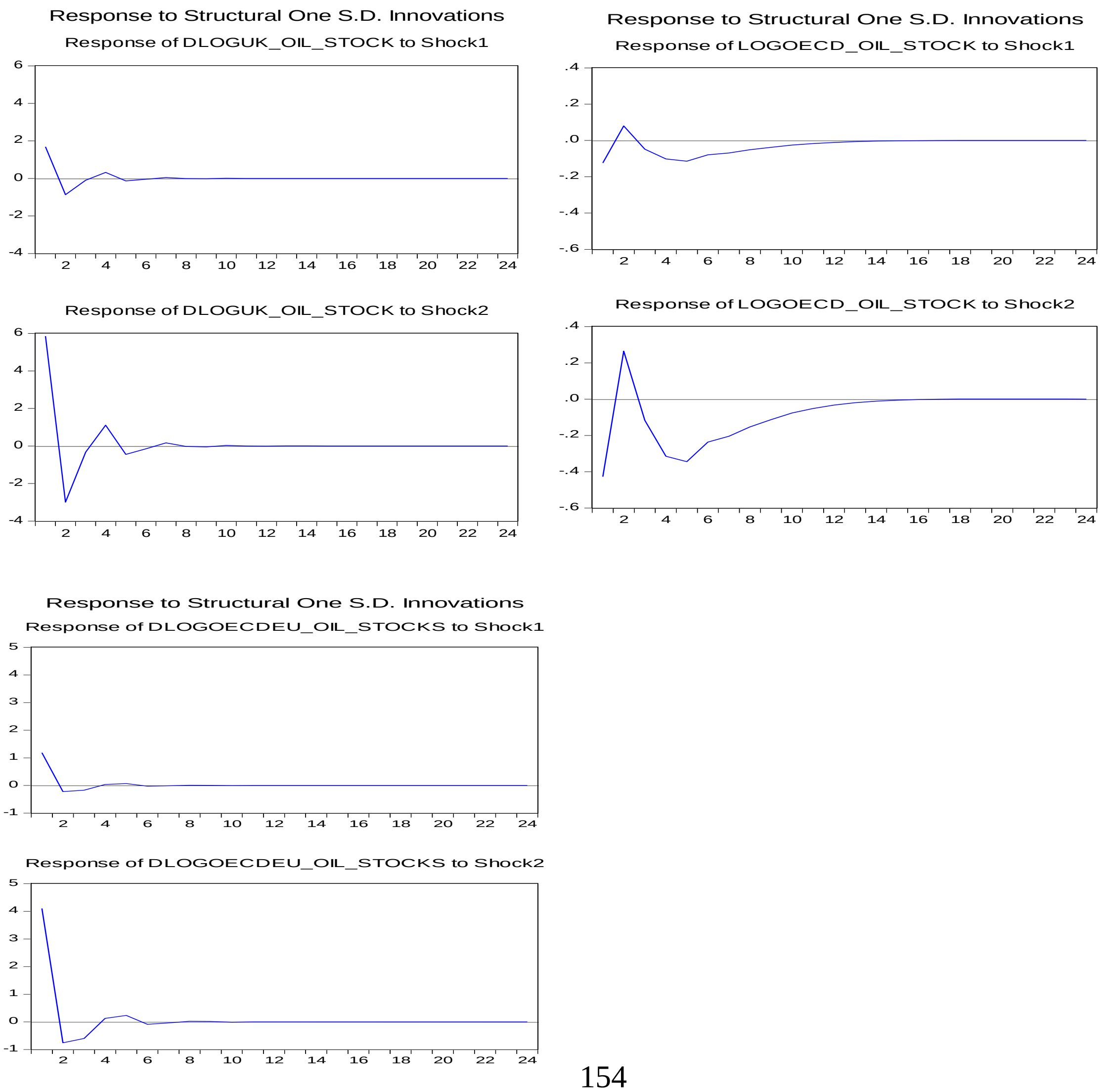
	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.302769	0.178864	1.692736	0.0905
C(2)	-0.609546	0.620671	-0.982076	0.3261
C(3)	2.761231	0.136482	20.23151	0.0000
C(4)	-1.839225	0.296920	-6.194356	0.0000
C(5)	0.064267	0.018957	3.390146	0.0007
C(6)	0.330911	0.064546	5.126769	0.0000
C(7)	0.043023	0.020007	2.150426	0.0315
C(8)	-0.030189	0.099504	-0.303391	0.7616
C(9)	-0.040902	0.072459	-0.564483	0.5724
C(10)	-0.520704	0.129691	-4.014967	0.0001

Log likelihood	-231.8365			
LR test for over-identification:				
Chi-square(5)	1292.232		Probability	0.0000

From the Table 5.11 it can be assumed that the movements in global oil inventories will be dependent on other variables than those included in this model. Nevertheless these results are rational and also expected. As already noted the assumption of a lower effect of the UK monetary policy at a global level can be to a certain level explained by the size of the economy and its relative position in a global context.

More accurate conclusions from dynamic of the shocks can be driven from the impulse response functions that show the response of oil inventories at different levels to monetary policy shocks which have been estimated in two ways. The first shock represents an unexpected movement in money supply while the second shock is modelled as an unexpected movement in interest rates. The results of the impulse response functions are presented in Figure 5.10.

Figure 5.10: Impulse response function to a one unit monetary policy shock



The argument proposed by Frankel (2007) is that higher interest rates lead to decreases in firms' desire to carry inventories. From Figure 5.10 the upper left graph shows the response of UK industrial oil inventories to structural shocks in UK monetary policy. While the first shock represents the response of UK oil inventories to a shock in money supply, the main shock is an increase in interest rates. Oil inventories are found to respond to a 1 per cent increase in interest rates with a sharp 9 per cent drop in the first three months. The effect of the shock dies off after eight months, confirming Frankel's (2007) short-term assumption. Interestingly, the response of oil inventories in OECD Europe countries to monetary policy shock shows a smaller but significant response. In the first three months the inventories drop by more than 5 per cent as a response to the increase in interest rates. As in the previous case, the effect dies in eight months. Different effects can be observed when estimating the response of OECD industrial oil inventories to the shock in UK monetary policy. In contrast to the national or international level, the global impact is very small since a 1 per cent increase in interest rates leads to a very small increase of 0.2 per cent in the second month followed by a decrease in oil inventories in the following four months. The effect is more persistent than in previous cases and dies in a year after the shock. Indeed, a smaller impact at a global level is not surprising. Nevertheless, even if the impact is not as strong as at the national or international levels, results are comparable with Anzuini et al. (2012) who came to a similar conclusion when analysing the impact of US monetary policy shock on OECD inventories.

Since the results show significant effects of UK monetary shocks at all levels it may be interesting to investigate the relative contribution of shocks to overall oil inventories fluctuations. This can be done by means of a forecast error variance decomposition, which measures the percentage share of the forecast error variance due to a specific shock at a specific time horizon. Results presented in Table 5.12 report the forecast error variance decomposition of the oil inventories at all levels with respect to the monetary shocks. The horizons at which forecast errors are calculated are 24 months and are indicated on the x-axis. In all the cases, the shock to interest rates explains most movements in oil inventories, but it does not explain all the fluctuations in prices. Overall, it can be concluded that UK monetary policy shocks, particularly unexpected movements in interest rates, may help to predict movements in oil inventories, however they cannot explain all fluctuations especially at a global level. This result is in line with study of Barsky and Kilian (2002) and Frankel (2007) who came to the conclusion that the most significant impact on commodity prices can be caused by interest rates.

Table 5.10: Variance decomposition of the shocks

UK_oil_stock

Period	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5
1	9.889051	4.189802	87.65216	0.048707	0.016805	8.092525
2	11.70665	4.201569	87.69998	0.041328	0.017513	8.039612
3	11.79481	4.202336	87.68293	0.043740	0.017310	8.053683
4	12.03716	4.203734	87.66733	0.043241	0.017149	8.068551
5	12.03725	4.203504	87.66544	0.043936	0.017207	8.069918
6	12.04569	4.203227	87.66610	0.043855	0.017238	8.069577
7	12.04579	4.203223	87.66608	0.043856	0.017258	8.069581
8	12.04996	4.203247	87.66587	0.043861	0.017256	8.069769
9	12.05000	4.203248	87.66585	0.043876	0.017257	8.069764
10	12.05005	4.203241	87.66587	0.043877	0.017258	8.069757
11	12.05005	4.203241	87.66587	0.043878	0.017259	8.069757
12	12.05010	4.203241	87.66586	0.043879	0.017259	8.069758

Factorization: Structural

OECD_oil_stock

Period	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5
1	1.140766	4.307551	88.67762	0.272167	0.038378	6.704287
2	1.212814	4.330715	89.84939	0.115694	0.019458	5.684746
3	1.296790	4.345779	89.85884	0.080028	0.023353	5.692004
4	1.323053	4.349433	89.97193	0.073217	0.021754	5.583664
5	1.342038	4.352515	90.05955	0.066381	0.023154	5.498401
6	1.357656	4.351353	90.13626	0.062525	0.023690	5.426169
7	1.372957	4.352520	90.18990	0.059631	0.024651	5.373302
8	1.385164	4.352596	90.22927	0.058228	0.025123	5.334781
9	1.395436	4.352864	90.25948	0.056900	0.025561	5.305193
10	1.403586	4.352889	90.28265	0.055863	0.025855	5.282744
11	1.410576	4.353009	90.30030	0.055047	0.026108	5.265532

12	1.416332	4.353085	90.31401	0.054448	0.026292	5.252164

Factorization: Structural

OECDEU_oil_stock

Period	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5
1	6.661911	5.139348	85.09991	0.097787	0.038168	9.624788
2	10.39939	5.144962	85.20899	0.089532	0.038196	9.518325
3	12.72004	5.140747	85.22115	0.091223	0.038378	9.508503
4	12.87588	5.140211	85.23079	0.090783	0.038751	9.499470
5	12.88179	5.139956	85.22994	0.090678	0.038723	9.500705
6	12.90503	5.139927	85.23163	0.090564	0.038741	9.499136
7	12.91540	5.139923	85.23162	0.090565	0.038741	9.499149
8	12.91934	5.139911	85.23166	0.090565	0.038746	9.499123
9	12.92300	5.139911	85.23165	0.090569	0.038746	9.499122
10	12.92410	5.139911	85.23166	0.090569	0.038746	9.499118
11	12.92413	5.139912	85.23166	0.090570	0.038746	9.499117
12	12.92420	5.139912	85.23166	0.090570	0.038746	9.499117

Factorization: Structural

5.7.5 SVAR supply channel

An environment of loose/tight monetary policy may not only affect the fundamentals of the oil market via the incentives to accumulate/give up inventories. A low interest rate policy causes the opportunity cost of leaving oil in the ground with the expectation of selling it later for a higher price may be higher. Therefore, producers will prefer to extract oil immediately and invest the revenue when monetary policy is tight and postpone the extraction of oil during low interest rates. Thus, based on this assumption in an environment of tight monetary policy, it may be possible to observe the increase in oil supply. This understandably may lead to increases in supply. However, in the event of easing monetary policy the opportunity cost is high, therefore suppliers may prefer to postpone extraction and therefore decrease the supply of oil. Following the approach described in Figure 5.9, the estimated SVAR model for IEA oil supply investigates the impact of easing monetary policy shocks (restriction set as -1) on the oil supply at a national level. The upper part of a structural VAR model, presented in Table

5.13, shows the matrix form and bottom part estimated coefficients with standard errors. Low standard errors for estimated coefficients suggest that identifying restrictions are correct.

Table 5.11: IEA oil supply

Structural VAR Estimates
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	-1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.201678	0.279193	0.722360	0.4701
C(2)	0.725889	0.015147	47.92299	0.0000
C(3)	-3.859246	0.208295	-18.52776	0.0000
C(4)	-3.294314	0.200311	-16.44596	0.0000
C(5)	0.040474	0.032477	1.246230	0.2127
C(6)	-0.003766	0.013577	-0.277383	0.7815
C(7)	0.052360	0.032780	1.597343	0.1102
C(8)	-0.024081	0.109764	-0.219387	0.8263
C(9)	0.113783	0.013583	8.376947	0.0000
C(10)	1.186718	0.135033	8.788358	0.0000

Log likelihood	-276.2327		
LR test for over-identification:			
Chi-square(5)	1414.669	Probability	0.0000

The last line of the matrix in the upper table shows the estimated equation for the IEA oil supply. The coefficients are significant except for price inflation (C6, $p>0.05$). Interestingly, higher values for coefficients have been estimated for money supply (C2=0.72) and industrial production (C9=0.11). Since the assumption is that easing monetary policy leads to cuts in supply, the estimated negative values of 3-months Treasury bills (C4=-3.294) suggest that the IEA oil supply decreases after observing cuts in the UK interest rates. The value of this coefficient is significant ($p<0.05$), and considering the low value of standard error (0.20) it can be assumed that the monetary policy in the UK has an effect on the movements in the oil supply and therefore indirectly may affect the oil prices. However, this cannot be concluded without considering an international perspective which is presented below. The results become even more interesting when comparing within the national, international and global levels. In Table 5.14, the results for the European oil supply also show that the money supply and interest rates play an important role. The negative value of the coefficient for the interest rate (-3.57) confirms the assumption that easing monetary policy leads to cuts in the oil supply in this case too. Also the values of estimated coefficients are higher than in the previous case, suggesting the importance of changes in UK monetary policy within European countries. Interestingly, when compared to previous results, in this case the inflation coefficient is significant ($p<0.05$) with a very low standard error (0.0289) and its value (0.15) is comparable to industrial production (0.12). Therefore it can be assumed that the oil supply in EU countries is also sensitive to movements in inflation and industrial production in the UK.

Table 5.12: EU27 oil supply

Structural VAR Estimates
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	-1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.223548	0.243170	0.919308	0.3579
C(2)	0.850946	0.245343	3.468391	0.0005
C(3)	-3.585949	0.175447	-20.43899	0.0000
C(4)	-3.573729	0.261709	-13.65536	0.0000
C(5)	0.033224	0.023849	1.393064	0.1636
C(6)	0.154781	0.028912	5.353584	0.0000
C(7)	0.054017	0.024127	2.238894	0.0252
C(8)	-0.033866	0.109764	-0.308538	0.7577
C(9)	0.125556	0.033534	3.744146	0.0002
C(10)	0.783093	0.175504	4.461981	0.0000

Log likelihood	-284.3134			
LR test for over-identification:				
Chi-square(5)	1256.664		Probability	0.0000

While in the previous model the estimated coefficient of inflation was significant, in the case of the OECD oil supply (Table 5.15) the importance of inflation in relation to the OECD oil supply is questionable since from the p-value (0.54 >0.05) the variable is not explanatory. On the other side, interest rates as well as money supply coefficients show significant levels, even if their values are lower than in previous cases, suggesting that other variables might be more explanatory for movements in the OECD oil supply. As is observable from these results, the relationship weakens as a broader area is considered.

Table 5.13: OECD oil supply

Structural VAR Estimates
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	-1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.203581	0.267404	0.761324	0.4465
C(2)	0.736103	0.014762	49.86327	0.0000
C(3)	-3.841388	0.204280	-18.80456	0.0000
C(4)	-3.289754	0.194511	-16.91292	0.0000
C(5)	0.042815	0.032523	1.316452	0.1880
C(6)	-0.007803	0.012787	-0.610264	0.5417
C(7)	0.055213	0.032861	1.680217	0.0929
C(8)	-0.024857	0.109764	-0.226454	0.8208
C(9)	0.117183	0.012816	9.143727	0.0000
C(10)	1.183503	0.120962	9.784081	0.0000

Log likelihood	-275.3933		
LR test for over-identification:			
Chi-square(5)	1429.744	Probability	0.0000

In the case of the oil supply in European countries, the coefficients for UK interest rates and inflation are not significant. Different results can be found in the case of oil net exporting countries as well as world oil supply. The low significance of the inflation rate (-0.04) and the interest rate (2.527) in the case of the OPEC oil supply (Table 5.16) signal that the impact of UK monetary policy on the OPEC oil supply may not be very significant. Moreover, a positive value of the coefficient for the interest rate is in contrast to the assumption suggesting that easing monetary policy will stimulate the supply in OPEC countries. The positive value of the coefficient has been found only in this case and will need to be further more investigated. Nevertheless, more insight into the relationship can be driven from impulse response functions that will be discussed in the following section. However, lower coefficients for the OPEC supply compared to previous models confirm the natural assumption that the effect of UK monetary policy will weaken at the global level.

Table 5.14: OPEC oil supply

Structural VAR Estimates
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	-1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	-0.176085	0.319077	-0.551855	0.5810
C(2)	0.517052	0.035759	14.45952	0.0000
C(3)	4.230002	0.252993	16.71981	0.0000
C(4)	2.527313	0.158753	15.91983	0.0000
C(5)	0.064344	0.042063	1.529719	0.1261
C(6)	-0.042068	0.009440	-4.456473	0.0000
C(7)	-0.003338	0.042651	-0.078260	0.9376
C(8)	-0.026318	0.109764	-0.239767	0.8105
C(9)	0.071626	0.010509	6.815917	0.0000
C(10)	1.750509	0.099529	17.58798	0.0000

Log likelihood	-279.2070		
LR test for over-identification:			
Chi-square(5)	1437.385	Probability	0.0000

SVAR models for the OPEC oil supply and the world supply (Table 5.16 and Table 5.17) show similar results, since UK inflation is found to be an explanatory variable at the 5 per cent confidence level. This is an interesting finding. Even the significance of the coefficient is low and markedly lower than at the European level, inflation as well as UK industrial production are still explanatory variables to the movements of world oil supply. Nevertheless, the interest rates with significant and negative values of the coefficient suggest that the world oil supply will also decrease as a reaction to easing UK monetary policy. Cuts in the world supply, assuming demand stays constant, may push the price for oil up. Therefore it can be assumed that world oil prices are, to the certain level, sensitive to UK monetary policy. The results also confirm that even if the UK money supply is important and explanatory for movements in world oil supply, its importance is not as high as in the previous case.

Table 5.15: World oil supply

Structural VAR Estimates
Estimation method: method of scoring (analytic derivatives)
Convergence achieved after 318 iterations

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	-1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

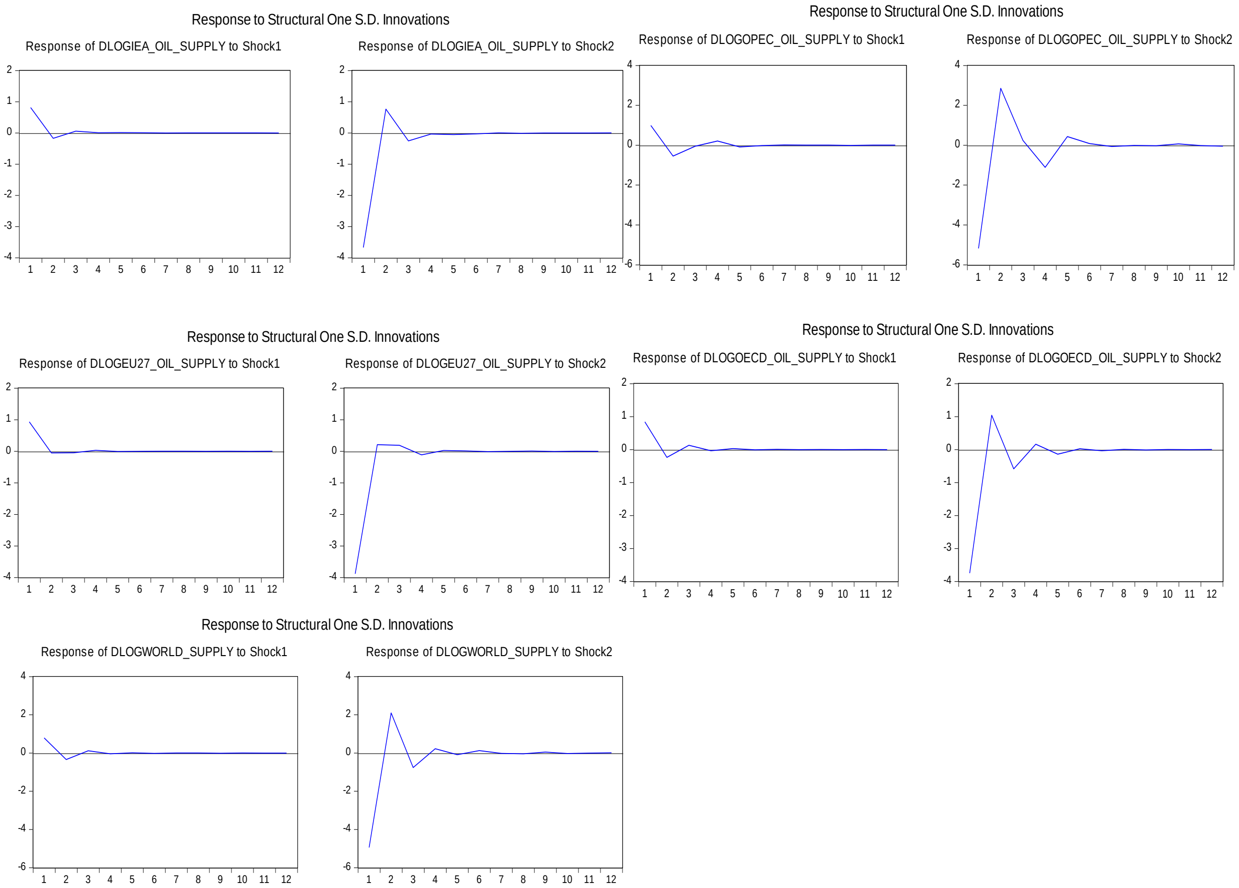
	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.134916	0.407188	0.331337	0.7404
C(2)	0.383535	0.012760	30.05776	0.0000
C(3)	-5.509451	0.320064	-17.21357	0.0000
C(4)	-2.428215	0.157781	-15.38977	0.0000
C(5)	0.044520	0.041434	1.074492	0.2826
C(6)	-0.017350	0.006389	-2.715785	0.0066
C(7)	0.042451	0.041721	1.017510	0.3089
C(8)	-0.024713	0.109764	-0.225148	0.8219
C(9)	0.056092	0.006666	8.414300	0.0000
C(10)	2.241975	0.131362	17.06716	0.0000

Log likelihood	-270.5493		
LR test for over-identification:			
Chi-square(5)	1536.122	Probability	0.0000

From the results, the effects of UK monetary policy and also developments in industrial production weaken as a more global level is taken into consideration. This finding is not surprising; however an important finding is, that the effect on national and international level is significant and should be therefore considered as a possible channel of transmission.

For a better understanding of the impact of UK monetary policy on oil supply at all levels, the impulse response function (Figure 5.11) is plotted at all levels. When plotting the impulse response function of oil supply at different levels as a response to monetary policy shocks, interesting results can be observed. As a reminder, *Shock 1* represents an unexpected movement in money supply and *Shock 2* represents an unexpected movement in interest rates. The assumption here is that lower interest rates lead to decreases in oil supply due to the lower opportunity cost of leaving oil in the ground since there is an expectation of selling it later for a higher price. Therefore a loose monetary policy leads to decreases in oil supply.

Figure 5.11: Impulse response function of oil supply to monetary policy shock



The structural impulse response analysis helps to distinguish dynamic responses of the oil supply at different levels. The upper left graph presents the response of the IEA oil supply to the expansionary monetary policy shocks. While a 1 per cent increases in money supply together with 1 per cent acceleration of inflation lead to 0.5 per cent decrease in the IEA oil supply, a 1 per cent cut in the interest rate slightly increases the oil supply, and continues in decrease afterwards. The effect dies soon, in the third month. A similar, result is obtained from the response of the EU 27 oil supply which shows smaller sensitivity than IEA oil supply, and OECD oil supply which shows higher sensitivity to the shock in UK monetary policy. These results indicate that a smaller response is assumed to be due to the international position of these countries as oil suppliers. Unlike European countries, the response of the

OPEC oil supply to expansionary shocks is a short-term higher than 2 per cent decrease in oil supply as a response to lower interest rates. Overall, the results of the UK position and the global importance of policy makers' decisions can be observed from the bottom left graph. The response of world oil supply to the UK's expansionary monetary policy is smaller, only a 0.3 per cent decrease. However, these results are comparable to the response of world oil supply to the shock in U.S monetary policy. The results of a similar study by Anzuini et al. (2012) show that the oil supply tends to response by a slight decrease in the short-term, however, the effect dies in the third month after the shock confirming the partial role of monetary policy in explaining movements in oil supply.

Since the aim is to investigate the importance of each shock in the UK economy in explaining the sensitivity of oil supply at the national, international and global levels, these questions are addressed by computing forecast error variance decomposition based on the estimated structural VAR model. Variance decomposition analysis with Cholesky decomposition allocates each variable's forecast error variance to the individual shocks. These statistics measure the quantitative effect that the shocks have on the variables (Appendix E). Results report the percentage of the variance of the error made in forecasting due to a specific shock at a specific time horizon. These estimates show the relative importance of each shock in explaining the movements of oil supply. Overall the results suggest that in all the cases, movements in the oil supply are to significant extent explained by their own movements however, the importance of inflation in explaining movements oscillates at about 10 per cent in the case of the IEA oil supply, and about 7 per cent in case of EU countries. As oil producers set production levels based on their predictions about future developments in the world economy, policy decisions in the UK are thus also assumed to be taken into consideration, however they cannot be taken as the only explanatory variables for movements in oil supply.

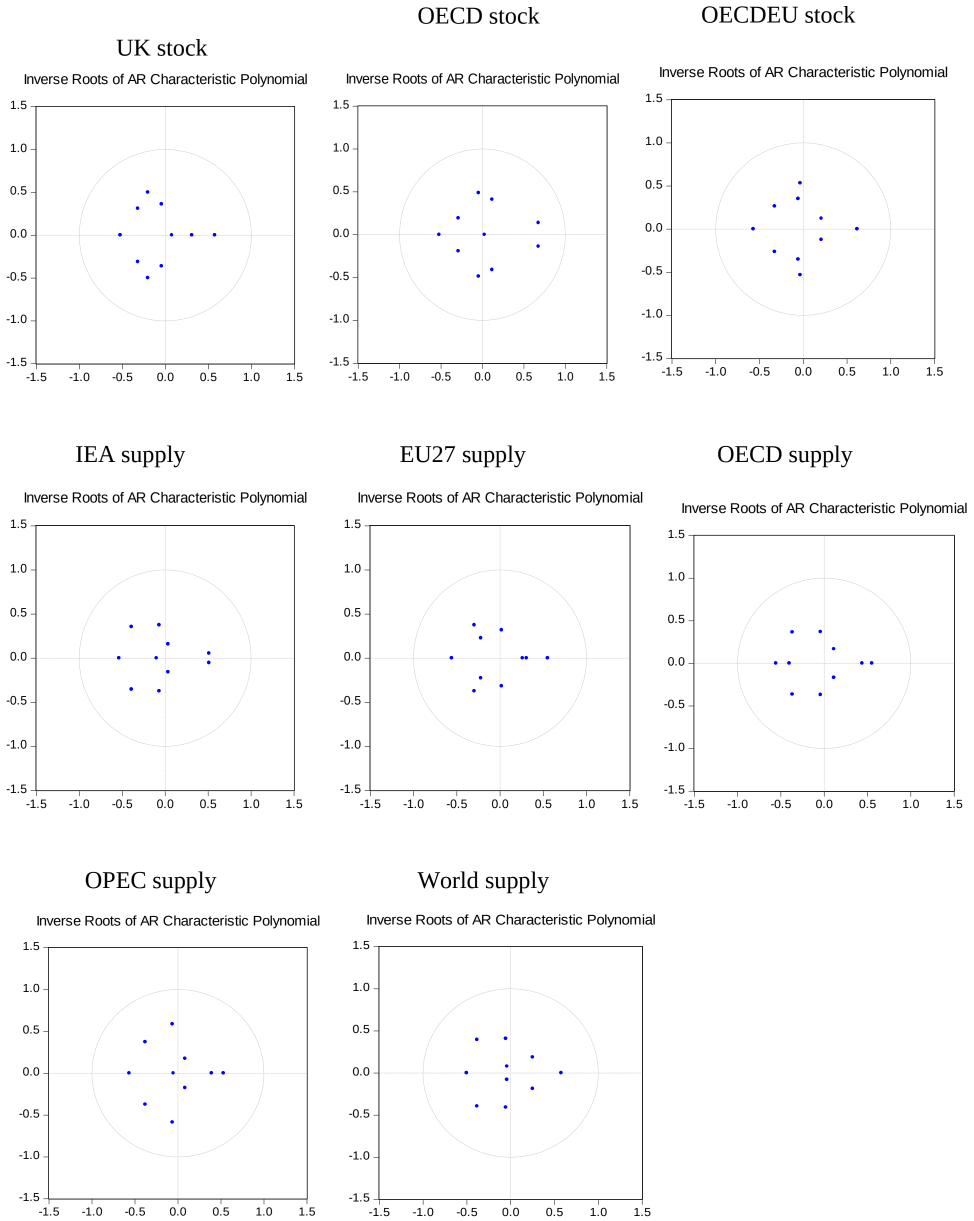
5.7.5.1 Model stability and Robustness check

As discussed in Section 5.2 several of the main contributors in this topic (Frankel, 2006; Arora and Tanner, 2013; Anzuini et al., 2012; and Krichene, 2007) did not consider a possibility of structural breaks in their studies, during the analysed period. Ignoring a potential structural break can lead to misinterpreting results, thus the next part is dedicated to testing the stability of model and investigate potential structural breaks.

5.7.5.2 Model stability

Due to the fact that the VAR models are used to simulate the transmission mechanism, it is important that the model exhibits stability in order to avoid generating unrealistic economic realisations. As such, various diagnostic tests have been performed and are presented below to assess the appropriateness of the VAR model's specification and restrictions. The first test of appropriateness is the assessment of the number of roots created in the AR characteristic polynomial. As presented in Figure 5.12, the first stability condition, which indicates that all roots of the characteristic polynomial are inside the unit circle, is satisfied, so the defined VAR models can be assumed to be stable.

Figure 5.12: Stability checks for models of inventory channels and supply channels



In addition, the possibility for the presence of autocorrelation is also tested and results can be found in Appendix C. Even if the first condition of stability is satisfied, VAR models still cannot be considered as stable until a more advanced method is applied. Therefore, as addition to the stability check, the next section investigates possible structural breaks during the analyzing period, since structural breaks can cause instability of model parameters.

5.7.6 Robustness check

Since the VAR systems are usually estimated over a relatively long sample period, the problem which arises is the main critique of Lucas (1976) that the coefficient describing the impact of monetary policy on macroeconomic variables estimated for one regime cannot be used to simulate the effects of a different monetary policy regime. For a long sample period this critique needs to be taken into consideration. The problem of estimating VAR systems over a relatively long sample period can be observed from parameters and their signs of instability (Rudebusch, 1998; Bernanke and Mihov 1998). Therefore a formal analysis of the stability is essential; applying the sample period used for investigating the transmission mechanism, in this case is 21 years. One of the stability tests, that is widely used and recognized, is the recursive one step Chow stability test, which is used on each VAR equation where large structural breaks can be identified for all system variables at multiple dates. However the Chow stability test is often criticized for its possible misleading results when the breaks are not on-off and the date of their appearance is unknown (Lindé, 2001). To take into account the criticism, the period is therefore split into three periods related to changes in monetary policy operational procedures discussed in Section 3.8 (Chapter 3). The stability is evaluated by estimating the model on a sample which contains only a single known break point. During the period of interest 1992-2013 a few known possible break points could be identified.

- 1992 Oct - 1997 April (beginning of inflation targeting discussed in Section 3.8.1)

- 1997 May - 2007 November (the BoE’s operational independence in November 1997 discussed in Section 3.8.2). However, other changes during this period which are related to the BoE’s operational independence can be found, such as: the inflation target was changed to 2.5 per cent with a 1 per cent tolerance range, better transparency in terms of regular monthly monetary meetings between the Chancellor of the Exchequer and the Governor of the Bank of England, public advices of the BoE to the Chancellor of the Exchequer.

- 2007 December – 2013 September. The official beginning of the financial crisis is taken as the 6th December 2007 when the BoE cut interest rates by a quarter of a percentage point to 5.5% (Bank of England, 2007). This cut was shortly (13 December 2007) followed by an announcement by the central banks (Federal Reserve, European Central Bank, the BoE and central banks of Canada and Switzerland) to provide billions in loans to banks in order to ease the availability of credit. This was coordinated by the U.S Federal Reserve (Edmonts et al., 2010). The decision of the BoE to cut interest rates was not based on a long-term inflation forecast however, it was due to limited liquidity and uncertainty in banking sector, and this can be taken as a possible change in policy strategy.

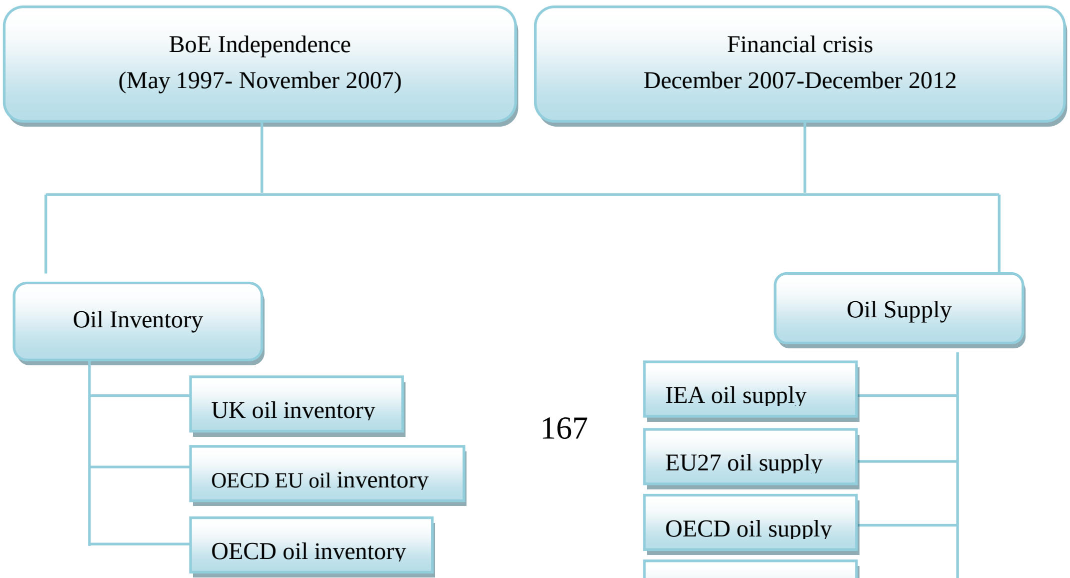
Given the above list of possible changes in operating procedures and the need of having a sufficient number of observations on either side of the potential break, the focus is on the following specific dates:

- The BoE independence in May 1997. The sample period is set from October 1992 to July 2001 giving an equal period before the change and after the change.

- The financial crisis in December 2007. The sample period is set from November 2006 to November 2008.

The stability is evaluated for the inventory channel as well as for the supply channel in respect to the above known potential break points. Given the two particular dates of known changes in operating procedures and the need for having a sufficient number of observations for the identification of potential break, it is necessary to estimate VAR models again in respect to the new time periods. For better interpretation, the following Figure 5.13 shows the sequence of steps in the process of break points identification.

Figure 5.13: The sequence of steps in break points identification



As results from the Chow test (Appendix F) show, for the inventory channel, the BoE's operational independence in May 1997 also meant a structural break in monetary policy. As already mentioned, holding oil inventories has an opportunity cost of using money to buy oil which goes into storage and is not immediately burnt instead of investing the amount needed at the risk-free rate. The day when operational independence was officially given to the BoE is considered as a positive move towards better transparency, since interest rates set by government were often questioned. As outlined by Mihov and Sibert (2006) in his investigation on whether a shift to instrument independence affects central bank behaviour when already operating towards an inflation targeting goal, the greater autonomy of the BoE has played an important role. His estimations show that during the period after obtaining operating independence, the response of the BoE to inflationary pressures ultimately increased with anchored inflation through the output gap. Therefore, it can be assumed that a higher level of transparency and credibility helped to anchor inflation expectations as well as expectations about future developments in interest rates. Thus, in relation to the model of transmission mechanism, results from the Chow test (Appendix F), also confirm these results since the null hypothesis of no structural break can be rejected, for stability the models for the UK inventory channel (1.430>0.2312), OECDEU inventory channel (1.2455>0.298) as well as for OECD inventory channel (1.331>0.265), lead to the necessity of splitting the period into the pre- and after-independence periods. Different results can be observed from the Chow test for the supply channel. In the case of the supply channel, the null hypothesis can be rejected only in the case of the OPEC oil supply (0.712>0.587) and world oil supply (0.886>0.477), while the rest of the models show no structural break on this date.

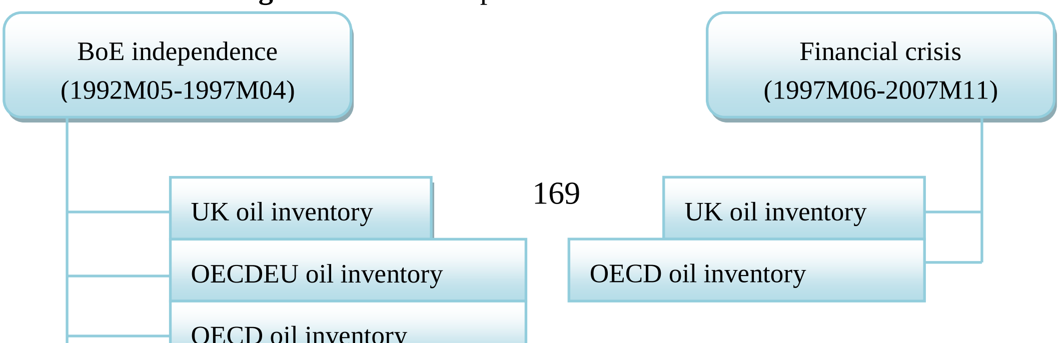
The investigation for the second possible structural break is the beginning of the financial crisis in the UK. The rationale of assuming the financial crisis to be a reason for change in monetary policy can be found in the aim of monetary policy before the crisis, which was to achieve low and stable inflation. The policy framework was inflation targeting with a short-term interest rate as an instrument. The importance of a short-term interest rate on market rates and the wider economy is significant, thus the decisions on setting of interest rates were done with careful consideration of using a wide variety of macroeconomic signals and in a manner that could be approximated with a certain level of reference to the Taylor rule (Section 3.8, Chapter 3). However, as outlined by Joyce et al., (2012) the way interest rates are set changed after the financial crisis. Due to the size of the recession, the Taylor rule would recommend negative nominal interest rates. However market interest rates are effectively bounded close to zero, thus the standard central bank interest rates at or close to zero and the usually reliable relationship between changes in official interest rates and market interest rates also broken, and other forms of monetary policy needed to be considered.

Thus there is a possibility that the financial crisis, which is dated from November 2007, also meant a structural break. As results from the Chow test show (Appendix F), surprisingly in this case the null hypothesis of no structural break can be rejected only in the case of UK oil industry stocks (1.323255>0.3493) and OECD oil industry stock (0.967>0.481) while for OECDEU oil industry stock this date does not represent a structural break. Interestingly, for the supply channels the null hypothesis cannot be rejected in any of the cases, thus all supply channel models are stable in respect to the financial crisis. Even if the null hypothesis of no structural break cannot be rejected, this conclusion cannot be applied for the entire period since there is also a possibility of unknown breaks. However, given the importance of the role of transparency and credibility in an inflation targeting framework, unknown breaks that can be classified as changes in monetary policy are not assumed to appear, therefore unknown breaks in the transmission mechanism developed in this chapter will not be investigated.

5.7.7 Re-estimated models of transmission mechanism in respect to structural breaks

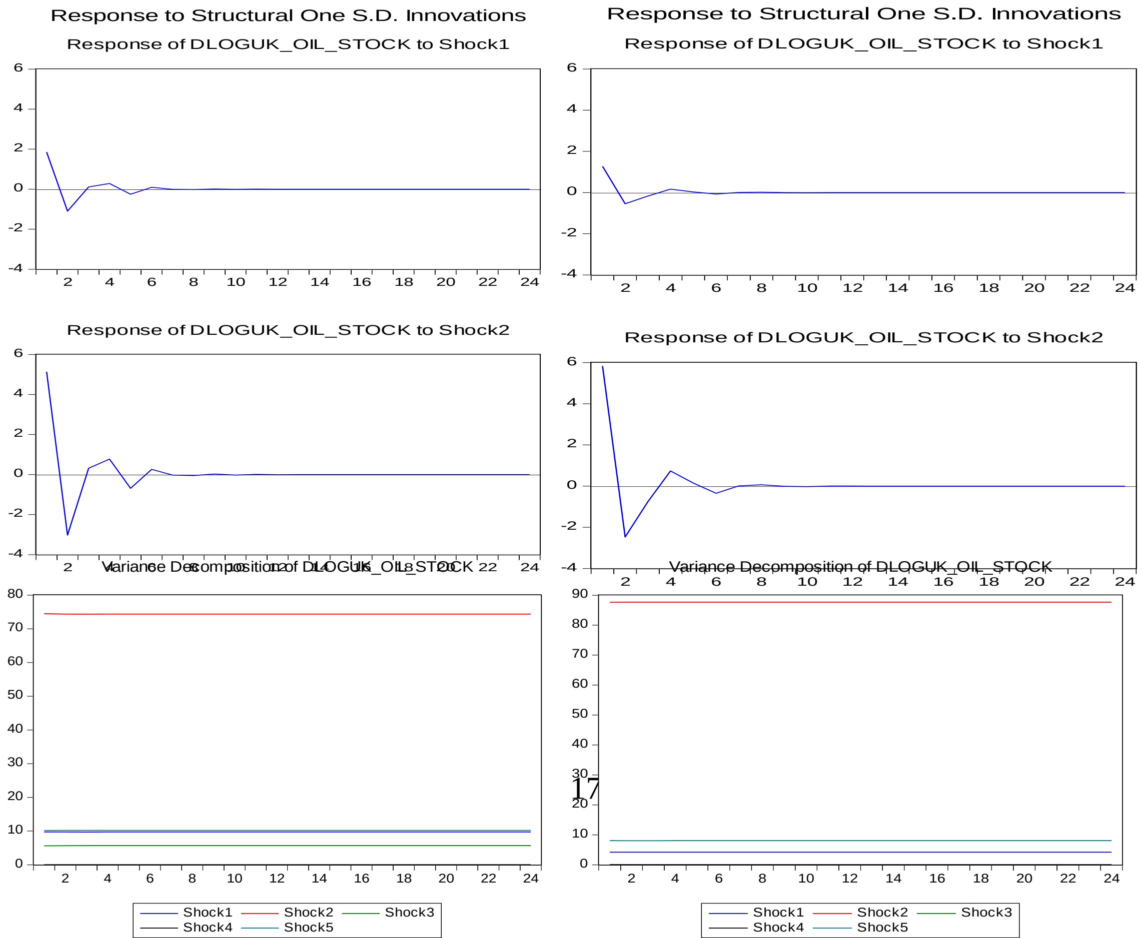
Since in the case of a few of the models, particularly the OECDEU oil inventory, UK oil inventory and OECD oil inventory as well as OPEC oil supply and World oil supply models, one or two structural breaks can be found. In order to investigate the stability of these models, it is necessary to estimate them again in respect to the structural break. The following Figure 5.14 shows the structural breaks identified in specific models.

Figure 5.14: The map of models with structural breaks



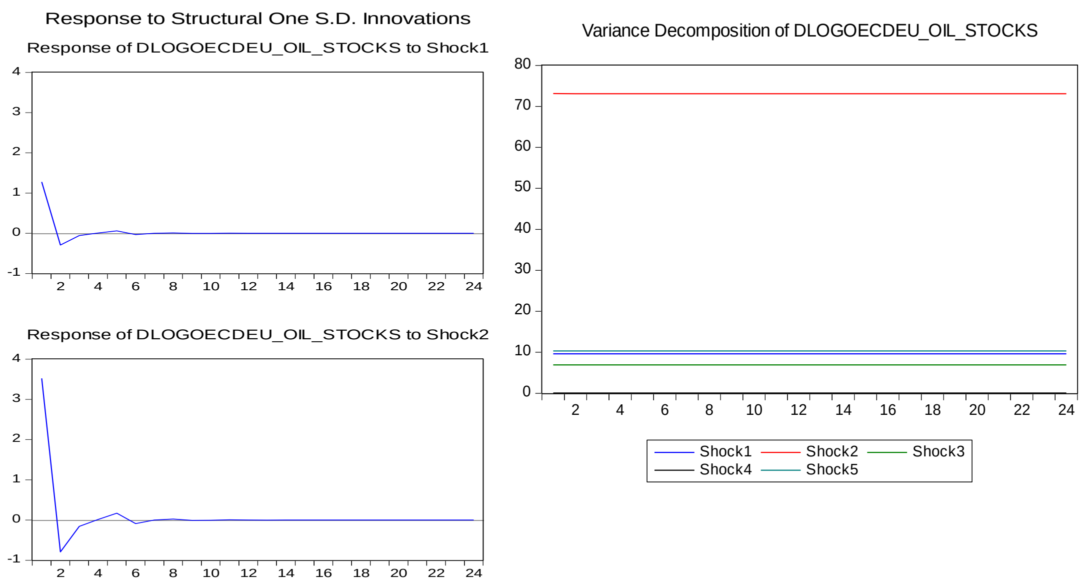
To account for the structural break, each of the models with a structural break is re-estimated again for the period stated in Figure 5.14. Re-estimated SVAR models can be found in Appendix G. The impulse response function of UK oil industry stock (Figure 5.15) to an unexpected movement in the money supply (Shock 1) as well as the response to an unexpected movement in the interest rate (Shock 2) has not changed significantly when compared to the response estimated for a whole period. A slightly smaller response to the second shock can be found during the first period. Interestingly, during the period before the crisis, the response of the UK oil stock to an unexpected increase in interest rates is stronger than it was before the BoE's operational independency (left graph in Figure 5.15) while the response to the shock in money supply is smaller. To some extent this may be explained by better transparency in policy decisions as well as the credibility of the BoE which consequently helps to anchor expectations (Mihov and Sibert, 2006).

Figure 5.15: Impulse response function and variance decomposition for the UK oil inventory



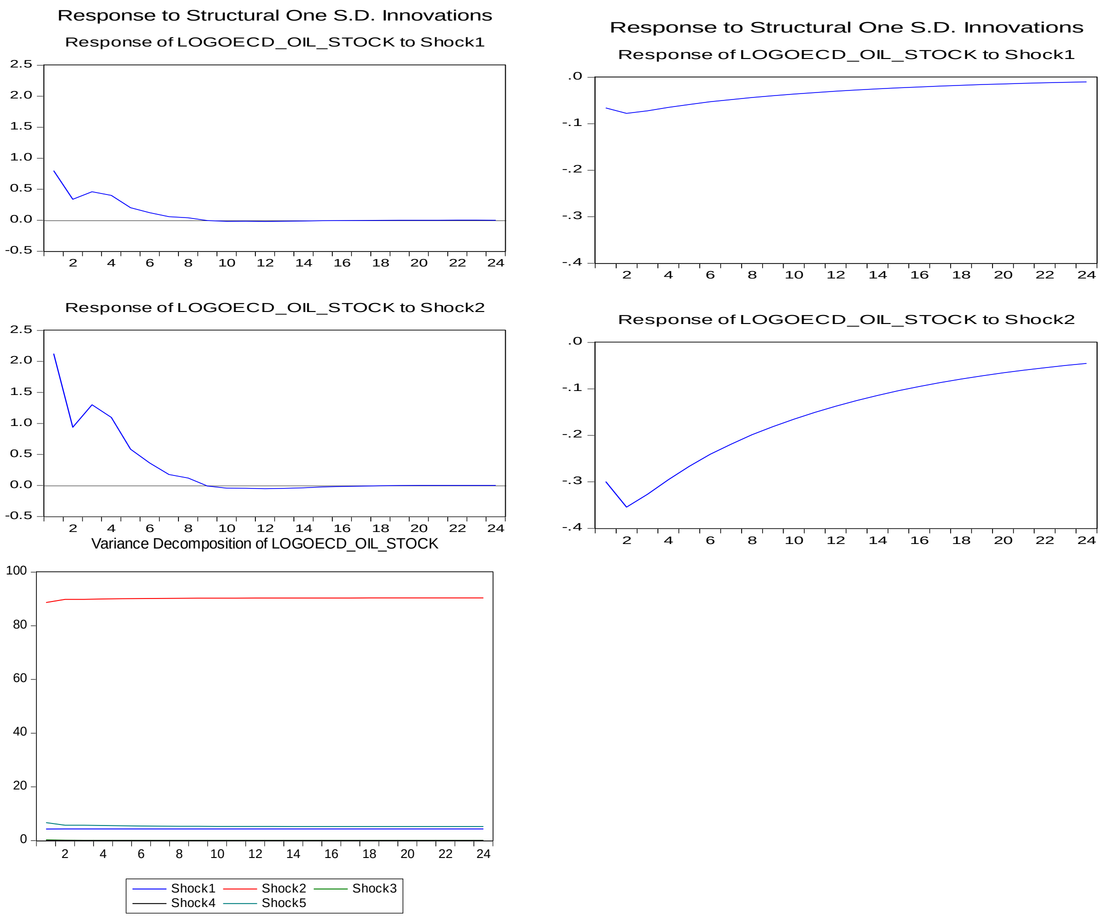
Similar changes in the size of the response to unexpected changes in the money supply and interest rates movements can be found in the case of the OECDEU oil industry stock (Figure 5.16).

Figure 5.16: Impulse response and variance decomposition of the OECDEU oil inventory



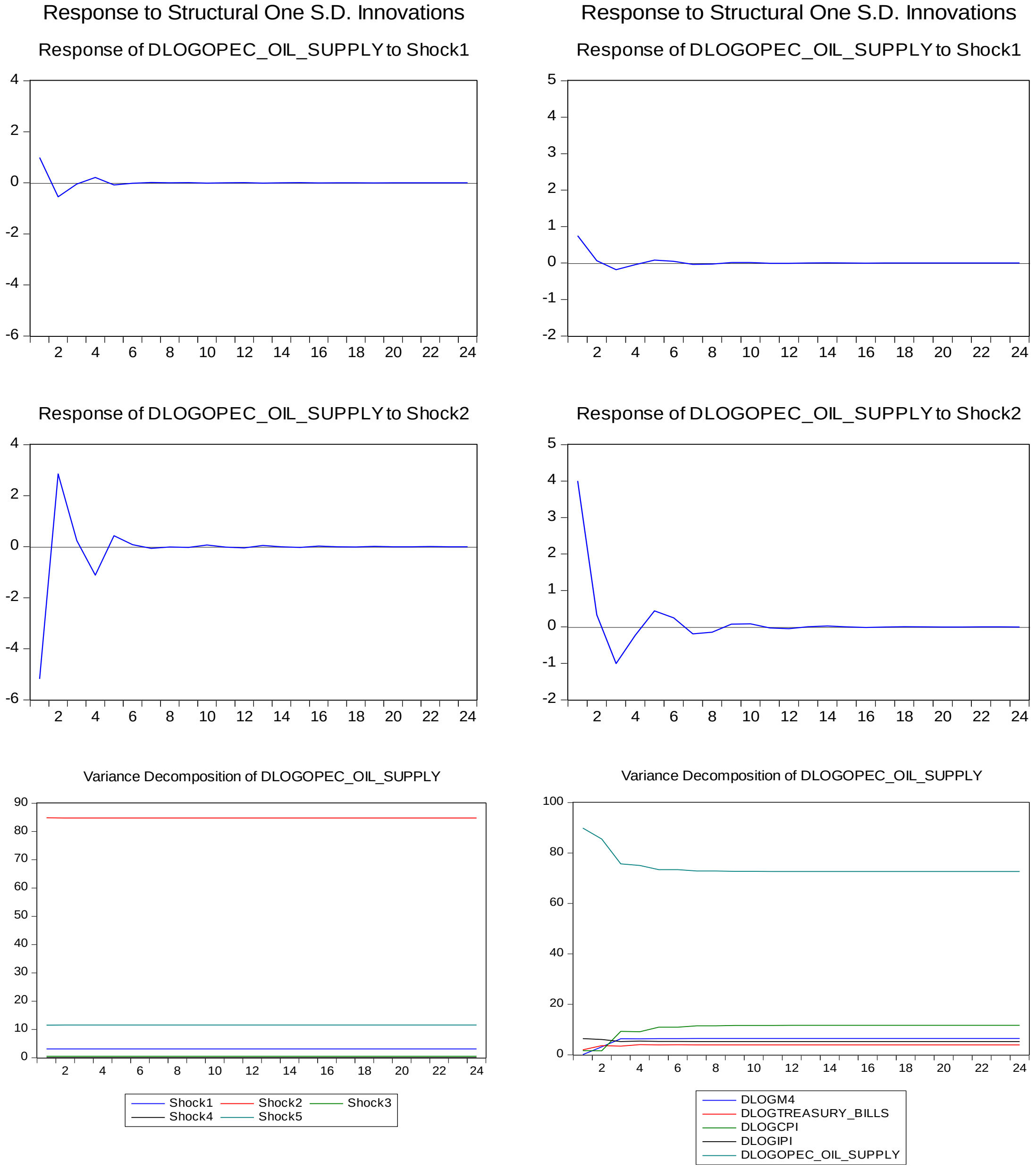
When investigating the impulse response of the OECDEU oil industry inventory to the money supply before the BoE's operational independence and comparing it to the response estimated for the whole period (Figure 5.10), the size of the response has not changed. However, the size of the response to the innovation in interest rates is slightly smaller than for the whole period even though it is the same in principle. Therefore, it can be concluded that before the BoE's operational independence, the decisions of holding oil industrial inventories in EU countries were slightly less sensitive to the policy decisions. In contrast to the results from the impulse response function for the UK oil stock and OECDEU oil stock, the results of the impulse response function for the OECD oil stock differs significantly in respect to both periods (Figure 5.17). While a decreasing response to the innovations in money supply as well as in interest rates can be observed in the first period, the response seems to be small and increasing before the financial crisis. This contrasting response of the OECD oil stock to the money supply shock and interest rate shock after the BoE’s independence is interesting given the importance to the size of the response after 1997.

Figure 5.17: Impulse response function and variance decomposition for the OECD oil inventory



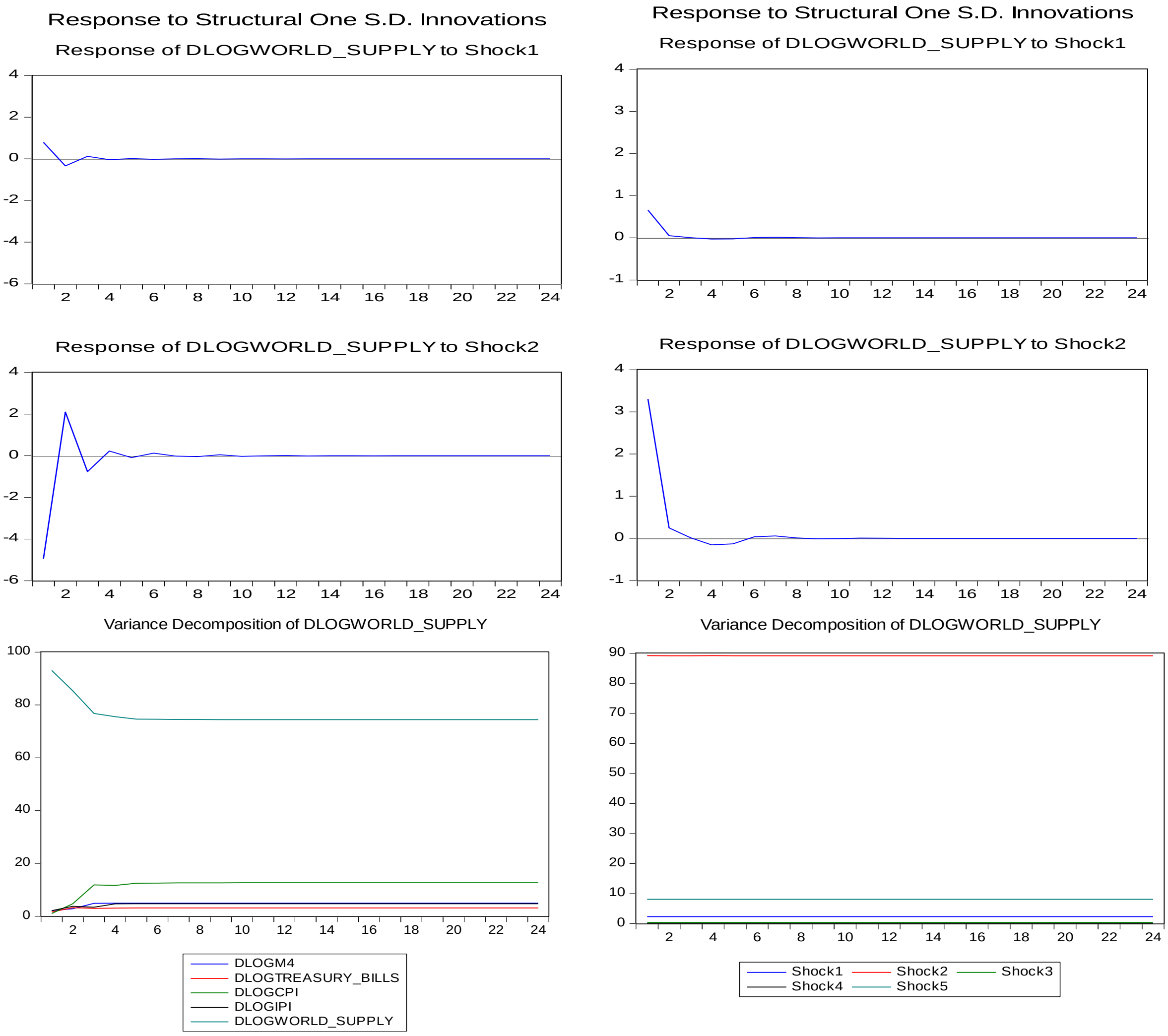
The response of the OPEC oil supply to the shock in money supply has not changed significantly before and after the BoE’s independence (Figure 5.18). The response to the shock in interest rates is significantly stronger. During the period of inflation targeting when interest rates were set by the Government (graph in the left), the shock in interest rates drove the oil supply up by 7 per cent. As observed, the response of the oil supply after the BoE’s independence show a drop by 5 per cent in the first two months following the shock.

Figure 5.18: Impulse response function and variance decomposition for the OPEC oil supply



Similar results can be obtained from the reaction of the world oil supply before and after the BoE's independence. Before the 2007M05 a unit shock to the money supply depressed the world oil supply by 1 per cent however, after the BoE's independence, the sensitivity is 0.8 per cent which is slightly weaker than before. However, even if the money supply does affect the world oil supply, the effect is not as strong as in the case of interest rates.

Figure 5.19: Impulse response function and variance decomposition for the world oil supply



It is interesting that in both cases (OPEC oil supply and the world oil supply) the effect of the oil supply changed direction after the operational independence of the BoE. A unit shock in 3-months Treasury bills, before the breaking point, led to a rise in the world oil supply by more than 6 per cent. While after the breaking point the world oil supply dropped by 3.1 per cent. Even though the size of the effect is not as strong as before, the actual change in direction is interesting.

5.8 Summary

The most up-to-date SVAR models of UK monetary policy and crude oil markets developed in this chapter evaluate the transmission of UK monetary policy across national borders particularly on international oil markets. Although, the findings confirm the results of other authors found in the effect of larger economies, and support the current understanding of the impact of monetary policy on crude oil markets, investigating possible structural breaks in monetary policy is assumed to contribute to a more complex analysis. Moreover, while most of the studies focus exclusively on oil prices and world oil production and supply, the approach adopted in this chapter extends these studies to the investigation of the relationship at the national, international and global levels. The key finding is that expansionary UK monetary policy leads to a statistically significant decline in the OPEC oil supply, while there is a statistically significant, but smaller effect on European oil supply movements. The effect of tight monetary policy seems to have the most significant effect on the UK's industrial oil stock and European industrial oil stock, confirming the assumption of the decline in firms' desire to carry inventories. The impact on the world industrial oil stocks is lower but comparable to the effect of US monetary policy.

Chapter 6 The effect of the different nature of persistent and transitory crude oil and food commodities shocks on the UK economy

6.1 Introduction

The theoretical framework for models introduced in this chapter is derived from the theories introduced in the second section of Chapter 3. The findings driven from econometric models developed in this chapter aim to contribute to recent understanding of the role of commodity prices as an indicator of inflation for a small open economy (the UK) operating under inflation targeting and also contribute to understanding of the sensitivity of the UK economy to developments in commodity markets. The main aim of this chapter is to examine how the movements in crude oil and food commodities impact the UK economy. The objectives formulated in order to achieve this aim are as follows:

1. *To investigate whether the shocks in oil prices and food prices are transitory or persistent for the UK economy.*
2. *To investigate whether different nature of the oil and food commodities shock has also different effect on the UK economy, and to measure the significance of the effect.*
3. *To investigate whether the effect of different nature of commodity shocks on headline inflation and core inflation differs, thus identify the importance of persistent and transitory shocks for the UK economy.*
4. *To investigate whether unprecedented and joined increase in commodity prices also means changes in the impact on the UK economy.*

The next section therefore provides a deeper insight into the problem by discussing the research already done on this topic and continues with preliminary data analysis in Section 6.3 which is necessary for estimating the model introduced in Section 6.4. Sections 6.5 and Section 6.6 focus on developing a theoretical rationale for estimating the model of transition effects under the assumption of different natured commodity shocks. Section 6.7, Section 6.8 and Section 6.9 continue in discussion on the results from estimated models.

6.2 Transition of shocks

Two decades of inflation targeting in the UK brought satisfactory results in terms of a low inflation rate and moderate growth Davis (2014). However, some authors such as Stevens (2003), Bernanke et al. (1999), and Mishkin (1999) disagree with the success of inflation targeting. As they argue, the period of low inflation was achieved due to favourable supply shocks which drove output up and stabilized prices at the same time. As discussed in Chapter 2, commodity supply shocks had been at the centre of attention during the 1970s and early 1980s. Nowadays, it has become clearer that a distinction between the shocks is crucial, as their impact on the economy may differ (Kilian, 2009). This chapter therefore focuses on investigating of the size of the effect of transitory and persistent shocks in commodity prices on the UK economy and their potential role as an additional indicator of inflation. The differentiation of the effect from the different nature of the shock is assumed to provide important implications for policy makers and help to better understand the time-varying sensitivity of the UK economy to movements in commodity markets.

It can also be assumed that commodity prices may act as useful indicator for the monetary authority faced with adverse supply shocks if there is a causal relationship between commodity price and other target variables like inflation and output, provided commodity prices precede the target variables. As discussed in Chapter 3, the link between commodity prices and consumer price inflation can arise through several channels. A negative shock in commodities, driven by global demand for final goods, can pass-through into domestic inflationary pressures, and the size of the effect depends on the openness of the economy. As the economic outlook of OECD (2009) shows, the direct impact of higher commodity prices on UK's domestic inflation during the 2001-2008 was 0.3 per cent in the case of energy prices and 0.2 per cent in the case of food prices. The direct impact on UK's domestic inflation was lower than in the U.S (0.5 per cent in the case of energy and 0.2 per cent in the case of food prices) however higher than the average of France, Germany, Italy and Canada, where the impact was found to be 0.2 per cent for energy prices and 0.1 per cent for food prices. On the other hand, during the years 2006-2008 the direct impact of higher commodity prices on UK's domestic inflation was significantly higher, 0.6 per cent in the case of energy prices and 0.7 per cent in the case of food prices. When compared to other countries such as the U.S, Germany, France, Italy and Canada which experienced only small increase in the size of the impact, the impact on the UK's inflation is the highest.

When assessing the impact of commodity prices on economy, it needs to be considered that commodities are important inputs into production. Persistent increases in commodity prices influence inflation expectations, thus agents may include rising input costs in the form of higher final-goods inflation (Cologni and Manera, 2009). Due to the fact that commodity prices are determined in auction markets, they are assumed to respond to expectations about future supply and demand, while the adjustment of consumer prices is slower. Therefore, it can be assumed that commodity prices may provide early signals of inflationary pressures. As discussed in Chapter 3, it must not be forgotten that crude oil and food commodities are storable thus inventory demand is influenced by expected future prices. This gives commodity prices a forward-looking element (Tkacz 2007). The recent increases in commodity prices have contributed to the global economic downturn in 2000s.

Given the status of a relative necessity and relatively inelastic demand, it could be said that commodities are truly the subject of concerns around the world, but specifically in economies with a high or moderate dependency on commodity import. The vulnerability of oil-importing countries to higher oil prices varies significantly depending on the degree to which they are net importers as well as the oil intensity of the economy. According to the IEA (2004) report, an increase in the oil price by $10 per barrel would lead to a decrease in output measured by GDP in OECD countries by 0.4 per cent in the first year and inflation would rise by 0.5 per cent. The same study also reveals that Euro-Zone countries would experience a slowdown of their economies by 0.5 percent and a rise of inflation by 0.5 percent. In contrast to the European countries, a study by Verheyen (2010) shows that the U.S economy seems to be more resistant to the shocks in oil price. His results show that while in the 1970s and 1980s the size of the effect of an oil price shock on the U.S economy was more significant, in the 1990s and 2000s the effect does not seem to be so significant.

Since it has been proven by previous studies (e.g. Hamilton, 1983, Huang et al. 2005, Kormilitsina, 2011, and Morana, 2013) that increases in oil prices have a negative impact on economic activities in oil importing countries, it is also believed that oil prices, to the certain level, also act as a driver of food prices. Even if oil does represent a direct input for production, this is not true for food prices. Nevertheless, the transmission channel of food prices inflation into the food importing as well as exporting countries can be identified. In the case of food importing countries, food prices may lead to higher import costs and also contribute to a slowdown of the economy by creating pressure on domestic wages.

Remarkable numbers of studies (see below) document the impacts of oil prices on economic activities in developed countries such as the U.S, Japan, New Zealand and Europe. However, only a very few studies investigate the impact of oil prices together with the impact of food prices. As documented by Kilian (2009) the nature of oil price shock is crucial for investigating the actual impact of the shock on the economy. In respect to his findings, a number of studies have been done mainly for the U.S (Blanchard and Galí, 2010; Peersman and Robays, 2012) as well as other countries (Rodríguez and Sánchez, 2005 investigated OECD countries, Cunado and Gracia, 2005; investigated a few European countries, Lescaroux and Mignon, 2009 investigated China, Zhang and Reed, 2008, investigated Japan, Cologni and Manera, 2008, investigated G-7 countries and finally Bjørnland, 2009, investigated the U.S, UK, Germany and Norway).

The most recent study for the UK has been done by Millard and Shakir (2013). Their investigation on the impact of oil shocks on the UK economy shows that the source of the shock does matter, as it indeed affects the size and nature of the impact on the UK economy. Their results also confirm that oil supply shocks lead to larger negative impacts on output and higher increases in inflation while shocks to world oil demand have a smaller and mostly positive impact on UK output. While in similar studies authors focus on commodity prices without considering the different nature of the shock, the novelty in Millard and Shakir's (2013) study can be found in application of Kilian's approach on the UK economy. Their study also supports the argument that even if the UK does not represent a large economy, their results may help to better understand changes in commodity markets, as well as changes in their impact on economies.

Indeed, the position of the UK economy in the commodity market is, with regard to its historical developments in oil and food dependency, interesting. The UK's food dependency can be measured by food self-sufficiency ratio which has been declining from 100 per cent in 1980s to 60 per cent in 2000s (Defra, 2006). According to Defra (2006), reasons behind this trend are numerous and linked with the changes in taste as well as shifts in comparative advantage. Nevertheless, it becomes obvious that the gap (remaining 40 per cent) represent the need for import of food products. Similar situation can be observed from the UK's position in energy self-sufficiency.

The UK turned from being a net energy importer in 1970s into a net energy exporter until the North Sea production reached its peak in 1999. Since then, the UK's crude oil production has decreased and reached the point where import of energy became a necessity, and the UK officially became a net energy importer in 2004 (National Statistics, 2013). Since then the UK has remained an exporter of oil products with 36 per cent of its energy being imported. Nevertheless, even the dependency on import is considerable; the UK belongs to one of the five EU countries with the lowest level of import dependency (European Commission, 2012a). Despite the large declines in oil production, the UK still manages to export 568 000 bbl/d (barrels per day), (out of the total 690 000 bb/d) to EU countries (EIA, 2013a). On the other hand, with oil import at more than 1 million bbl/d, the UK belongs to a group of oil import intensive countries. It may be assumed that the combination of being an oil importer and approaching a certain level of oil export may help to absorb some of the negative effects of oil shocks while gaining the advantage of rises in oil prices. Even if the UK does not hold an important position in world oil or food consumption, it represents a model of an open small-developed country which is an oil importer with increasing dependency on imported food and crude oil. This dependency of the UK on commodities brings the concerns about the sensitivity of the UK economy to commodity shocks as well as implications for policy makers.

Therefore, the main aim of this chapter is to examine the effect of persistent and transitory shocks in commodity prices on the UK economy and also investigate the transmission effect of the different nature of commodity shocks into UK headline and core inflation. This will provide information on whether movements in commodity markets are a good indicator of future inflation in the UK and help to understand the sensitivity of the UK economy to movements in commodity markets.

Thus the outcome of this chapter aims to contribute to the current knowledge on the effects of oil shocks and food shocks in several areas. The research focuses on the UK, a country which is important in terms of openness and level of global integration. Since there is a lack of literature and research focusing on the UK, this research contributes in providing an up-dated analysis on the topic. The period from 1992 to 2013 covers a period of a few structural breaks which, to the best of author's knowledge, have not been investigated in a similar context. The study also extends Killian's argument on the nature of oil shocks to the matter of food price shocks which, again to the best knowledge of the author, has not been investigated for any of the developed countries. This chapter focuses not only on the effect of the different nature of shocks, but also investigates whether these shocks are transitory or persistent in the UK economy by modelling core inflation as well as headline inflation.

6.3 Preliminary data analysis

As discussed in Section 4.11 (Chapter 4), the unit root test of time-series shows that most of the series are non-stationary, but stationary at the first difference. The next step is therefore lag identification so the VAR model can be estimated with an appropriate lag length, followed by the Johansen test for cointegration. In respect to the objectives of this chapter, the estimation of models can be split into two sections. The first section of this chapter follows the study of Harrison et al. (2011) and investigates the existence of a long-term relationship and the possible transitory or persistent nature of commodity price shocks applied on the UK's conditions.

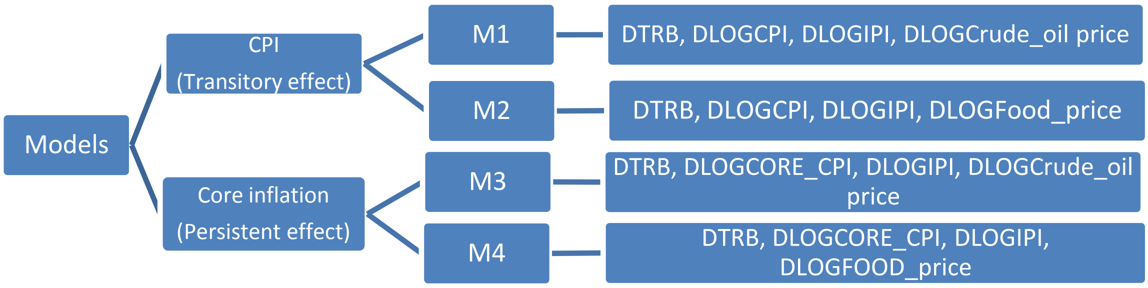
6.3.1 Lag length selection

As findings from the unit-root test show (Table 4.1) most of the variables are non-stationary, and the intention is to investigate whether there is any long-run relationship. Thus, it is necessary to test for a cointegration relationship between series, where the lag length determination for Johansen's cointegration is the first step (see Chapter 4, Figure 4.1). As Hafer and Sheehan (1989) state, the accuracy of forecasts from VAR models varies significantly for alternative lag lengths therefore attention should be paid to an appropriate method of lags selection. The importance of lag length determination is demonstrated by Braun and Mittnik (1993). Their study show that estimates of a VAR whose lag length differs from the true lag length are inconsistent additionally the impulse response functions and variance decompositions are therefore of zero relevance. Due to the non-stationarity of data used, lags are specified as lags in the first difference terms used in the auxiliary regression. Thus a VAR model with first differenced variables can be expressed as:

$$i_t = \alpha_1 \pi_{t-1} + \gamma \pi_{t-2} + \sum_{i=1}^{k} \beta_i Y_{t-i} + \dots z_{t-i} + e_t \qquad (6.1)$$

Where: i_t is the short-term interest rate (3-months Treasury bill), π_t represents inflation, Y_{t-i} represents output measured as an industrial production index, followed by commodities variables generally expressed as z_{t-i}, and e_t represents the error of measurement. Therefore other variables which are not included in the analysis can however be explanatory to i_t. The 4-variables VAR models are estimated from the Equation 6.1. For a clearer picture, Figure 6.1 shows the structure of models estimated in the first section.

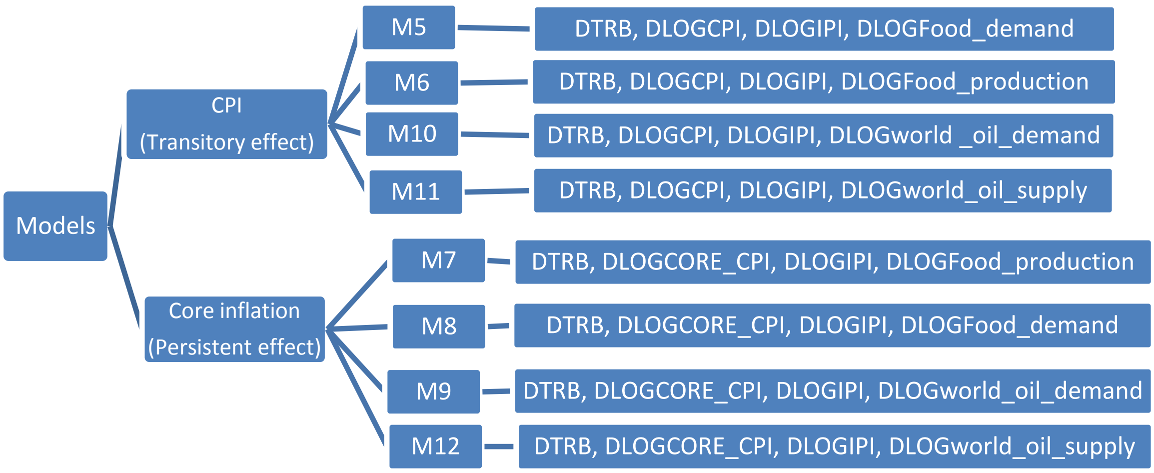
Figure 6.1: Structure of estimated models for Section 1



Source: Author

As a reminder, the first section of this chapter ideologically follows the works of Cologni and Manera (2008) and Harrison et al. (2011) who investigated the effect of oil prices on the economy; however, this chapter extends the investigation to measuring the size of the transitory effect and the persistent effect on the economy. Therefore to identify the persistent and transitory effect on the UK economy, four models (Figure 6.2) are estimated. While the first section focuses purely on the commodity price effect, the second section of this chapter follows the approach introduced by Kilian (2009) as well as the most recent work of Millard and Shakir (2013). Nevertheless, the shocks are not only distinguished by their nature, as introduced by Kilian (2009) and later adopted for the UK by Millard and Shakir (2013), but are also investigated in respect to their transitory and persistent effect on the UK economy.

Figure 6.2: Structure of estimated models for Section 2



Source: Author

Figure 6.2 therefore shows the models estimated in the second section. Each shock is investigated separately in respect to its transitory and persistent effects on the economy. Also, compared to the previous studies, an extension in scope can be found in the inclusion of food markets. The results for the lag length selection for each of the models estimated in this chapter are provided in Table 6.1.

Table 6.1: Lag order selection criteria

Model 1

VAR Lag Order Selection Criteria
Endogenous variables: DTRB DLOGCPI DLOGIPI DLOGCRUDE_OIL
Exogenous variables: C
Sample: 1991M01 2013M09
Included observations: 242

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1214.875	NA	5.30e-10	-10.00723	-9.949559	-9.983997
1	1295.846	158.5978	3.10e-10*	-10.54419*	-10.25584*	-10.42803*
2	1302.249	12.32848	3.35e-10	-10.46487	-9.945850	-10.25579
3	1318.088	29.97652	3.36e-10	-10.46354	-9.713847	-10.16153
4	1329.743	21.67316	3.48e-10	-10.42763	-9.447267	-10.03270

Model 2

VAR Lag Order Selection Criteria
Endogenous variables: DTRB DLOGCPI DLOGIPI DLOGFOOD
Exogenous variables: C
Sample: 1991M01 2013M09
Included observations: 242

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1452.336	NA	7.44e-11	-11.96972	-11.91205	-11.94649
1	1543.430	178.4223*	4.00e-11*	-12.59033*	-12.30199*	-12.47417*
2	1550.433	13.48520	4.31e-11	-12.51597	-11.99696	-12.30689
3	1560.887	19.78521	4.51e-11	-12.47014	-11.72045	-12.16814
4	1568.681	14.49349	4.83e-11	-12.40232	-11.42196	-12.00740

Model 3

VAR Lag Order Selection Criteria
Endogenous variables: DTRB DLOGCORE_CPI DLOGIPI DLOGCRUDE_OIL
Exogenous variables: C
Sample: 1991M01 2013M09

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1110.552	NA	7.15e-10	-9.706593	-9.646429	-9.682318
1	1194.340	163.9017	3.95e-10*	-10.30123*	-10.00041*	-10.17986*

2	1202.856	16.36010	4.22e-10	-10.23558	-9.694104	-10.01711
3	1218.491	29.48634	4.23e-10	-10.23237	-9.450243	-9.916808
4	1236.914	34.09887	4.14e-10	-10.25363	-9.230842	-9.840966

Model 4

VAR Lag Order Selection Criteria

Endogenous variables: DTRB DLOGCORE_CPI DLOGIPI DLOGFOOD

Exogenous variables: C

Sample: 1991M01 2013M09

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1328.205	NA	1.06e-10	-11.61583	-11.55567	-11.59156
1	1417.909	175.4734	5.55e-11*	-12.26236*	-11.96154*	-12.14099*
2	1427.762	18.92904	5.86e-11	-12.20844	-11.66697	-11.98997
3	1439.896	22.88287	6.07e-11	-12.17452	-11.39239	-11.85896
4	1454.366	26.78346	6.15e-11	-12.16111	-11.13832	-11.74844

Model 5

VAR Lag Order Selection Criteria

Endogenous variables: DTRB DLOGCPI DLOGIPI DLOGFOOD_DEMAND_SA

Exogenous variables: C

Sample: 1990M01 2013M09

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1504.920	NA	8.33e-12	-14.15963	-14.09629	-14.13403
1	1569.186	125.4998	5.28e-12*	-14.61496*	-14.29830*	-14.48698*
2	1585.051	30.38378*	5.29e-12	-14.61369	-14.04371	-14.38332
3	1598.484	25.21798	5.42e-12	-14.58947	-13.76616	-14.25671

Model 6

VAR Lag Order Selection Criteria

Endogenous variables: DTRB DLOGCPI DLOGIPI DLOGFOOD_PROD_SA

Exogenous variables: C

Sample: 1990M01 2013M09

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1924.214	NA	7.08e-13	-16.62523	-16.56562	-16.60119
1	1994.462	137.4557	4.42e-13	-17.09491	-16.79687*	-16.97470*
2	2011.114	32.00680*	4.40e-13*	-17.10056*	-16.56408	-16.88418
3	2024.404	25.08316	4.51e-13	-17.07709	-16.30217	-16.76454
4	2033.733	17.28440	4.78e-13	-17.01933	-16.00598	-16.61061

Model 7

VAR Lag Order Selection Criteria

Endogenous variables: DTRB DLOGCORE_CPI DLOGIPI DLOGFOOD_PROD_SA

Exogenous variables: C

Sample: 1990M01 2013M09

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1778.969	NA	9.23e-13	-16.35916	-16.29686	-16.33399
1	1850.962	140.6687	5.51e-13	-16.87522	-16.56371*	-16.74939*

2	1870.554	37.55973	5.33e-13*	-16.90834*	-16.34761	-16.68183
3	1885.696	28.46829	5.38e-13	-16.90042	-16.09049	-16.57324
4	1900.592	27.45870*	5.44e-13	-16.89025	-15.83111	-16.46240

Model 8

VAR Lag Order Selection Criteria
Endogenous variables: DTRB DLOGCORE_CPI DLOGIPI DLOGFOOD_DEMAND_SA
Exogenous variables: C
Sample: 1990M01 2013M09

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1351.301	NA	1.02e-11	-13.96167	-13.89405	-13.93429
1	1424.943	143.4683	5.59e-12	-14.55900	-14.22090*	-14.42208*
2	1441.853	32.24277	5.54e-12	-14.56843	-13.95984	-14.32197
3	1459.804	33.48373	5.43e-12	-14.58865	-13.70958	-14.23265
4	1476.333	30.14557*	5.40e-12*	-14.59412*	-13.44458	-14.12859

Model 9

VAR Lag Order Selection Criteria
Endogenous variables: DTRB DLOGCORE_CPI DLOGIPI LOGWORLD_OIL_DEMANDINT
Exogenous variables: C
Sample: 1991M01 2013M09

Lag	LogL	LR	FPE	AIC	SC	HQ
0	527.2670	NA	5.49e-08	-5.366841	-5.299702	-5.339657
1	615.4612	171.8657	2.62e-08	-6.107295	-5.771602*	-5.971377*
2	627.3385	22.65812	2.73e-08	-6.065010	-5.460764	-5.820358
3	653.8767	49.53813	2.45e-08*	-6.173095*	-5.300295	-5.819708
4	669.4441	28.42041	2.47e-08	-6.168657	-5.027304	-5.706537

Model 10

VAR Lag Order Selection Criteria
Endogenous variables: DTRB DLOGCPI DLOGIPI LOGWORLD_OIL_DEMANDINT
Exogenous variables: C
Sample: 1991M01 2013M09

Lag	LogL	LR	FPE	AIC	SC	HQ
0	570.8987	NA	5.18e-08	-5.424868	-5.360900	-5.399005
1	656.7078	167.5125	2.65e-08*	-6.092897*	-5.773057*	-5.963584*
2	664.3644	14.65384	2.88e-08	-6.013056	-5.437343	-5.780292
3	684.9313	38.57529*	2.75e-08	-6.056759	-5.225174	-5.720544
4	697.7872	23.62031	2.84e-08	-6.026672	-4.939214	-5.587006

Model 11

VAR Lag Order Selection Criteria

Endogenous variables: DTRB DLOGCPI DLOGIPI LOGWORLD_OIL_SUPPLY

Exogenous variables: C

Sample: 1991M01 2013M09

Lag	LogL	LR	FPE	AIC	SC	HQ
0	330.0444	NA	4.13e-09	-7.952302	-7.834902	-7.905168
1	368.0601	71.39532	2.42e-09*	-8.489271*	-7.902266*	-8.253597*
2	376.2074	14.50623	2.94e-09	-8.297742	-7.241134	-7.873530
3	387.6016	19.17564	3.31e-09	-8.185406	-6.659194	-7.572655
4	407.6299	31.75218*	3.04e-09	-8.283657	-6.287841	-7.482368

Model 12

VAR Lag Order Selection Criteria

Endogenous variables: DTRB DLOGCORE_CPI DLOGIPI LOGWORLD_OIL_SUPPLY

Exogenous variables: C

Sample: 1991M01 2013M09

Lag	LogL	LR	FPE	AIC	SC	HQ
0	304.7325	NA	4.30e-09	-7.914012	-7.791342*	-7.864987
1	334.4983	55.61503	2.99e-09*	-8.276270*	-7.662919	-8.031145*
2	344.5284	17.68473	3.52e-09	-8.119168	-7.015137	-7.677944
3	351.4469	11.47018	4.50e-09	-7.880182	-6.285470	-7.242858
4	367.6282	25.12354	4.56e-09	-7.884952	-5.799559	-7.051528

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

The Akaike information criteria as well as the Schwarz information criteria suggest one lag length for most of the models except of the Model 6 and Model 7 (2 lags), Model 8 (4 lags) and Model 9 (3 lags). Lütkepohl (1993) stresses that lags need to be estimated for each model separately since assuming symmetrical lags can lead to an over-fitting (selecting a higher order lag length than the true lag length) causing an increase in the mean-square forecast errors of the VAR, and that under fitting the lag length often generates autocorrelated errors. As mentioned earlier, the AIC criterion is used for lag length selection as discussed in Chapter 4. The results from the test of autocorrelation for all models can be found in Appendix H.

6.3.1.1 Investigation on the presence of a long-term relationship

As discussed in the methodology (Chapter 4), when running the Johansen cointegration test, there are five different models to consider. Ahking (2002) suggests that the first and the fifth model are not so realistic, particularly the model without an intercept or trend in the CE or VAR, and the model with the intercept and the quadratic trend in the CE, and the intercept and linear trend in the VAR; however, there are still three models to choose from. Johansen (1992) suggests using Parantula's (1989) principle, which means the joint hypothesis of both the rank order and the deterministic components. Therefore, following the Parantula (1989) principle, Table 6.2 presents the cointegration test for Models 1-4, the rest of the models can be found in Appendix J except for Models 9-12 which are excluded from testing for cointegration due to the results of unit roots (Table 4.1).

Table 6.2: Results of the Johansen Cointegration Test

Model 1

Sample: 1991M01 2013M09
Series: TRB LOGCPI LOGIPI LOGCRUDE_OIL
Lags interval: 1 to 1

Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	2	3	2	3	4
Max-Eig	1	0	0	0	0

*Critical values based on MacKinnon-Haug-Michelis (1999)

Model 2

Sample: 1991M01 2013M09
Series: TRB LOGCPI LOGIPI LOGFOOD
Lags interval: 1 to 1

Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	2	2	2	1
Max-Eig	1	2	2	1	1

*Critical values based on MacKinnon-Haug-Michelis (1999)

Model 3

Sample: 1991M01 2013M09
Series: TRB LOGCORE_CPI LOGIPI LOGCRUDE_OIL
Lags interval: 1 to 1

Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	0	0	0	0
Max-Eig	0	0	0	0	0

*Critical values based on MacKinnon-Haug-Michelis (1999)

Model 4

Sample: 1991M01 2013M09
Series: TRB LOGCORE_CPI LOGIPI LOGFOOD
Lags interval: 1 to 1

Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	0	0	0	0
Max-Eig	0	0	0	0	0

*Critical values based on MacKinnon-Haug-Michelis (1999)

The results of investigating long-term relationships show interesting findings. Trace statistics and Maximum Eigenvalue statistic identify no long-term relationship for Model 3 and Model 4. These results are in line with results obtained by Taylor (2000) who also did not find a long-term relationship and explained it as the response of firms to increases in costs by raising their own prices, depending on how persistent the increase was expected to be. The argument that persistence is higher in high-inflation environments supports the role of inflation targeting and anchoring inflation expectation as shown by Davis (2014). The fact that inflation expectations are assumed to be well anchored may also explain the lack of a long-term relationship. As outlined by Choudhri and Hakura (2006), low and more stable inflation is associated with the lower inflationary impact of commodity price shocks due to well anchored expectations. As presented earlier, the assumption of the link between commodity prices and inflation arises through both direct and indirect channels. Since the cointegration test shows no evidence of long-term relationship between oil prices or food prices and core inflation, it may be assumed that the indirect effect, also called a second round effect, does not hold in the long-term. In other words, movements in crude oil prices and food prices do not have a long-term impact on inflation expectations which could be otherwise observed in the responses of core inflation. Therefore, it can be assumed that since UK firms operate in an environment of stable and low inflation, their expectations about the persistence of oil price shocks or food price shocks are not long-term, and thus are well anchored. This may consequently lead to a break in the pass-through channel since higher commodity prices are not reflected in the prices of final goods. Nevertheless, the nonexistence of a relationship in the long-term does not reject the existence of a relationship in the short-term. As presented by Cologni and Manera (2008), short-run effects may be more important than long-run effects since expectations about temporary increase in commodity prices may depress savings (motivate borrowings) and consequently through a fall in real balances lead to increase in price level. Thus, an alternative methodology for investigating on the response of core inflation to commodity price shocks in the short-term is by estimating the SVAR models. As outlined by Cheung (2009) the direct effect/channel of commodity prices can be observed from the response of the headline inflation which includes prices such as food and energy. However, even if the effect of these prices is only relative, it does not necessarily lead to higher overall inflation if not accommodated by monetary policy. From the cointegration test results in Table 6.2, the long-term direct relationship can be confirmed in the case of crude oil prices as well as food prices (Model 1 and Model 2).

Even if the Trace statistics identified at least two cointegrating equations for Model 1, the Maximum Eigenvalue identified just one cointegrating equation and only in one case. Following Ahking's (2002) argument of the first and last data trends not being realistic, the first and last trends are excluded from the selection. Based on the results it can be assumed that there is a persistence of the shock in oil prices in headline inflation. Interesting results can be found in the case of food prices where both tests show at least one cointegrating equation. The different number of cointegrating equations estimated in Model 1 and Model 2 given by Maximum Eigenvalue and Trace statistics has been explained by Lűtkepohl at al. (2001). Their investigation on the performance of both tests shows, that even if both tests perform well, but in small samples, the Trace statistics tends to outperform Maximum Eigenvalue thus, their suggestion is to prefer the Trace statistics. Therefore a VEC model with 3 cointegrating equations for Model 1 and VEC model with 2 cointegrating equations for Model 2 will be estimated.

Even more interesting is the finding of a long-term relationship in respect to the nature of shock (Appendix J). Both, Maximum Eigenvalue and Trace statistics found a minimum of one cointegration relationship in models with food demand and food supply in both headline as well as core inflation. The actual existence of a long-term relationship leads to opening a discussion on the role of food prices, food demand, and food supply in the UK economy, and motivation for estimating the long-run relationship.

For the purposes of different objectives, this chapter will be further split into three key sections where the first section is focused on the investigation of whether oil price and food price shocks are persistent or transitory for the UK economy. The second section will focus on extending these results in respect to the nature of the shock and will follow the approach introduced by Kilian (2009). The last section will investigate possible structural breaks in estimated models and therefore is a novelty among up-to-date studies on this topic, using VAR models which tend to overlook the importance of structural breaks.

Therefore, the outcome of the investigation on the relationship between series will be SVAR models for capturing the short-term relationship between series in Model 3 and Model 4, and VEC models for investigating the long-term relationship as well as the short-term relationship between series in Model 1 and Model 2 in the first section. The second section will use Models 5-12 for investigating the effect of commodity shocks with different natures.

6.3.1.2 Causality directions

Cointegration results in the previous section indicated cointegrating relationships and also short-run movements. Therefore in this section, the analysis focuses on finding the causality direction of the variables. All data used for the Granger causality test are in first differences since the condition for using a Granger causality test is the stationarity of series (Hamilton, 1994). Also, the Granger causality test is sensitive to different lag lengths therefore the lag selection is based on the results in Table 6.1.

The selected results of the Granger causality test are presented in Appendix I. The results show that the current rate of inflation is not correlated to the past values of food prices or developments in food demand and food supply. In contrast, the null hypothesis of *"WORLD_OIL_SUPPLY does not Granger Cause DLOGCPI"* can be rejected suggesting that different natures of crude oil shocks could have different impacts on the economy since headline inflation is found to be correlated to past values of the world oil supply as well as world oil demand while being unresponsive to world oil prices. Applying the estimated inflation forecast model may suggest that the inclusion of oil supply and oil demand as explanatory variables of inflation should be considered. On the other hand, while headline inflation seems to be correlated to past values of oil supply and oil demand, core inflation is found to be correlated to past values of oil demand since the null hypothesis *"LOGWORLD_OIL_DEMAND does not Granger Cause DLOGCORE_CPI"* can be rejected ($p<0.05$). Interestingly, from the results, the present values of the crude oil price index seems to be correlated to the past values of interest rates, which have been investigated in the previous chapter although the relationship seems to work both ways, since the null hypothesis of "*oil price does not Granger Cause TRB"* can be also rejected ($p<0.05$). Although, interest rates seem to be correlated to the past values of food prices since the null hypothesis of *"Food prices do not Granger-cause TRB*" can be rejected ($p<0.05$). This implies that the role of food prices for policy makers may be more important than expected. The null hypothesis *"DTRB does not Granger-cause world_oil_supply"* cannot be rejected ($p>0.05$). The same conclusion can be driven from testing the null hypothesis of *"DTRB does not Granger-cause dlogoil_price"*, confirming that current developments in the world oil market are correlated to the past decisions of policy makers in the UK. Nevertheless, the relationship is found to work both ways. UK interest rates are found to be correlated to past values of world oil demand as well as oil prices. The use of the Granger causality test gives an insight into a possible relationship between variables. However, it is necessary to be cautious with these results due to the limitations of this test discussed in Chapter 4. The next part is therefore dedicated to a theoretical estimation of the SVAR models.

6.4 Are commodity price shocks transitory or persistent in the UK economy?

6.4.1 SVAR model specification and estimation

Since no evidence on the existence of a long-term relationship between commodity prices and core inflation could be identified, a long-term relationship between oil prices, food prices and headline inflation was found. Therefore a structural (identified) VAR model is estimated. The identification of the model is reached by imposing restrictions derived from economic theory for Model 3 and Model 4. Re-calling the Equation 4.17 from Section 4.5.2 that presents a structural economic model with n endogenous variables and constants, the selection of appropriate lag length of the system is based on information criteria in Table 6.1.

To investigate whether oil price and food price shocks are transitory or persistent in the UK economy, two 4-variable SVAR models and two 4-variable VEC models are estimated for purposes in this section of the chapter.

$$\begin{bmatrix} e_{TRB} \\ e_{CPI} \\ e_{ipi} \\ e_{com} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & \alpha_{14} \\ 0 & 1 & 0 & \alpha_{24} \\ 0 & \alpha_{32} & 1 & \alpha_{34} \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & 1 \end{bmatrix} \begin{bmatrix} u_{TRB} \\ u_{CPI} \\ u_{ipi} \\ u_{com} \end{bmatrix} \tag{6.2}$$

In the first equation (matrix 6.2), coefficients of matrix α_{12} and α_{13} are restricted to zero. This restriction is based on the assumption that monetary policy cannot respond immediately to developments in consumer prices (headline inflation represented as $\alpha_{12} = 0$) or developments in output (industrial production index represented as $\alpha_{13} = 0$) due to lags in statistical publications (Sims and Zha, 1998). The response of monetary policy to oil prices or food prices is not restricted (α_{14}) since data on commodity prices are highly frequent and available daily. Therefore the assumption is that commodity prices, due to their availability, can be implemented into policy decision making (Cheung, 2009). The second equation represents the reaction of consumer prices that are assumed not to react immediately to changes in monetary policy or economic developments but may react faster to commodity prices (McCoy, 1997). Thus, in the case of headline inflation there are no restrictions on the response to movements in commodities. Since it takes up to two years until inflation fully accommodates the decisions of policy makers expressed by movements in interest rates, the restrictions are also imposed on α_{21} (Hammond, 2012). Consumer prices are also not assumed to respond immediately to the changes in output (Ireland, 2008) therefore it is necessary to impose a restriction on α_{23} = 0. In the third equation, the only restriction is the restriction imposed on the reaction of output to changes in monetary policy since it reacts only with one lag (Bernanke and Blinder, 1992). The last equation represents the response of commodity prices (in this model oil prices or food prices) or demand/supply for food and oil commodities. There are no restrictions applied to any of the coefficients of the system. The justification of not imposing restrictions is based on the argument that commodity prices are forward-looking and accommodate new information quickly since they are traded in auction markets (Angel, 1992). Therefore this model assumes rational expectations that current oil prices and food prices already contain all the available information about future price events if a certain level of slower reaction is considered as well due to the contracts (Cheung, 2009).

6.4.2 VEC model specification and estimation

Since a VEC model needs to be estimated for Model 1 and Model 2, the estimated VEC model, under assumption of the lag length 1, for the evolution of the four variables X_t, P_t, R_t and Y_t with estimated one cointegrating relationship can be written in a form:

$$\Delta x_t = \beta_{x0} + \beta_{xx1}\Delta x_{t-1} + \beta_{x11}\Delta p_{t-1} + \beta_{x21}\Delta r_{t-1} + y_{t-1} + \lambda_x(x_{t-1} - \alpha_0 - p_{t-1} - r_{t-1} + y_{t-1}) + v_t^x$$

$$\Delta p_t = \beta_{10} + \beta_{1x1}\Delta x_{t-1} + \beta_{111}\Delta p_{t-1} + \beta_{121}\Delta r_{t-1} + \beta_{131}y_{t-1} + \lambda_1(x_{t-1} - \alpha_0 - p_{t-1} - r_{t-1} + y_{t-1}) + v_t^1$$

$$\Delta r_t = \beta_{20} + \beta_{2x1}\Delta x_{t-1} + \beta_{211}\Delta p_{t-1} + \beta_{221}\Delta r_{t-1} + \beta_{231}y_{t-1} + \lambda_2(x_{t-1} - \alpha_0 - p_{t-1} - r_{t-1} + y_{t-1}) + v_t^2$$

$$\Delta y_t = \beta_{30} + \beta_{3x1}\Delta x_{t-1} + \beta_{311}\Delta p_{t-1} + \beta_{321}\Delta r_{t-1} + \beta_{331}y_{t-1} + \lambda_3(x_{t-1} - \alpha_0 - p_{t-1} - rt{-}1{+}yt{-}1{+}vt3 \quad (6.3)$$

If the commodity prices deviate from their equilibrium, adjustments in X_t, P_t and R_t are expected in order to Y_t (commodity prices) move back to their long-run equilibrium. The error correction coefficientsλ_x, λ_1, λ_2 and λ_3 measure the responses. The VEC model (Equation 6.3) enables to investigate the short-term adjustments in headline inflation, short-term interest rates and industrial index under the assumption of the deviation of oil prices and food prices from their long-term equilibrium.

The next part presents the estimated models as well as impulse response functions from these models and discusses the potential implications for policy makers.

6.4.3 VEC Model 1

Based on the results from cointegration test, where the Trace statistics identified three cointegrated equations, a VEC model is estimated using the Equation 6.3, and presented in Table 6.4. It is convenient to note that the restrictions imposed on coefficients differ to those presented in matrix 6.2. While restrictions in matrix 6.2 represent short-term restrictions, restrictions in VEC Model 1 (and VEC Model 2) are imposed on long-term relationship while there are no short-term restrictions in order to observe the reaction of short-term interest rates, headline inflation and industrial production to a deviation of oil prices (and food prices) from their long-term equilibrium. Particularly, the upper part of Table 6.4 shows the long-rung equilibrium where coefficient of crude oil price is normalized in each vector (restricted to 1) and also zero restrictions are imposed on other coefficients, to estimate the effect of movements in oil prices to interest rates, headline inflation and industrial production. The coefficients are jointly significant ($p<0.05$). Thus, in the long-term, the first cointegration equation (CointEq1 in upper part of the table), TRB is unrestricted, while coefficients of inflation and industrial production are restricted to zero. The first error-correction equation (CointEq1 in lower part of the Table 6.4) relates to crude oil prices with TRB. It can be observed that if crude oil price lies above its long-run equilibrium, then TRB will decrease (-0.026) in the next period. CointEq2 relates to crude oil prices with CPI. The results from estimated coefficients show that if crude oil price is above its long-run equilibrium, headline inflation increase (0.0135) in the next period. The last error correction equation, CointEq3, relates to crude oil prices with industrial production. The reaction of industrial production is similar to headline inflation and shows that if crude oil price moves above its long-run equilibrium, industrial production increases (0.0078) in the next period.

Table 6.3: VEC Model 1

Vector Error Correction Estimates
Included observations: 250 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegration Restrictions:
B(1,2)=0, B(1,3)=0, B(1,4)=1
B(2,1)=0, B(2,3)=0, B(2,4)=1
B(3,1)=0, B(3,2)=0, B(3,4)=1
Convergence achieved after 1 iterations.
Restrictions identify all cointegrating vectors

Cointegrating Eq:	CointEq1	CointEq2	CointEq3
TRB(-1)	-0.225712	0.000000	0.000000
	(0.03843)		
	[-5.87263]		
LOGCPI(-1)	0.000000	-2.148233	0.000000
		(0.31216)	
		[-6.88184]	

LOGIPI(-1)	0.000000	0.000000	-29.11075
			(3.68006)
			[-7.91040]
LOGCRUDE_OIL(-1)	1.000000	1.000000	1.000000
@TREND(91M01)	-0.023176	0.004879	-0.050343
	(0.00338)	(0.00409)	(0.01332)
	[-6.84705]	[1.19404]	[-3.77812]
C	0.043297	-3.297904	139.1911

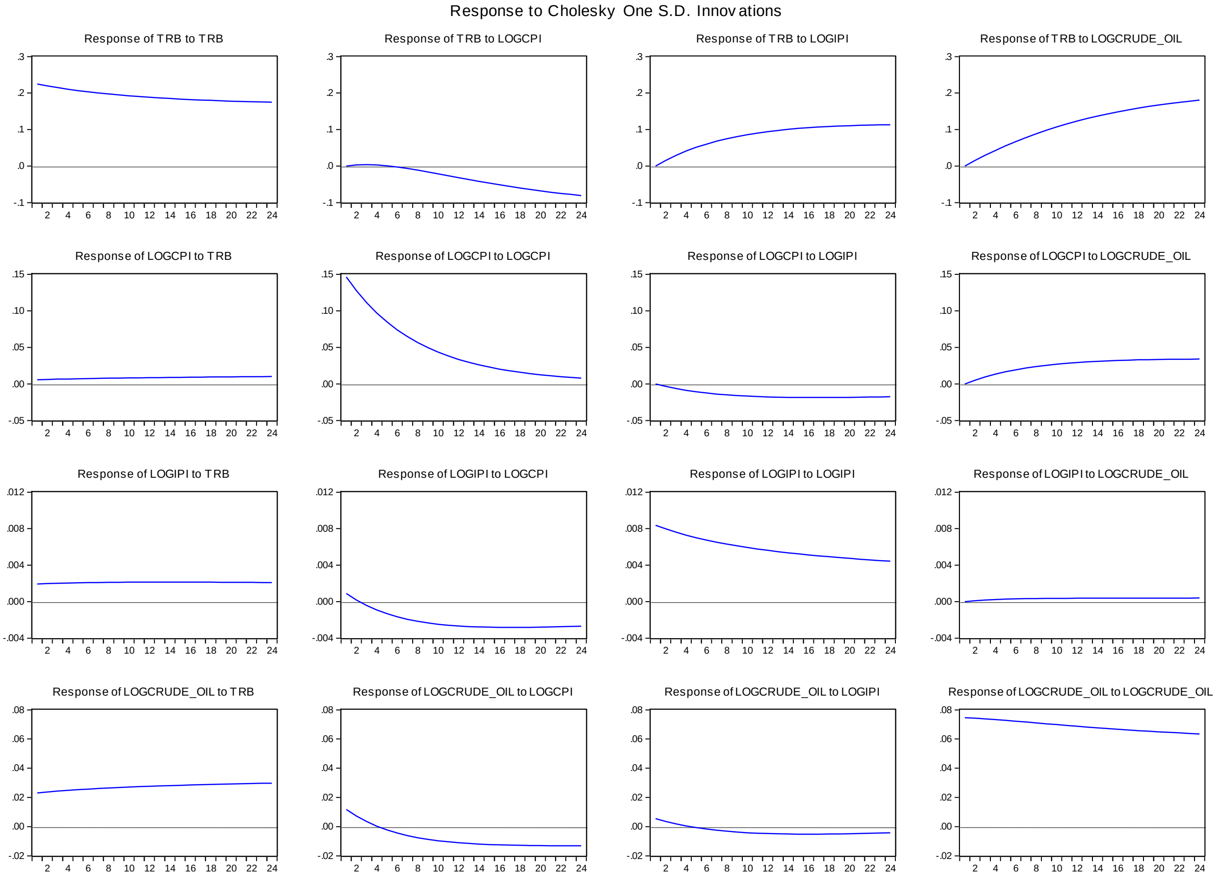
Error Correction:	D(TRB)	D(LOGCPI)	D(LOGIPI)	D(LOGCRUDE_OIL)
CointEq1	0.258013	-0.008660	-0.002612	-0.026342
	(0.06038)	(0.03938)	(0.00232)	(0.02129)
	[4.27307]	[-0.21990]	[-1.12561]	[-1.23716]
CointEq2	0.002657	0.061379	0.002195	0.013509
	(0.02240)	(0.01461)	(0.00086)	(0.00790)
	[0.11863]	[4.20132]	[2.54941]	[1.71024]
CointEq3	-0.059177	0.015574	0.001661	0.007879
	(0.01635)	(0.01066)	(0.00063)	(0.00577)
	[-3.61943]	[1.46051]	[2.64424]	[1.36653]
C	-0.038894	-0.003811	-2.46E-05	0.007050
	(0.01421)	(0.00927)	(0.00055)	(0.00501)
	[-2.73730]	[-0.41121]	[-0.04508]	[1.40694]

The standard errors of coefficients are jointly small. The strongest response can be observed from the reaction of short-term interest rate. Interestingly, oil prices seem to be an explanatory variable for headline inflation as well as for industrial production. The relevance of oil prices for headline inflation suggests that oil prices may provide beneficial information when included into the projection of inflation forecast. Although, it can be assumed that the dependency of developed countries on oil is decreasing, oil prices are still found to be explanatory for the UK industrial production. The significance of oil prices as an explanatory variable of UK inflation has also been found to be significant by Cologni and Manera (2008). Their findings from the G-7 analysis show that the central banks (including the BoE) respond to oil prices only indirectly. Even if it is interesting to find that the short-term interest rates response to the movements in oil prices, better understanding can be obtained from the impulse response functions estimated in the next section.

6.4.3.1 Impulse response functions VEC Model 1

Proceeding with the VEC Model 1 analysis, an impulse response function is estimated in order to analyse the response of consumer price inflation (and variables in the system) to an oil price shock. Figure 6.3 presents the results of the impulse response function of each variable, which are interpreted as their reaction to an unexpected shock to the system. For each variable the vertical axis measures the response of particular variables and the horizontal axis shows the number of months after the shock has been initialized. In this case the period is set for 24 months in order to observe the initial effect as well as the longer-term effect. Therefore, each row shows the reaction of the variables to the specific shock.

Figure 6.3: Impulse response functions Model 1



Even if the main focus is on the impact of the shock in oil prices, it is worth looking at the response of the system to the other shocks in order to evaluate the relevance of the outcome. The first column shows the response of the system to the unit shock in 3-months Treasury bills. In a 24 months range after the shock, the response from consumer prices to the shock can be traced. The response is stronger in the longer period. This result is as expected since it takes up to two years until the effect of changes in interest rates reaches consumer prices. Furthermore the output measured as industrial production shows response to the changes in interest rates in the short-term being stronger after the fourth month following the shock. The response of oil prices to the shock in interest rates is smaller in the short-term, increasing in the longer-term. Interestingly, the effect does not die in the first year showing a certain level of persistence. The second column shows the response of the system to a shock in headline inflation. The response of 3-months Treasury bill is found to smaller than expected, confirming findings of Cologni and Manera (2008). According to Berument (1999), the impact of expected inflation through the level of inflation creates the inflation risk and higher inflation risk leads to rises in 3-months Treasury bills. This may explain the smaller reaction in 3-months Treasury bills even though they do not represent the tool of the Bank of England. The effect on decline in industrial production as a shock in headline inflation can be explained through uncertainty about the future profitability of investment projects (especially when inflation is also associated with increased price variability). This leads to more conservative investment strategies than would otherwise be the case, ultimately leading to lower levels of investment and possibly to lower levels of economic growth.

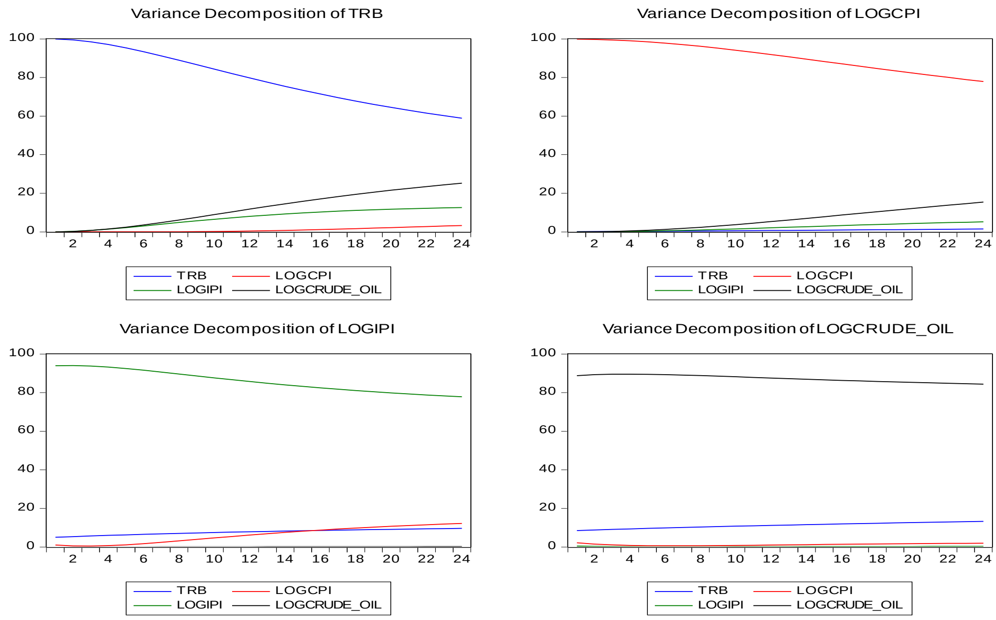
The response of economic variables in the system to the shock in oil prices (last column) can be observed. A positive shock in oil prices leads to a small response of UK's industrial production as an initial reaction. However, interest rate responses by an increase in the second month after the shock in oil prices. An increase in inflation as a response to the shock in oil prices is observed. The increase in headline inflation, could be explained by the consumers' expectations of a temporary rise in energy prices which as stated by Cologni and Manera (2008) further increase the price level.

Nevertheless, the modest response of headline inflation to the shock in oil prices can be explained by natural time lag in response as well as the stickiness of prices. In contrast to the headline inflation, the response of industrial production to an unexpected increase in oil prices is very small.

6.4.3.2 Variance decomposition VEC Model 1

From the variance decomposition functions presented in Figure 6.4 it can be observed that as expected in all cases, the largest percentage of errors are attributable to own shocks. However, nearly 20 per cent of the forecast error variance of a CPI is determined by innovations in crude oil prices, which demonstrate the significance of movements in crude oil prices in CPI forecasting.

Figure 6.4: Variance decomposition Model 1



From the upper left graph in Figure 6.4, it can be observed that movements in crude oil prices together with movements in output measured as industrial production explain the most of the forecast error in the short-term interest rate suggesting their importance for explaining the response of monetary policy to developments in crude oil prices.

6.4.4 VEC Model 2

While Model 1 is a VEC model with three cointegrated equations, Model 2 is estimated as a VEC model with two cointegrated equations due to the results of the cointegration test (Table 6.2). Re-calling the Equation 4.21 from Chapter 4 (Section 4.7), if variables in the system are non-stationary, but stationary at first difference and a cointegration can be traced (Table 6.5), the VAR method is not applicable. It is convenient to point out that even if Model 2 is a VEC with a linear trend, the restrictions on coefficients are equivalent to those presented in VEC Model 1. Nevertheless, there is no cointegrating equation to trace the response of industrial production to deviation in food prices from their equilibrium.

Table 6.4: VEC Model 2

Vector Error Correction Estimates
Included observations: 250 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegration Restrictions:
B(1,2)=0, B(1,3)=0, B(1,4)=1
B(2,1)=0, B(2,3)=0, B(2,4)=1
Maximum iterations (500) reached.
Restrictions identify all cointegrating vectors

Cointegrating Eq:	CointEq1	CointEq2		
TRB(-1)	-0.715856 (0.81216) [-0.88142]	0.000000		
LOGCPI(-1)	0.000000	-0.547739 (0.05785) [-9.46820]		
LOGIPI(-1)	0.000000	0.000000		
LOGFOOD(-1)	1.000000	1.000000		
@TREND(91M01)	-0.071670 (0.02571) [-2.78810]	-0.000816 (0.00039) [-2.07400]		
C	8.368206	-4.180542		
Error Correction:	**D(TRB)**	**D(LOGCPI)**	**D(LOGIPI)**	**D(LOGFOOD)**
CointEq1	0.002875 (0.00398) [0.72172]	0.001307 (0.00248) [0.52687]	0.000454 (0.00015) [3.01629]	-0.000477 (0.00051) [-0.93163]
CointEq2	0.258585 (0.08652) [2.98886]	0.293873 (0.05387) [5.45523]	0.003257 (0.00327) [0.99652]	0.008126 (0.01112) [0.73106]
C	-0.038894 (0.01460) [-2.66326]	-0.003811 (0.00909) [-0.41906]	-2.46E-05 (0.00055) [-0.04462]	0.002447 (0.00188) [1.30396]

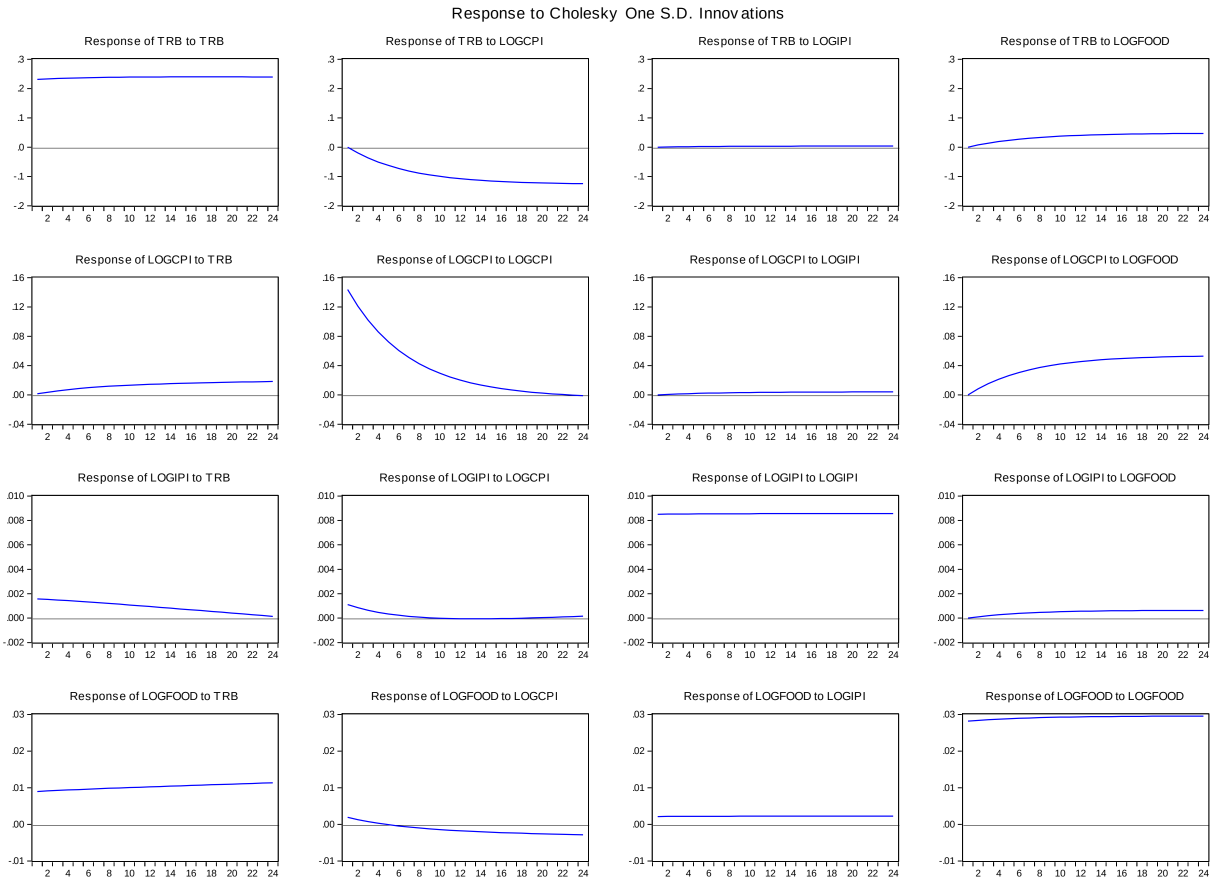
From the cointegrating equation in error correction model (CointEq1 in lower part of the Table 6.5), it can be observed if food prices increase above their long-run equilibrium, the short-term interest rate decrease. As pointed by Cologni and Manera (2008) the reduction in interest rates can be seen as a reaction of monetary policy to offset the losses in output, but for the price of increases in inflationary pressures. From the second cointegrating equation, if food prices increase above their long-run equilibrium, headline inflation increases (0.008) in the next period. However, when compared to the results from VEC Model 1, the response of consumer price inflation as well as monetary policy seems to be weaker.

As discussed earlier, the advantage of a VEC model is that it allows for capturing the short-term as well as the long-term relationship between variables. While the results from Table 6.5 indicate a positive response of monetary policy to inflation from the food prices, impulse response functions in Figure 6.6 this demonstrate how strong the response to the shock in food prices is.

6.4.4.1 Impulse response functions VEC Model 2

From Figure 6.5, the reaction of policy makers (the response of the TRB to the shock in food prices) is slightly smaller than in the case of oil prices (Figure 6.4) suggesting that policy makers might consider food price shock to be relevant, however not as important as oil price shocks since oil commodities represent a direct input into production. Also when compared with the previous case, the response of headline inflation to the shock in food prices is comparable. Unfortunately, the results from the shock in food prices cannot be compared to other studies since there is a lack of similar analysis for small open developed economies.

Figure 6.5: Impulse response functions Model 2



Finding that the response of headline inflation to the shock in food prices is as strong as in the case of oil prices is interesting, since food commodities do not represent direct inputs in production. However, at the same time it could attribute to decreasing food self-sufficiency in the UK thus the sensitivity of prices might be time-varying.

6.4.4.2 Variance decomposition VEC Model 2

Figure 6.6: Variance decomposition Model 2

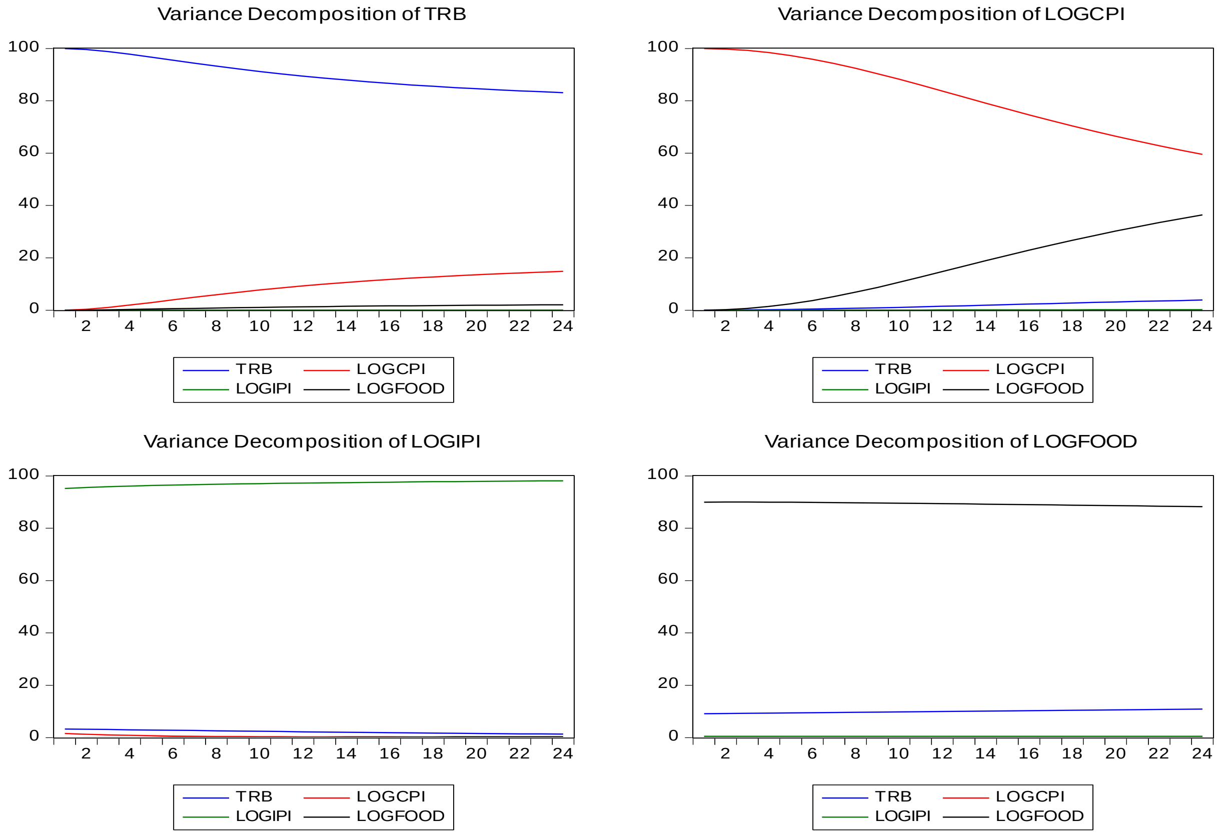


Figure 6.6 presents the variance decompositions of different shocks in order to examine how important each of the shocks is as a component of the overall (unpredictable) variance of each of the variables over time. Interestingly, the decomposition of headline inflation shows that the shock in food prices account for nearly 40 per cent of the inflation variance while interest rates account for less than 10 per cent. When compared to the previous model where oil prices account for only 20 per cent of the inflation variance (Figure 6.4), results from Figure 6.6 suggest that food prices may play more important role in the UK economy than assumed. Nevertheless, food prices account only for less than 5 per cent of the short-term interest rate variance suggesting that food prices do not explain variations in monetary policy very well.

6.4.5 SVAR Model 3

Based on the results from the cointegration test, SVAR Model 3 investigates the persistent effect of oil prices and is estimated by using the matrix 6.2 restrictions. Only coefficients C(1), C(4) and C(6) are significant ($p<0.05$) for oil prices, suggesting that core UK inflation is not an explanatory variable for oil prices. The coefficient C(5), which represents oil prices as the explanatory variable for interest rates is also insignificant. Nevertheless, oil prices are an explanatory variable for industrial production. Due to the zero restrictions on oil prices in the equation for core inflation, it is not possible to identify whether oil prices are an explanatory variable for core inflation, and therefore the effect of oil prices is also persistent. This can be further investigated by estimating impulse response functions in the next section.

Table 6.5: SVAR Model 3

Structural VAR Estimates
Estimation method: method of scoring (analytic derivatives)
Structural VAR is over-identified (4 degrees of freedom)

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	0	0	C(5)
0	1	0	0
0	C(2)	1	C(6)
C(1)	C(3)	C(4)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.132356	0.013100	10.10373	0.0000
C(2)	-0.011769	0.071215	-0.165260	0.8687
C(3)	-0.088638	0.136359	-0.650032	0.5157
C(4)	1.875015	0.005535	338.7725	0.0000
C(5)	0.050926	0.148095	0.343872	0.7309
C(6)	0.477397	0.010728	44.50015	0.0000

Log likelihood	-293.0533		
LR test for over-identification:			
Chi-square(4)	3045.847	Probability	0.0000

Estimated A matrix:

1.000000	0.000000	0.000000	0.000000
0.000000	1.000000	0.000000	0.000000
0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	1.000000

Estimated B matrix:

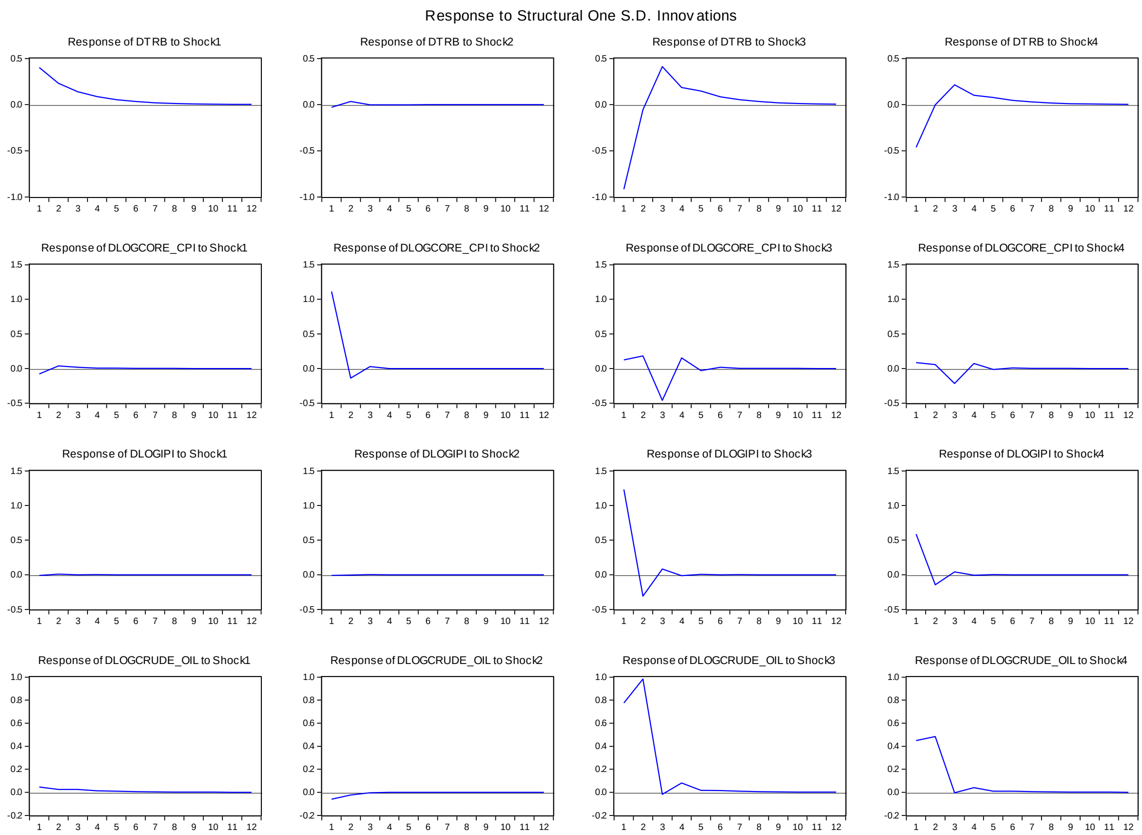
0.401443	-0.028299	-0.917678	-0.462416
-0.078297	1.112002	0.125122	0.085196
-0.011111	-0.009966	1.231683	0.586589
0.046794	-0.059629	0.774416	0.449806

6.4.5.1 Impulse response functions SVAR Model 3

The impulse response functions estimated for Model 3 show the response of variables to the shocks labelled as *Shock 1* (represents shock to TRB), *Shock 2* (represents shock to core inflation in Model 3 and Model 4), *Shock 3* (represents shock to IPI) and *Shock 4* (represents shock to oil prices in Model 3 and food prices in Model 4).

The first column in Figure 6.7 shows the response of the system to the unit shock in 3-months Treasury bills. The response of variables in the system to the shock in interest rates as well as inflation does not vary from the responses in Model 1 and Model 2 and has been already discussed. Therefore, in this part, the discussion is focused only on the last column that shows the response of variables in the system to the shock in oil prices. Interestingly, core inflation responds to an unexpected increase in oil prices by slowing down. This finding is corroborated by Verheyen (2010) as well as Herrera et al. (2011) and can be interpreted as a decreasing relationship between commodity prices and the economic situation. Even if there is evidence of a response from the TRB and the core inflation, the response dies after six months in the case of inflation, and after eight months in the case of the TRB.

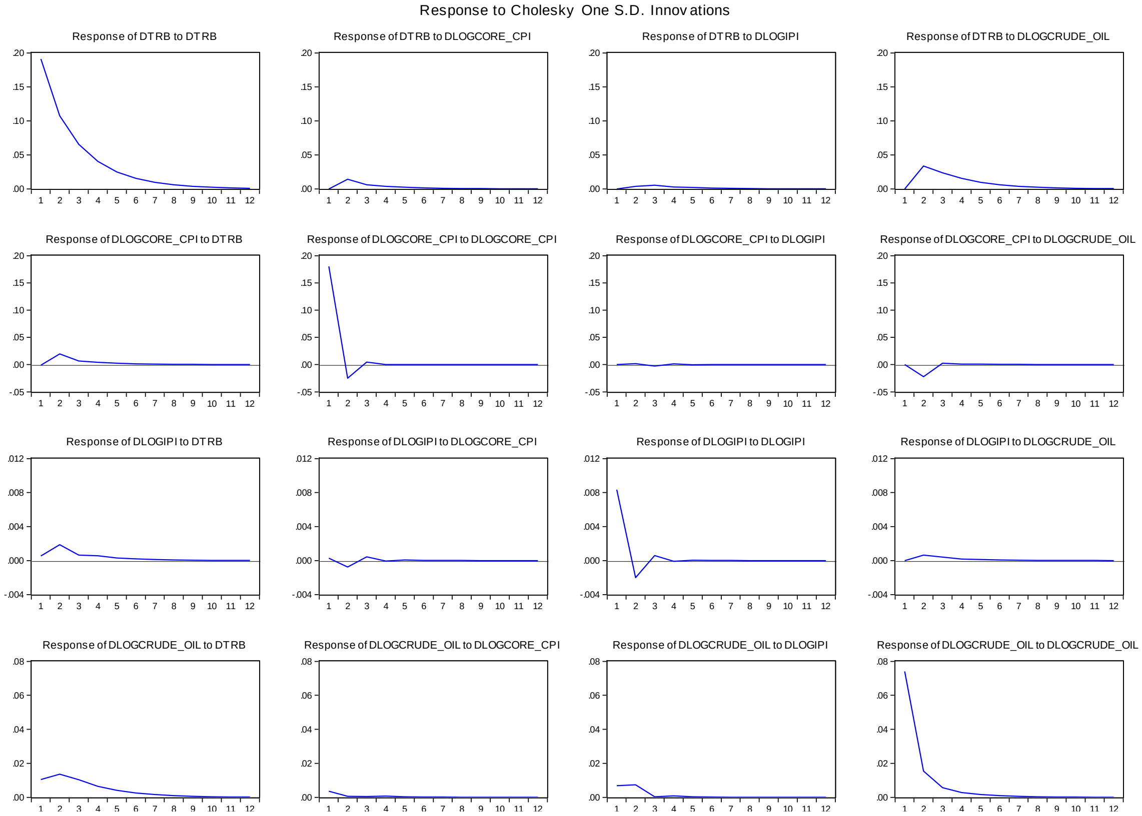
Figure 6.7: Impulse response function Model 3 (Structural decomposition)



When comparing the results with structural impulse response and the Cholesky ordering

(Figure 6.8), the response of variables in system to the individual shocks is very similar. Since the results do not change significantly, it supports the validity of the estimated model.

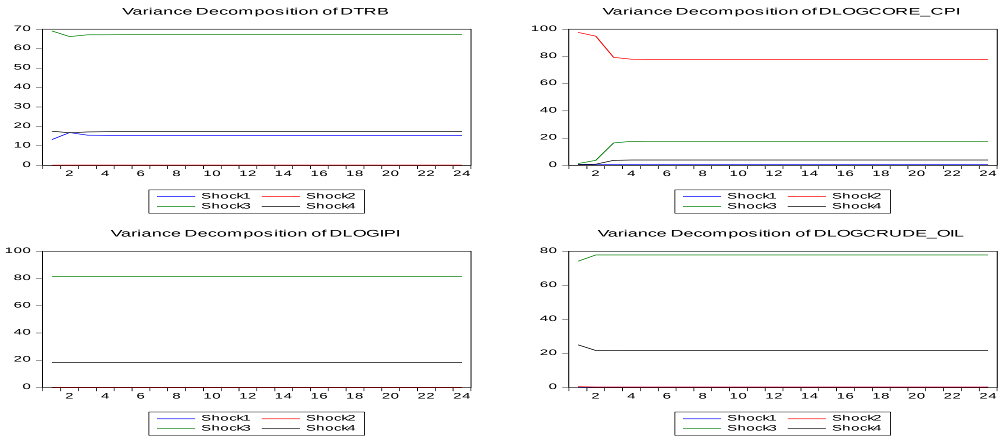
Figure 6.8: Impulse response function Model 3 (Cholesky ordering)



6.4.5.2 Variance decomposition SVAR Model 3

The variance decomposition functions (Figure 6.9) shows that 20 per cent of forecast error variance in core inflation is determined by industrial production in the UK as in the previous results. However, only 5 per cent by world oil prices. It is significantly lower when compared with the forecast error in headline inflation (Model 1).

Figure 6.9: Variance decomposition Model 3



The results suggest that oil prices are more important in explaining the headline inflation than core inflation. From the results, it may be assumed that oil price shocks are more transitory than persistent for the UK economy.

6.4.6 SVAR Model 4

The last model estimated in this section is SVAR Model 4 which represents a model of the persistent effect of food prices using matrix 6.2.

Table 6.6: SVAR Model 4

Structural VAR Estimates
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations
Structural VAR is over-identified (4 degrees of freedom)

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	0	0	C(5)
0	1	0	0
0	C(2)	1	C(6)
C(1)	C(3)	C(4)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.018336	0.004454	4.116589	0.0000
C(2)	-0.004162	0.079726	-0.052199	0.9584
C(3)	0.011247	0.106397	0.105712	0.9158
C(4)	1.310361	0.002390	548.2045	0.0000
C(5)	0.003886	0.109967	0.035339	0.9718
C(6)	0.724918	0.002234	324.4987	0.0000

Log likelihood	-81.30283		
LR test for over-identification:			
Chi-square(4)	3084.671	Probability	0.0000

Estimated A matrix:

1.000000	0.000000	0.000000	0.000000
0.000000	1.000000	0.000000	0.000000
0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	1.000000

Estimated B matrix:

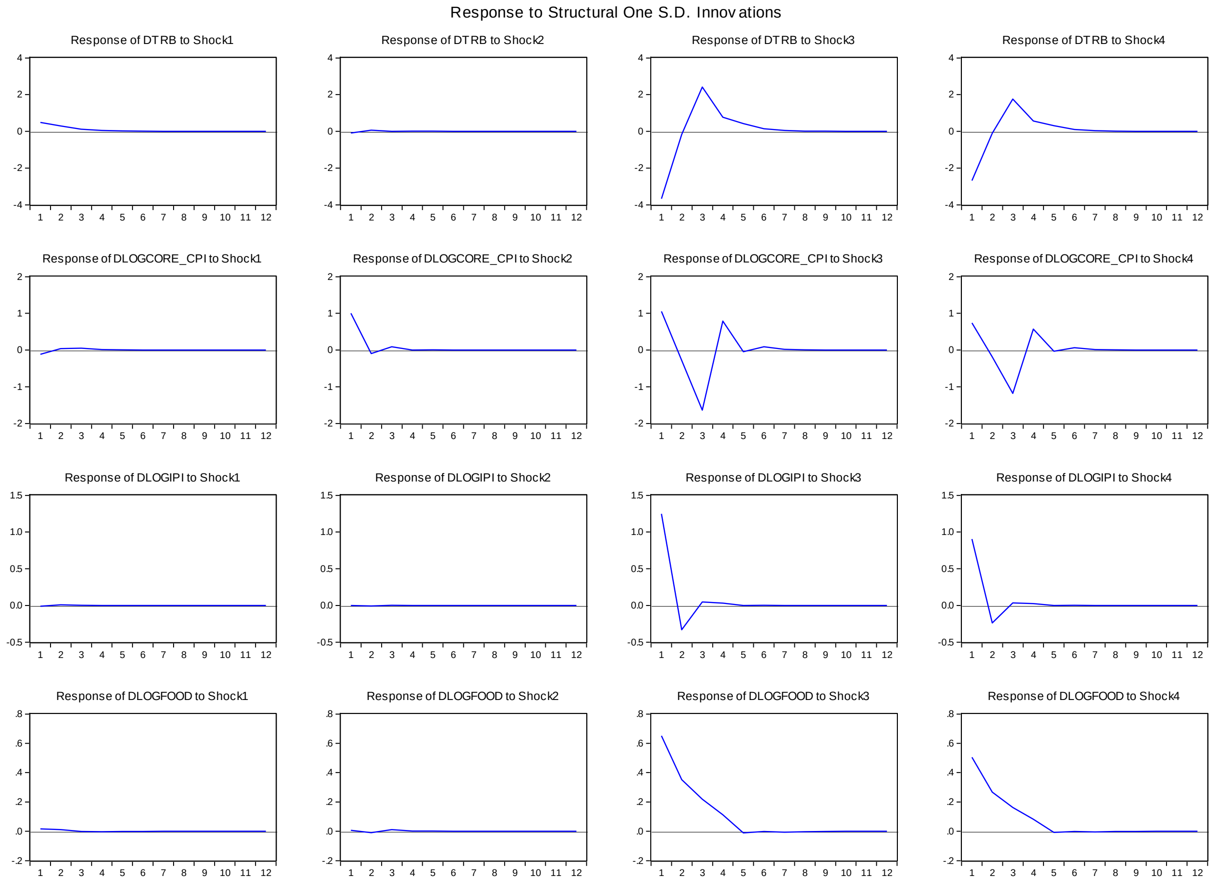
0.492966	-0.087528	-3.672537	-2.684336
-0.112602	1.004176	1.050045	0.737144
-0.011033	-0.001030	1.248515	0.903516
0.015532	0.006703	0.651716	0.504451

As in Model 3, the coefficients C(1), C(4) and C(6) are jointly significant ($p<0.05$). The coefficient C(3) for industrial production, is not an explanatory variable for world food prices. It is interesting to find out that the coefficient C(5) which represents food prices as the explanatory variable for interest rates is also insignificant. This means that policy makers react indirectly not only to oil prices, but also to food prices. The statistical insignificance of the coefficient may also suggest that the shocks in oil prices and food prices are taken as exogenous and short-term supply shocks thus policy makers tend to be more relaxed and do not react by increasing the interest rates.

6.4.6.1 Impulse response function SVAR Model 4

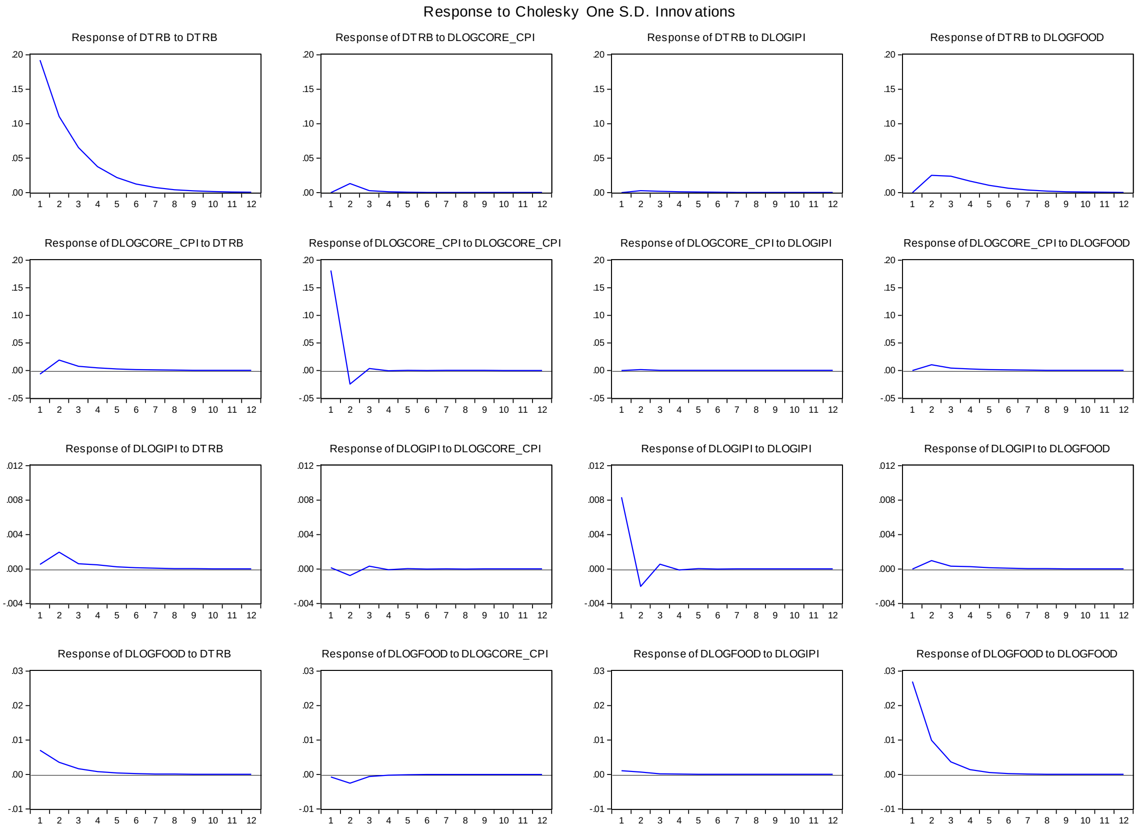
In contrast to Model 3, where the main focus is on examining the response of core inflation to the shock to oil prices, the impulse response functions estimated for Model 4 show the response of core inflation to the shock in food prices (Figure 6.10). Also, in this case, the first column shows the response of the system to the unit shock in 3-months Treasury bills. In a range of 12 months after the shock, there is no response from consumer prices to the shock. As explained in the previous model this result is not surprising due to the time lag. Very similar results can be obtained for the response estimated as an impulse response with structural decomposition of industrial production to the changes in interest rates. While in the previous case there was a slight increase in oil prices as a response to the shock in interest rates, as shown in Figure 6.8, food prices do not seem to respond to the shock in interest rates, confirming the results from Chapter 5). Similarly, a shock to the core inflation does not affect movements in food prices. However, an increase in industrial output seems to depress food prices slightly in the first six months. In contrast to the results from impulse response function with structural decomposition, Cholesky ordering shows no response of food prices to the shock in industrial production.

Figure 6.10: Impulse response function Model 4 (Structural decomposition)



The response of economic variables in the system to the shock in food prices can be observed, but the size of the response is moderate, with initial drop in the case of core inflation. An initial sharp decrease in industrial production as a response to the shock in food prices quickly dies after three months. Nevertheless these findings are comparable with the results of Baumeister et al. (2010). It is also interesting to find a response of interest rate to an increase in food prices which is can be assumed to be due to the proportion of food commodities in inflation index.

Figure 6.11: Impulse response function Model 4 (Cholesky ordering)

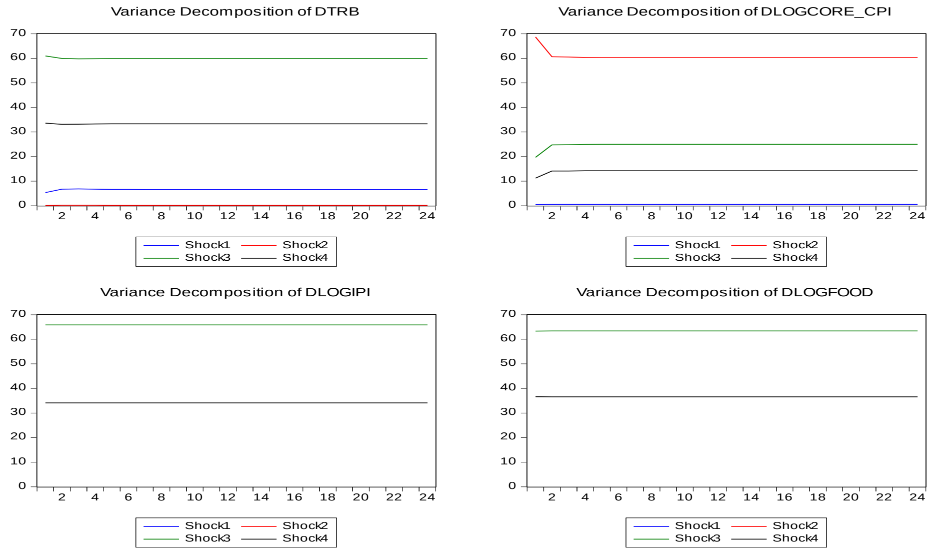


When comparing the results with structural impulse response and Cholesky ordering (Figure 6.11), the response of variables in the system to the individual shocks is very similar. Since the results do not change significantly, it supports the validity of the estimated model based on the restrictions presented in matrix 6.2.

6.4.6.2 Variance decomposition SVAR Model 4

From the variance decomposition functions presented in Figure 6.12 it can be observed that the largest percentage of the errors contributes to own shocks in all cases. In Model 1 nearly 20 per cent of the forecast error variance of consumer price inflation was determined by innovations in crude oil prices. While in case of Model 4, more than 20 per cent of the forecast error variance of core inflation is determined by innovations to industrial production, and more than 10 per cent by innovations to food prices.

Figure 6.12: Variance decomposition Model 4



6.4.7 Summary

Following the approach of Harrison et al. (2011), the first section of this chapter investigated the size of persistent and transitory shocks in oil and food prices. Findings are in line with the results of other authors on other developed countries, but also reveal important implications for policy makers in the UK. Oil prices seem to be of higher importance than oil prices since the size of the transitory effect is stronger however, in the case of persistent effect, food prices show stronger effect. Nevertheless, the aim of the next part is to extend these studies to a very new approach in understanding commodity shocks which was first introduced by Kilian (2009).

6.5 Transition effects from different natured commodity shocks

As explained in Chapter 2, while in the 1980s the oil price was mainly driven by supply cuts, an increase in the real oil prices in 2000s was driven by several factors such as fluctuations in the growth of emerging countries, as well as OECD countries, causing oil demand to strengthen, the easing monetary policy and possibly speculations. Nevertheless, the financial crisis in 2008 broke the period of growth and had an impact on oil prices too. Even if the decrease in demand for oil also caused the drop in oil prices, prices were still driven mostly by expectations of future global recession. As recognized by Kilian (2009), the distinction between the different natures of the oil shocks has important implications for policy makers. The results reveal that the supply channel of transmission for the U.S economy is found to be weak, while demand channel of transmission play an important role (Kilian 2008, Peersman and Robays, 2012). The implication for policy makers driven by these findings differs as well, and the effect can be presented as following. An exogenous oil price shock can lead to recession as well as deflation where the expected reaction of policy makers would be lowering interest rates in order to eliminate the recessionary impact. Kilian's (2009) results show that the Federal Reserve does respond to oil supply shocks by approaching expansionary policy as opposed to tightening policy in the case of positive oil demand shocks. Therefore it can be assumed that the distinction between supply and demand side oil shocks is important for the implementation of policy decisions.

Nevertheless, oil prices have always been a complicated puzzle for policy makers and a challenge for inflation targeting countries seeking to achieve the balance of trade between inflation and output. In this line, Harrison et al. (2011) investigated the effect of a permanent world energy price increase on the UK economy in the dynamic general equilibrium model and identified a high level of sensitivity of the UK economy as well as changes in the response of policy makers. Indeed their results contribute to filling the gap in knowledge of the sensitivity of the UK economy and the reaction of monetary policy to an oil price shock which has been investigated in the previous section. As noted earlier, their approach has been extended in the first section of this chapter by the inclusion of food price shocks. As results show, the importance of a food price shock is often overlooked, as the effect of food prices is often assumed to be significant only in developing countries. However, the limitation to Harrison's et al. (2011) model can be found in not accounting for the different natures of shocks, which are proven to have differentiated impacts on the economy and thus need to be taken as an important implication for policy makers. The most recent study on this topic has been introduced by Millard and Shakir (2013) who applied Kilian's (2009) approach on the UK economy. Their results show that the source of the oil shock matters for the response of the UK economy, since shocks in oil supply lead to larger falls in output and increases in prices than in the case of world demand shocks.

The findings also reveal that the response of the UK economy to different natured oil shocks has changed over time. Until 2006 the shocks in world demand tend to lead to significant rises in output with little effect on inflation, but after this time have affected inflation. Nevertheless, their study covers the period from the 1980s to 2000s, they account for only one structural break in 1980s. However, from the discussion in Chapter 2 it can be argued that a possible structural break can be also found in the 2000s since all commodities experienced a joint increase which may be considered as unusual. This section therefore follows Kilian's

(2009) approach and investigates the effect of different natured shocks, which is modelled as exogenous to the UK economy. Although the UK economy is considered as a small open economy, the innovations in the commodity prices may be considered as exogenous to the economy and have little relevance for policymakers. It is assumed that even the shocks are taken to be exogenous, it is important to understand the causes of these shocks since it has been proved by previous authors that the impact is found to be different across the countries and as showed by Millard and Shakir (2013) it is also time-varying.

The novelty is that based on the importance of food prices for the UK economy, identified in the first section, Kilian's (2009) approach is extended to encompass different natures of food commodity shocks. To the best of the author's knowledge, this has not been investigated for any of the developed or even developing countries. Also, approach undertaken in following section is in contrast to assumption stated by Harrison et al. (2011) who interpret their results on the response of the policy makers and the economy to the shocks whilst under the assumption that the UK is a self-sufficient in oil and gas. The model developed in this section encounters the UK's sensitivity to food and oil commodities which is not so straightforward. Another contribution to the previous research is that the effects of the different natures of commodities shocks are also investigated in respect to their transitory and persistent nature. Therefore the objectives of this section are the following:

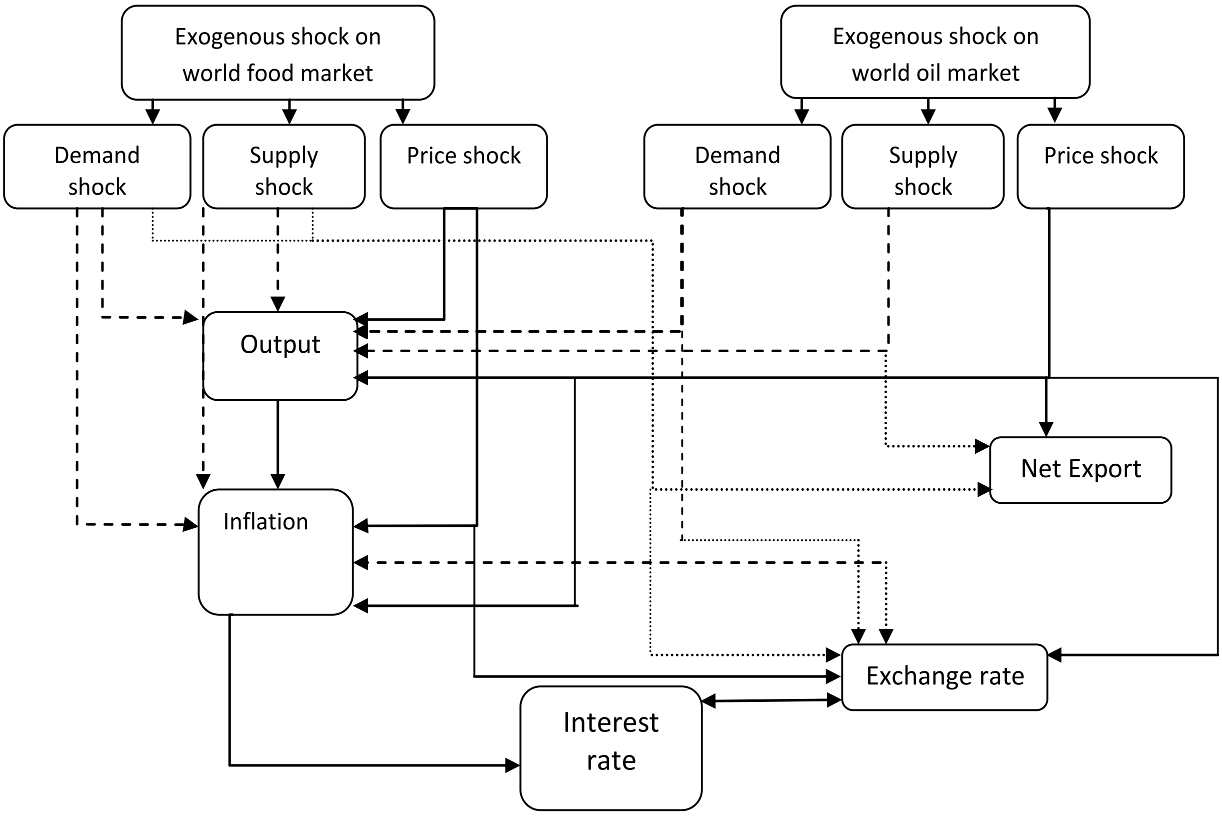
- *To investigate whether different natured commodity shocks have a different effect on the UK economy.*
- *To measure the significance of the effect and investigate whether there are any implications for policy makers in the distinction between the effect of shocks in food and oil commodities.*
- *To investigate whether the effect of the different nature of commodity shocks on headline inflation and core inflation differs, and thus identify the importance of persistent and transitory shocks for the UK economy.*

In the next part, the theoretical model of how oil and food shocks may potentially be transmitted into the UK economy is discussed in respect to specific characteristics of the UK economy and its position in the commodity market.

6.6 Theoretical assumptions on the transmission mechanism of oil and food commodities shocks to the UK economy

According to Kilian (2009), the nature of the commodity shocks can be distinguished by supply side effects, demand side effects and speculation effects. While three different natures of shocks can be recognized, this chapter focuses on the first two. As recognized by Lardic and Mignon (2008), increases in oil price negatively affect inflation, consumption and investment in oil-importing countries, while understandably; a positive effect in terms of rise in output can be expected in oil-exporting countries. The positive effect on oil-exporting countries can be explained by the transfer of income from oil importing countries to oil exporting countries. On the other hand, the transmission channel of food prices is different and cannot be forgotten. A study by Galesi and Lombardi (2013) provides important evidence that food prices also transform a country's domestic inflation, output and interest rates. The transmission of these two necessities can be explained as follows. For oil importing country an oil price shock is assumed to have a negative impact on the economy. The increase in oil price leads to an increase in manufacturing costs since oil represents a direct input into the production, and thus industrial production falls. As food does not represent a direct input into production, the effect of increasing the food price will increase import bills which could consequently negatively affect the net export and slow down the national output. Consequently, an increase in oil and food prices represents additional costs. However, this is a very simplified view on the transmission of these shocks. Based on the theoretical arguments a theoretical transmission channel designed in a way specific to the position of the UK economy for the purpose of this chapter is proposed in Figure 6.13.

Figure 6.13: Transmission of specific oil and food price shocks into the UK economy



Source: Author

In Figure 6.13 the full line represents a well established relationship already investigated by previous studies on the UK economy. The broken line represents an investigation into the possible relationship introduced in this section with limited or no evidence available for the UK. The dotted line represents a relationship which has not been investigated for the UK economy but is not in the scope of this section.

Beginning with the specification of a commodity shock, this model follows Kilian's assumption but extends it to a different nature of food shock. Since the UK is an oil importer, but a producer and exporter of oil as well as other sources of energy, an increase in world oil prices may impact the economy in two ways. Firstly, as an oil exporter, an increase in oil prices improves the net export balance on one hand and at the same time shifts demand to its substitutes which the UK is exporting as well. Thus the UK could be gaining the advantage from rising oil prices, but at the same time as oil importing country, it may also experience a reduction in industrial production due to higher costs causing output growth to slow. Higher energy prices will be reflected in higher inflation which in the case of a persistent shock could lead to tightening monetary policy. In the case of a supply shock it is assumed that an oil supply shock does not have a significant impact on the UK economy. A transitory shock should be absorbed since a short-term gap in stocks can be replaced by domestic production. However, it is assumed that a persistent shock may lead to output disturbances and higher inflation. It is interesting to investigate the impact of a world oil demand shock on the UK. Even if the UK also exports oil, it is a price taker with inelastic oil production due to limited oil resources. Therefore an increase in world oil demand may stimulate the economy by gaining the advantage of higher prices, and improving the net-export, but at the same time it may also raise the costs of production due to higher prices and depress the output growth. Therefore, at this point it is difficult to predict the reaction of policy makers since the actual impact of a different nature of shock is unknown. The same applies to a shock on the world food market.

As noted before, food self-sufficiency in the UK is declining and its position as a food importer has strengthened over the last decade (Gov, 2012). As a food importer, in the case of a transitory shock of higher global food prices, the significant impact on output is due to the low elasticity of domestic demand for food products, and a higher level of competition is not expected. However, due to the proportion of food products in the UK CPI basket, which is currently 10.6 percent (Gooding, 2013), the transitory effect is inevitable but should be, to a certain level, absorbed under the assumption of inflation expectations being well anchored. On the other hand, the persistent effect of higher food prices may lead to changes in consumers' preferences and spending that consequently negatively impacts output. Nevertheless, an increase in global food demand which is more likely to be persistent than transitory, would stimulate the UK economy through improved net export and rises in production. In this case, the reaction of policy makers would not be plausible since the rise in inflation should be well managed by anchored expectations. However, the UK food export is, according to Food and Drink Federation (2013), mainly to other European countries (75.9% in 2012) which, in the current world situation, may not represent an advantage. The European market is currently depressed and food demand is driven by emerging economies. Although the world demand might be rising, the European demand is declining. It is assumed that higher prices driven by demand from emerging economies, in combination with declining demand in the European market, may have a negative rather than a positive effect on the UK economy in terms of higher inflation and a decline in output. In the case of a persistent effect, interest rates should respond to higher inflation. It is not assumed that a food supply shock, whether persistent or transitory, could have a very significant effect on the UK economy for two reasons. Firstly, the self food-sufficiency in the UK is still high enough to absorb exogenous shocks and secondly, food commodities do not represent a direct cost in production.

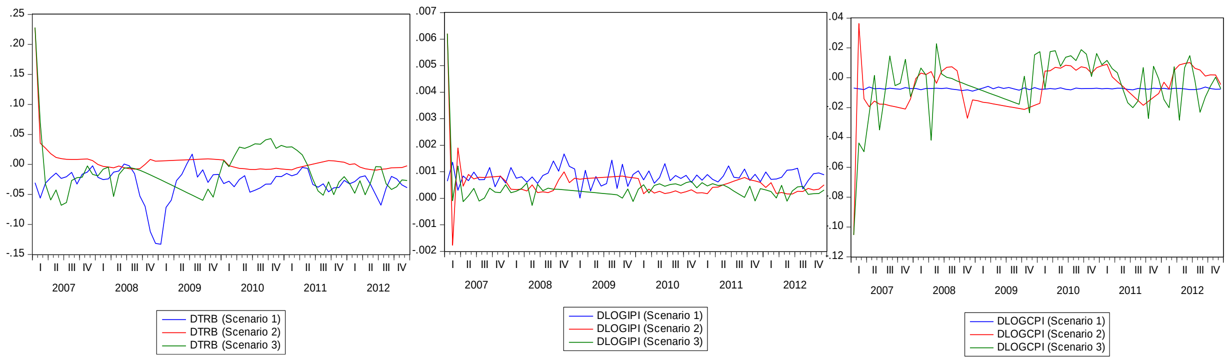
6.7 The transitory and persistent effect of an oil specific shock

The understanding of how commodity markets developments are transmitted to the economy is important to determine the appropriate policy reaction in response to oil shocks as well as food shocks. First, the magnitude of the final effects on inflation and output depends on which channels are operative as well as on their relative strengths (Kilian, 2008). Secondly, the timing of the impact is also important for policy decisions. Given that monetary policy actions affect headline inflation only with a lag, the direct effects of rising energy prices are unavoidable (Baumeister et al. 2009). However, if the initial oil shock to relative energy prices also creates indirect effects by feeding into the price of non-energy goods and services (core inflation) over longer horizons, there is a stabilisation role for central banks. Therefore this part focuses on the pass-through after different natures of oil shocks and food shocks in the UK for two reasons. The first reason is to test the validity of assumptions introduced in Figure 6.13. Secondly, as discussed in Section 6.6, there exist significant differences in the inflationary consequences between oil-importing and oil-exporting economies after an exogenous oil shock or food shock. The latter group is actually not confronted with rising consumer prices, which can be explained by an appreciation of the nominal as well as real effective exchange rates. Therefore, this part investigates the relative importance of different transmission channels in oil-importing economies by applying a procedure proposed in Peersman and Robays (2012).

The idea is to examine the transmission of oil shocks and food shocks by disentangling the effects on consumer prices and economic activity into several separate effects that are captured by the responses of different price measures and GDP components. This should help in understanding the responses of monetary policy in the UK when compared with other countries. To do so, it is necessary to re-estimate models introduced in Section 6.4 from the Equation 6.3, in a way that the different natures of commodity shocks are estimated as exogenous shocks to the UK economy. The exogenous shock is modelled as a 10 per cent increase above the equilibrium. The novelty of this method when compared to studies discussed in the previous part can be found in simulating different natures of commodity shocks whose nature is taken as exogenous rather than endogenous. Moreover, Kilian's (2009) approach is extended and applied to food commodities. The motivation for this investigation can be found in the recent findings of Millard and Shakir (2013) who also considered the effect of commodity shocks as exogenous for the UK economy. The first part of their estimation over the period 1971-1985 shows that oil price shocks had large effects on UK output and inflation in the late 1970s and early 1980s. Although their results confirm the results of previous studies on different economies, Millard and Shakir (2013) also found that since the UK became a net oil exporter, the effects of all these shocks had become small. An important finding from their study, which is applicable to the assumption introduced in this section, is that the effects of the shocks on interest rates suggests that interest rates hardly moved in response to oil price shocks. The results from the second period of their analysis (2004-2011) reveal an important finding. Their findings show that the sensitivity of the UK output to oil supply and oil-specific demand shocks has generally increased since 2004. Although Millard and Shakir's (2013) study is similar to the one introduced in this section, their study does not investigate whether the effect has a persistent or transitory nature (also, the inflation is measured using the RPI).

Figure 6.14 and Figure 6.15 show the estimated reaction of the UK economy to an unexpected shock in oil, modelled under three different scenarios. Figure 6.14 shows the transitory effect of a different nature of oil shock particularly a 10 percent increase in world oil prices (Scenario 1), 10 percent increase in world oil supply (Scenario 2) and 10 percent increase in world oil demand (Scenario 3) on key economic variables: 3-months Treasury bills, headline (core) inflation and the industrial production index.

Figure 6.14: The effect of transitory crude oil shocks on the UK economy

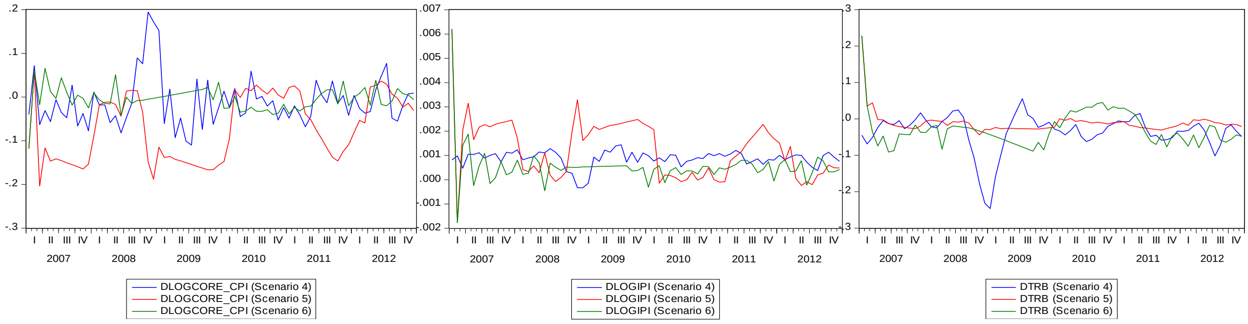


The size of the transitory effect of all three shocks can be observed from the effect on headline inflation. As findings from Figure 6.14 show, there is not a significant response of consumer prices to a 10 percent increase in oil prices (Scenario 1). While the findings of Millard and Shakir (2013) show that from the mid-1990s the inflationary effect of oil price movements on UK inflation has generally been positive and has increased since around 2005, results from the model (Figure 6.14) show that there is not a significant response of consumer prices to 10 percent increase in oil prices (Scenario 1). The insignificant response of headline inflation to the actual shock in oil prices confirms the assumption of well-anchored inflation expectations, thus monetary authorities do not need to undertake tightening measures. The findings of Galesi and Lombardi (2013) also show that the response of UK headline inflation is statistically insignificant and has the same behaviour as Middle Eastern countries. The counterintuitive results could be explained by the fact that the UK is also an oil producer. The response of industrial production is not very significant. However, consumer prices rise significantly as a positive reaction to an increase in oil supply by 10 per cent (Scenario 2), due to stimulated industrial production and increased output. This response of inflation is also documented by Furlong and Ingenito (1996). The actual increase in world oil demand by 10 percent also has an inflationary effect on the UK economy, but interestingly the size of the effect is higher than in the case of the supply side effect. Contrary to this result, Millard and Shakir (2013) found evidence that the impact of oil-specific demand shocks on UK inflation is small, while oil supply shocks tend to be associated with larger negative impacts on output, but positive impact on inflation.

The results from Figure 6.14 show that the growth of industrial production responds negatively to all three shocks with similar size of effect oscillating around the zero level after the first quarter following the shock. Interest rates fall in order to stimulate the economy in the second year after the increase in the world oil demand, which slows down production and can be observed in falling inflation. Interest rates also react positively after the third year following the shock in world oil demand, when prices are fully accommodated into higher headline inflation. Several important findings can be driven from the results. Firstly, even if the UK became an oil-importing country, the size and sensitivity of industrial production on the world oil market is not as significant as in the 1970s and 1980s when compared to the results of Hendry (1991). Secondly, the size of the effect of a world oil demand shock on consumer prices seems to be more significant than in the case of a supply driven shock. Also, the reaction of monetary policy to a demand side shock seems to be of higher significance than a supply side shock. This is an important implication for policy makers given the expected future growth in oil demand from emerging economies. Even if this is only a transitory effect of the shock, underestimation of its impact may have a negative implication on the credibility of UK monetary policy. Nevertheless, these results confirm the findings of Millard and Shakir (2013) that the impact of oil shocks on UK output and inflation varies according to the source of the underlying shock.

However, this conclusion is valid only for a transitory effect. Figure 6.15 shows the results from the same scenarios as Figure 6.14, but in this case the investigation is focussed on the persistence of the shocks.

Figure 6.15: Effect of persistent crude oil shocks on the UK economy

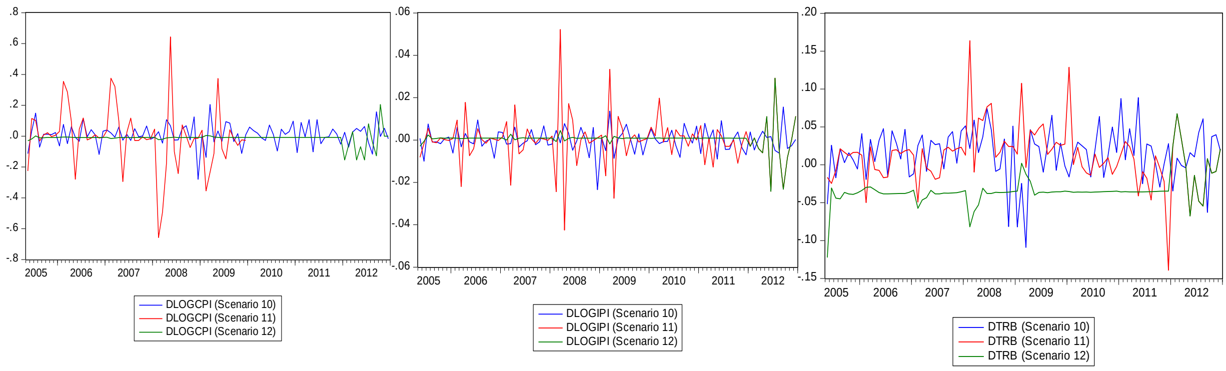


If only the direct effects of oil price shocks are relevant, then prices of non-energy goods and services should not be influenced by the oil shock, and the final effect on inflation is determined by the increase in relative prices. Thus the persistent effect of all three shocks can be observed from the effect on core inflation. Interestingly, compared to the insignificant response of headline inflation to the shock in oil prices, the response of core inflation shows signs of high significance (Figure 6.15, Scenario 4). An oil price shock does not affect UK headline inflation significantly, but core inflation suggests that increases in crude oil prices pass-through into the domestic CPI with a substantial delay. Also, core inflation falls as a response to the 10 per cent increase in oil supply due to lower input production costs as in the case of headline inflation, but again the size of this persistent effect is stronger than a transitory effect. Surprisingly, a shock driven by an increase in world oil demand will rise core inflation, nevertheless, the effect loses its strength in the second year following the shock and oscillates around zero afterwards. The response of industrial production to the all three sources of oil shock is similar as in size to the previous case. However, while in a transitory model the response of industrial production was most significant in the case of an oil price shock, in a model of persistent shocks industrial production responds to a world oil supply shock more than to an actual oil price shock. As in the previous case, an important implication for policy makers can be derived also from these results. The results confirm the findings of Peersman and Robays (2012) that not all oil shocks are necessarily harmful to an oil importing economy. Since the UK is an oil importing country, it is also a producer and exporter of alternative sources of energy which can be, to a certain level, substitutes for oil. Therefore while an increase in oil prices negatively impacts the economy, there might also be a shift in demand for its substitutes. The UK also takes advantage of increasing oil prices since it exports oil to European countries. In this case, the UK benefits from increases in oil prices by an upward shift in the demand for oil substitutes.

6.8 Transitory and persistent effects of a food specific shock

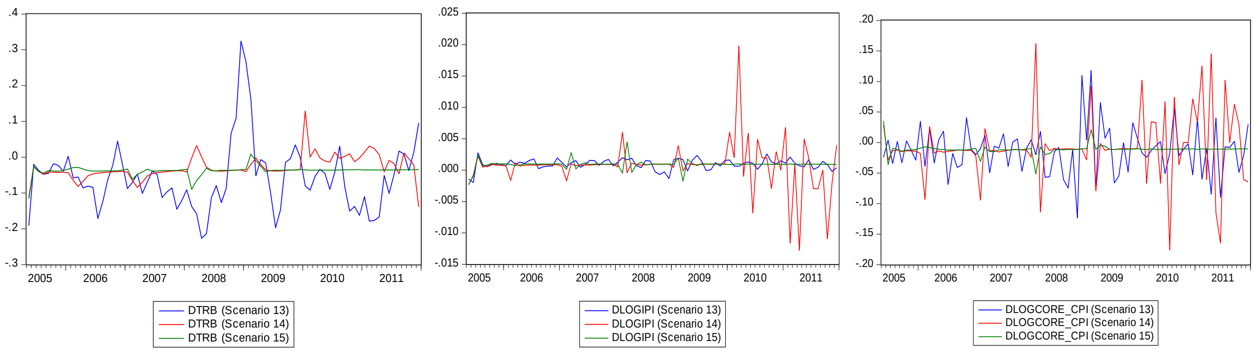
As Figure 6.16 shows, the transitory shock of higher world food prices (Scenario 10) does not have a significant impact on industrial production. Nevertheless, the effect is stronger than in the case of a transitory oil price shock. This effect can be explained by the position of food commodities in production. Since food commodities are not direct production inputs, a rise in food price therefore does not lead to a decrease in output. Consumer prices do react to higher global food prices; however, the transitory effect is not so significant since inflation expectations are well anchored.

Figure 6.16: Effect of transitory food commodity shocks on the UK economy



In contrast, a 10 percent increase in food demand (Scenario 11) raises consumer prices substantially by 0.6 percent. The significant effect on inflation would lead to the reaction of the monetary authority to increase interest rates. While in the previous case where a transitory oil supply shock seems to be of higher importance to policy makers, in this case, a food demand shock is of higher importance than a shock in the food supply. Interestingly, a transitory shock in the food supply has zero effect on the UK economy. In the case of persistent shocks, it is found that the effect of food price shocks (Scenario 13) on core inflation are statistically significant for the UK and the second round effect is nearly as strong as in the case of persistent oil price shocks. A transitory food price shock does not affect UK headline inflation significantly, but does affect core inflation, suggesting that increases in food prices pass-through into the domestic CPI with a substantial delay. This effect leads to the reaction of the monetary authority and increase in interest rates. The shock in food demand (Scenario 14) has a more significant impact on core inflation than the shock in food supply.

Figure 6.17: Effect of persistent food shocks on the UK economy



The weaker effect of food supply shocks on the UK economy compared to the effect of an oil supply shock can be explained by the different level of dependency of the UK economy on these two commodities. The UK economy is more dependent on oil import than on food import even if the UK's food self-sufficiency has a declining trend. On the other hand, positive persistent food demand shock stimulates the economy and will pass-through into core inflation. It is found that there is a different reaction from policy makers in response to persistent shocks. A rise in core inflation due to a general rise in world food prices seems to be of higher importance to policy makers than a rise due to food demand shock. This finding is interesting due to the fact that the effect of a food demand shock has a comparable affect on core inflation to a rise in global food prices. Considering the estimated long-term projection of an increasing trend in world food demand, policy makers should pay closer attention to developments in the food market (FAO, 2009).

6.8.1 Summary

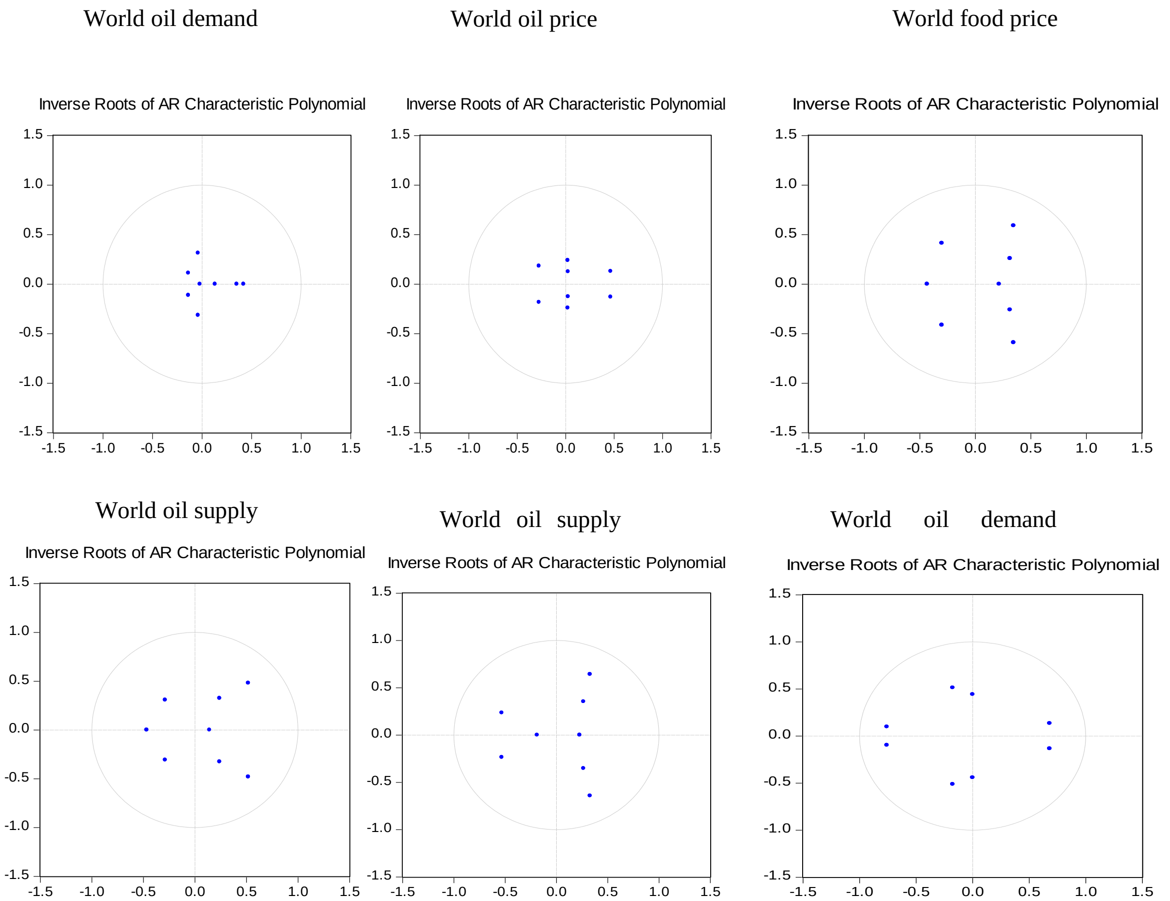
This section investigated the changing nature of oil price shocks and their impact on the UK economy over time from 1992 to 2013. The three types of underlying exogenous shocks have been investigated, as well as their persistent and transitory effects on the UK economy.

Although, previous studies have focused on this topic, the inclusion of the effect of food shocks extends the findings and contributes to a more complex analysis of the role of commodities in the UK economy. The models developed in this section of the effects of different underlying shocks to oil and food on the UK economy represents a contribution to the knowledge as they jointly consider different natured structural shocks to the oil and food commodities.

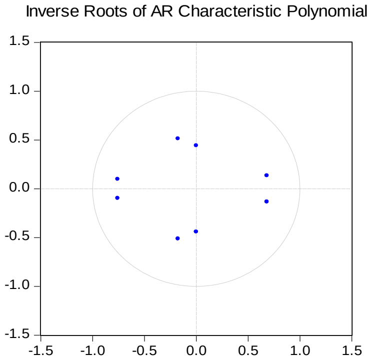
6.9 Model Stability and Robustness Check

Due to the fact that VAR models are used to simulate the transmission mechanism, it is important that the model exhibits stability in order to avoid generating unrealistic economic realisations. The first test of appropriateness is an assessment of the number of roots created in the AR characteristic polynomial. As presented in Figure 6.18, the first stability condition, which indicates that all roots of the characteristic polynomial are inside the unit circle, is satisfied, so the defined models are stable.

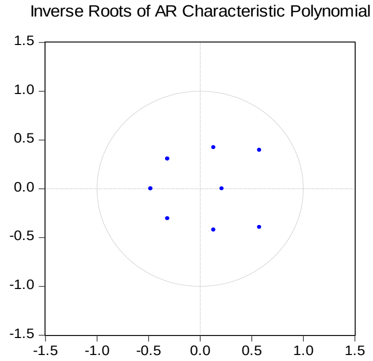
Figure 6.18: Roots test



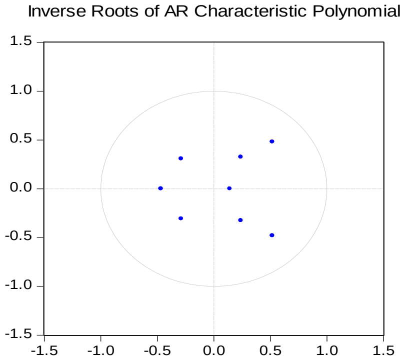
World oil demand (core)



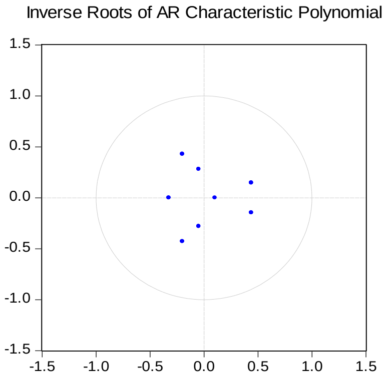
Oil price (core)



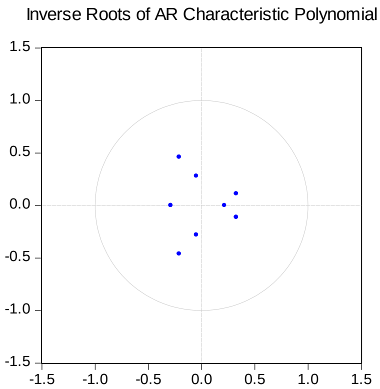
Food price (core)



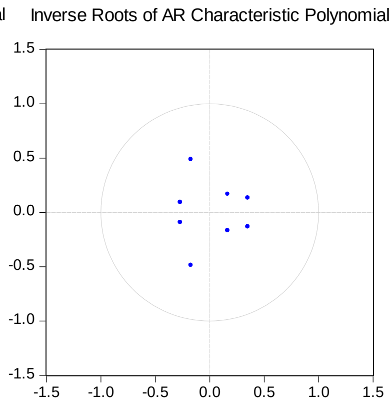
Food production (core)



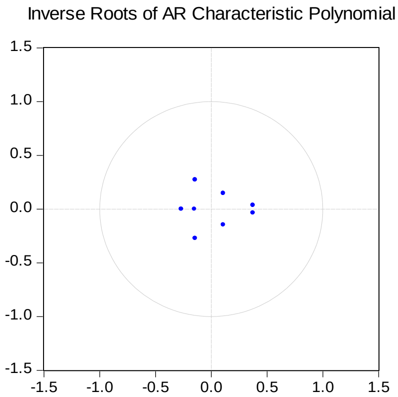
Food production



Food demand



Food demand (core)



Even if the first condition of stability is satisfied, VAR models still cannot be considered as stable until more advanced method is applied. Therefore as an addition to the stability check, the next section investigates possible structural break during the period analyzed, since structural breaks can cause the instability of model parameters.

6.9.1 Robustness check

As discussed in Section 2.2.3, crude oil prices as well as world food prices, particularly prices of wheat, coarse grains, rice, and oilseed crops have been increasing since 2005 and have reached their peak in 2008. The reasons for the price spike are complex and combine reinforcing factors driven by demand, easing of monetary policy in developed countries, devaluation of the U.S dollar, speculations and low inventories. Nevertheless, the combination of factors led to new peaks during the period analysed in this chapter. It is therefore assumed that the peak in 2008 could also mean a structural break. Recalling the discussion on VAR critique by Lucas (1976), for validating findings in a longer period it is necessary to take into consideration possible significant changes that could be considered as a break. While in Chapter 5, the structural breaks are tested in respect to the changes in monetary policy, this chapter focuses on breaks in respect to the changes in commodity markets, particularly crude oil and food commodities, specifically the peak in prices of all commodities in 2008. While Millard and Shakir (2013) split their period in 1986 since it coincided with the beginning of Great Moderation in the U.S and this date has been used in many previous studies of the oil market but does not consider any breaks during the period of 2004-2011. In this section, based on the behaviour of commodities discussed in Chapter 2, it is assumed that the unusual joint movements in commodity prices represent a change in commodity markets which needs to be considered as a break. However, the reasons behind commodity price peaks are numerous and therefore when testing for a structural break it may not be plausible to test for breaks in movements in the demand or supply of commodities as these jointly led to a price peak. As in Chapter 5, in this case the Chow test is used for testing the structural break. Results are presented in Table 6.8.

Table 6.7: Chow test for Model 1, Model 2, Model 3 and Model 4

Model 1
Chow Breakpoint Test: 2008M07
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2006M01 2012M11

F-statistic	4.256967	Prob. F(3,77)	0.0078
Log likelihood ratio	12.73680	Prob. Chi-Square(3)	0.0052
Wald Statistic	12.77090	Prob. Chi-Square(3)	0.0052

Model 2
Chow Breakpoint Test: 2008M07
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2006M01 2012M11

F-statistic	2.155219	Prob. F(4,75)	0.0823
Log likelihood ratio	9.030823	Prob. Chi-Square(4)	0.0603
Wald Statistic	8.620877	Prob. Chi-Square(4)	0.0713

Model 3
Chow Breakpoint Test: 2008M06
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2006M01 2012M11

F-statistic	1.539924	Prob. F(3,77)	0.2109
Log likelihood ratio	4.836087	Prob. Chi-Square(3)	0.1842
Wald Statistic	4.619771	Prob. Chi-Square(3)	0.2019

Model 4
Chow Breakpoint Test: 2008M07
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2006M01 2012M11

F-statistic	4.013082	Prob. F(3,77)	0.0104
Log likelihood ratio	12.05756	Prob. Chi-Square(3)	0.0072
Wald Statistic	12.03925	Prob. Chi-Square(3)	0.0072

From the results, the null hypothesis of no breaks at the specified date can be rejected for Model 1 and Model 4 since $p<0.05$ thus the chosen date does represent a change in commodity movements. These findings reveal important implications for models developed in this part, as Model 1 and Model 4 estimated in Sections 6.7 and Section 6.8 need to be re-estimated again in respect to the peak in the market which represents a structural break. Nevertheless, it is interesting that the H0 hypothesis can be rejected for both food and oil prices, however in the case of food prices, the H0 hypothesis can be rejected in the case of persistent shocks.

6.9.2 Impulse response functions of re-estimated models in respect to structural breaks

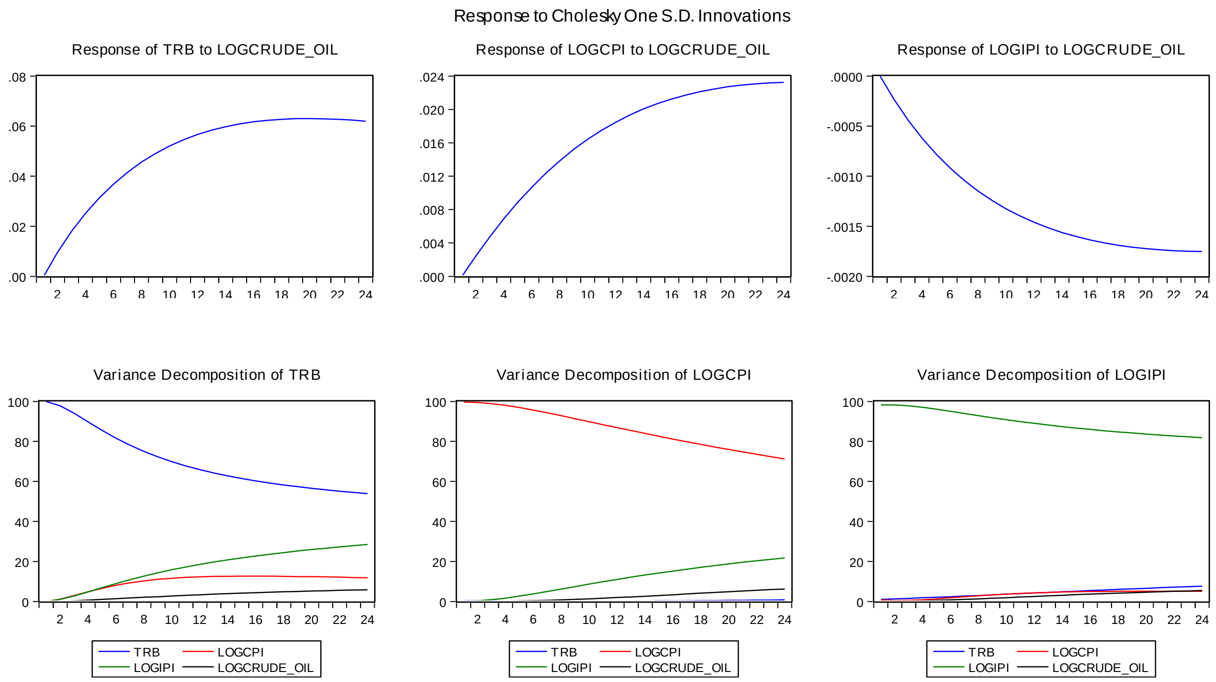
It should be noted that the oil and food price peaks coincide with the financial crisis. This may possibly has affected the sensitivity of the UK economy, and the response may be affected by the financial crisis too. The re-estimated models in respect to the identified structural breaks can be found in Appendix K. The re-estimated coefficients of VEC Model 1 reveal interesting findings. While before the break, the shift in oil price above its long-run equilibrium, the short-term interest rate would decrease in the next period. This implies that before the commodity price peak, the reaction of monetary policy was towards to stabilizing output growth to offset the losses in real GDP and increase inflationary pressures. However, when compared with the period after the commodity price peak, the short-term interest rate increases when a shift in oil price above its long-run equilibrium is observed. This implies the assumption of Cologni and Manera (2008) who pointed that monetary authority in a flexible inflation-targeting after the shock increase interest rate with negative impact on output. The negative impact on output can be observed from the CoinEq3 in Appendix K, where results show that if oil price shifts above its long-run equilibrium, inflation decreases however, the decrease in the next period is also observable in industrial production. In the case of Model 4, food prices seem to be an explanatory variable, for the UK's industrial production as well as the UK's interest rate, however, the coefficient for food price does not seem to be explanatory neither for UK monetary policy nor core inflation before or after the break.

Figure 6.19 shows the results from impulse response functions for all key economic variables. While the response of 3-months Treasury bills, as well as headline inflation, to a unit shock in oil price becomes weaker after the oil price peak, the response of the Industrial production index changes completely. Interestingly, the response of 3-months Treasury bills is positive and stronger before the peak. This suggests that even if the inflation is more responsive to the oil price shocks after the commodity price peak, monetary policy is less responsive. This can be observed also from variance decomposition. While before the commodity price peak, the oil prices explained nearly 20 per cent of the variation in short-term interest rates, the effect is weaker after the peak. Interestingly, from the variance decomposition it may be suggested that monetary policy pays more attention to the developments in inflation and output after the commodity price peak than before the peak. In addition, after the commodity price peak, inflation explains more than 40 per cent of variations in industrial production compared to less than 10 per cent in the period before the commodity price peak.

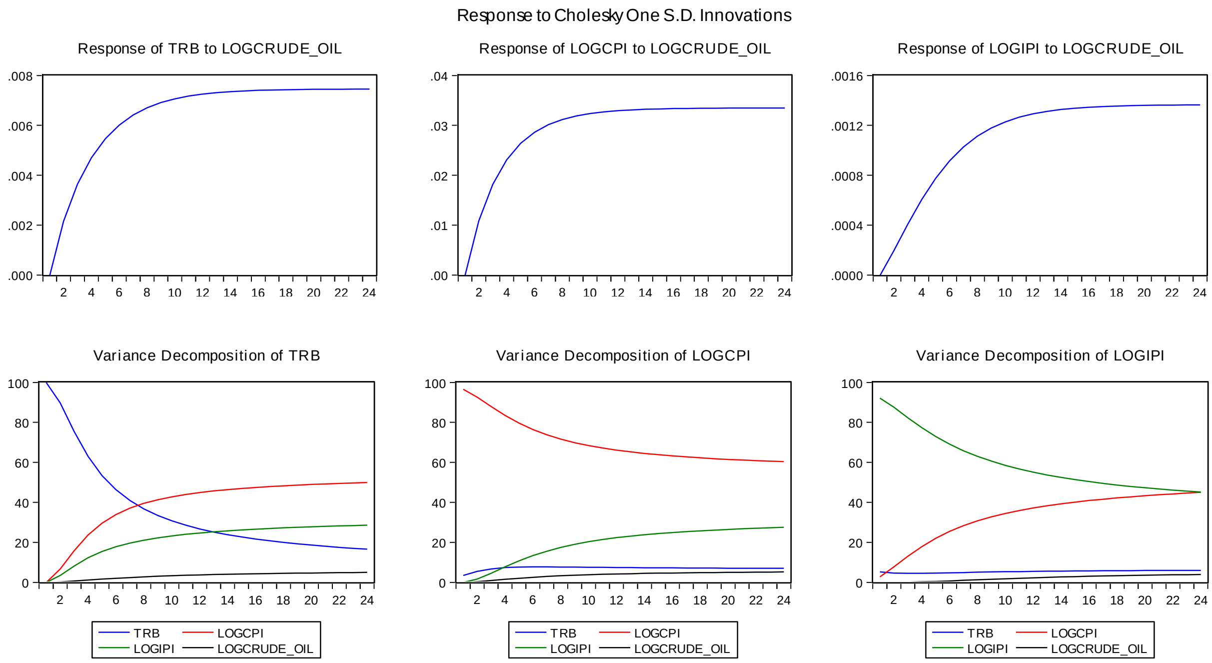
Since shocks in oil prices (as well as food prices) are in most of the cases considered as transitory (IMF, 2011) it is better to let higher prices be absorbed by higher headline inflation. This explains the weak response of policy makers to increases in oil prices after the peak. Nevertheless, during the peak, the price for crude oil increased from $50 per barrel in early 2007 to $140 per barrel in the summer of 2008. Since the prices nearly tripled, the risk of a possible increase in inflation expectations might have forced policy makers to factor this increase into decision making (Bolton, 2013).

Figure 6.19: Impulse response and Variance decomposition of Model 1

Before the commodity price peak

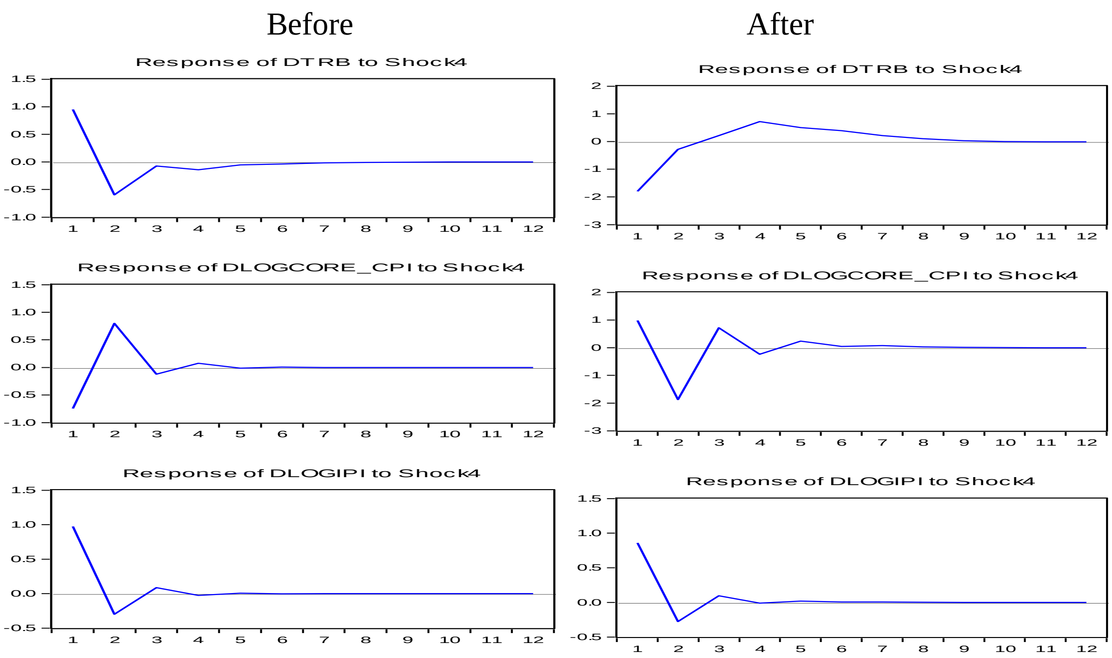


After the commodity price peak



This change in the sensitivity of inflation also reflects how well inflation expectations are anchored. While a stronger response before the peak shows that increases in oil prices were left to be absorbed by inflation, while after the peak expectations about inflation are anchored by the reaction of policy makers. Contrary to headline inflation, a more significant response can be found in core inflation. Figure 6.20 shows the impulse response functions of core inflation together with 3-months Treasury bills and the industrial production index to a unit shock in food prices. Even if oil and food price shocks tend to be transitory rather than persistent, commodity shocks also have a persistent effect on the UK economy. Nevertheless, it is interesting to find that the reaction of core inflation to the shock in food prices is strong, and also that it is more responsive after the peak resulting from the stronger reaction of policy makers after the peak.

Figure 6.20: Impulse response of Model 4



As in the previous case, industrial production has not changed with the peak and the effect stays the same. This might be due to lags in the reaction function of industrial production to changes in economy.

6.10 Summary

This chapter investigated the effect of different natures of oil and food commodities shocks on the UK economy. While findings are comparable to previous studies which focus on larger economies, they also reveal important results that should be considered.

Firstly, the finding that an oil price shock does not affect the UK's headline inflation significantly, but does affect core inflation, suggests that increases in crude oil pass-through into the domestic CPI with a substantial delay. Also, the rise in core inflation due to a general rise in world food prices is found to have a higher importance to policy makers than a rise due to a food demand shock. This finding is interesting due to the fact that the effect of a food demand shock has a comparable effect on core inflation as a rise in global food prices. In addition, it was also found that policy makers react differently in response to persistent shocks. The rise in core inflation due to a general rise in world food prices seems to be of higher importance to policy makers than the rise due to a food demand shock. This finding is important since the effect of a food demand shock has a comparable effect on core inflation as a rise in global food prices. Secondly, the analysis of potential structural breaks in the behaviour of commodities reveals interesting findings too.

Before the peak in 2008, food prices seem to be an explanatory variable for the UK's industrial production as well as the UK's interest rate, however, the coefficient for food price does not seem to be explanatory either for UK monetary policy or core inflation before or after the break. Another interesting finding is the response of headline inflation to the shock in oil prices. While before the peak, the size of the response was stronger, the trend after the peak in 2008 changed and headline inflation became less responsive to the shock. Nevertheless, it is interesting to find that the reaction of core inflation to the shock in food prices is strong and also more responsive after the peak, resulting from the stronger reaction of policy makers after the peak. These findings prove that different natures of commodity shocks do matter to the UK economy, and opens a discussion on their implications for policy makers.

Chapter 7 Discussion

7.1 Introduction

This chapter provides a brief overview of the research, including a statement of the problem and the major methods involved. The majority of the chapter is, however, devoted to a summary and discussion of the aim and objectives stated in Chapter 1, as well as to a discussion of the relevance of the results and their possible implications for policy makers. The discussion consists of two main sections. Section 7.2 discusses the results regarding the sensitivity of commodities to developments in the UK monetary policy. The discussion continues in Section 7.3 where the results regarding the reverse relationship – the sensitivity of the UK economy to commodity shocks are discussed.

7.2 Background of the findings: the sensitivity of commodity markets to the UK's monetary policy shocks

The significant rise in commodity prices in the 2000s led to a surge of studies in the literature that investigated the causes of commodity shocks, which went beyond the traditional explanations, and the effects of the shocks on the countries' economies (Frankel, 2006). Various explanations of the unprecedented rises have been introduced, from the effect of the growing demand from emerging economies (Trostle, 2008), which to a certain level may explain the movements in a few commodities, but certainly not all of them, to the popular explanation of mysterious movements-speculations (Nikos, 2008). The novelty in explaining the recent movements in the commodity markets is incorporating the effect of monetary policy, specifically easing monetary policy, and the role of low interest rates (Krichene, 2008; Taylor, 2009; Frankel, 2006). However, the link between monetary policy and commodity prices is not new. The first idea of the existence of a relationship between monetary policy and commodity prices can be found in the early works of Frankel (1986) inspired by Working (1949).

Naturally, studies on the impact of economic developments on commodity prices focus on emerging economies, given the importance of the size of the consumption, especially in oil. The investigation on the effect of easing monetary policy on commodity prices has been concentrated on the U.S as one of the largest economies (Arora and Tanner, 2013; Anzuni et al. 2012; Kilian, 2009; Kirchne, 2007; Barsky and Kilian, 2004) and given the importance of its global position, as well as the size of the U.S. However, Frankel (2006), in an extension to his original paper (Frankel, 1986), raises an argument about the importance of investigating the effect of monetary policy in small open economies: *"the U.S is not the whole world. It is less than 1/3 of the Gross World Product, even if its importance in monetary and financial markets is evidently greater than that."* Thus, Frankel (2006) applied his earlier argument on the effect of monetary policy in small open economies on commodities and found a high statistical significance in the case of the UK, Australia and Canada. Another study, which may be used to support the rationale for investigating the impact of the UK's monetary policy on commodity markets, is a study of Roache and Rossi (2009) who investigated the effects of announcements about interest rate decisions on commodity markets in several countries, including the UK. Their findings reveal that the prices of gold react significantly to announcements about interest rate decisions but significance can be also found also in the case of other commodities.

The rationale behind the investigation of the impact of UK monetary policy on commodity markets can be understandably challenged by the argument that the position of the UK in the global context is not as strong as in the case of the U.S, thus the effect on commodity prices can be expected to be small. Since Frankel's (2006) study is, to the best of the author's knowledge, one of the kinds investigating the impact of smaller open economies, there is a lack of literature on the UK to support or reject the argument. Frankel's (2006) study can be considered as introductory to the effect of smaller countries, which is certainly not as complex as the effect in the case of the U.S, thus this thesis aimed to evaluate the sensitivity of oil and food commodities to shocks in UK's monetary policy in an extended model. The following sections therefore discuss the findings with respect to the research objectives.

7.2.1 Identification and measurement of the size of the effect of economic and monetary developments in the UK on food prices and crude oil prices

In order to investigate the strength and relevance of the argument that monetary policy in small open economies may also play a role in commodity markets, and provide the support for the argument a test of the null hypothesis has been approached as the first step. However, it should be noted that the effect of UK monetary policy on commodity prices may not be strong, but this cannot be confirmed due to the size of the economy and due to a lack of evidence.

Thus the desired effect of using the Granger causality test was to investigate whether movements in crude oil prices and food prices are related to economic and monetary developments in the UK.

The results of the Granger causality test (Table 5.1, Chapter 5) showed that current food prices are not correlated to the past values of UK interest rates. Additionally, the results show that current food prices are not correlated to the past values of money supply, IPI, or 3-month Treasury bills. Clearly, current food prices do not seem to be related to the developments in the UK economy. This may increase support for the argument that current unprecedented rises in food prices have been driven by other factors than past economic or monetary developments in the UK. However, as shown by Piesse and Thirtle (2009) the recent food commodity price events have also been caused by low stock. Although, as the results from the Granger causality test show, UK monetary policy may not affect food commodity stocks directly. A study by Sousa and Zaghini (2007) on the global monetary policy shocks showed that easing monetary policy in the UK had a statistically significant effect on global liquidity. As presented by Baffes and Haniotis (2010) high global liquidity explained the high commodity prices, including food prices. Thus it is assumed that there might be a channel, most likely an indirect channel, on how developments in the UK economy affect food commodities through increases in global liquidity which consequently raises the prices of food commodities. Contrary to food prices, current oil prices seem to be correlated to past developments in the UK economy.

As the results show, while money supply, thus liquidity, does not play an important role for oil prices, current oil prices are found to be correlated to the past values of UK industrial production and also to the past values of 3-month Treasury bills. The results are comparable to the findings of Arora and Taner (2013) for the U.S. Their results from the Granger causality test also show that the null hypothesis of U.S interest rates does not cause oil prices to be rejected. This is an important finding, which can be used to support to the argument that it is worth to pay attention to investigation on the effect of the UK monetary policy on oil prices, even if the economy is not considered to have as significant effect as the U.S economy for instance. In other words, economic developments as well as monetary developments in the UK may play a role in oil markets. Given the importance of the smaller size of the UK economy, the findings on the existence of the relationship between UK industrial production and oil prices are interesting since the size of the UK's oil demand is not assumed to be as important as in other countries such as China. This may be explained by the specific position of the UK as an oil importer as well as an exporter in the oil market.

Nevertheless, the results of the Granger causality tests should be taken with caution. Even if the lag length has been estimated with respect to the sensitivity of the test, the risk of misleading results from the test due to its sensitivity cannot be completely avoided. Also, since the Granger causality test does not provide any information about the size of the effect of the monetary or economic shock on commodities, the investigation continues by adopting a similar approach to that found in works of Akram (2009), Anzuni et al. (2012) and Arora and Tanner (2013). As stated in the objectives in Chapter 1, due to a lack of empirical evidence for the UK, for the investigation on the relationship between monetary policy and commodity markets, the aim was to adopt the econometric modelling used in the most recent studies, but adjusted for UK conditions. Before discussing the models in relation to the model developed in the first section of Chapter 5, it should be noted that the above mentioned authors (Akram, 2009; Anzuni et al., 2012; Arora and Tanner, 2013) focus on the effect of U.S monetary policy. Understandably, it would be more convenient if results could be compared to studies on UK monetary policy but this is not possible due to the lack of evidence for the UK. Nevertheless, the disadvantage of missing evidence for the UK can be seen as an opportunity for contribution to the knowledge. Although the model estimated in Chapter 5 to some extent follows the approach taken in the above mentioned studies, it also differs in several key areas and introduces a more complex analysis. The first difference is in the frequency of time-series used for model estimation. While time-series in model developed in Chapter 5, as well as those used by Anzuni et al. (2012) and Arora and Tanner (2013) are at a monthly frequency, Akram (2009) uses quarterly data.

As explained in Chapter 4 (Section 4.10) even if quarterly data could have been used, to capture the economic impact of important events, it was preferable to use data at a higher frequency. Also, when it is considered that the sample period in Akram’s (2009) study covers the years 1990-2007 (17 years), quarterly data limits the number of observations, and thus can affect the reliability of the tests used for the analysis as well as the reliability of the results (a full table with a comparison of the models can be found in Appendix L). The analysing period differs as well. However, Anzuni et al. (2012) and Arora and Tanner (2013) cover a period from the 1970s to the 2000s, and thus estimate the model through decades of several changes in monetary policy as well as disturbances on commodity markets. Akram’s (2009) model and the model developed in the first section of Chapter 5, focus on a period known as the Great moderation. Akram’s (2009) motivation for focusing on the period of the Great moderation was to extend previous studies, which proved the effect of monetary policy on commodity markets, and investigate whether the effect has changed in that period without significant disturbances to commodity markets as observed in the 1970s and 1980s.

Based on Frankel's (2006) finding that the relationship between monetary policy and commodity prices is time-varying, and based on the Lucas' (1976) critique, and considering the lack of evidence for the UK, the period considered for model estimated in Chapter 5 starts in 1992 after the disturbances in monetary policy in the UK, and the adoption of inflation targeting, as discussed in Chapter 2. This gives an important condition for the stability of the estimated model. Also the chosen period provides an opportunity to investigate the sensitivity of oil prices and food prices during the longest period of inflation targeting investigated so far. The econometric strategy approached by Akram (2009), Anzuni et al. (2012) and Arora and Tanner (2013) is a VAR model. Although Akram (2009) and Arora and Tanner (2013) did consider the non-stationarity of time-series, and applied the test for cointegration, after obtaining conflicting results approached estimating the VAR model, Anzuni et al. (2012) adopted the VAR model without investigating the long-term relationship. As discussed in Section 4.4 (Chapter 4) the adjustments to account for the nature of economic time-series is a necessary condition which includes the investigation of a possible long-term relationship if series are found to be I(1). Thus the model estimated in the first section of Chapter 5 was also tested for a possible long-term relationship with a positive result. Therefore, contrary to the above mentioned studies, the model used for investigating the effect of UK monetary policy on commodity prices is a VEC model.

The variables considered in model developed in Chapter 5 have been adjusted to the UK conditions thus contrary to Anzuni et al. (2012) the money supply is captured by M4 rather than M2. In contrast to this model, Akram (2009) and Arora and Tanner (2013) also include effective exchange rate since the price of oil is in US dollars so it may impact oil demand and supply. Following Akram (2009) and Anzuni et al. (2012) who were the first to investigate the effect on food prices in U.S conditions, model estimated in Chapter 5 also assumes that the effect and its size may differ in relation to commodities thus it investigates the effect on oil and food separately. While Akram (2009) uses Cholesky decomposition, which is an effective method for solving systems of linear equations, as discussed in Section 4.2 (Chapter 4), in line with the philosophical approach to econometric modelling introduced by the Cowles Commission, the restrictions on the matrix for model estimated in Chapter 5 as well as the model used by Anzuni et al. (2012) are derived from economic theory.

The investigation of the relationship between economic and monetary developments in the UK and commodity prices starts with an evaluation of the effect of increased production in the UK. The assumption is based on the concept of the Cobweb model which uses forces of demand and supply to explain the movements in commodity prices. Thus it is assumed that increased industrial production (used as an output measurement) led to increases in the UK demand for oil commodities and is reflected in higher oil prices, since oil production (the oil supply) is not responsive in the short-run. The obvious limitation of this theoretical assumption is that the response of the oil supply in the form of higher oil prices would apply only if the increase in demand was significant and could not be satisfied by oil stocks, ceteris paribus. So when the size of the UK economy is considered, as well as the actual consumption of oil or food commodities compared to larger economies, the expected impact is smaller. However, the investigation of the effect is still interesting since the UK is also an oil exporting country, so to some extent may contribute to the developments in oil prices. Nevertheless, the results from impulse response functions (Chapter 5, Section 5.6.2) do not provide evidence for this assumption, since even if the UK became a net-oil importing country, it does not have as a significant effect on world oil prices, as the amount of oil consumption, when compared to other larger economies, is modest. For instance, a study by Roache (2012) shows nearly a 3 per cent increase in crude oil prices as a response to a positive, 1 per cent shock in China's economic activity. In contrast to China, results from model estimated in Chapter 5 show that a positive 1 per cent shock to the UK's industrial production can cause a short-term small rise of nearly 0.02 per cent in oil prices as a response of supply to the higher demand. However, in the long-run the oil prices oscillate back to the equilibrium.

Even if a 1 per cent increase in industrial production can have an important impact on the UK economy, in the world context this increase is statistically insignificant thus the response of oil prices is weak in the short-term as well. Although, the impact of a shock in UK industrial production is not as significant as in China, it does not mean that the role of the UK economic developments is not important. When examining the response of oil prices to a shock in the U.S industrial production, Arora and Tanner (2013) also identified an increase in oil prices by 0.04 per cent in the first 6 months following the shock and oscillation back to the equilibrium. Similarly, Akram's results (2009) showed an increase in oil prices in the first 5 months by 0.05 per cent and oscillation to equilibrium afterwards. To support the argument, Kilian (2009) also found that a 1 per cent positive shock to global aggregate demand leads to an increase in the real price of oil of about 1 percent after 12 months. Therefore the results of the effect of the UK's output shock on oil prices can be classified as reasonable.

Similarly the effect on food prices is small. A decrease in food prices is caused by higher demand for oil due to higher industrial production, which consequently leads to a lower demand for food products (see Chapter 3 for discussion). However, the effect is again very small. Food prices respond only by a 0.016 per cent decrease to a 1 per cent positive shock to industrial production. Therefore taking into consideration the size of the change and its impact, it can be concluded that although the shock to the UK's output measured as industrial production does play a role in terms of commodity price determination, its role is not so significant.

From the evaluation of the results in the second part of Chapter 5 which focuses on the evaluation of the effect of monetary policy, the assumption here follows the earlier concept introduced by Frankel (1986), who extended the famous theory of overshooting (discussed in Chapter 3, Section 3.3.4) introduced by Dornbush (1976) by bridging the theory of storage (discussed in Chapter 3, Section 3.3.1) and theory of overshooting. Frankel (1986) developed his argument on the assumption that monetary policy has effects on the real prices of commodities and the rise in inflation leads to a shift out of money into commodities. Thus, the increased demand for commodities in combination with expected increases in inflation, according to Frankel (1986) drives the commodity prices. To summarize Frankel's concept of overshooting: A restrictive monetary policy can be presented as a cut in the money supply, which in the long-run leads to drop in commodity prices, while in the short-run there will not be any reaction since in the short-run, commodity prices are assumed to be fixed. The reduction in money supply understandably leads to an increase in interest rates. The arbitrage condition which is an unconditional assumption of Frankel's model holds, and implies that commodities are storable so the rate of return on interest rate cannot be higher than the expected rate of increase in commodity prices and storage costs.

The commodity prices are expected to overshoot, in order to future capital gain which is sufficient to compensate higher interest rate. When investigating the effect of a shock in nominal interest rates, the results from plotting the impulse response functions reject Frankel's assumption about the UK's conditions. The long-term impact of the 1 per cent cut in the nominal interest rate (modelled as a negative shock in the interest rate) on the oil prices, as reported in Figure 5.5 is relatively small since a unit shock leads to a reduction in oil prices by 0.06 per cent however the shock is persistent since the response function does not reach a stable level prior to a 24-month forecast horizon.

Similarly to oil prices, food prices also respond to the nominal interest rate shock with a negative drop without reaching a stable level prior to a 24-month forecast horizon. Therefore the theory of overshooting does not apply. However, when estimating the model with 3-months Treasury bills, the response seems to differ. A monetary expansion through the lower 3-months Treasury bills rate generates an increase in both oil and food prices. The impact on oil is sharp, peaking in the third month after the shock and decreasing afterwards with oscillation close to the long-term equilibrium. Nevertheless, the effect does not vanish even after two years. Contrary to oil prices, the effect on food prices is not as strong and sharp however, it also peaks in the first half of the year after the shock. Interestingly, the effect vanishes after 18 months when price returns back to the equilibrium. When evaluating the significance of the sensitivity of commodity prices, country specifics need to be taken into account. As mentioned at the beginning, there is a rational assumption that the size of the effect of UK monetary policy might be smaller than in the case of the U.S. While results from this study show that a 1 per cent cut in 3-months Treasury bills leads to more than 0.6 per cent increase in oil prices and a 0.3 per cent increase in food prices, the results of Anzuini et al. (2012) show a 3 per cent increase in oil prices and around a 4 per cent increase in food prices as a response to a 1 per cent cut in the FED. Even if the response to the UK's loose monetary policy is smaller, considering the position of the UK and the size of economy, the results may be still considered as notable.

7.2.1.1 Summary

The objective of providing the evidence on the sensitivity of world oil and world food prices to developments in UK monetary policy was achieved by estimating a model which adopts a similar approach to the most recent studies, but is adjusted for UK conditions. This model also contributes to the previous models by extending them by introducing oil prices as well as food prices into the model. The results of the model confirm Frankel's (1986) original assumption that expansionary monetary policy thus, cuts in interest rate, lead to higher commodity prices. The results from impulse response functions show that a 1 per cent cut in 3-months Treasury bills increases oil prices by 0.06 per cent and food prices by 0.03 per cent.

7.2.2 An investigation of the channels of transmission of the UK monetary shocks on commodity markets and an evaluation of their sensitivity at different levels

Since results from the investigation in the previous section show the sensitivity of oil and food prices to shocks in the UK's monetary policy as well as the economy, and although the impact is statistically significant but smaller in size, the next objective was to explore the issue in more depth by investigating how sensitive oil markets at different levels are to developments in the UK's monetary policy. The rationale behind this objective is based on the results from the previous section which show a statistically significant but only small impact on oil and food prices, which leads to the investigation of the assumption that the impact may be stronger at a national and international level. The concept of investigating the effect on a national and international as well as a global level represents a contribution to the most recent understanding of the channels, as this investigation extends the current concept introduced by Frankel (2006) to a concept applicable for evaluating the impact of small open economies. The pioneering work on this topic can again be found in work of Frankel (2006) who, based on the characteristics of storable commodities, acknowledges the importance of the level of inventories and introduced a distinction between channels of how monetary policy can affect commodity prices. Specifically, it is possible to distinguish between the inventory channel, supply channel and speculation channel. The aim of this objective is to explore and extend the inventory channel and supply channel.

Due to the different nature of the data needed to explore the speculation channel, and the scope of such research (which is in the area of financial markets) it is beyond the scope of this thesis, thus this channel is left unexplored for further investigation. As in the previous section, since neither the inventory nor the supply channel have been investigated at different levels in previous studies, due to this lack of evidence, the investigation begins with testing the hypothesis of the relationship between the UK's monetary policy and inventory and supply channel at different levels. The results of the Granger causality test for the oil supply channel release interesting findings. The null hypothesis of no relationship between the UK monetary policy and oil supply, and oil industrial stock, can be rejected in a few cases. Interestingly, the current movements in the OPEC oil supply as well as the world oil supply are found to be correlated to past movements in 3-months Treasury bills, while no Granger cause is found at the EU27 oil supply or IEA oil supply. Since the assumption is that the effect will be stronger at a national and international level than at a global level, these results do not provide support for this assumption. On the other hand, the current UK oil stocks are found to be correlated to past movements in 3-months Treasury bills suggesting that the 3-months Treasury rate plays an important role for the levels of national industry oil stocks while there is no support for international or global oil stocks. However, due to the limitations of the Granger causality test, the investigation is approached by estimating the VAR model.

To start with the results from estimating the inventory channel are presented. As Gilbert's (2011) results show, low stocks have been one of the important drivers of commodity prices in the 2000s. The argument presented by Frankel (2006) is that high interest rates lead to a decrease in firms' desire to carry inventories. The motivation to carry lower levels of inventories was explained by Kaldor (1939) as a consequence of convenient yield, the benefit of using the stored commodity was discussed in Section 3.3.1. The results from plotted impulse response functions for UK oil inventories responded to 1 per cent increase in interest rates by a sharp 9 per cent drop in the first three months. The effect of the shock died off after eight months, confirming Frankel's short-term assumption. Interestingly the impulse response of oil inventories in OECD-European countries to a monetary policy shock is found to be smaller but still statistically significant. The results show that in the first three months the inventories drop by more than 5 per cent in response to a 1 per cent increase in 3-months Treasury bills. However, the effect is found to be only short-term, as assumed by Frankel (2006), as it dies in eight months. A different effect can be observed when estimating the effect of a UK monetary shock on the industrial oil inventories of all OECD countries, in other words, when estimating the global impact, in contrast to national or international level, the global impact is found to be smaller, since a 1 per cent increase in interest rates leads to an increase of 0.2 per cent in second month followed by a decrease in oil inventories in the following four months. The effect dies in a year after the shock. Indeed, a smaller impact at global level is not surprising and confirms the results from the first objectives.

Nevertheless, even if the impact is not as strong as at the national or international level, the results are comparable with Anzuini et al. (2012) who came to a similar conclusion when analysing the impact of the U.S monetary policy shock on OECD inventories. As noted, low inventories have been found to be one of the drivers of commodity prices. Keynes'(1930) concept of the Gipson paradox explains that commodity prices are driven by low interest rates, which means that the natural interest rate which represents the net storage cost and real return to holding commodities is higher, so there must be compensation in the form of a higher price. Also, if there are expectations about the interest rate remaining low (such as after the financial crisis) the higher cost of storage will negatively affect the level of inventories which increases the factor of scarcity explained by Hotteling (1939) and as a consequence, leads to increases in prices. The results show that the effect of a cut in 3-months Treasury bills is strongest at the national level and weakens at the international level with only a small impact at the global level, confirming the assumption that the impact of the UK's monetary policy may be stronger at the national and international level than at the global level.

The relative contribution of monetary shocks to overall oil inventory fluctuations as measured by a forecast error variance decomposition, shows that the shock in 3-months Treasury bills explains the movements in oil inventories the most, but it does not explain all the fluctuations. Overall, it can be concluded that UK monetary policy shocks, particularly unexpected movements in interest rates, may help to predict movements in oil inventories, however they cannot explain all fluctuations, especially at a global level. This result is in line with a study by Barsky and Kilian (2002) and Frankel (2007), who came to the conclusion that the most significant impact on commodity prices can be caused by interest rates. As discussed, commodity prices have been driven by low inventories (Gilbert, 2011). It has been found that low inventories are a response to firms' depressed desire to hold inventories due to higher interest rates which do not compensate the costs, it is important for policy makers to understand the effect of easing monetary policy in order to include all relevant information for policy decisions. The findings that restrictive monetary policy has a negative and significant impact on inventories at the national as well as international level may be a useful indicator for policy makers when deriving conclusions from forecasting commodity prices.

For instance, the headline inflation in the UK in 2009 was the highest amongst major advanced economies and exceeded the official inflation target of 2 per cent. According to the IMF (2011) this overrun was unanticipated by most forecasters, also due to unexpected increases in international commodity prices. It may be assumed that if the effect of low interest rates on commodity prices is considered when projecting the forecast for commodities, the significant rise in commodity prices could be identified and incorporated into policy decisions. The findings of the significant response of European inventories to a shock in the 3-months Treasury Bills rate may also have an implication for the European Central Bank (ECB).

For the oil supply channel, Frankel's (2006) assumption is that lower interest rate causes the opportunity cost of leaving oil in the ground, with the expectation of selling it later for a higher price, to possibly be higher. Therefore, producers are assumed to prefer to immediately extract the oil and invest the revenue when monetary policy is tight and postpone the extraction of oil during low interest rates. However, in this case the effect of easing monetary policy means that the opportunity cost of leaving oil in the ground is low; therefore suppliers may prefer to postpone extraction and therefore decrease the supply of oil. The results from the impulse response analysis show that a 1 per cent increases in money supply as well as 1 per cent acceleration of inflation lead to 0.5 per cent decrease in IEA oil supply. A 1 per cent cut in 3-month Treasury bills only slightly increases the oil supply however the effect dies soon in the third month. A similar, but smaller, response is obtained from the response of the EU 27 oil supply and OECD oil supply to the shock in UK monetary policy. These results indicate that a smaller response is assumed to be due to the international position of these countries as oil suppliers. Unlike European countries, the response of the OPEC oil supply to an expansionary shock is a short-term 1 per cent decrease in oil supply as a response to lower interest rates.

Overall the response of the world oil supply to the UK expansionary monetary policy is small, only about 0.3 per cent decrease. However, these results are comparable to the response of the world oil supply to a shock in US monetary policy. The results of a similar study by Anzuini et al. (2012) show that the oil supply tends to respond with only a slight increase in the short-term, however the effect dies in the third month after the shock. This confirms the partial role of monetary policy in explaining movements in oil supply.

The results from computing the forecast error variance decomposition, suggest that in all cases, movements in the oil supply are to a significant extent explained by their own movements however the importance of inflation in explaining movements oscillates about 10 per cent in the case of the IEA oil supply, and by only about 7 per cent in case of EU countries. As oil producers set production levels based on their predictions about future developments in the world economy, policy decisions in the UK are proved to be taken into consideration, however they cannot be taken as the only explanatory variable for movements in the oil supply at any level.

The implication for policy makers can be formulated as the following. The empirical results reported in Chapter 5 suggest that oil inventories and the oil supply at different levels reflect monetary easing in the UK. Thus, it might be useful for the BoE and the ECB to pay closer attention to commodity prices. As noted earlier in Section 2.1, even though inflation targeting countries such as the UK do not directly target commodity prices, developments in commodity markets, which are believed to be reflected in futures prices, are considered in projecting their economic outlook. Nevertheless, as discussed earlier, results from projecting the economic outlook shows the forecast of future inflation has been underestimated mainly due to the fact that futures prices did not reflect developments in commodity prices (Stockton, 2012; Cabanillas and Terzi, 2012; ECB, 2013). By providing the evidence that monetary policy in a small open economy such as the UK matters for commodity markets, the discussion is open for rethinking the importance of easing monetary policy in terms of its effect on commodity markets at different levels.

7.2.2.1 Summary

The results from the model provide evidence for the effect of changes in UK monetary policy on oil inventories and oil supply at a national as well as an international and global level, proving that easing monetary policy matters for oil markets. As showed, the effect is significant at the national level and then loses strength compared to the global level. Nevertheless, it provides supportive evidence for Frankel's (2006) argument that the attention of central banks should be more focused on commodities as they show that easing monetary policy can provide earlier signals of rising inflation.

7.2.3 Has the sensitivity of commodity markets to developments in the UK's monetary policy changed during the 2000s?

As noted earlier, even though most research in this area, as found in the studies by Akram (2009), Anzuini et al. (2012), and Arora and Tener (2013), contributes to a better understanding of the important role that has been played by monetary policy in commodity markets through the last four decades, a weak point can be found. The period analysed in these studies cover two or more decades, during which several significant changes in monetary policy can be found. Ignoring the changing environment and investigating the impact of monetary policy on commodity markets without considering developments in monetary policy can be taken as an area of their research which needed be explored. Therefore, during the period from 1992-2013, a few known changes to the UK's monetary policy have been identified and tested. Specifically, the investigated dates are: the operational independence of the BoE in May 1997 and the financial crisis in December 2007. One could argue that there are more than two known changes in the monetary policy, such as quantitative easing and the introduction of the state-contingent guidance in August 2013. However, it should be noted that for investigating the structural break and the impact of such a break on system of variables, it is necessary to have sufficient data on both sides of the break (before the change and after the change). Understandably, that is a limitation for examining the effect of the state-contingent guidance and also for the policy of quantitative easing. The pioneering work by Glick and Leduc (2012) shows that no evidence can be found on an effect of recent U.S monetary policy shocks (specifically quantitative easing) on commodity prices.

Nevertheless, from the investigation in Chapter 5, the BoE’s independence has been found to represent a structural break in the case of the oil inventory channel for the UK, OECD Europe and OECD and in the case of the supply channel, for OPEC and world. The financial crisis has been found to be a structural break for the UK’s oil inventory and OECD oil inventory.

During the period after the BoE’s operational independence, the response of the UK’s oil inventories to an unexpected 1 per cent cut in 3-months Treasury bills is slightly stronger than it was before the BoE’s operational independence, while the response to the shock in money supply is found to be smaller. When looking at the impulse response of OECD European, oil inventories to the money supply before the BoE’s operational independence, and comparing it to the response estimated for the whole period, the size of the response has not changed. However, the size of the response is found to be slightly smaller than for the whole period. Therefore, it can be assumed that before the BoE’s operational independence, the decisions to hold oil inventories in EU countries was slightly less responsive to the policy decisions, possibly due to lower credibility since the interest rates were set by the Government. The results for OECD oil inventories differ significantly in respect to the both periods (Figure 5.17). While a decreasing response to the innovations in money supply as well as in the 3-months Treasury bills can be observed in the first period, the response seems to be small but increasing before the financial crisis. The contrasting response of the OECD oil stock to the money supply shock and interest rate shock after the BoE’s independence is interesting given the importance to the size of the response after 1997.

The response of the OPEC oil supply to the shock in money supply did not change significantly before or after the BoE’s independence (Figure 5.18), but the response to the shock in interest rates was significantly stronger. However, during the period of inflation targeting when interest rates were set by the Government, the shock in interest rates led to an increase in the oil supply by 7 per cent. The response of the OPEC oil supply after the BoE's independence shows a drop by 5 per cent in the first two months after the shock. The results show that the response of oil inventories at all investigated levels is time-varying, and firms' willingness to hold oil inventories is more responsive to changes in monetary policy since the BoE's operational independence. On the other hand, the response of the oil supply seems to be less responsive. As results show, a 1 per cent increase in the money supply depressed the world oil supply by 1 per cent, and after the BoE's independence, the reaction at 0.8 per cent was slightly weaker than before. However, even if money supply does affect the world oil supply, the effect is not as strong as found in the case of 3-months Treasury bills.

It is interesting that in both cases (OPEC oil supply and world oil supply) the effect of the oil supply changed the direction after the operational independence of the BoE. A 1 per cent cut in 3-months Treasury bills, before the breaking point, led to a raise in world oil supply by more than 6 per cent. While after the breaking point the world oil supply dropped by 3.1 per cent. Even the size of the effect is not as strong as before, the actual change in direction is interesting. The findings provide evidence for Frankel's (2006) argument that it is worth policy makers paying attention to the effect on commodity markets, since movements in commodities can also act as a monetary condition indicators.

7.2.3.1 Summary

The main argument investigated was based on Frankel's (2006) assumption that rising commodity prices and developments in commodity markets during the 2000s might have provided beneficial information to policy makers about easing monetary policy. Frankel's assumption was investigated in UK conditions, and the results revealed interesting findings. Firstly, the effect of the UK monetary policy, investigated at different levels, seems to be important for the UK's oil inventories as well as European oil inventories and the OPEC supply. Also, the results from the test of a structural break show that the response of oil inventories is weaker, but still significant, after the BoE's operational independence. This may be the result of the higher credibility of the BoE.

7.3 Background of the findings: the effect of commodity shocks on the UK economy

After experiencing oil price shocks in the 1970s and 1980s, the fear of the effect of high oil prices and their impact on the economy stays alive for generations. The long-term depression and years of economic suffering around the world cannot be forgotten. It is therefore not surprising that recent rises in commodity prices also raise the question of the effect of these shocks on economies. Since rises in commodity prices during the 2000s have not led to depression and years of suffering as they did in 1970s, the relevance of commodity price shocks as a significant source of economic fluctuations in developed countries has been called into question. Nevertheless, these shocks did increase inflationary pressures. For instance a study by Galesi and Lombardi (2013), of the period from 1999 to 2007, investigates the impact of shocks in oil and food prices using a GVAR model. Their study shows that the direct inflationary effects of oil price shocks affect mostly developed countries with only a small impact on emerging economies, while shocks in food prices also cause inflationary pressures on developed countries, but predominantly in emerging economies. As their results reveal, a shock in oil prices led to inflationary pressures in the U.S by 1.1 per cent and in the EU by 0.6 per cent. Galesi and Lombardi (2013) also found that the pass-through effect of oil price shocks into core inflation (second round effect) was not statistically significant for the EU nor for the U.S, suggesting that the monetary policy framework contributed to well anchored inflation expectations, thus avoiding the pressures to pass into core inflation. On the other hand, food price shocks passed through into U.S core inflation and led to increases of 0.1 per cent.

Blanchard and Gali (2010) investigated the most popular explanations of why the new peaks in commodity prices did not have such a strong affect as in the 1970s, by investigating factors such as a smaller share of oil in production, more flexible labor markets, and improvements in monetary policy as possible reasons for a weaker effect. Their results show that all factors mentioned above, accounted for only mild effects deriving from the shocks on inflation and economic activity.

Although, the findings that the effects of the shocks on the economy are different and mostly weaker, it cannot be concluded that movements in commodity markets do not play an important role for policy makers. Even though developments in commodity markets showed that oil prices, as well as other indices of commodity prices, were close to the all-time highs, the reaction of policy makers stayed relaxed, until they passed-through into the core rate. This was mostly due to the assumption of a supply-driven shock; however, as mentioned before, the commodity price shocks in the 2000s are mostly characterized as being demand-driven. As study by Davis (2012) on the UK shows that a shock to commodity price inflation had a positive and significant effect on core inflation before the BoE's operational independence period in 1997, but an insignificant effect on core inflation after operational independence, until 2007. Also, the persistence of inflation fell after operational independence. The common explanation for these changes in core-headline inflation dynamics is change in monetary policy where policy became more credible and more focused on inflation stabilization.

Although anchoring the inflation expectation has been successful, the recent increases in commodity prices are not characterized by short-term increases, thus they need to be taken into consideration due to their possible impact on inflation expectations. According to the inflation report of the BoE (2013), in 2014 the UK's inflation is projected to be sensitive to sharp movements in commodity prices. However, the strength of these movements is relative, and therefore a range of views among Committee members remains. Therefore the objective is to examine the persistent and transitory effects of the movements in crude oil and food commodities and how they impact the UK economy.

7.3.1 Are oil and food price shocks transitory or persistent in the UK economy?

The evaluation of the impact of persistent and transitory shocks in oil prices as well as food prices on the UK economy during the period of inflation targeting (1992-2013) may provide beneficial information on the sensitivity of the UK economy to commodity prices and the reaction of policy makers to commodity shocks since these are proven to be time-varying.

The investigation of the transitory effect of oil prices and food prices reveals several interesting results. An increase in oil prices above their long-term equilibrium assumes short-term interest rate to increase in the next period (Millard and Shakir, 2013). This finding suggests that the decisions of policy makers in the UK about interest rates are influenced by movements in oil prices. The response of short-term interest rates can be explained by a finding that oil prices are found to be an explanatory variable for headline inflation as well as for industrial production which experience increase in the short term after the increase in oil prices above their long-term equilibrium. Even though the traditional view is, that shocks in commodity prices are taken as highly volatile, supply side, exogenous shocks, thus, monetary policy does not react to supply shocks. It is argued that monetary policy should focus on demand-side pressures as well as the second-round effects on inflation that could lead to a wage-price spiral where workers demand a pay rise higher than or equal to expected inflation in order to maintain their real income. Nevertheless, in the 2000s, rises in commodity prices were not short-term and kept rising to unprecedented levels; therefore the change was much more persistent. Only at the peak of the subprime crisis, in late 2008, commodity prices suffered a major reversal, but even in a world that was not fully recovered from the crisis, commodity prices rose again (Gregorio, 2012).

As the results from Model 1 (the transitory effect of oil prices) reveal, a positive shock to oil prices leads to statistically insignificant response in the UK's industrial production as an initial reaction. According to Bratsky and Kilian (2004), if the output is assumed to be a function of imported inflation, labour and capital services, the magnitude of the shock to commodity prices on output will be small due to elasticity (in the case of oil) being less than unity. The results from Rotemberg and Woodford (1996) show that, a 10 per cent increase in oil prices led to a less than 0.5 per cent decrease in the output production. However, more recent study of EIA (2012) reveals that during the period 2005-2010, a 10 per cent increase in the ratio of natural gas to petroleum leads to a 19 per cent increase in the relative use of petroleum compared with natural gas showing a high elasticity thus rejecting the argument proposed by Bratsky and Kilian (2004).

For the UK, the study by Sertelis et al. (2009) shows that the UK has a mild substitutability between electricity and other fuels when the price of electricity is changing, however, they also found a strong substitutability between natural gas and coal in the UK irrespective of whether the price of gas or coal changes. An important argument made by Sertelis et al. (2009) is that the substitution does not depend on the level of economic development but on the specific structure of the national economy. This also supports the assumption presented in Section 6.6 that the UK is interesting to investigate due to its position on the commodity market. Nevertheless, the higher elasticity of substitution in the UK may be explanatory for the results in Figure 6.3 showing the weak reaction of industrial production to the shock in oil prices.

However, interest rates responded with an increase in the second month after the shock in oil prices observing an increase in headline inflation. Since the 3-months Treasury bills are not a tool of monetary policy, they are correlated to the nominal interest rate (Figure 4.3) and tend to reflect inflation expectations. An opposite response of inflation to the shock in oil prices is observed. If it is assumed that inflation expectations are well anchored, then an increase in headline inflation as a reaction to the oil price shock could be explained by the increase in input costs in production.

Nevertheless, the modest response of headline inflation to the shock in oil prices can be explained by a natural time lag, as well as the stickiness of prices. On the other hand, food prices seem to be of lower importance than oil prices since the size of the transitory effect is slightly weaker. The 3-months Treasury bills is found to be negatively dependent on the level of food prices, suggesting that policy makers do consider the movements in food prices when setting interest rates. This implies that as a response to an increase in food prices above their long-run equilibrium, short-term interest rates decrease in the next period. The reaction of policy makers (the response of the TRB to the shock in food prices) is slightly lower than in the case of oil prices, suggesting that policy makers might consider food price shocks to be slightly less important than oil price shocks. This is interesting as from the results of impulse response functions (Figure 6.5) it can be observed that the response of headline inflation is about the same as in the case of oil prices. If the higher weight of food products in the UK's consumer price index, which is 93 points while the weight of energy in the index is 48 out of which gas and other fuels account for 28 (Gooding, 2013), is considered more relaxed reaction of policy makers may be explained by their expectations of food price shocks being only transitory. It may be assumed that policy makers do not consider food prices to have an effect on long-term inflation expectations. The increase in the industrial production index, as a reaction to the shock in food prices, peaks in the second month after the shock and is found to be very weak.

Investigating the persistent effects of oil and food prices is interesting since according to Segal (2011), oil prices do not pass into the core inflation anymore. As Segal (2011) assumes, monetary policy no longer has to tighten in response to high oil prices.

Blinder and Rudd (2008) found that food price rises and other factors were more important than oil price shocks in explaining the two large inflation spikes in the 1970s. Also, Hooker (2002) found that oil prices fed through to core inflation in the U.S only until to 1981. A more up-to-date study by Blanchard and Galí (2010) used VAR models for analyzing the periods from 1970–83 and 1984–2006 and found a significantly lower impact of oil prices in the U.S on both inflation and output during 1984-2006 than during 1970-1983. On the other hand, Hunt et al. (2001) found that a 50 per cent increase in the oil price has a direct effect on the CPI through gasoline and other direct energy costs of 1.3 per cent for the Euro area, 0.6 per cent in the UK, and 0.8 per cent in Canada. According to Hunt et al. (2001), the impacts on core inflation pass through two channels. While in the CPI the increase appears directly, in the core inflation, the shock passes through the increase in workers' demand for wages as a response to rises in the CPI, thus it consequently leads to rises in costs and is therefore reflected in core inflation. Also, the role is played by inflation expectations which are also reflected in the core inflation. A study by Moccero et al. (2011) shows the relatively strong impact of a permanent shock to commodity import price levels on core inflation developments for the Euro Area, while the impact is only mild for the UK.

Interestingly, the results from the SVAR Model 3 show that oil prices are not an explanatory variable for the UK's interest rates. Also, core inflation responds to an unexpected increase in oil prices by slowing down. This finding is corroborated by Verheyen (2010) as well as Herrera et al. (2011) and can be interpreted as a decreasing relationship between oil prices and the economic situation. Even if there is evidence of a response to oil prices from the TRB and core inflation, the effect dies after six months in the case of core inflation, and after eight months in the case of the TRB. Also, the results from Model 4 show that the response of monetary policy to a persistent shock in food prices is stronger than in the case of persistent oil price shock. This finding is interesting as stronger response of monetary policy to food price shock is expected in the case of developing countries. However, as noted by Catão and Chang (2010), food price shocks are not less important than oil price shocks especially in small open economies.

Even though these results confirm the results of previous studies, it is not clear whether increases in persistent effect of oil and food price shocks has been found due to the re-established relationship since the 1980s, or whether the fact that they co-occured with the financial crisis also plays a role. Confirmation or rejection this doubt, requires an investigation of whether the peak in 2008, which co-occurred with the financial crisis, led to the changes in the effect on the UK economy.

7.3.1.1 Summary

The results from the investigation of the persistent and transitory shocks of food and oil prices on UK economy reveal that the size of a transitory oil price shock shows signs of significance and lead to statistically significant inflationary pressures. In addition, a transitory shock in food prices is found to be inflationary and statistically significant given the importance of the weight of food prices in the consumer price index. These results are in contrast with the findings of Galesi and Lombardi (2013) who found that the transitory inflationary effects of oil price shocks affect mostly developed countries while transitory shocks in food prices cause only small inflationary pressures in developed countries. Nevertheless, it can be concluded that the policy framework is successful in anchoring inflation expectations. The findings from the investigation of persistent shocks confirm the results of Davis (2012) who concluded that evidence for the pass-through effect of the shocks in commodity prices into the UK core inflation can be found until 1997, while the pass-through effect is small after 2007. The results from models estimated in Chapter 6 show that the pass-through effect from a shock in oil prices into the UK core inflation is smaller, but is statistically significant in the case of food prices. These findings confirm the results of Galesi and Lombardi (2013) who also found that the pass-through effect of oil price shocks into core inflation (the second round effect) is statistically significant, but smaller for the EU countries, suggesting that the monetary policy framework contributed to well anchored inflation expectations, and thus avoided the pressures to pass into the core inflation significantly. Their results also show that food price shocks passes through into core inflation in European countries with a higher significance than in the case of oil prices.

7.3.2 Does the effect of a shock in food and oil commodities differ in relation to the nature of the shock?

While the previous objective focused on the analysis of the persistent and transitory effect of oil price and food price shocks, a more sophisticated analysis is provided by Kilian (2009), who decomposes oil price movements into three components: changes in oil supply, changes in aggregate global demand and changes in oil-specific demand. The oil-specific demand is based on the assumption of the Hotelling rule and the role of scarcity (see discussion in Chapter 3), thus shift in the price of oil is assumed to be driven by a higher precautionary demand which is associated with insecurity about the availability of the future oil supply. Kilian’s (2009) results from his VAR model of the global economy show that oil supply shocks have a significantly smaller impact on oil prices than the other two types of shock. He also applied his model of the global economy to the U.S economy and found that both oil supply disruptions and oil market-specific demand shocks significantly lower the U.S’s GDP growth. Kilian’s (2009) results also reveal that the risk of a stagflationary response depends significantly on the origin of the oil price increase and is more likely to be due to a shock in oil demand rather than a shock in the oil supply.

When analysing the decomposed transitory oil and food price shocks for the UK economy, modelled as exogenous shocks, the results show that consumer prices measured as CPI rise significantly by 10 per cent as a positive reaction to an increase in oil supply, as also documented by Furlong and Ingenito (1996). The actual increase in the world oil demand by 10 percent also has an inflationary effect on the UK economy, but the size of the effect is higher than in the case of the supply side effect. In contrast, the results of Millard and Shakir (2013) show that the impact of oil-specific demand shocks on UK inflation is small, oil supply shocks tend to be associated with larger negative impacts on output, but a positive impact on inflation, while results from Chapter 6 reveal that the growth of industrial production responds negatively to all three shocks with a similar size of effect oscillating around the zero level after the first quarter following the shock. Even though the UK became an oil-importing country, the size of the sensitivity of industrial production to the world oil market is not as significant as in the 1970s and 1980s when compared to the results of Hendry (1991). Also, results from investigation in Chapter 6 reveal that the size of the effect of a world oil demand shock on consumer prices seems to be more significant than in the case of a supply driven shock and the reaction of monetary policy to a demand side shock seems to be of higher significance than a supply side shock.

In contrast to the effect of a shock in oil demand, a 10 percent increase in the food demand is found to drive consumer prices substantially by 0.6 per cent. While a transitory oil supply shock seems to be of higher importance to policy makers, policy makers seem to pay higher attention to a food demand shock than to a shock in the food supply since a shock in the food supply is found to have a zero effect on the UK economy. The statistically insignificant impact of food supply shocks on the UK economy can be explained by the fact that even though food self-sufficiency in the UK is declining, it has not reached the level when the economy becomes sensitive to the food supply. Understandably, a higher food demand is reflected in higher prices of food products (however this strongly depends on the competitiveness of the market) and thus passes through into headline inflation. Given the importance of the weight of food commodities on the CPI, policy makers understandably have to pay attention to the effect of such a shock as it can lead to changes in the long-term inflation expectations if the effect turns out to be persistent.

As noted earlier, if only the direct effects of oil price shocks are relevant, then prices of non-energy goods and services should not be influenced by the oil shock, and the final effect on inflation is determined by the increase in relative prices. Thus, it becomes natural to investigate the effect of decomposed shocks on core inflation. Interestingly, the response of core inflation to a shock in oil prices shows signs of high significance. Also, core inflation falls as a response to a 10 per cent increase in the oil supply due to lower input production costs, the size of this persistent effect is stronger in the case of transitory effect. Surprisingly, a shock driven by an increase in the world oil demand is found to raise core inflation, but the effect loses its strength in the second year following the shock and oscillates around zero afterwards. The results confirm the findings of Peersman and Robays (2012) that not all oil shocks are necessarily harmful to an oil importing economy. Since the UK is an oil importing country, it is also a producer and exporter of alternative sources of energy which can be, to a certain level, substitutes for oil.

Therefore while an increase in oil prices negatively impacts the economy, since the elasticity of the substitution of energy in the UK is higher, there might also be a shift in demand for its substitutes (see Section 6.6 for a discussion on the proposed theoretical model). Interestingly, the effect on core inflation is found to be more significant in the case of a food demand shock than food supply shock. A positive persistent food demand shock is assumed to stimulate the economy and thus pass-through into core inflation. It has also been found that a rise in core inflation due to a general rise in world food prices seems to be of higher importance to policy makers than a rise due to food demand shock. This finding is interesting due to the fact that the effect of a food demand shock has a comparable affect on core inflation to a rise in global food prices. The findings reveal that there is a different reaction from policy makers in response to persistent shocks. This was also confirmed by Millard and Shakir (2013).

7.3.2.1 Summary

Following the approach introduced by Kilian (2009) the effect of a commodity shock when decomposed into changes in oil supply, oil demand and oil price has been investigated. The results reveal that the UK’s industrial production responds negatively to all kinds of decomposed shocks, which is in line with the results from Millard and Shakir (2013) who found evidence of significant negative impact on output in the case of an oil supply shock. It has been found that a 10 per cent increase in food demand leads to a substantial increase in consumer prices by 0.6 per cent. Additionally, a transitory oil supply shock is found to be important for policy makers. It has also been found that policy makers are more sensitive to a food demand shock than to a food supply shock, which can be explained by the food self sufficiency ratio, which even though it is smaller than a few decades ago, is high enough to avoid high sensitivity of the food supply. In addition, core inflation is found to respond positively to an increase in the oil supply, which may be due to lower input production costs. These results confirm the findings of Peersman and Robays (2012) whose study shows that not all commodity shocks are harmful, and also the results of Millard and Shakir (2013), who proved that the sensitivity of the UK economy to commodity shocks is time-varying. Most importantly it has been proven that the reaction of policy makers depends on the nature of the commodity shock.

7.3.3 Has the size of persistent and transitory shocks changed after the new peak in commodity prices in 2008?

As has been proven by Millard and Shakir (2013), the impact of commodity shocks in the UK is time-varying. The events in commodity markets in the 2000s and at their peak in 2008, encouraged to investigate whether the reaction of policy makers to commodity prices had changed since the new peak. By using the Chow test a structural break can be found in the case of oil prices and their transitory effect, as well as food prices and their persistent effect.

While before the break, an increase of oil prices above their long-run equilibrium led to a cut in interest rates in the next period, during the period after the break the results shows the need for an increase in interest rates in the next period. The size of the response of 3-months Treasury bills and headline inflation to a unit shock in oil price changes after the oil price peak, whereas the response of the industrial production index changes significantly. Interestingly, the response of 3-months Treasury bills is positive and weaker after the peak. The response of headline inflation to the shock in oil prices is found to be time-varying too. Before the peak, the size of the response was weaker, the trend after the peak in 2008 changed, and the headline inflation became more sensitive to the shock. This change in the sensitivity of short-term interest rates may either be due to the assumption of anchored inflation expectations, or the deflationary effect of the financial crisis on the UK economy. It may be assumed that while a slightly weaker response of inflation before the peak shows that increases in oil prices were not left to be absorbed fully by inflation as the interest rates show higher sensitivity then after the peak. Industrial production became more sensitive to the developments in oil prices after the peak which could be also explained by overall worsening of economic condition due to the financial crisis.

In the case of the persistent effect of food prices, they seem to be an explanatory variable for the UK's industrial production but not for the interest rate. Nevertheless, the coefficient for food price does not seem to be explanatory neither for UK monetary policy or core inflation before or after the break.

Contrary to headline inflation, a more significant response can be found in core inflation. The impulse response functions of core inflation, together with 3-months Treasury bills and the industrial production index, to a unit shock in food prices is found to be stronger. Even if oil and food price shocks tend to be transitory rather than persistent, commodity shocks also have a persistent effect on the UK economy. Nevertheless, it is interesting to find that the reaction of core inflation to a shock in food prices is strong, and also that it is more responsive after the peak resulting from the stronger reaction of policy makers after the peak.

7.3.3.1 Summary

The results reveal that during the period of 1992 to 2008 headline inflation was less sensitive to shocks in oil prices, while the relationship breaks after the peak in 2008 which coincides with the financial crisis. Nevertheless, the response of the interest rate is found to be stronger before the peak. The pass-through effect of a food price shock into the UK's core inflation is found to be stronger after the break in 2008. These results confirm the findings of Millard and Shakir (2013) on the time-varying effect of commodity price shocks. Even though the time-varying effect has been investigated for the commodity price peak in 2008, it is difficult to come to a conclusion about changes in the responsiveness of core inflation as well as headline inflation before and after the peak in 2008 are due to the new peak in commodity prices, due to the financial crisis, or a combination of both.

7.4 Conclusion

This research has contributed to the body of knowledge by examining the two-way relationship between UK monetary policy and commodity markets at different levels by estimating VAR models and VEC models for investigating the short-term as well as long-term relationships. It has been found that a higher UK interest rate decreased the size of the UK's oil inventory significantly. The decrease in oil inventory within OECD European countries can also be observed, however, the size of the decrease in desire to carry inventories after the increase in interest rates is smaller when compared to the UK's oil inventories. Only a small decrease in the OECD oil inventories has been found, confirming the assumption that even though the sensitivity of oil inventories to the UK's interest rate may be smaller at the more global level, the effect may be significant at national or international levels. The response of oil inventories confirms the assumption proposed by Frankel (2006) and results are comparable to similar studies such as Azuini et al. (2012). In addition, it has been found that lower interest rates motivate the postponement of extraction due to higher opportunity costs, since a negative shock in the UK's interest rate is found to decrease the IEA oil supply as well as the world oil supply, even though the response of the oil supply is found to be small. Similarly to the findings of previous research, it was found that oil inventories are more sensitive to developments in monetary policy than oil supply. It has been also found, that oil inventories are more responsive to the developments in UK monetary policy since the BoE's operational independence. A comparison of the sensitivity of oil inventories and oil supply at different levels to developments in monetary policy, to the results of previous research however was not possible as this is the first study which focuses on the investigation at different levels.

In addition, the discussion chapter has also outlined the results for the transitory and persistent effect of oil price shocks and food price shocks. It has been shown that oil price shocks as well as food price shocks are found to have only a smaller transitory effect (but the effect of food prices is found to be stronger). Additionally, the persistent effect of the shock was found to be significant in the case of a food price shock but smaller in the case of an oil price shock, confirming the results of similar studies. An important finding is that the effect is time-varying and the sensitivity of core inflation was higher after the commodity price peak in 2008, however it is not clear whether the change in sensitivity is due to the peak or the financial crisis.

Chapter 8 Concluding remarks

8.1 Introduction

This chapter contains the summary of key findings and discusses the contribution to the research of two-way relationships between oil prices, food prices and the UK monetary policy in an inflation targeting environment. In addition, it also discusses the limitations of the research in the light of the methods used for econometric modelling and the approach adapted. This is followed by a discussion on suggestions for further research.

The purpose of this study was to investigate the two-ways sensitivity between developments in monetary policy and commodity markets. In order to do so, the theory of overshooting, as well as the theory of storage, has been used in application with the most recent model for analysing the sensitivity of commodity markets to developments in monetary policy introduced by Frankel (2006) and model of channels how shocks in commodity markets impact the economy by Kilian (2009).

The importance of investigating this relationship has become important in recent years, considering the results of previous studies as well as the findings of this study on the sensitivity; it becomes clearer that closer attention needs to be paid to these relationships. Moreover, when it is considered that the UK's monetary policy, as well as the ECB's monetary policy, are set to follow the forward guidance in the next few years, and giving the importance to the findings of sensitivity of the commodities to developments in monetary policy, raising trend in commodity prices may be assumed to stay open for a discussion on the impacts. On the other hand, as the nature of commodity shocks is found to become more persistent than transitory to the UK's economy, it also becomes crucial for policy makers to consider the time-varying sensitivity and carefully implement it in inflation forecasting, as well as in economic outlook projections.

8.2 Summary of key findings

The results provide the evidence for the sensitivity of oil industrial inventories and oil supply at national, international and global level on developments in the UK monetary policy, proving that easing monetary policy matters for oil markets. As shown, the effect is significant at a national level and loses the strength at a global level. Nevertheless, it provides the supportive evidence for the argument by Frankel (2006) that the attention of central banks should be more focused on commodities as they reflect the easing of monetary policy and can therefore be beneficial in providing earlier signals of rising inflation. The implication for policy makers can be formulated as follows. The empirical results reported in Chapter 5 suggest that oil inventories and oil supply at national, international and global levels reflect monetary easing in the UK. Since the impact has been also found at an international level, thus, it might be useful for the BoE and also for the ECB to pay closer attention to commodity prices. Even though in an environment of inflation targeting, commodity prices are not directly targeted, but developments in commodity markets are considered in projecting the economic outlook, as well as the inflation forecast. Nevertheless, as recent experience from projecting the economic outlook shows that the forecast of future inflation has been underestimated mainly due to the fact that futures prices did not reflect developments in commodity prices (Stockton, 2012; Cabanillas and Terzi, 2012; ECB, 2013). By providing the evidence that also monetary policy in a small open economy such as the UK matters for commodity markets, opens a discussion on rethinking the effect of easing monetary policy in terms of its effect on commodity markets at different levels.

It was also found that the sensitivity of oil industrial inventories and oil supply is time-varying; specifically oil inventories became less sensitive to changes in UK monetary policy after the BoE's operational independence.

The results from an investigation of the persistent and transitory shocks of food and oil prices on the UK economy reveal that the size of transitory oil price shocks does not lack of significance since it lead to statistically significant inflationary pressures. In addition, also a transitory shock in food prices is found to be inflationary and statistically significant given the importance to the weight of food prices in the consumer price index. These results confirm however are also in contrast with the findings of Galesi and Lombardi (2013) who found that the transitory inflationary effects of oil price shocks affect mostly developed countries while transitory shocks in food prices cause only small inflationary pressures in developed countries. Nevertheless, it can be concluded that the policy framework is successful in anchoring inflation expectations. The findings from an investigation on the persistent shocks confirm the results of Davis (2012) who concluded that evidence for pass-through effect of the shocks in commodity prices into UK core inflation can be found until 1997 while the pass-through effect is small after 2007. The results also show that the pass-through effect from a shock in oil prices into UK core inflation is small, but is statistically significant, in the case of food prices. These findings confirm the results of Galesi and Lombardi (2013) who also found that the pass-through effect of oil price shocks into core inflation (second round effect) is not statistically significant for the EU, suggesting that the monetary policy framework contributed to well anchored inflation expectations, and thus avoided the pressures to pass into core inflation. Their results also show that food price shocks pass through into core inflation in European countries with greater significance than in the case of oil prices.

The investigation on decomposed commodity shocks reveal that the UK's industrial production responds negatively to all (oil supply, oil demand and oil price) shocks and are in line with the results of Millard and Shakir (2013) who found the evidence of a significant negative impact on output in the case of oil supply shocks. It has been found that a 10 per cent increase in food demand leads to an increase in consumer prices of 0.6 per cent. The transitory oil supply shock is found to be important for policy makers. It has been found that policy makers are more sensitive to a food demand shock than to a food supply shock what can be explained by the UK's food self-sufficiency ratio which even though it is smaller than a few decades ago, it is high enough to avoid high sensitivity in food supply. In addition, core inflation is found to respond to increases in oil supply positively, which may be due to lower input production costs. The results confirm the findings of Peersman and Robays (2012) whose study shows that not all commodity shocks are harmful to the economy, but also the results of Millard and Shakir (2013) who proved that the sensitivity of the UK economy to commodity shocks is time-varying. Most importantly it has been proven that the reaction of policy makers depends on the nature of the commodity shock.

The results also reveal that during the period 1992 to 2008 headline inflation was less sensitive to the shocks in oil prices while the relationship breaks after the peak in 2008 which is coincident with financial crisis. Nevertheless, the response of interest rates is found to be weaker after the peak. The pass-through effect of a food price shock into the UK's core inflation is found to be stronger after the break in 2008. Even though the time-varying effect has been investigated for the commodity price peak in 2008, the conclusion about whether the responsiveness of core inflation and headline inflation to oil and food price shocks have changed since 2008 was due to the new peaks in commodity prices or resulted from the financial crisis is difficult to make.

8.3 Contributions to knowledge

The discussion of the major findings of this study from the previous section leads to a reflection on the contribution of the research in the scope of knowledge on two-way relationships between commodities and the UK economy in terms of their sensitivity. Much literature and research can be found on drivers of commodity prices (Trostle, 2008; Nikos, 2008; Ratti and Vespignani, 2013); however only limited research has been done on the sensitivity of commodity prices on developments in monetary policy. As mentioned, the pioneering work on this topic was done by Frankel (2006), recently followed by Akram (2009), Anzuni et al. (2012) and Arora and Tenner (2013) who investigated the sensitivity of world oil inventories and world oil supply to changes in U.S monetary policy. However, the previous research focused mainly on investigating the sensitivity of world oil prices to developments in U.S monetary policy, while the effect of small-open economies has been left without sufficient attention.

The originality of the thesis lies in the approach adopted. This study, to the author's best knowledge, is the first of its kind to apply Frankel's (2006) approach to a small-open economy in an environment of inflation targeting and extends the investigation on the sensitivity of world oil industrial inventories and world oil supply to investigation at national, international and global levels. The sample of 21 years covers the period from the beginning of inflation targeting to the beginning of forward guidance and therefore investigates sensitivity in the environment which has not been investigated to this extent so far. The study contributes to knowledge of the subject by discovering of new facts on the sensitivity of the two-way relationships between the UK monetary policy and commodity markets.

An investigation of the effect of easing monetary policy on national level has benefits in providing information on the sensitivity of UK oil inventories as well as oil supply which has not been investigated so far. Measuring the actual impact may be beneficial not only to policy makers but also to investors since oil still plays a crucial role in the economy. Moreover, the rationale in investigating the sensitivity of EU oil industrial inventories to the easing of UK monetary policy is also beneficial giving the importance to the UK's position in the EU. The fact that European oil inventories are sensitive to the UK's monetary policy has not be known before and an application for the ECB may be based on the ability of commodity markets to send a signal about forming inflation expectations and further expected adjustments in interest rates. Thus the results contribute to knowledge of the subject by discovering new facts on the sensitivity of oil industry inventories; not only in the UK, but also in Europe and at more global levels.

Moreover, when the methodology approach is considered, this thesis also contributes to the knowledge of the subject by testing for structural breaks during the period analyzed in order to investigate whether the most recent changes in monetary policy, such as the BoE's operational independence and the financial crisis, has led to higher sensitivity of oil inventories and oil supply at different levels. This area, to the author's best knowledge, has not been investigated so far.

Another area of originality of the thesis can be found in the approach adopted for investigating the sensitivity of the UK economy to developments in commodity markets. Rather than measuring the effect of increasing commodity prices on the UK economy this thesis extents all known recent studies on this topic to the approach firstly adopted in the U.S by Kilian (2009). The approach adopted by Kilian (2009) is innovatory as it distinguishes the effect that commodity shocks have in light of the nature of the shock. Nevertheless, even thought this approach offers a more complex investigation on the sensitivity of the economy, it has not been used in UK conditions until the study by Millard and Shakir (2013).

The originality of the approach introduced in this thesis can be found by introducing a theoretical model of the sensitivity of the UK economy to the food and oil commodities and under the specific position of the UK as an oil importer and energy exporter. The theoretical model which has been developed for the purpose of this thesis is further empirically investigated where the findings contribute to knowledge of the subject by discovering that policy makers must pay closer attention to food price shocks as their persistence has been found to be significant that consequently may lead to higher inflation expectations.

The originality of this thesis, when compared to the study by Millard and Shakir (2013), and its findings relates to the in investigation of both food and oil commodities and also in testing for the structural breaks which confirms the time-varying sensitivity of the UK economy to the commodity shocks in a context which has not been investigated so far.

The findings may be beneficial for further research when it is considered that in the next years, interest rates are assumed to be set at their current historical lowest level based on the forward guidance adopted by the BoE in August 2013.

8.4 Limitations of the research

The major limitations of this study arise from the nature of the data used. As discussed in Chapter 4, time-series tend to suffer from the trend and thus are non-stationary. However, not all the series used in econometric modelling were found to be non-stationary; therefore a special care has been paid to avoid problems of spurious regression and autocorrelation by selecting the correct lag lengths. Even though the methodology of lag length selection adopted in this thesis followed generally accepted and used approaches, since all of the tests have some drawbacks, there is a possibility for misspecified lag length. Also, the Granger causality test and VAR/ VEC models are known for their sensitivity on lag length selection; thus a misspecification of the lag length could possibly lead to misleading results. In addition, when testing for structural breaks, the Chow test was used for identification of known potential breaks, such as the BoE's operational independence, financial crisis or commodity price peak in 2008. Nevertheless, there is a possibility of more than the above mentioned breaks which have not been investigated due to the limitations of using the Chow test.

In addition to the limitations arising from an investigation of structural breaks, the study did not cover important know events such as every announcement of quantitative easing or the recent adoption of forward guidance. The reason for leaving the investigation of these known breaks aside, again arises from the limitations of the Chow test which requires an equal sample on both sides (before the investigated break and after the break). Unfortunately, due to the limitation of the data available, it was not possible to test for the effect of forward guidance since it was adopted in August 2013. Thus it would be possible to collect only a very small sample of data which consequently led to inability to use a VAR model since this approach also requires a minimum sample. Even though there are other methods for testing the known structural breaks, unfortunately these are not available in the software used for econometric modelling.

Another limitation lies in the lack of knowledge on this topic in UK conditions. The findings can be only compared to the studies on larger economies such as the U.S since the approach adopted in this thesis has been used only for the large economies so far.

Moreover, the findings that the sensitivity of UK inflation on commodities has changed after the commodity price peak in 2008 need to be taken with caution since the peak coincided with financial crisis. The results could be interpreted with higher confidence if the peak happened to be during the *"Great Moderation"* (the period before the crisis).

In addition, the use of VAR/VEC modelling certainly has its advantages, however it has disadvantages too. Only limited information can be obtained from the estimated VAR/VEC model; thus impulse response functions and variance decomposition were used for the interpretation of the dynamic relationship. Nevertheless, the disadvantage of using the impulse response functions lies again in the interpretation problem. This became a complication in several cases when the explanation of the results was not straightforward and also a few results were difficult to interpret too.

8.5 Scope for further research

The results of this study reveal some interesting findings on the two-way sensitivity between monetary policy and commodity prices. Nevertheless, since there is a lack of knowledge on this topic in relation to small open economies, it would be interesting to extend the investigation in a few areas. Firstly, since European oil industry inventories are found to be sensitive to the easing of UK monetary policy, it would be interesting to investigate the sensitivity of UK oil industry inventories to the ECB’s monetary policy. In addition, there is not a study which focuses on the investigation of the relationship between monetary policy and oil inventories within the European Union. Such a study could possibly reveal important information which could be used by policy makers when setting interest rates but also for projections of the economic outlook.

As discussed earlier, the inflation forecast for the UK as well as for the EU underestimated inflation which was also due to insufficient information about inflation expectations obtained from the behaviour of commodity markets.

In a longer time period, the model developed in this thesis could be used for evaluating the effect of forward guidance on the sensitivity of commodity markets and for investigating whether the new approach, which may impact has impacted the expectations about future inflation, has passed-through into firm’s desire of holding inventories.

Bibliography

Aghion, P., Banerjee, A., (2005) *Volatility and Growth*, Oxford University Press: Oxford and New York.

Ahking, F., (2002) `Model mis-specification and Johansen's.` *Journal of Macroeconomics*, 24 (1), pp.51-56.

Ahmed, Sh., Levin, A., Wilson, B., A., (2004) ` Recent U.S. Macroeconomic Stability: Good Policies, Good Practices, or Good Luck?` *The Review of Economics and Statistics*, 86 (3), pp. 824-832.

Akaike, H.. (1969) `Fitting autoregressive models for prediction.` *Annals of the Institute of Mathematical Statistics*, 21, pp. 243 247.

Akram, F., (2009) `Commodity prices, interest rates and the dollar.` *Energy Economics*, 31, pp. 838-851.

Alquist, R., Coibion, O., (2013) `The Comovement in Commodity Prices: Sources and Implicaitons.` *IMF Working Paper, WP/13/140* [online] Available at: http://www.imf.org/external/pubs/ft/wp/2013/wp13140.pdf [Accessed 14 October 2013].

Alquist, R., Kilian, L., Vigfusson, R., J., (2011) `Forecasting the Price of Oil.` *Bank of Canada Discussion Paper 2011-6*, [online] Available at: http://www.bankofcanada.ca/wp-content/uploads/2011/07/dp2011-06.pdf [Accessed 10 August 2013].

Algieri, B., (2012) `Price Volatility, Speculation and Excessive Speculation in Commodity Markets: Sheep or Shepherd Behaviour?` *ZEF- Discussion Papers on Development Policy No. 166*, [online] Available at: http://ssrn.com/abstract=2075579 [Accessed 15 August 2013].

Alom, F., Adjunct, B., D., Hu, B., (2013) ` Macroeconomic effects of world oil and food price shocks in Asia and Pacific economies: application of SVAR models.` *OPEC Energy Review*, 37(3), pp. 327–372.

Anderson, D., Sweeney, D., Williams, T., (2008) *Statistics for Business & Economics, Revised*, 10th ed. London: South Western Educational Publishing. pp. 38-41.

Angell, W., (1992) `Commodity prices and monetary policy what have we learned?` *Cato Journal*, 12 (1), pp.185-192.

Anzuini, A., Lombardi, M., J., Pagano, P. (2012) `The impact of monetary policy shocks on commodity prices.` *European Central Bank Working Paper 1232*, Available at: http://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp1232.pdf [Accessed 13 March 2012].

Arora, V., Tanner, M., (2013) `Do oil prices respond to real interest rates?` *Energy Economics*, 36, pp. 546-555.

Arora, V., Porquerasb, P., G., Shic, Sh., (2013) `The divergence between core and headline inflation: Implications for consumers' inflation expectations.` *Journal of Macroeconomics*, [online] Available at: http://www.sciencedirect.com/science/article/pii/S016407041300116X# [Accessed 17 November 2013].

Arseneau, D., M., Leduc, S., (2013) ` Commodity Price Movements in a General Equilibrium Model of Storage.` *IMF Economic Review*, 61, pp. 199–224.

Asso, P., F., Leeson, R., (2012) Monetary Policy Rules: From Adam Smith to John Taylor. In: Koenig, E., F., Leeson, R., Kahn, G., A. ed. *The Taylor Rule and the Transformation of Monetary Policy*. Stanford: Hoover Institution Press, pp. 46-51.

Asteriou, D., Hall, S., (2011) *Applied Econometrics*. 2nd ed. New York: Palgrave Macmillan.

Awokuse, T., O., Yang, J., (2003) `The informational role of commodity prices in formulating monetary policy: A re-examination.` *Economics Letters*, 79, pp. 219-224.

Baffes, J., Dennis, A., (2013) `Long-Term Drivers of Food Prices.` *The World Bank Policy Research Working Paper 6455*, [online] Available at: http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2013/05/21/000158349_20130521131725/Rendered/PDF/WPS6455.pdf [Accessed 15 October 2013].

Baffes, J., Haniotis, T., (2010) `Placing the 2006/08 Commodity Price Boom into Perspective.` World Bank Policy Research Working Paper No. 5371, [online] Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1646794 [Accessed 06 August 2013].

Bagliano, F., C., Favero, C., A., (1998) `Measuring Monetary Policy with VAR Models: An Evaluation`. *European Economic Review*. 42 (6), pp. 1069–1112.

Baillie, R., T., Bollerslev, T., Mikkelsen, H.,O., (1996) `Fractionally integrated generalized autoregressive conditional heteroskedasticity.` *Journal of Econometrics*, 74, pp. 3 – 30.

Bakhshi, H., Yates, A., (1999) `To Trim or Not to Trim? An Application of a Trimmed Mean Inflation Estimator to the United Kingdom (1999).` *Bank of England Working Paper*

No. 97. [online] Available at: http://ssrn.com/abstract=176688 [Accessed 14 September 2013].

Ball, L., M., Sheridan, N., (2004) Does Inflation Targeting Matter? In *The Inflation Targeting Debate*, Bernanke, B., S., Woodford, M., [eds.], University of Chicago Press for the National Bureau of Economic Research, pp. 249–282.

Banerjee, A., Dolado, J., J., Galbraith, J. W., Hendry, D., F., (1993) *Co-integration, Error Correction and the Econometric Analysis of Non-Stationary Data*. Oxford: Oxford University Press.

Bank of England, (1999) *Vector autoregression models*. [online] London: Bank of England. Available at: http://www.bankofengland.co.uk/publications/Documents/other/beqm/1999/five.pdf [Accessed 28 July 2012].

Bank of England, (2007) *News Release* [online] Available at: http://www.bankofengland.co.uk/publications/Pages/news/2007/156.aspx [Accessed 26 October 2012].

Bank of England, (2012a) *Explanatory notes M4* [online] Available at: http://www.bankofengland.co.uk/statistics/Pages/iadb/notesiadb/m4.aspx [Accessed 15 Jun 2012].

Bank of England, (2012b) *Statistical Interactive Database - interest & exchange rates data* [online] Available at: http://www.bankofengland.co.uk/statistics/Pages/default.aspx [Accessed 20 September 2012].

Bank of England, (2013a) *Monetary policy trade-offs and forward guidance.* [online] Available at: http://www.bankofengland.co.uk/publications/Documents/inflationreport/2013/ir13augforwardguidance.pdf [Accessed 23 August 2013].

Bank of England, (2013b) *Overview of the Inflation Report August 2013*. [online] Available at: http://www.bankofengland.co.uk/publications/Pages/inflationreport/infrep.aspx [Accessed 07 November 2013].

Barsky, R., B., Kilian, L., (2002) `Do We Really Know That Oil Caused Great Stagflation? A Monetary Alternative.` *NBER Macroeconomics Annual*, 16 [online] Available at: http://www.nber.org/chapters/c11065.pdf [Accessed 15 March 2012].

Barsky, R., P., Kilian, L., (2004) `Oil and the Macroeconomy Since the 1970s.` *Journal of Economic Perspectives, American Economic Association*, 18(4), pp. 115-134.

Baumeister, Ch., Kilian, L., (2013) `Do Oil Price Increases Cause Higher Food Prices?` *Bank of Canada*, [online] Available at: http://www.bankofcanada.ca/wp-content/uploads/2013/10/BK_food.pdf [Accessed 15 November, 2013].

Baumeister, C., Peersman, G., Robays, I., (2010) The economic consequences of oil shocks: Differences across countries and time in Fry, R., Jones, C., Kent, C., (eds), *Inflation in an era of relative price shocks*. Sydney: Reserve Bank of Australia.

Belke, A., (2010) `Global liquidity and commodity prices—a cointegrated VAR approach for OECD countries.` Applied Financial Econometrics, 20, pp. 227–242.

Belke, A., Bordon, I., G., Volz, U., (2013) `Effects of Global Liquidity on Commodity and Food Prices.` *World Development*, 44, pp. 31-43.

Belke, A., Klose, J., (2011) `Does the ECB rely on a Taylor Rule during the Financial Crisis? Comparing Ex-post and Real Time Data with Real Time Forecasts.` Economic Analysis and Policy, 41(2), pp. 147- 171.

Benth, F., E., Brandis, T., M., (2009) `The information premium for non-storable commodities.` *The Journal of Energy Markets*, 2(3), pp. 111-140.

Bernanke, B., S., (1983) `Irreversibility, Uncertainty, and Cyclical Investment.` *Quarterly Journal of Economics. February*, 98(1), pp. 85-106.

Bernanke, B., S., (1986) `Alternative explorations of the money-income correlation.` *Carnegie-Rochester Series on Public Policy*, 25, pp. 49-99.

Bernanke, B., S., Blinder, A., S., (1992) `The Federal Funds Rate and the Channels of Monetary Transmission.` *American Economic Review*, 82 (4), pp. 901-921.

Bernanke, B., Boivin, J., Eliasz, S., P., (2005) `Measuring the Effects of Monetary Policy: A Factor-augmented Vector Autoregressive (FAVAR) Approach.` *Quarterly Journal of Economics*, 120, pp. 387–422.

Bernanke, B., S., Gertler, M., Watson, M., W., (2004) `Oil Shocks and Aggregate Macroeconomic Behavior: The Role of Monetary Policy: Reply,` *Journal of Money, Credit and Banking*, 36(2), pp. 287-291.

Bernanke, B., S., Kuttner, K., (2005) `What explains the stock market's reaction to Federal Reserve policy?` *Journal of Finance*, 60, pp. 1221-1257.

Bernanke, B., S., Laubach, T., Mishkin, F., S., Posen, A., S., (1999) *Inflation Targeting: Lessons from the International Experience.* Princeton: Princeton University Press.

Bernanke, B., S., Mihov, I., (1998) `Measuring Monetary Policy.` *The Quarterly Journal of*

Economics, 113(3), pp. 869-902.

Bernanke, S., Laubach, T., Mishkin, F., Posen, A., (2001) *Inflation Targeting: Lessons from the International Experience*. 1st ed. Princeton: Princeton University Press.

Berument, H., (1999) `The impact of inflation uncertainty on interest rates in the UK.` *Scottish Journal of Political Economy*, 46 (2), pp. 207-218.

Bessler, D., A., (1984) `Relative Prices and Money: A Vector Autoregression on Brazilian Data.` *American Journal of Agricultural Economics*, 66, pp. 25–30.

Bilke, L., Stracca, L., (2007) `A persistence-weighted measure of core inflation in the Euro area.` *Journal of Econonometric Modelling*, 24, pp. 1032-1047.

Bisgaard, S., Kulahci, M., (2011) *Time Series Analysis and Forecasting by Example.* Canada: John Wiley&Sons Inc.

Bjørnland, H., C., (2009) `Oil Price Shocks And Stock Market Booms In An Oil Exporting Country.` *Scottish Journal of Political Economy*, 56(2), pp. 232-254.

Blanchard, O., J., Galí, J., (2010) `The Macroeconomic Effects of Oil Price Shocks: Why are the 2000s so different from the 1970s?` *NBER Working Papers 13368.* Available online at: http://www.cepr.org/pubs/new-dps/dplist.asp?dpno=6631.asp.asp [Accessed 12 Jun 2013].

Blanchard, O., J., Leigh. D., (2013) `Growth Forecast Errors and Fiscal Multipliers.` *American Economic Review*, 103(3), pp. 117-20.

Blanchard, O., Quah, D., (1989) `The Dynamic Effects of Aggregate Demand and Supply Disturbances.` *The American Economic Review*. 79 (4), p. 655- 673. Available at: http://www.jstor.org/stable/1827924 [Accessed 22 May 2011].

Blattman, C., Hwang, J., Williamson, J., G., (2007) `The Impact of the Terms of Trade on Economic Development in the Periphery, 1870-1939: Volatility and Secular Change.` *Journal of Development Economics*, 82, pp.156-179.

Blinder, A., S., Rudd, J., B., (2008) `The Supply-shock Explanation of the Great Stagflation.' NBER Working Paper 14563, pp. 5-18.

Bloch, H., Dockery, A., M., Morgan, C., V., Sapsford, D., (2007) `Growth, commodity prices, inflation and the distribution of income.` *Metroeconomica*, 58, pp.23-34.

Bloomberg, S., B., Harris, E., S., (1995) `The Commodity-Consumer Prices Connection: Fact or Fable?` *Federal Reserve Bank of New York Economic Policy Review*,1(3), pp. 21–38.

Bodenstein, M., Hebden, J., Nunes, R., (2012) ` Imperfect credibility and the zero lower bound.` *Journal of Monetary Economics*, 59 (2), pp. 135–149.

Bolton, P., (2013) *Oil prices*, House of Commons paper SN/SG/2106, [online] Available at: http://www.parliament.uk/briefing-papers/sn02106.pdf [Accessed 10 October 2013].

Boswijk, P., Franses, P., (1992) `Dynamic specification and cointegration.` *Oxford Bulletin of Economics and Statistics.* 54, pp. 369 380.

Boughton, J., M., Branson, W., (1988) `Commodity Prices as a Leading Indicator of Inflation.` NBER Working Paper No. 2750, [online] Available at: http://www.nber.org/papers/w2750.pdf [Accessed 15 Jun 2013].

Boughton, J., M., Branson, W., (1991) `Commodity Prices as a Leading Indicator of Inflation.` in *Leading Economic Indicators,* Lahiri, K., Moore, G., (eds.) Cambridge University Press.

Bordo, M., D., (1980) `The Effect of Monetary Change on Relative Commodity Prices and the Role of Long-Term Contracts.` *Journal of Political Economy*, 61, pp. 1088-1109.

Bosworth, B., Lawrence, R., (1982) *Commodity Prices and the New Inflation*. Washington: D.C: Brookings Institution, pp142-185.

BP, (2013) *Statistical review of World Energy June 2013* [online] Available at: http://www.bp.com/content/dam/bp/pdf/statistical-review/statistical_review_of_world_energy_2013.pdf [Accessed 28 August 2013].

Brant, P., T., Williams, J., T., (2007) *Multiple time series models: Quantitative applications in the social sciences.* London: Sage Publications Ltd.

Braun, P., A., Mittnik, S., (1993) `Misspeciffications in Vector Autoregressions and Their Effects on Impulse Responses and Variance Decompositions.` *Journal of Econometrics*, 59, pp. 319-41.

Breusch, T., S., (1978) `Testing for Autocorrelation in Dynamic Linear Models.` *Australian Economic Papers*, 17, pp. 334-55.

Brayton, F., Levin, A., Lyon, R., Williams, J., (1997) `The evolution of macro models at the Federal Reserve Board.` *Carnegie-Rochester Conference Series on Public Policy* [online] Available at: http://ideas.repec.org/a/eee/crcspp/v47y1997ip43-81.html [Accessed 14 May 2011].

Brennan, M., J., (1958) `The supply of storage.` *American Economic Review*, 47, pp. 50-72.

Brischetto, A., Richards, A., (2006) `The performance of trimmed mean measures of underlying inflation.` Reserve Bank of Australia Research Discussion Paper 2006-10, [online] Available at: http://www.rba.gov.au/publications/rdp/2006/pdf/rdp2006-10.pdf [Accessed 21 October 2013].

Brockwell, P., J., Davis, R., A., (2009) *Time series: theory and methods*. 2nd edition, New York: Springer Science, pp. 12-14.

Brooks, Ch., (2008) *Introductory Econometrics for Finance*. 2nd ed. Cambridge: Cambridge University Press.

Browne, F., Cronin, D., (2010) `Commodity prices, money and inflation.` *European Central Bank, Working Paper series No. 738,* pp. 4-34.

Bullard, J., (2011) `Measuring inflation: The core is rotten.` *Federal Reserve Bank of St. Louis Review,* 93(4), pp. 223-233.

Burbridge, J., Harrison, A., (1984) `Testing for the Effects of Oil-Price Rises Using Vector Autoregressions.` *International Economic Review*, 25(1), pp. 459-484.

Buyuksahin, B., Harris, J., H., (2011) `Do Speculators Drive Crude Oil Futures Prices?` *The Energy Journal*, 32 (2), pp.167-202.

Byun, C., (2013) *Speculation in Commodity Futures Market, Inventories and the Price of Crude Oil*. [online] Available at: http://econ.ucsd.edu/~s1byun/pdfs/inventory_sj.pdf [Accessed 05 August 2013].

Cabanillas, L., G., Terzi, A., (2012) `The accuracy of the European Commission's forecasts re-examined.` *European Commission Economic Papers 476,* [online] Available at: http://ec.europa.eu/economy_finance/publications/economic_paper/2012/pdf/ecp476_en .pdf [Accessed 16 October 2013].

Carney, M., (2013) *Inflation report press conference*. [online] Available at: http://www.bankofengland.co.uk/publications/Documents/inflationreport/2013/irspnote 070813.pdf [Accessed 15 August 2013].

Carter, C., A., Rausser, G., C., Smith, A., (2011) `Commodity Booms and Busts.` *Annual Review of Resource Economics*, 3, pp. 87-118.

Catão, L., Chang. R., (2010)`World food prices and monetary policy.` *NBER Working Paper No. 16563*, pp. 1-16.

Cavalcanti, T., V., Mohaddes, K., Raissi, M., (2012) `Commodity Price Volatility and the Sources of Growth.` *IMF Working Paper, WP/12/12* [online] Available at: http://www.imf.org/external/pubs/ft/wp/2012/wp1212.pdf [Accessed 12 October 2013].

Census, (2012) A Basic Seasonal Adjustment Glossary. United States Census Bureau, [online] Available at: http://www.census.gov/srd/www/x13as/glossary.html [Accessed 14 January 2013].

Chatrath, A., Adrangi, B., Dhanda, K., K., (2002) `Are commodity prices chaotic?` *Agricultural Economics,* 27, pp. 123–137.

Clark, T., E., Terry, S., J., (2010) `Time Variation in the Inflation Pass through of Energy Prices`. *Journal of Money, Credit and Banking.* 42 (7), pp. 1419–1433.

Charemza,W., Deadman,D., (1997) *New Directions in Econometric Practice: General to Specific Modelling, Cointegration and Vector Autoregression*. 2nd ed. U.S: Edward Elgar Publishing Ltd.

Chatfield, C., (2000) *Time-series forecasting,* New York: Chapman & Hall.

Chatfield, C., (2004) *The analysis of time series, an introduction,* 6th ed. New York: Chapman & Hall.

Celasun, O., Ratnovski, L., Mihet, R., (2012) `Commodity Prices and Inflation Expectations in the United States.` International Monetary Fund, [online] Available at: http://www.imf.org/external/pubs/cat/longres.aspx?sk=25803.0 [Accessed 15 November 2013].

Chen, S., S., (2009) `Oil price pass-through into inflation`. *Energy Economics.* 31, pp. 126-133.

Chen, Sh., Jackson, J., D., Hyeongwoo, K., Pramesti, R., (2013) `What Drives Commodity Prices?` *Auburn Economics Working Paper Series*, auwp2013, [online] Available at: http://EconPapers.repec.org/RePEc:abn:wpaper:auwp2013-03 [Accessed 14 October 2013].

Cheung, C., (2009) `Are Commodity Prices Useful Leading Indicators of Inflation?` Bank of Canada Discussion Paper [online] Available at: https://www.econstor.eu/dspace/bitstream/10419/66921/1/592151344.pdf [Accessed 15 May 2013].

Cheung, Y., W., Lai, K., (1993) `Finite-sample size of Johansen's likelihood ratio test for cointegration.` *Oxford Bulletin of Economics and Statistics.* 55, pp. 313-328.

Chevallier, J., (2013) `Price relationships in crude oil futures: new evidence from CFTC disaggregated data.` Environmental Economics and Policy Studies, 15 (2), pp. 133-170.

Chevallier, J., Ielpo, F., (2013) `Twenty years of jumps in commodity markets.` *International Review of Applied Economics,* 20(13), pp. 25-43.

Coletti, D., Lalonde, R., Masson, P., Muir, D., Snudden, S., (2012) `Commodities and Monetary Policy: Implications for Inflation and Price Level Targeting.` *Bank of Canada Working Paper 2012-16*, [online] Available: http://publications.gc.ca/collections/collection_2012/banque-bank-canada/FB3-2-112-16-eng.pdf [Accessed 17 October 2013].

Choudhri, E., U., Hakura, D., S., (2006) `Exchange Rate Pass-Through to Domestic Prices: Does the Inflationary Environment Matter?` *Journal of International Money and Finance*, 25 (6), pp. 614–639.

Chowdhury, I., Hoffmann, M., Schabert, A., (2006) ` Inflation dynamics and the cost channel of monetary transmission.` *European Economic Review*, 50(4), pp. 995-1016.

Christ, C., F., (1994) `The Cowles Commission's Contributions to Econometrics at Chicago, 1939-1955.` *Journal of Economic Literature*, 32(1), pp. 30-59.

Christiano, L., J., Eichenbaum, M., and Evans, C., L., (1996) `The Effects of Monetary Policy Shocks: Evidence from the Flow of Funds.` *Review of Economics and Statistics*. 78, pp. 16-34.

Christiano, L., J., Eichenbaum, M., Evans, C., L., (1999) *Monetary Policy Shocks: what have we learned and to what end?* In: Taylor, J., Woodford, M., (eds.) *Handbook of Macroeconomics*. New York: Elsevier, pp. 65-148.

Clements, M., P., Hendry, D., F., (1995) `Forecasting in cointegrated systems.` *Journal of Applied Econometrics*. 10, pp. 127–146.

Clements, M., Hendry, D., (1998) *Forecasting Economic Time Series*. Cambridge: Cambridge University Press.

Cochrane, J., (1991) `A critique of the application of unit root tests.` *Journal of Economic Dynamics and Control*. 15 (2). pp. 275-284.

Cody, B., J., Mills, L., O., (1991) `The Role of Commodity Prices in Formulating Monetary Policy.` *Review of Economics and Statistics,* 73, pp. 358–365.

Cogley, T., (2002) `A Simple Adaptive Measure of Core Inflation.` *Journal of Money, Credit and Banking*, 34 (1), pp. 35-45.

Collins, K., (2008) *The Role of Biofuels and Other Factors in Increasing Farm and Food Prices: A Review of Recent Development with a Focus on Feed Grain Markets and Market Prospects.* [online] Available at: http://www.globalbioenergy.org/uploads/media/0806_Keith_Collins_-

_The_Role_of_Biofuels_and_Other_Factors.pdf [Accessed 10 August 2013].

Cologni, A., Manera, M., (2008) `Oil prices, inflation and interest rates in a structural cointegrated VAR model for the G-7 countries.` *Energy Economics*, 30, pp. 856-888.

Cologni, A., Manera, M., (2009) `The asymmetric effects of oil shocks on output growth: A Markov-Switching analysis for the G7 countries.` *Economic Modelling*, 26(1), pp. 1-29.

Cook, S., (2004) `Finite-Sample Properties of the GLS-Based Dickey-Fuller Test in the Presence of Breaks in Innovation Variance.` *Australian Journal of Statistics*. 33 (3), pp. 305-314. Available online at: http://www.stat.tugraz.at/AJS/ausg043/043Cook.pdf [Accessed 03 March 2013].

Crawford, G., Liew, J., K., Marks, A., (2013) ` Spot Commodities as Inflation Protection.` *The Journal of Wealth Management*, 16(3), pp. 87-111.

Creti, A., Joëtsa, M., Mignon, V., (2013) `On the links between stock and commodity markets' volatility.` *Energy Economics*, 37, pp. 16-28.

Culver, S., E., Papell, D., H., (1997) `Is there a unit root in the inflation rate? Evidence from sequential break and panel data models.` *Journal of Applied Econometrics*. 12, pp. 435-444. Available online at: http://www.nek.lu.se/NEKJWE/time_series/culver_papell_97.pdf [Accessed 20 February 2013].

Cunado, J., Gracia, P., F., (2005) `Oil prices, economic activity and inflation: Evidence for some Asian countries.` *Quarterly Review of Economics and Finance*, 45 (1), pp. 65-83.

Cuthbertson, K., S., Hall, G., Taylor, M., P., (1992) *Applied Econometric Techniques*. U.S.: University of Michigan Press.

Davis, J., S., (2012) `The Effect of Commodity Price Shocks on Underlying Inflation: The Role of Central Bank Credibility.` Federal Reserve Bank of Dallas Working Paper No. 134, [online] Available at: http://www.dallasfed.org/assets/documents/institute/wpapers/2012/0134.pdf [Accessed 15 October 2013].

Deaton, A., Laroque, G., (1992) `On the behaviour of commodity prices.` Review *of Economic Studies*, 59(1), pp. 1-23.

Dedola, L., Lippi, F., (2005) `The Monetary Transmission Mechanism: Evidence from the Industries of Five OECD Countries.` *European Economic Review*, 49(6), pp. 1543–1569.

Defra, (2006) *Food Security and the UK: An Evidence and Analysis*. [online] Available at: http://archive.defra.gov.uk/evidence/economics/foodfarm/reports/documents/foodsecurity.pdf [Accessed 15 March 2013].

Defra, (2010) *The 2007/08 Agricultural Price Spikes: Causes and Policy Implications*. [online] Available at: http://archive.defra.gov.uk/foodfarm/food/pdf/ag-price100105.pdf [Accessed 29 June 2014].

Defra, (2014) Index of Producer Prices of Agricultural Products (United Kingdom). [online] Available at: https://www.gov.uk/government/publications/agricultural-price-indices [Accessed 27 June 2014].

DeGrauwe, P., (2006) `What have we learnt about monetary integration since the Maastricht treaty?` *Journal of Common Market Studies,* 44(4), pp.711-730.

Department of Energy and Climate Change, (2013) *Oil statistics*. [online] Available at: https://www.gov.uk/government/organisations/department-of-energy-climate-change/series/oil-statistics [Accessed 05 August 2013].

Department of Energy and Climate Change, (2013) *Monthly: Typical/average annual retail prices of petroleum products and a crude oil price index*. [online] Available at: https://www.gov.uk/government/statistical-data-sets/oil-and-petroleum-products-monthly-statistics [Accessed 27 June 2014].

DePratto, B., Resende, C., Maier, P., (2009) `How Changes in Oil Prices Affect the Macroeconomy.` *Bank of Canada Working Paper 2009-33,* pp. 2-37.

DeSerres, A., Guay, A., (1995) `Selection of truncation lag in structural VARs (or VECMs) with long-run restriction.` *Bank of Canada Working paper 95-9*. Available at: http://publications.gc.ca/site/eng/54517/publication.html [Accessed 04 January 2013].

Dickey, D., Fuller, W., (1979) `Distribution of the estimation for autoregressive time series with a unit root.` *Journal of American Statistical Association*. 74 (366), pp. 427-431.

Dickey, D., Fuller, W., (1981) `Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root.` *Econometrica*. 49 (4), pp. 1057-1072.

Dornbusch, R., (1976) `Expectations and Exchange Rate Dynamics.` *Journal of Political Economy*, 84, pp. 1161-1176.

Downing, E., Harker, R., (2012) `Food Prices and Affordability.` *House of Commons,* [online] Available at: http://www.parliament.uk/briefing-papers/SN06436.pdf [Accessed 11 November 2013].

Drakos, K., Konstantinou, P., Th., (2013) `Investment decisions in manufacturing: assessing the effects of real oil prices and their uncertainty.` *Journal of Applied Econometrics*, 28 (1), pp. 151–165.

Driskill, R., A., (1981) `Exchange Rate Dynamics, Portfolio Balance, and Relative Prices.` *American Economic Review,* 70, pp. 776-783.

Drobny, A., (1988) *Real Wages and Employment: Keynes, Monetarism and the Labour Market.* London: Taylor & Francis e-Library.

Durbin, J., Watson, G., S., (1951) `Testing for Serial Correlation in Least Squares Regression II.` *Biometrika,* 38 (1/2), pp. 159-177. Available at: http://www.jstor.org/discover/10.2307/2332325?uid=3738032&uid=2129&uid=2&uid=70&uid=4&sid=21102447841617 [Accessed 16 August 2012].

Dwyer, A., Gardner, G., Williams, T., (2011) `Global Commodity Markets –Price Volatility and Financialisation.` *Reserve Bank of Australia Quarterly bulletin,* [online] Available at: http://www.rba.gov.au/publications/bulletin/2011/jun/pdf/bu-0611-7.pdf [Accessed 12 June 2012].

Edelstein, P., Kilian, L., (2009) `Retail Energy Prices and Consumer Expenditures`. *Journal of Monetary Economics.* 56 (6), pp. 766-779.

Edmonds, T., Jarrett, T., Woodhouse, J., (2010) `The credit crisis: a timeline.` Commons Library Standard Notes, SN/BT/4991, [online] Available at: www.parliament.uk/briefingpapers/commons/lib/research/briefings/snbt-04991.pdf [Accessed 18 October 2013].

Eggertsson, G., B., Woodford, M., (2003) `The zero bound on interest rates and optimal monetary policy.` *Brookings Papers on Economic Activity*, 1, pp. 139-211.

EIA, (2011a) *Annual Energy Review 2011.* [online] Available at: http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf [Accessed 28 August 2013].

EIA, (2011b) *Country analysis briefs*. [online] Available at: http://www.eia.gov/cabs/united_kingdom/Full.html [Accessed 20 November 2012].

EIA, (2012) *Fuel Competition in Power Generation and Elasticities of Substitution.* [online] Available at: http://www.eia.gov/analysis/studies/fuelelasticities/pdf/eia-fuelelasticities.pdf [Accessed 01 October 2013].

EIA, (2013a) Annual Energy Outlook 2013 [Online] Available at: http://www.eia.gov/forecasts/aeo/data.cfm [Accessed 15 Jun 2013].

EIA, (2013b) *What Drives Crude Oil Prices? An analysis of 7 factors that influence oil markets, with chart data updated monthly and quarterly*. [online] Available at: http://www.eia.gov/finance/markets/supply-opec.cfm [Accessed 06 August 2013].

EIA, (2013c) *International Energy Statistics* [online] Available at: http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=50&pid=53&aid=1 [Accessed 20 May 2013].

EIA, (2013d) *Spot Prices for Crude Oil and Petroleum Products*. [online] Available at: http://www.eia.gov/dnav/pet/pet_pri_spt_s1_m.htm [Accessed 15 October 2013].

Eickmeier, S., Pijnenburg, K., (2013) `The Global Dimension of Inflation – Evidence from Factor-Augmented Phillips Curves.` *Oxford Bulletin of Economics and Statistics*, 75(1), pp 103–122.

Elliott, G., Granger, C., Timmermann, A., (2006) *Handbook of Economic Forecasting, Volume 1*. Oxford: Elsevier.

Emmons, W., R., Yeager, T., J., (2002) *The Futures Market as Forecasting Tool: An Imperfect Crystal Ball* [online] Available at: http://www.stlouisfed.org/publications/re/articles/?id=448 [Accessed 02 August 2012].

Enders, W., (2003) *Applied Econometric Time Series.* U.S: Wiley.

Engle, R., F., (1982) `Autoregressive conditional heteroscedasticity, with estimates of the variance of United Kingdom inflation.` *Econometrica* 50, pp. 987–1007.

Engle, R., F., Granger, C., J., W., (1987) `Cointegration and error correction: Representation, estimation and testing.` *Econometrica*. 55, pp. 251–276.

Erten, B., Ocampo, J., A., (2013) `Super Cycles of Commodity Prices Since the Mid-Nineteenth Century.` *World Development*, 44, pp.14–30.

European Central Bank, (2001) *Monthly bulletin*. [online] Available at: http://www.ecb.europa.eu/pub/pdf/mobu/mb200102en.pdf [Accessed 16 September 2013].

European Central Bank, (2011) `The supply of money – Bank behaviour and the implications for monetary analysis.` Monthly Bulletin, [online] Available at: http://www.ecb.europa.eu/pub/pdf/other/art1_mb201110en_pp63-79en.pdf [Accessed 20 November 2013].

European Central Bank, (2013) `Commodity prices and their role in assessing Euro Area growth and inflation.` *ECB monthly bulletin*, [online] Available at:

http://www.ecb.europa.eu/pub/pdf/other/art1_mb201310en_pp53-68en.pdf [Accessed 16 October 2013].

European Commission, (2012) *Energy production and imports* [online] Available at: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Energy_production_and_imports [Accessed 20 February 2013].

Ewing, B., T., Malik, F., (2013) ` Volatility transmission between gold and oil futures under structural breaks.` *International Review of Economics & Finance*, 25, pp. 113–121.

Ezekiel, M., (1938) `The Cobweb Theorem.` *Quarterly Journal of Economics*, 53, pp.225-280.

FAO, (2008) Crop Prospects and Food Situation, *GIEWS report,3, pp. 1-32.*

FAO, (2009) *Global agriculture towards 2050,* Food and Agriculture Organization of the United Nations, [online] Available at: http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf [Accessed 16 December 2013].

FAO, (2013a) Crop Prospects and Food Situation, *GIEWS report, 2, pp. 1-32.*

FAO, (2013b) Databases [online] Available at: http://statistics.amis-outlook.org/data/index.html [Accessed 17 September 2013].

Fattouh, B., Kilian, L., Mahadeva, L., (2012) *The Role of Speculation in Oil Markets: What Have We Learned So Far?* [online] Available at: http://www.ourenergypolicy.org/wp-content/uploads/2013/06/milan030612.pdf [Accessed 09 August 2013].

Fatum, R., Scholnick, B., (2008) `Monetary policy and exchange rate responses: do only surprises matter?` *Journal of Banking and Finance*, 32, pp. 1076-1086.

Faust, J., (1998) `The Robustness of Identified VAR Conclusions About Money.` *Carnegie-Rochester Conference on Public Policy.* 49, pp. 207–244.

Favero, C., A., (2001) *Applied macroeconomics.* Oxford: Oxford University Press.

Finn, M., G., (2000) `Perfect competition and the effects of energy price increases on economic activity.` *Journal of Money, Credit, and Banking*, 32, pp. 400–416.

Fischbacher, U., Hens, T., Zeisberger, S., (2013) `The impact of monetary policy on stock market bubbles and trading behavior: Evidence from the lab.` *Journal of Economic Dynamics and Control*, 37(10), pp. 2104-2122.

Fishelson, G., (1983) ` Hotelling rule, economic responses and oil prices.` *Energy Economics*, 5(3), pp. 153-156.

Food and Agriculture Organization of the United Nations (2013) *Food price index* [online] Available at: http://www.fao.org/worldfoodsituation/foodpricesindex/en/ [Accessed 16 Jun 2013].

Food and Drink Federation, (2013) *UK Food and Drink Export Performance.* [online] Available at: http://www.fdf.org.uk/exports/ukexports.aspx [Accessed 22 October 2013].

Frankel, J., A., (1986) Expectations and Commodity price dynamics: Overshooting model. *American Agricultural Economics Association*, 68 (2) pp. 344-350.

Frankel, J., A., (2006) `The effect of monetary policy on real commodity prices.` NBER Working Paper No.12713.

Frankel, J., A., (2007) The effect of monetary policy on real commodity prices. In Campbell, J. (eds) *Asset prices and monetary policy,* U.S.: University of Chicago press.

Frankel, J., (2012) `Product Price Targeting—A New Improved Way of Inflation Targeting.` *Macroeconomic Review,* Special Feature B, [online] Available at: http://www.mas.gov.sg/~/media/MAS/Monetary%20Policy%20and%20Economics/Education%20and%20Research/Research/Economics%20Essays/2012%20Apr/MRApr12_SF_B.pdf [Accessed 01 November 2013].

Frankel, J., (2013) `Effects of speculation and interest rates in a "carry trade" model of commodity prices.` *Journal of International Money and Finance,* [online] Available at: http://www.sciencedirect.com/science/article/pii/S0261560613001083 [Accessed 15 October 2013].

Frankel, J., Hardouvelis, G., (1986) `Commodity prices, overshooting, money surprises, and FED credibility.` *NBER working paper*, 1121, pp.1-24.

Frankel, J., A., Rodriguez, C., (1982) `Exchange Rate Dynamics and the Overshooting Hypothesis.` *International Monetary Fund Staff Papers,* 24, pp. 1-30.

Frankel, J., Savarelos, G., (2012) `Can leading indicators assess country vulnerability? Evidence from the 2008–09 global financial crisis?` *Journal of International Economics*, 87 (2), pp. 216–231.

Fratzscher, M., Schneider, D., Van Robays, I., (2013) `Oil prices, exchange rates and asset prices.` *Discussion Papers, DIW Berlin 1302,* [online] Available at: http://www.econstor.eu/handle/10419/74495 [Accessed 08 August 2013].

Friedman, M., (2004) `Why the Federal Reserve Should Not Adopt Inflation Targeting.`

International Finance, 7(1), pp.129–136.

Fuller, W., A., (2009*) Introduction to statistical time series*. 2nd edition, Canada: John Willey &Sons, pp. 3-4.

Furlong, F., T., (1989) `Commodity Prices as a Guide for Monetary Policy.` *Federal Reserve Bank of San Francisco Economic Review*, 1, pp. 21–38.

Furlong, F., T., Ingenito, R., (1996) `Commodity Prices and Inflation.` *Federal Reserve Bank of San Francisco Economic Review*, 2, pp. 27-47.

Gaitan, B., Tol, R., S., Yetkiner, I., H., (2006) *The Hotelling's Rule Revisited in a Dynamic General Equilibrium Model.* [online] Available at: http://ideas.repec.org/h/izm/prcdng/200619.html [Accessed 25 July 2013].

Galesi, A., Lombardi, M., J., (2013) External shocks and international inflation linkage. Mauro, F., Pesaran, H., eds. In: *The GVAR handbook: Structure and Applications of a Macro Model of the Global Economy for Policy Analysis*. Oxford: United Kingdom, pp. 83-97. Garratt, A., Lee, K., Pesaran, M., H., Shin, Y (2012) *Global and National Macroeconometric Modelling: A Long-Run Structural Approach*. Oxford University Press: Oxford, pp. 38-42.

Garner, C., A., (1995) `How Useful Are Leading Indicators of Inflation?` *Federal Reserve Bank of Kansas City Economic Review*, 2, pp. 5–18.

Geman, H., (2005) *Commodities and Commodity Derivatives*. John Wiley & Sons, New York.

Geweke, J., (1984) Inference and causality in economic time series models. In: Z. Griliches, Z., Intriligator, M., D., (eds.) *Handbook of Econometrics*. Amsterdam: Elsevier Science Publishers.

Gilbert, Ch., (2010) `How to Understand High Food Prices.` *Journal of Agricultural Economics*, 61(2), pp. 398-425.

Gilbert, Ch., (2011) International Agreements for Commodity Price Stabilisation. OECD Food, Agriculture and Fisheries Papers [online] Available at: http://www.oecd-ilibrary.org/agriculture-and-food/international-agreements-for-commodity-price-stabilisation_5kg0ps7ds0jl-en [Accessed 04 August 2013].

Ginindza, M., Maasoumi1, E., (2013) ` Evaluating inflation targeting based on the distribution of inflation and inflation volatility.` *The North American Journal of Economics and Finance*, [online] Available at: http://www.sciencedirect.com/science/article/pii/S1062940813000338 [Accessed 17

November 2013].

Glick, R., Leduc, S., (2012) `Central bank announcements of asset purchases and the impact on global financial and commodity markets.` *Journal of International Money and Finance*, 31(8), pp. 2078-2101.

Godfrey, L., G., (1978) `Testing for Higher Order Serial Correlation in Regression Equations When the Regressors Include Lagged Dependent Variables.` *Econometrica*, 46, pp. 1303-1310.

Gonzalo, J., (1994) `Five Alternative Methods of Estimating Long-Run Equilibrium Relationships.` *Journal of Econometrics*, 60 (2), pp. 203-233.

Goodfriend, M., King, R., G., (1997) `The New Neoclassical Synthesis and the Role of Monetary Policy`. In: Bernanke, B., S., Rotemberg, J. (eds.) *NBER Macroeconomics Annual 1997, Volume 12.* New York: MIT Press, pp. 231–296. Available at: http://www.nber.org/chapters/c11040.pdf [Accessed 23 Jun 2012].

Gooding, P., (2013) *Consumer Prices Index and Retail Prices Index: The 2012 Basket of Goods and Services*, Office for National Statistics [online] Available at: http://www.ons.gov.uk/ons/rel/cpi/consumer-price-indices/may-2013/stb---consumer-price-indices---may-2013.html [Accessed 19 July 2013].

Gordon, D., Leeper, E., M., (1994) `The Dynamic Impacts of Monetary Policy: an Exercise in Tentative Identification`. *Journal of Political Economy*. 102, pp. 1228-1247.

Gorton, G., B., Hayashi, F., Rouwenhorst, K., G., (2013) ` The Fundamentals of Commodity Futures Returns.` *Review of Finance*, 17 (1), pp. 35-105.

Gospodinov, N., Jamali, I., (2013) Does Expansionary Monetary Policy Drive Commodity Prices Up? Evidence from Futures Markets. [online] Available at: http://alcor.concordia.ca/~gospodin/research/MPshocks.pdf [Accessed 06 August 2013].

Gospodinov, N., (2013) ` Commodity Prices, Convenience Yields, and Inflation.` *The Review of Economics and Statistics*, 95(1), pp. 206-219.

Gottschalk, J., (2001) `An Introduction into the SVAR Methodology: Identification, Interpretation and Limitations of SVAR models`. *Kieler Arbeitspapiere 1072*, Available online at: http://hdl.handle.net/10419/17887 [Accessed 03 March 2012].

Gouel, Ch., (2013) `Food Price Volatility and Domestic Stabilization Policies in Developing Countries.` *NBER Working Paper No. 18934,* [online] Available at: http://www.nber.org/papers/w18934 [Accessed 16 October 2013].

Gourinchas, P., O., Kose, M., A., Helbling, T., (2013) ` Policy Responses to Commodity Price Movements.` *IMF Economic Review*,61, pp. 1–5

Government, (2012) *Overseas trade*. [online] Available at: https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs/series/overseas-trade [Accessed 26 July 2013].

Granger, C., W., J., (1969) ` Investigating Causal Relations by Econometric Models and Cross-spectral Methods.` *Econometrica*, 37(3), pp. 424-438.

Granger, C., W., J., (1981). `Some Properties of Time Series Data and Their Use in Econometric Model Specification.` *Journal of Econometrics*, 16 (1), pp. 121–130.

Granger, C., W., J., (1986) `Developments in the study of cointegrated economic variables.` *Oxford Bulletin of Economics and Statistics*. 48, pp. 213–228.

Gredenhoff, M., Karlsson, S., (1999) `Lag-length selection in VAR-models using equal and unequal lag-length procedures.` *Computational Statistics*. 14 (2), pp. 171-187.

Gregorio, J., (2012) *Commodity prices, Monetary policy and Inflation*. [online] Available at: http://www.imf.org/external/np/seminars/eng/2011/tur/pdf/JDeG.pdf [Accessed 15 September 2012].

Gregorio, D., Landerretche, O., Neilson, C., (2007) `Another Pass-through Bites the Dust? Oil Prices and Inflation`. *Economía.* 7(2), pp. 155-196.

Griffiths, W., Lutkepohl, H., (1990) `Confidence Intervals for Impulse Responses from VAR Models: A comparison of asymptotic theory and simulation approaches.` *Department of Econometrics University of New England Working paper 42*, Available at: http://www.une.edu.au/business-school/working-papers/econometrics/emetwp42.pdf [Accessed 25 Jun 2013].

Guo, H., Kliesen, K., (2005) `Oil Price Volatility and U.S. Macroeconomic Activity.` *Federal Reserve Bank of St. Luis Review,* 87 (6), pp. 669-683.

Hacker, S., (2010) The Effectiveness of Information Criteria in Determining Unit Root and Trend Stratus. *CESIS Electronic Working Paper Series 213*, Available: http://www.kth.se/dokument/itm/cesis/CESISWP213.pdf [Accessed 01 November 2012].

Hafer, R., W., Sheehan, R., G., (1989) `The Sensitivity of VAR Forecasts to Alternative Lag Structures.` *International Journal of Forecasting*. 5 (3), pp. 399-408.

Halvorsen, R., Smith, T., R., (1991) `A Test of the theory of exhaustible resources.` *The*

Quarterly Journal of Economics, 32 (1), pp. 123-140.

Hamilton, J., D., (1983) `Oil and the Macroeconomy since World War II.` *Journal of Political Economy*, 92 (2),pp. 228-248.

Hamilton, J., D., (1988) `A Neoclassical Model of Unemployment and the Business Cycle.` *Journal of Political Economy*, 96 (3), pp. 593-617.

Hamilton, J., D., (1994) *Time series analysis*. U.S: Princeton University Press.

Hamilton, J., D., (2003) `What is an Oil Shock?` *Journal of Econometrics*, 113, pp. 363-398.

Hamilton, J., D., (2009) `Understanding Crude Oil Prices.` *The Energy Journal*, 30, pp.179-206.

Hamilton, J., D., (2013) *Historical Oil Shocks*. In Routledge Handbook of Major Events in Economic History, Parker, R., and Whaples, R., [edts] New York: Routledge Taylor and Francis Group, pp. 239-265.

Hammond, G., (2012) State of the art of inflation targeting. Bank of England Handbook n. 29, [online] Available at: http://www.bankofengland.co.uk/education/ccbs/handbooks/pdf/ccbshb29.pdf [Accessed: 03 March 2012].

Hamori, S., (2007) `The information role of commodity prices in formulating monetary policy: some evidence from Japan.` *Economics Bulletin*, 5, pp. 1-7.

Hannan, E., J., Quinn, B., G., (1979) `The determination of the order of an autoregression.` *Journal of the Royal Statistical Society*. pp. 190-195.

Hansen, B., E., (2001) `The New Econometrics of Structural Change: Dating Breaks in US labour Productivity.` *Journal of Economic Perspective*, 15 (4), pp. 117-128.

Harrison, R., W., (2009) `The Food versus Fuel Debate: Implications for Consumers.` *Journal of Agricultural and Applied Economics*, 41 (2), pp. 493–500.

Harrison, R., Thomas, R., Weymarn, I., (2011) 'The impact of permanent energy price shocks on the UK economy.' *Bank of England Working Paper*, 433 [online] Available at: http://www.bankofengland.co.uk/publications/Documents/workingpapers/wp433.pdf [Accessed: 15 Jun 2013].

Harvey, A., C., (1990) *The Economic Analysis of Time*. London School of Economics Handbooks in economics series, 2nd ed. London: MIT Press.

Harvey, A., C., (1997) `Trends, Cycles and Autoregression.` *The Economic Journal*, 107, pp.192-201.

Hassan, K., Salim, R., A., (2011) ` Is there any Link between Commodity Price and Monetary Policy? Evidence from Australia.` *Economic Analysis and Policy*, 41 (3), pp. 205-215.

Hatanka, M., (1996) *Time-Series-Based Econometrics: Unit Roots and Cointegrations*. Oxford: OUP Oxford.

Hatemi, A., (2004) `Multivariate tests for autocorrelation in the stable and unstable VAR models.` *Economic Modelling.* 21 (4), pp. 661–683.

Helbling, T., (2012) ` Commodities in Boom.` Finance and Development, 49 (2), pp. 30-31.

Hendry, D., (1991) `Modelling UK inflation, 1875-1991.` *Journal of Applied Econometrics*, 16, pp. 255-275.

Hendry, D., F., (2001) `Modelling UK inflation, 1875-1991.` *Journal of Applied Econometrics*, 16(3), pp. 255-275.

Hendry, D., F., Juselius, K., (2000) `Explaining cointegration analysis: Part I.` *Energy Journal.* 21, pp. 1–42.

Herrera, A., M., Lagalo, L., G., Wada, T., (2011) `Oil Price Shocks And Industrial Production: Is The Relationship Linear?` *Macroeconomic Dynamics*, 15(3), pp. 472-497.

HM Treasury, (1992a) *HM Treasury* [online] Available at: http://www.hm-treasury.gov.uk/d/foi_dis_1_inflation_objective_240992.PDF [Accessed 14 December 2010].

HM Treasury, (1992b) *The UK's economics* [online] Available at: http://62.164.176.164/d/foi_dis_6_cx_metting_051092.PDF [Accessed 16 December 2010].

Hogan, S., Johnson, M., Laflèche, T., (2001) `Core Inflation.` *Bank of Canada Technical Report No. 89*, [online] Available at: http://www.bankofcanada.ca/wp-content/uploads/2010/01/tr89.pdf [Accessed 21 October 2013].

Hommes, C., (2013) *Behavioral Rationality and Heterogeneous Expectations in Complex Economic Systems*. Cambridge University Press: Cambridge, pp. 95-129.

Hooker, M., A., (2002) `Are Oil Shocks Inflationary? Asymmetric and Nonlinear Specifications versus Changes in Regime`. *Journal of Money, Credit and Banking*. 34 (2), pp. 540-561.

Hoover, K., D., (2004) `Lost Causes.` *Journal of the History of Economic Thought*, 26(2), pp.149-164.

Hoover, K., D., (2012) *Causality in Economics and Econometrics*. In The New Palgrave Dictionary of Economics, Durlauf, S., N., and Blume, L., E., (edts.) [Online] Available at: http://www.palgraveconnect.com/pc/doifinder/10.1057/9781137336583. [Accessed: 15 September 2013].

Hotelling, H., (1939) `The Economics of Exhaustible Resources.` *The Journal of Political Economy*, 39(2), pp. 137-175.

Hua, P., (1998) `On Primary Commodity Prices: The Impact of Macroeconomic/Monetary Shocks.` *Journal of Policy Modelling*, 20, pp. 767–790.

Huang, B., N., Hwang, M., J., Peng, H., P., (2005) `The asymmetry of the impact of oil price shocks on economic activities: An application of the multivariate threshold model.` *Energy Economics*, 27, pp. 445-476.

Hubbard, R, G., Weiner, R., J., (1986) `Inventory Optimization in the U.S. Petroleum Industry: Empirical Analysis and Implications for Energy Emergency Policy.` *Management Science*, 32 (7), pp. 122-132.

Hulten, Ch., R., Robertson, J., W., Wykoff, F., C., (1989) `Energy Obsolescence and the Productivity Slowdown.` in Jorgenson, D., W., Landau, R., [eds.] Cambridge: MIT Press.

Hume, D., (1979) *A Treatise of Human Nature.* Reprinted from the Original Edition by L.A. Selby-Bigge, M.A. (1896), Oxford: Clarendon Press, [online] Available at: http://michaeljohnsonphilosophy.com/wp-content/uploads/2012/01/5010_Hume_Treatise_Human_Nature.pdf [Accessed 15 September 2013].

Hunt, I., P., Laxton, D., (2001) `The Macroeconomic Effects of Higher Oil Prices.` *IMF Working Paper WP/01/04*,pp.10-25.

IMF, (2011)` United Kingdom: Selected Issues Paper.` Country Report No. 11/221, pp. 4-13.

IEA, (2004) *Analysis of the impact of High Oil Prices on the Global Economy*. [online] Available at: http://www.iea.org/textbase/npsum/high_oil04sum.pdf [Accessed 04 March 2013].

IEA, (2013) *Monthly Oil Data Services.* [online] Available at: http://www.iea.org/stats/mods.asp [Accessed 6 August 2013].

IMF, (2011) *Target what you can hit: Commodity price swings and monetary policy.* [online] Available at: http://www.imf.org/external/pubs/ft/weo/2011/02/pdf/c3.pdf [Accessed 19

July 2013].

Inoue, A., Kilian, L., (2003) `In-sample or Out-of-sample tests of predictability: Which one should we use?` *European Central Bank working paper*, *195*, pp. 9-38.

Ireland, P., N., (2008) `Monetary Transmission Mechanism,` in Durlauf, S., N., and Blume, L., (eds.) *The New Palgrave Dictionary of Economics*, 2nd edition, United Kingdom: Palgrave MacMillan.

Isaac, A., G., Rapach, D., E., (1997) `Monetary Shocks and Relative Farm Prices: A Re-examination.`*American Journal of Agricultural Economics*, 79, pp. 1332-1339.

Issing, O., (2013) *Challenges for Monetary Policy.* German Institute for Economic Research, [online] Available at: http://www.diw.de/documents/dokumentenarchiv/17/diw_01.c.426881.de/issing_omt_konferenz_2013.pdf [Accessed 02 November 2013].

Irwin, S., H., (2013) `Commodity Index Investment and Food Prices: Does the "Masters Hypothesis" Explain Recent Price Spikes?` *Agricultural Economics (forthcoming)*, [online] Available at: http://agec-110.ace.illinois.edu/irwin/research/Irwin_IAAE_Paper.pdf [Accessed 09 August 2013].

Irwin, S., H., Sanders, D., R., (2012) `Financialisation and structural change in commodity futures markets.` *Journal of Agricultural and Applied Economics*, 44 (3), pp. 371–396.

Ivanov, V., Kilian, L., (2001) A Practitioner's Guide to Lag-Order Selection for Vector Autoregressions. CEPR Discussion Paper 2685. Available at http://www.cepr.org/pubs/new-dps/dplist.asp?dpno=2685 [Accessed 15 May 2012].

Jacks, D., S., (2013) ` From Boom to Bust: A Typology of Real Commodity Prices in the Long Run.` *NBER Working Paper No. 18874*, [online] Available at: http://www.nber.org/papers/w18874 [Accessed 20 October 2013].

Jaditz, F., (1994) `Seasonality: Economic data and model estimation.` Monthly Labour Review. Available at: http://www.bls.gov/mlr/1994/12/art2full.pdf. [Accessed 03 January 2013].

Jang, K., Ogaki, M., (2004) `The effects of monetary policy shocks on exchange rates: A structural vector error correction model approach.` *Journal of the Japanese and International Economies*, 18(1), pp. 99-114.

Jimenez, R., Sanchez, M., (2005) `Oil price shocks and real GDP growth: Empirical evidence for some OECD countries.` *Applied Economics*, 37, pp. 201–228.

Johansen, S., (1991) `Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models.` *Econometrica*. 59, pp. 1551-1580.

Johansen, S., (1992) `Determination of Cointegration Rank in the presence of a linear trend.` *Oxford Bulletin of Economics and Statistics*, 54 (3), pp. 383-397.

Jonson, P., D., (1976) ` Money and Economic Activity in the Open Economy: The United Kingdom, 1880-1970.` *Journal of Political Economy*, 84(5), pp. 979-1012.

Johnson, R., (2009) *Statistics: Principles and Methods*, 6th ed. U.S.: John Wiley & Sons, pp. 81-115.

Joyce, M., Lasaosa, A., Stevens, I., Tong, M., (2011) `The financial market impact of quantitative easing in the United Kingdom.`*International Journal of Central Banking*, 7(3), pp. 113–161.

Juvenal, L., Petrella, I., (2011) `Speculation in the Oil Market.` Research Division, Federal Reserve Bank of St. Louis Working Paper 2011-027E, [online] Available at: http://research.stlouisfed.org/wp/2011/2011-027.pdf [Accessed 27 July 2013].

Kaabia, B., Gil, J., M., Chebbi, H., (2002) `The effect of long-run identification on impulse response functions: An application to the relationship between macroeconomics and agriculture in Tunisia.` *Agricultural Economic Review*, 3(2), pp. 36-48.

Kaldor, N., (1939) `A note on the theory of the forward market.` *Review of Economic Studies*, 8, pp. 196-201.

Kaldor, N., (1976) `Inflation and Recession in the World Economy.` *The Economic Journal*, 86 (344), pp. 703-714.

Kapetanios, G.,Yates,T., (2011) `Evolving UK and US macroeconomic dynamics through the lens of a model of deterministic structural change.` *Bank of England Working paper. 434*, pp. 5-53.

Katos, A., Lawler, K., Seddighi, H., (2000) *Econometrics: A Practical Approach*. London: Routledge.

Kennedy, P., (2003) *A guide to econometrics.* 5th ed. London: MIT Press.

Keynes, J., M., (1930) *A Treatise on Money*. New York: Macmillan, pp.198- 208.

Kahn, G., A., (2012) The Taylor rule and the practice of central banking. In: Koenig, E., F., Leeson, R., Kahn, G., A. ed. The Taylor Rule and the Transformation of Monetary Policy. Stanford: Hoover Institution Press, pp. 64-73.

Kilian, L., (2001) `Impulse response analysis in vector autoregressions with unknown lag order`. *Journal of Forecasting*. 20, pp. 161-179.

Kilian, L., (2008) `The Economic Effects of Energy Price Shocks.` *Journal of Economic Literature, American Economic Association*, 46(4), pp. 871-909.

Kilian, L., (2009) `Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market.` *American Economic Review*, 99 (3), pp.1053-1069.

Kilian, L., Lee, T., K., (2013) `Quantifying the Speculative Component in the Real Price of Oil: The Role of Global Oil Inventories.` *CEPR Discussion Paper No. DP9297*,[online] Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2210267## [Accessed 09 August 2013].

Kilian, L., Murphy, D. P. (2010) `The Role of Inventories and Speculative Trading in the Global Market for Crude Oil.` University of Michigan Working paper, [online] Available at: http://www.cftc.gov/ucm/groups/public/@swaps/documents/file/plstudy_28_cepr.pdf [Accessed 06 August 2013].

Kilian, L., Murphy, D., P., (2012) `Why Agnostic Sign Restrictions Are Not Enough: Understanding The Dynamics Of Oil Market Var Models.` *Journal of the European Economic Association*, 10(5), pp. 1166-1188.

Kilian, L., Murphy, D., P., (2013) `The role of inventories and speculative trading in the global market for crude oil.`*Journal of Applied Econometrics.* DOI: 10.1002/jae.2322.

Kim, J., (2000) `Constructing and estimating a realistic optimizing model of monetary policy.` *Journal of Monetary Economics*, 45(2), pp. 329-359.

King, M., L., (1985) `A point optimal test for autoregressive disturbances.` *Journal of Econometrics*. 27, pp. 21–37.

King, R., G., (2000) `The New IS-LM Model: Language, Logic, and Limits.` *Federal Reserve Bank of Richmond Economic Quarterly,* 86 (3), pp. 45-103.

King, R., G., Watson, M., W., (1997) `Testing long-run neutrality.` *Economic Quarterly, Federal Reserve Bank of Richmond*, issue Sum, pp. 69-101.

King, R., G., Plosser, C., I., Stock, J., H., Watson, M., W., (1991) `Stochastic trends and economic fluctuations.` *American Economic Review*, 81, pp. 819-840.

Kirwan, J., Maye, D., (2013) `Food security framings within the UK and the integration of local food systems.` *Journal of Rural Studies*, 29, pp. 91-100.

Klaus, A., Billi, R., M., (2007) `Discretionary Monetary Policy and the Zero Lower Bound on

Nominal Interest Rates.` *Journal of Monetary Economics*, 54(3), pp. 728–752.

Kliesen, K., L., (2008) `Oil and the U.S. macroeconomy: An update and a simple forecasting exercise.` *Federal Reserve Bank of St. Louis Working Paper* 2002, pp. 2-14.

Kliesen, K., L., Poole, W., (2000) `Agriculture Outcomes and Monetary Policy Actions.` *Federal Reserve Bank of St. Louis Review*, 82, pp. 1–12.

Knittel, Ch., R., Pindyck, R., S., (2013) `The simple economics of commodity price speculation.` Center for Energy and Environmental Policy Research Working paper 2013-006, [online] Available at: http://web.mit.edu/ceepr/www/publications/workingpapers/2013-006.pdf [Accessed 07 August 2013].

Koehler, A., B., Murphree, E., S., (1988) `A Comparison of the Akaike and Schwarz Criteria for Selecting Model Order.` *Journal of the Royal Statistical Society*. 37 (2), pp. 187-195.

Koop, G., Pesaran, M., Potter, S., (1996) `Impulse response analysis in nonlinear multivariate models.` *Journal of Econometrics.* 74, pp. 119-147.

Koopman, S., J., Harvey, A., C., Doornik, J., A., Sheppard, N., (2006) *Structural Time Series Analyser, Modeller and Predictor*. London: Timberlake Consultants.

Kormilitsina, A., (2011) `Oil Price Shocks and the Optimality of Monetary Policy.` *Review of Economic Dynamics*, 14(1), pp. 199-223.

Krautkraemer, J., A., (1998) `Non-renewable Resource Scarcity.` *Journal of Economic Literature,* 36(4), pp. 2065–2107.

Krichene, R., (2007) `An Oil and Gas Model.` *International Monetary Fund Working paper*, 07/135, Available at: http://www.imf.org/external/pubs/ft/wp/2007/wp07135.pdf [Accessed 02 July 2013].

Krugman, P., R., (1999) `It's back: Japan's slump and the return of the liquidity trap.` *Brookings Papers on Economic Activity*, 2,pp. 137-187.

Krugman, P., R., (2008) *Speculation and Signatures.* [online] Available at: http://www.princeton.edu/~pkrugman/Speculation%20and%20Signatures.pdf [Accessed 09 August 2013].

Kuttner, K., (2001) `Monetary policy surprises and interest rates: Evidence from the Fed funds futures market.` *Journal of Monetary Economics*, 47, pp. 523-544.

Kuttner, K., Posen, A., (2012) `How Flexible Can Inflation Targeting Be and Still Work?`

International Journal of Central Banking, 8(1), pp. 65-99.

Labys, W., Maizels, A., (1990) `Commodity price fluctuations and Macro-Economic Adjustments in the Developed Countries.` *WIDER working paper,* 88, pp. 1-51.

Lamont, N., (1993) *Britain and the Exchange rate Mechanism Chancellor's Speech presented at the European Policy Forum*, London, [online] Available at: http://www.ft.com/cms/0d584700-7ac1-11d9-a8c9-00000e2511c8.pdf [Accessed: 15 October 2011].

Landier, A., Sraer, D., Thesmar, D., (2013) `Banks' Exposure to Interest Rate Risk and The Transmission of Monetary Policy.` NBER Working Paper No. 18857, [online] Available at: http://www.nber.org/papers/w18857 [Accessed 07 August 2013].

Lardic, S., Mignon, V., (2008) `Oil prices and economic activity: An asymmetric cointegration approach.` *Energy Economics*, 30(3), pp. 847-855.

Lautier, D., (2009) *Convenience Yield and Commodity Markets* [online] Available at: http://www.ifd.dauphine.fr/fileadmin/mediatheque/recherche_et_valo/FDD/CAHIER_22_LAUTIER.pdf [Accessed 02 May 2013].

Leamer, E., E., (1985) `Vector Autoregressions for Causal Inference.` *Carnegie-Rochester Conference Series on Public Policy*, 22 (1), pp. 225-304.

LeBlanc, M., Chinn, M., D., (2004) `Do High Oil Prices Presage Inflation? The Evidence from G-5 Countries`. *UC Santa Cruz Economics Working Paper 561*. Available at: http://www.escholarship.org/uc/item/9rr929sm#page-2 [Accessed 14 May 2012].

Leeper, E., (1997) `Narrative and VAR approaches to monetary policy: Common identification problems`. *Journal of Monetary Economics*. 40 (3), pp. 641-657.

Lescaroux, F., Mignon, V., Mignong, V., (2009) `The symposium on China's impact on the global economy: Measuring the effects of oil prices on China's economy: A factor-augmented vector autogressive approach.` *Pacific Economic Review,* 14 (32), pp. 410-425.

Liew, V. Khim−Sen, (2004) `Which Lag Length Selection Criteria Should We Employ?` *Economics Bulletin*. 3 (33), pp. 1−9.

Lin, C., (2011) `Estimating Supply and Demand in the World Oil Market.` *The Journal of Energy and Development*, 34(1), pp. 5-33.

Lindé, J., (2001) `Testing for the Lucas Critique: A Quantitative Investigation.` *The American Economic Review*, 91(4), pp. 986-1005.

Livernois, J., (2009) `On the Empirical Significance of the Hotelling Rule.` *Review on Environmental Economics and Policy*, 3 (1), pp. 22-41.

Loayza, N., V., Rancière, R., Servén, L., Ventura, J., (2007) `Macroeconomic Volatility and Welfare in Developing Countries: An Introduction.` World Bank Economic Review, 21 (3), pp. 343-57.

Lucas, Jr., R., E., (1976) `Econometric Policy Evaluation: A Critique.` In: Bruner, K., Meltzer, A., H., (eds.) The Philips Curve and Labour Markets, Carnegie-Rochester Conference Series on Public Policy. *Journal of Monetary Economics*, 1, pp. 19-46.

Lucia, C., Bartlett, M., (2014) `Implementing a biofuel economy in the EU: Lessons from the SUSTOIL project and future perspectives for next generation biofuels.` *Renewable and Sustainable Energy Reviews*, 29, pp. 22-30.

Lütkepohl, H., (1993) *Introduction to Multiple Time Series Analysis*. New York: Springer.

Lütkepohl, H., (1985) `Comparison of criteria for estimating the order of a vector autoregressive process.` *Journal of Time Series Analysis*. 6, pp. 35-52.

Lütkepohl, H., Saikkonen, P., Trenkler, C., (2001) `Maximum eigenvalue versus trace tests for the cointegrating rank of a VAR process.` *The Econometric Journal*, 4(2), pp. 278-310.

Maizels, A., (1992) *Commodities in Crisis: The Commodity Crisis of the 1980s and the Political Economy of International Commodity Policies*, New York: Oxford University Press, pp.135-224.

Malikane, Ch., Mokoka, T., (2012) ` Monetary policy credibility: A Phillips curve view.` *The Quarterly Review of Economics and Finance*, 52 (3), pp. 266–271.

Malliaropulos, D., (1995) `Testing long-run neutrality of money: evidence from the UK` *Applied Economics Letters*, 2(10), pp. 347-350.

Marquis, M., H., Cunningham, S., R., (1990) `Is There a Role of Commodity Prices in the Design of Monetary Policy? Some Empirical Evidence.` *Southern Economic Journal*, 57, pp. 394–412.

Mason, Ch., F., (2012) `Why do Firms Hold Oil Stockpiles?` FEEM Working Paper No. 100.2011, [online] Available at: http://ssrn.com/abstract=1992359 [Accessed 14 December, 2013].

McCoy, D., (1997) `How useful is structural VAR analysis for Irish Economics?` *Central Bank of Ireland Technical Paper*, 2/RT/97 [online] Available at:

http://www.centralbank.ie/publications/documents/2RT97.pdf [Accessed 14 March 2013].

McNees, S., K., (1986) `Forecasting Accuracy of alternative techniques: A comparison of US macroeconomic forecasts.` *Journal of Business and Economic Statistics*. 4 (1), pp. 5-15.

Miffre, J., Brooks, Ch., (2013) `Do Long-Short Speculators Destabilize Commodity Futures Markets?` *International Review of Financial Analysis*, 30, pp. 230–240.

Mihov, I., Sibert, A., (2006) `Credibility and Flexibility with Independent Monetary Policy Committees.` *Journal of Money, Credit and Banking*, 38(1), pp. 23-46.

Millard, S., Shakir, T., (2013) `Oil shocks and the UK economy: the changing nature of shocks and impact over time.` *Bank of England working paper 476*, pp. 4-28.

Mills, T., C., (2013) ` Constructing U.K. Core Inflation.` *Econometrics*, 1(1), pp. 32-52.

Misati, R., N., Nyamongo, E., M., Assistant, I., M., (2013) `Commodity price shocks and inflation in a net oil-importing economy.` *OPEC Energy Review*, 37 (2), pp. 125–148.

Mishkin, F., (1999) `International Experiences with Different Monetary Regimes.` *Journal of Monetary Economics*, 43, pp. 579-606.

Mishkin, F., Posen,A. (1997) `Inflation targeting: Lessons from four countries.` *NBER Working paper series, 6126*. [online] Available at: http://www.nber.org/papers/w6126 [Accessed 12 December 2011].

Mitchell, D., (2009) `A Note on Rising Food Prices.` *World Bank Policy Research Working Paper No. 4682*, [online] Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1233058 [Accessed 09 August 2013].

Mitra, S., Boussard, J., M., (2009) *Storage and the Volatility of Agricultural Prices: A Model of Endogenous Fluctuations*. [online] Available at: http://www.fordham.edu/images/academics/graduate_schools/gsas/economics/dp2008_11_mitra_boussard.pdf [Accessed 05 July 2013].

Moccero, D.,Watanabe, Sh., Cournede, B., (2011) `What drives inflation in the major OECD economies?` *OECD Economics Department Working Papers No. 854*, pp. 12-26.

Monacelli, T., (2013) ` Is Monetary Policy in an Open Economy Fundamentally Different?` *IMF Economic Review*, 61, pp. 6–21.

Morana, C., (2013) `The Oil price-Macroeconomy Relationship since the Mid- 1980s: A global perspective.` Working Paper, 28 [online] Available at:

http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2041326 [Accessed: 15 May 2013].

Morgan, M., S., (1990) *The History of Econometric Ideas*. Cambridge: Cambridge University Press.

Mork, K., A., (1989) `Oil and the Macroeconomy When Prices Go Up and Down: An Extension of Hamilton's Results.` *Journal of Political Economy*, 97(3), pp. 740-744.

Mork, K., A., Olsen, O., Mysen, H., T., (1994) `Macroeconomic Responses to Oil Price Increases and Decreases in Seven OECD Countries.` *Energy Journal*, 15 (4), pp.19-35.

Moutos, T., Vines, D., (1992) `Output, Inflation and Commodity Prices.` *Oxford Economic Papers*, 44(3), pp. 355-372.

Murray, D., (2013) *Boom and bust again: policy challenges for a commodity-based economy*. The University of Alberta Press, Canada, pp. 33-40.

National Statistics, (2013) *UK energy in brief*, Department of Energy and Climate Change, [online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224130/uk_energy_in_brief_2013.PDF [Accessed 15 November 2013].

Naifar, N., Dohaiman, M., (2013) ` Nonlinear analysis among crude oil prices, stock markets' return and macroeconomic variables.` *International Review of Economics and Finance,* 27, pp. 416–431.

Nelson, E., (2013) `Key aspects of longer-term asset purchase programs in UK and US monetary policy.` *Oxford Economic Papers*, 65 (1), pp. 92-114.

Nelson, E., Nikolov, K., (2004) `Monetary Policy and Stagflation in the UK.` *Journal of Money, Credit and Banking*, 36(3), pp. 293-318.

Neslin, S., A., Shoemaker, R., W., (1983) ` Using a Natural Experiment to Estimate Price Elasticity: The 1974 Sugar Shortage and the Ready-to-Eat Cereal Market.` *Journal of Marketing*, 47 (1), pp. 44-57.

Nielsen, B. (2011) `The asymptotic distribution of unit root tests of unstable autoregressive processes.` *Econometrica*, 69, pp. 211-219.

Nikos, A., (2008) `Food Price Surges: Possible Causes, Past Experience and Long-term Relevance.` *Population and Development Review*, 34, pp. 599-629.

Nissanke, M., (2012) Issues and Challanges for Commodity Markets in the Global Economy: An Overview. In: Nissanke, M., Mavrotas, G. (eds.) *Commodities, Governance and Economic Development under Globalization*. Hampshire: Palgrave and Macmillan, pp.

39-61.

Nixon, D., Smith, T., (2012) `What can the oil futures curve tell us about the outlook for oil prices?` Bank of England Quarterly Bulletin, 2012:01, pp. 39-47.

Nordhaus, W., Showen, J., (1997) A Technique for Analyzing and Decomposing Inflation. In: Joel Popkin (eds) *Analysis of Inflation: 1965-1974*. U.S.: NBER, pp. 333 - 360.

OECD, (2003) *Industrial Production Index.* [online] Available at: http://stats.oecd.org/glossary/detail.asp?ID=1339 [Accessed 17 Jun 2013].

OECD, (2009) Responses to inflation shocks: Do G7 countries behave differently? OECD Economic Outlook, [online] Available at: http://www.oecd.org/eco/outlook/41719698.pdf [Accessed 14 July 2013].

Office for National Statistics, (2013a) *Consumer Price Inflation Reference Tables, July 2013* [online] Available at: http://www.ons.gov.uk/ons/taxonomy/index.html?nscl=Economy#tab-data-tables [Accessed 20 August 2013].

Office for National Statistics, (2013b) *Statistical bulletin: Labour Market Statistics, August 2013,* [online] Available at: http://www.ons.gov.uk/ons/rel/lms/labour-market-statistics/august-2013/statistical-bulletin.html [Accessed 23 August 2013].

Office for National Statistics, (2013c) *A Guide to the Index of Production.* [online] Available at: http://www.ons.gov.uk/ons/guide-method/method-quality/specific/economy/index-of-production/index-of-production-overview.pdf. [Accessed 21 October 2013].

Olson, M., (1988) `The Productivity Slowdown, the Oil Shocks, and the Real Cycle.` *Journal of Economic Perspectives,* 2 (4), pp. 43-69.

Orden, D., (1986) `Agriculture, trade, and macroeconomics: The U.S. case.` *Journal of Policy Modeling,* 8(1), pp. 27-51.

Orden, D., Fackler, P., L., (1989) `Identifying Monetary Impacts on Agricultural Prices in VAR Models.` *American Journal of Agricultural Economics*, 71, pp. 495-502.

Osborne, G., (2013) *Chancellor speech on the economy.* Government, [online] Available at: https://www.gov.uk/government/speeches/chancellor-speech-on-the-economy [Accessed 17 November 2013].

Pant, M., Mhleisen, M., Thomas, A., H., (2010) `Peaks, Spikes, and Barrels: Modelling Sharp Movements in Oil Prices.` *International Monetary Fund*, WP 10/186, pp. 6-16.

Papell, D., H., (1984) `Activist Monetary Policy and Exchange-Rate Overshooting: The

Deutsche Mark/Dollar Rate.` *Journal of International Money and Finance,* 3, pp. 293-310.

Parantula, S., G., (1989) `Testing for Unit Roots in the Time Series Data.` *Econometrics Theory,* 5, pp. 256-271.

Peersman, G., Robays, I.,V., (2012) `Cross-country Differences in the Effects of Oil Shocks.` *Energy Economics,* 34 (5), pp. 1532-1547.

Phillips, P., Perron, P., (1988) `Testing for a unit root in time series regression.` *Biometrika*. 75 (2), pp. 335-346.

Phillips, P., C., Yu, J., (2011) `Dating the timeline of financial bubbles during the subprime crisis.` *Quantitative Economics,* 2 (3), pp. 455–491.

Pierce, D., A., Haugh, L., D., (1977) `Causality in Temporal Systems: Characterisations and aSurvey.` *Journal of Econometrics*, 5 (3), pp. 265-293.

Piesse, J., Thirtle, C., (2009) `Three Bubbles and a Panic: An Explanatory Review of the Food Commodity Price Spikes of 2008.` *Food Policy*, 34(2), pp. 25-34.

Pindyck, R., S., (2001) `The Dynamics of Commodity Spot and Futures Markets: A Primer.` *The Energy Journal*, 22 (3), pp. 89-120.

Pindyck, R., S., Rotemberg, J., J., (1990) `Dynamic factor demands and the effects of energy price shocks.` *American Economic Review*, 73, pp.1066-1079.

Pirrong, C., (2012) *Commodity Price Dynamics: A Structural Approach.* Cambridge University Press: Cambridge, pp.73-107.

Rabanal, P., (2007) `Does Inflation Increase After a Monetary Policy Tightening? Answers Based on an Estimated DSGE Model.` *Journal of Economic Dynamics and Control* , 31, pp. 906–37.

Rao, B., B., (2007) `Estimating short and long run relationships: A guide to applied economists.` *Applied Economics,* 39, pp. 1613-1625.

Reicher, Ch., P., Utlaut, J., F., (2013) ` Monetary policy shocks and real commodity prices.` *The B.E. Journal of Macroeconomics*, 13(1), pp. 32-67.

Rosa, C., (2013) `The High-Frequency Response of Energy Prices to Monetary Policy: Understanding the Empirical Evidence.` *Federal Reserve Bank of New York Staff Reports, No. 598,* [online] Available at: http://www.newyorkfed.org/research/staff_reports/sr598.pdf [Accessed 13 November 2013].

Ratti, R., A., Vespignani, J., L., (2013a) ` Crude oil prices and liquidity, the BRIC and G3 countries.` *Energy Economics,* 39, pp. 28-38.

Ratti, R., A., Vespignani, J., L., (2013b) ` Liquidity and crude oil prices: China's influence over 1996–2011.` *Economic Modelling*, 33, pp. 517–525.

Reicher, Ch., P., Utlaut, J., (2010) ` The relationship between oil prices and long-term interest rates.` Kiel Institute for the World Economy Working paper No. 1637, pp. 2-32.

Reifschneider, D., L., Roberts, J., M., (2006) `Expectations Formation and the Effectiveness of Strategies for Limiting the Consequences of the Zero Bound.` *Journal of the Japanese and International Economies*, 20(3), pp. 314–337.

Reifschneider, D., Williams, J., (2000) `Three Lessons for Monetary Policy in a Low-Inflation Era.` *Journal of Money, Credit, and Banking*, 32(4), pp. 936–966.

Roache, Sh., K., (2012) `China's Impact on World Commodity Markets.` International Monetary Fund Working paper WP/12/115, pp. 2-24.

Roache, Sh., Rossi, M., (2009) `The effects of Economic news on commodity prices: Is gold just another commodity?` *International Monetary Fund Working paper,* WP/09/140, [online] Available at: http://ideas.repec.org/p/imf/imfwpa/09-140.html [Accessed 31 October 2013].

Roberts, D., Nord, S., (1985) `Causality tests and functional form sensitivity.` *Applied Economics* 17, pp. 135

Roeger, W., (2005) `International oil price changes: Impact of oil prices on growth and inflation in the EU/OECD.` *International Economics and Economics Policy,* 2, pp.15–32.

Rodríguez, R., Sánchez, M., (2005) `Oil price shocks and real GDP growth. Empirical evidence for some OECD countries.` [online] Available at: http://www.ecb.int/pub/pdf/scpwps/ecbwp362.pdf [Accessed 26 November 2012].

Rosegrant, M., W., Ringler, C., Msangi, S., Sulser, T., B., Zhu, T., Cline, S., A., (2008) `International Model for Policy Analysis of Agricultural Commodities and Trade.` *International Food Policy Research Institute Working paper,* [online] Available at: http://www.ifpri.org/publication/international-model-policy-analysis-agricultural-commodities-and-trade-impact-0 [Accessed 10 August 2013].

Rotemberg, J., J., Woodford, M., (1996) `Imperfect Competition and the Effects of Energy Price Increases on Economic Activity.` *Journal of Money, Credit and Banking,* 28(4), pp. 550-77.

Routledge, B., R., Seppi, D., J., Spatt, C., S., (2000) `Equilibrium forward curves for commodities.` *Journal of Finance*, 55(3), pp. 1297-1338.

Rudebusch, G., D., (1998) `Do Measures of Monetary Policy in a VAR Make Sense?` *International Economic Review*, 39(4), pp. 907-931.

Rusnak, M., Havranek, T., Horvath, R., (2013) `How to Solve the Price Puzzle? A Meta-Analysis.` *Journal of Money, Credit and Banking*, 45(1), pp. 37–70.

Rühla, Ch., Applebya, P., Fennemab, J., Naumova, A., Schafferb, M., (2012) `Economic development and the demand for energy: A historical perspective on the next 20 years.` *Energy Policy*, 50, pp. 109–116.

Sanders, D., R., Irwin, S., H., (2010) `A speculative bubble in commodity futures prices? Cross-sectional evidence.` *Agricultural Economics*, 41, 25-32.

Sargent, T., J., (1973) `Interest rates and prices in the long run: a study of Gibson paradox.` Journal of Money, Credit and Banking, 4, pp. 385-449.

Saunders, H., (2013) ` Is what we think of as "rebound" really just income effects in disguise?` *Energy Policy*, 57, pp. 308–317.

Segal, P., (2011) `Oil price shocks and the macroeconomy.` *Oxford Review of Economic Policy*, 27(1), pp. 169-185.

Serletis, A., Timilsina, G., Vasetsky, O., (2009) `On Interfuel Substitution Some International Evidence.` *The World Bank Policy Research Working Paper 5026*,[online] Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/4226/WPS5026.pdf?sequence=1 [Accessed 05 October 2013].

Shaun, R., (2010) *`What Explains the Rise in Food Price Volatility?`* International Monetary Fund Working Paper, 129, pp. 4-32.

Schuh, G., E., (1974) `The Exchange Rate and U.S. Agriculture.` *American Journal of Agricultural Economics*, 56, pp. 1-13.

Schumpeter, J., A., (1939) *Business cycles: A theoretical and statistical analysis of the capitalist process*, Volume. 1 and Volume 2, McGraw-Hill: New York.

Schwarz, G., (1978) `Estimating the dimension of a model.` *The Annals of Statistics*. 6, pp. 461-464.

Shi, Sh., Arora, V., (2012) `An application of models of speculative behaviour to oil prices.` *Economic Letters*, 115 (3), pp. 469–472.

Shibata, R., (1976) `Selection of the order of an autoregressive model by Akaike's Information Criterion.` *Biometrica*. 63, pp. 117-126.

Seim, A., L., Zetterberg, J., (2013) `Testing the impact of inflation targeting and central bank independence on labour market outcomes.` *Oxford Economic Papers*, 65 (2), pp. 240-267.

Seymen, A., (2008) `A Critical Note on the Forecast Error Variance Decomposition.` *ZEW Discussion Papers, No. 08-065*, Available at: http://econstor.eu/bitstream/10419/24761/1/dp08065.pdf [Accessed 12 Jun 2012].

Sims, C., A., (1980) `Macroeconomics and Reality.` *Econometrica*. 48 (1), pp. 1-48.

Sims Ch., A., (1982) `Policy Analysis with Econometric Models.` *Brookings Papers on Economic Activity*, pp. 107-152.

Sims, Ch, A., (1992) `Interpreting the macroeconomic time series facts: The effects of monetary policy.` *European Economic Review*, 36(5), pp. 975-1000.

Sims, C.,A., Zha, T., A., (1998) `Does Monetary policy generate Recessions?` *Federal Reserve Bank of Atlanta Working Paper*, 98, [online] Available at: http://sims.princeton.edu/yftp/mpolicy/szmd2.pdf [Accessed: 14 March 2013].

Skidelsky, R., (2012) *Problems of monetary policy: Theory and Evidence*. University of Warwick, [online] Available at: http://www2.warwick.ac.uk/knowledge/business/monetarypolicy/ [Accessed 15 February 2013].

Smith, J., L., (2009) `World Oil: Market or Mayhem?` *Journal of Economic Perspectives*, 23, pp. 145-164.

Sockin, M., Xiong, W., (2013) `Feedback Effects of Commodity Futures Prices.` *NBER Working Papers 18906*, [online] Available at: http://ideas.repec.org/p/nbr/nberwo/18906.html [Accessed 25 August 2013].

Sousa, J., M., Zaghini, A., (2007) `Global monetary policy shocks in the G5: A SVAR approach.` *Journal of International Financial Markets, Institutions and Money*, 17(5), pp. 403-419.

Startz, R., (2009) *Eviews Illustrated for version 7*. U.S: Quantitative Micro Software, LLC.

Steindel, Ch., Cacchetti, S., Chu, R., (2000) `The Unreliability of Inflation Indicators.` *Current Issues in Economics and Finance*, 6 (4), 125-138.

Stern, D., I., (2011) `From Correlation to Granger Causality.` *Crawford School Research*

Paper No 13, Available at: https://crawford.anu.edu.au/pdf/crwf_ssrn/crwfrp_1113.pdf [Accessed 25 Jun 2013].

Stevens, G., (2003) *Inflation Targeting: A Decade of Australian Experience*, Reserve Bank of Australia [online] Available at: http://www.rba.gov.au/speeches/2003/sp-dg-100403.html [Accessed: 16 July 2013].

Stock, J., H., Watson, M., W., (1988) `Variable Trends in Economic Time Series.` *Journal of Economic Perspectives*, 2(3), pp. 147-174.

Stock, H., Watson, W., (1999) `Forecasting inflation.` *Journal of Monetary Economics*, 44(2), pp. 293–335.

Stock, J, H., Watson, M., (2011) *Introduction to Econometrics,* 3rd ed. Essex: Pearson Education Limited, pp.7-10.

Stockton, D., (2012) `Review of the monetary policy committee's forecasting capability.` *Bank of England Publications*, [online] Available at: http://www.bankofengland.co.uk/publications/Documents/news/2012/cr3stockton.pdf [Accessed 11 October 2013].

Strongin, S., (1995) `The identification of monetary policy disturbances. Explaining the liquidity puzzle`. *Journal of Monetary Economics*. 35, pp. 463-497.

Surrey, M., J., C., (2009) `Money, Commodity prices and Inflation: Some Simple Tests.` *Oxford Bulletin of Economics and Statistics*, 51 (3), pp. 219–238.

Svensson, L., (1997) `Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets.` *European Economic Review,* 41, pp.1111–1146.

Svensson, L., (1999) `Inflation Targeting as a Monetary Policy Rule.` *Journal of Monetary Economics,* 43(3), pp.607–654.

Svensson, L., (2009) `Transparency under flexible inflation targeting: experiences and challenges.` *Sveriges Riksbank Economic Review*, 1, pp. 5–44.

Taylor, J., B., (1993) `Discretion Versus Policy Rules in Practice.` *Carnegie-Rochester Conference Series on Public Policy,* 39, pp.195–214.

Taylor, J., B., (2000) `Low Inflation, Pass-Through, and the Pricing Power of Firms.` *European Economic Review*, 44 (7), pp. 1389–1408.

Taylor, J., B., (2009) `The Financial crisis and the policy responses: An empirical analysis of what went wrong.`*NBER Working paper series 14631*, pp. 1-25.

Taylor, J., B., Springs, J., (1989) `Effects of the Monetary Macroeconomy on Canadian

Agricultural Prices.` *The Canadian Journal of Economics*, 23, pp. 1278–1289.

Tegene, A., (1990) `The Impact of Macrovariables on the Farm Sector: Some Further Evidence.` *Southern Journal of Agricultural Economics,* 22, pp. 77–85.

Timilsina, G., R., Mevel, S., Shrestha, A., (2011) `Oil price, biofuels and food supply.` *Energy Policy*, 39 (12), pp. 8098–8105.

Tkacz, G., (2007) `Gold Prices and Inflation.` Bank of Canada working paper, 35 [online] Available at: http://www.bankofcanada.ca/wp-content/uploads/2010/02/wp07-35.pdf [Accessed: 20 May 2013].

Toda, H., Y., Phillips, P., C., B., (1993) `Vector Autoregressions and Causality.` *Econometrica*, 61(6), pp. 1367-1393.

Trostle, R., (2008) *Global Agricultural Supply and Demand: Factors contributing to the Recent Increase in Food prices*. Diane Publishing: New York, pp.13-20.

Turnovsky, S., J., (1983) `The Determination of Spot and Futures Prices with Storable Commodities.` *Econometrica*, 51(5), pp. 1363-1387.

Tweeten, L., G., (1980) `Macroeconomics in Crisis: Agriculture and Underachieving Economy.` *American Journal of Agricultural Economics*, 62, pp. 853-860.

United Nations, (2011) Price Formation in Financialized Commodity Markets: The Role of Information. [online] Available at: http://unctad.org/en/Docs/gds20111_en.pdf [Accessed 26 November 2012].

United Nations, (2013) World Economic Situation and Prospects, Global outlook. [online] Available at: http://www.un.org/ru/publications/pdfs/2013%20world%20economic%20situation%20and%20prospects.pdf [Accessed 15 October 2013].

Upadhyaya, Sh., (2010) `Compilation of Energy Statistics.` United *Nations Industrial Development Organization Working paper*, 1, pp. 4-44.

Vansteenkiste, I., (2011) `What Is Driving Oil Futures Prices? Fundamentals Versus Speculation.` *ECB Working Paper, No. 1371*, pp. 4-24.

Varcelli, A., (1991) *Methodological foundations of macroeconomics: Keynes and Lucas*. Cambridge: Cambridge University Press. Available at: http://catdir.loc.gov/catdir/samples/cam031/90036075.pdf [Accessed 20 December 2012].

Vavra, P., Goodwin, B., K., (2005) `Analysis of Price Transmission Along the Food Chain.`

OECD Food, Agriculture and Fisheries Working Papers, 3, [online] Available at: http://www.oecd.org/agriculture/agricultural-policies/40459642.pdf [Accessed 03 March 2013].

Verheyen, F., (2010) *Monetary Policy, Commodity Prices and Inflation - Empirical Evidence from the U.S* [online] Available at: http://ssrn.com/abstract=1711851 [Accessed: 15 Jun 2013].

Yang, J., Bessler, D., A., Leatham, D., J., (2001) ` Asset Storability and Price Discovery in Commodity Futures Markets: A New Look.` *The Journal of Futures Markets*, 21(3), pp. 279–300.

Wan, A., T., K., Zou, G., Banerjee, A., (2007) `Power of autocorrelation tests near the unit root in models with possibly mis-specified linear restrictions.` *Economics Letters*. 94, pp. 213–219.

Wang, Y., Sh., Chueh, Y., L., (2013) `Dynamic transmission effects between the interest rate, the U.S dollar, and gold and crude oil prices.` *Economic Modelling*, 30, pp. 792-798.

Williams, J., (1986) *The economic function of futures markets,* Cambridge University Press.

Williams, J., C., Wright, B., D., (1991) *Storage and commodity markets.* Cambridge University Press: Cambridge.

Wold, H., (1939) `Study in Analysis of Stationary Time Series.` *Journal of the Royal Statistical Society*, 102(2), pp. 295-298.

Woodford, M., (2012) `Inflation Targeting and Financial Stability.` *NBER Working Paper 17967*, [online] Available at: http://www.nber.org/papers/w17967 [Accessed 25 March 2013].

Woodford, M., (2013) ` Forward Guidance by Inflation-Targeting Central Banks.` *Risk Bank,* [online] Available at: http://www.riksbank.se/Documents/Forskning/Konferenser_seminarier/2013/Woodford.pdf [Accessed 17 November 2013].

Wooldridge, J., M., (2008) *Introductory Econometrics: A Modern Approach*. USA: South-Western Learning.

World Bank, (2012a) *Food Production Index Database* [online] Available at: http://data.worldbank.org/indicator/AG.PRD.FOOD.XD [Accessed 10 January 2013].

World Bank, (2012b) *Prices (Pink Sheet).* [online] Available at: http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTDECPROSPECTS/0,, contentMDK:21574907~menuPK:7859231~pagePK:64165401~piPK:64165026~theSitePK:476883,00.html [Accessed 10 November 2012].

Working, H., (1948) `Theory of the inverse carrying charge in futures markets.`*Journal of Farm Economics*, 30, pp. 1–28.

Working, H., (1949) ` The Theory of Price of Storage.` *The American Economic Review*, 39 (6), pp. 1254-1262.

Wright, B., (2011) `The economics of grain price volatility.` *Applied Economic Perspectives and Policy*, 33, 32-58.

Zeisel, H., (1989) `On the power of the Durbin–Watson test under high autocorrelation.` *Communications in Statistics. Theory and Methods.* 18, pp. 3907–3916.

Zhang, Y., J., (2008) *Market Efficiency Test in the VIX Futures Market*. Cambridge: ProQuest.

Zhang, Y., J., (2013) `Speculative trading and WTI crude oil futures price movement: An empirical analysis.` *Applied Energy*, 107, pp. 394-402.

Zhang, Q., Reed, M., (2008) `Examining the impact of the world crude oil prices on china's agricultural commodity prices: The case of corn, soybean and pork.` The Southern Agricultural Economics Association, [online] Available at: http://ageconsearch.umn.edu/handle/6797 [Accessed 17 Jun 2013].

Zilberman, D., Hochman, G., Rajagopal, D., Sexton, S., Timilsina, G., (2013) ` The Impact of Biofuels on Commodity Food Prices: Assessment of Findings.` *American Journal of Agricultural Economics,* 95 (2), pp. 275-281.

Appendix A Granger causality test

Pairwise Granger Causality Tests
Sample: 1992M08 2013M09
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
DLOGFOOD_SA does not Granger Cause DI_NOMINAL	241	9.45252	0.0001
DI_NOMINAL does not Granger Cause DLOGFOOD_SA		0.44099	0.6439
DLOGIPI does not Granger Cause DI_NOMINAL	106	1.37069	0.2586
DI_NOMINAL does not Granger Cause DLOGIPI		0.04128	0.9596
DLOGM4 does not Granger Cause DI_NOMINAL	215	1.94839	0.1451
DI_NOMINAL does not Granger Cause DLOGM4		2.19793	0.1136
DLOGOIL_SA does not Granger Cause DI_NOMINAL	241	5.38471	0.0052
DI_NOMINAL does not Granger Cause DLOGOIL_SA		0.99379	0.3717
DTREASURY_BILLS does not Granger Cause DI_NOMINAL	242	46.4420	1.E-17
DI_NOMINAL does not Granger Cause DTREASURY_BILLS		0.68839	0.5034
DLOGCIPI does not Granger Cause DI_NOMINAL	241	0.26988	0.7637
DI_NOMINAL does not Granger Cause DLOGCIPI		0.31916	0.7271
DLOGIPI does not Granger Cause DLOGFOOD_SA	106	0.52270	0.5945
DLOGFOOD_SA does not Granger Cause DLOGIPI		1.59467	0.2080
DLOGM4 does not Granger Cause DLOGFOOD_SA	215	0.22843	0.7960
DLOGFOOD_SA does not Granger Cause DLOGM4		1.87837	0.1554
DLOGOIL_SA does not Granger Cause DLOGFOOD_SA	241	0.27086	0.7630
DLOGFOOD_SA does not Granger Cause DLOGOIL_SA		7.02885	0.0011
DTREASURY_BILLS does not Granger Cause DLOGFOOD_SA	241	0.27121	0.7627
DLOGFOOD_SA does not Granger Cause DTREASURY_BILLS		4.70952	0.0099
DLOGCIPI does not Granger Cause DLOGFOOD_SA	241	2.22575	0.1102
DLOGFOOD_SA does not Granger Cause DLOGCIPI		2.80265	0.0627
DLOGM4 does not Granger Cause DLOGIPI	100	1.84715	0.1633
DLOGIPI does not Granger Cause DLOGM4		0.68822	0.5050
DLOGOIL_SA does not Granger Cause DLOGIPI	106	1.03801	0.3579
DLOGIPI does not Granger Cause DLOGOIL_SA		4.01815	0.0209
DTREASURY_BILLS does not Granger Cause DLOGIPI	106	1.42016	0.2465
DLOGIPI does not Granger Cause DTREASURY_BILLS		2.08282	0.1299
DLOGCIPI does not Granger Cause DLOGIPI	106	3.09176	0.0497
DLOGIPI does not Granger Cause DLOGCIPI		1.02849	0.3613

DLOGOIL_SA does not Granger Cause DLOGM4	215	0.20947	0.8112
DLOGM4 does not Granger Cause DLOGOIL_SA		2.39334	0.0938
DTREASURY_BILLS does not Granger Cause DLOGM4	215	1.54529	0.2157
DLOGM4 does not Granger Cause DTREASURY_BILLS		0.55576	0.5745
DLOGCIPI does not Granger Cause DLOGM4	215	0.21025	0.8106
DLOGM4 does not Granger Cause DLOGCIPI		0.90135	0.4076
DTREASURY_BILLS does not Granger Cause DLOGOIL_SA	241	4.18112	0.0164
DLOGOIL_SA does not Granger Cause DTREASURY_BILLS		6.15036	0.0025
DLOGCIPI does not Granger Cause DLOGOIL_SA	241	1.66163	0.1920
DLOGOIL_SA does not Granger Cause DLOGCIPI		0.16356	0.8492
DLOGCIPI does not Granger Cause DTREASURY_BILLS	241	1.80353	0.1670
DTREASURY_BILLS does not Granger Cause DLOGCIPI		0.86332	0.4231

Appendix B: Cointegration tests

Sample: 1992M01 2013M09
Included observations: 101
Series: TREASURY_BILLS LOGCPI LOGM4 LOGIPI LOGUK_OIL_STOCK
Lags interval: 1 to 2
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	1	0	0	2
Max-Eig	1	2	2	2	2

*Critical values based on MacKinnon-Haug-Michelis (1999)

Sample: 1992M01 2013M09
Included observations: 101
Series: TREASURY_BILLS LOGCPI LOGM4 LOGIPI LOGOECDEU_OIL_STOCKS
Lags interval: 1 to 2
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	0	1	0	1
Max-Eig	1	1	1	1	2

*Critical values based on MacKinnon-Haug-Michelis (1999)

Sample: 1992M01 2013M09
Included observations: 101
Series: TREASURY_BILLS LOGCPI LOGM4 LOGIPI LOGOECD_OIL_STOCK
Lags interval: 1 to 2
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	1	0	0	2
Max-Eig	1	1	1	1	2

*Critical values based on MacKinnon-Haug-Michelis (1999)

Sample: 1992M01 2013M09
Included observations: 83
Series: TREASURY_BILLS LOGCPI LOGM4 LOGIPI LOGIEA_OIL_SUPPLY
Lags interval: 1 to 2
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	0	0	0	0
Max-Eig	1	0	0	1	1

*Critical values based on MacKinnon-Haug-Michelis (1999)

Sample: 1992M01 2013M09
Included observations: 83
Series: TREASURY_BILLS LOGCPI LOGM4 LOGIPI LOGEU27_OIL_SUPPLY
Lags interval: 1 to 2
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	0	0	0	1
Max-Eig	1	1	1	1	1

*Critical values based on MacKinnon-Haug-Michelis (1999)

Sample: 1992M01 2013M09
Included observations: 83
Series: TREASURY_BILLS LOGCPI LOGM4 LOGIPI LOGOECD_OIL_SUPPLY
Lags interval: 1 to 2
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	0	0	0	0	0
Max-Eig	0	0	0	1	1

*Critical values based on MacKinnon-Haug-Michelis (1999)

Sample: 1992M01 2013M09
Included observations: 83
Series: TREASURY_BILLS LOGCPI LOGM4 LOGIPI LOGOPEC_OIL_SUPPLY
Lags interval: 1 to 2
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	0	0	0	0	0
Max-Eig	0	1	1	1	1

*Critical values based on MacKinnon-Haug-Michelis (1999)

Sample: 1992M01 2013M09
Included observations: 83
Series: TREASURY_BILLS LOGCPI LOGM4 LOGIPI LOGWORLD_SUPPLY
Lags interval: 1 to 2
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	0	0	0	0	0
Max-Eig	0	1	1	1	1

*Critical values based on MacKinnon-Haug-Michelis (1999)

Appendix C: Autocorrelation test

Model 1 - UK oil industry stocks

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 101

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	7.766117	NA*	7.843779	NA*	NA*
2	16.14698	NA*	16.39395	NA*	NA*

3	23.37455	0.0215	25.90027	0.0242	25
4	29.75190	0.0226	31.56810	0.0264	50
5	37.69162	0.0496	38.59812	0.0404	75

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 2 - OECD Europe oil industry stocks

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 101

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	5.802428	NA*	5.860453	NA*	NA*
2	14.08477	NA*	14.31012	NA*	NA*
3	31.30023	0.0193	32.05258	0.0165	25
4	52.02346	0.0350	53.63037	0.0369	50
5	68.41328	0.0413	70.87384	0.0435	75

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 3 - OECD oil industry stocks

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 101

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	15.11873	NA*	15.26992	NA*	NA*
2	28.87813	NA*	29.30728	NA*	NA*
3	59.34038	0.0001	60.70206	0.0001	25
4	79.65270	0.0048	81.85200	0.0030	50
5	95.29116	0.0570	98.30495	0.0369	75

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 4 - IEA oil supply

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 83

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	7.460459	NA*	7.551441	NA*	NA*
2	14.86991	NA*	15.14384	NA*	NA*
3	29.62670	0.0186	30.45401	0.0207	25

4	52.25478	0.0264	54.22781	0.0314	50
5	67.41154	0.0374	70.35616	0.0393	75

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 5 - EU27 oil supply

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 83

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	6.290545	NA*	6.367259	NA*	NA*
2	11.95003	NA*	12.16649	NA*	NA*
3	29.54284	0.0119	30.41902	0.0190	25
4	53.84689	0.0294	55.95366	0.0313	50
5	66.73695	0.0409	69.67001	0.0422	75

*The test is valid only for lags larger than the VAR lag order.

Model 6 - OPEC oil supply

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 83

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	5.092863	NA*	5.154971	NA*	NA*
2	12.14229	NA*	12.37846	NA*	NA*
3	25.24827	0.0185	25.97591	0.0219	25
4	43.85003	0.0373	45.51953	0.0399	50
5	63.22678	0.0419	66.13839	0.0478	75

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 7 - OECD oil supply

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 83

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	6.603960	NA*	6.684497	NA*	NA*
2	13.07103	NA*	13.31125	NA*	NA*
3	26.20867	0.0195	26.94155	0.0218	25
4	43.45194	0.0318	45.05789	0.0376	50

5	59.50206	0.0448	62.13687	0.0458	75

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 8 - World oil supply

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 83

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	5.179238	NA*	5.242400	NA*	NA*
2	11.28850	NA*	11.50250	NA*	NA*
3	22.88369	0.0154	23.53252	0.0165	25
4	40.02286	0.0226	41.53950	0.0271	50
5	63.66263	0.0417	66.69463	0.0421	75

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Appendix D: Granger causality test

Pairwise Granger Causality Tests
Sample: 1992M01 2013M09

Null Hypothesis:	Obs	F-Statistic	Prob.
DLOGEU27_OIL_SUPPLY does not Granger Cause DLOGCPI	221	0.99254	0.4126
DLOGCPI does not Granger Cause DLOGEU27_OIL_SUPPLY		0.89667	0.4668
DLOGIEA_OIL_SUPPLY does not Granger Cause DLOGCPI	221	0.34902	0.8445
DLOGCPI does not Granger Cause DLOGIEA_OIL_SUPPLY		0.91085	0.4585
DLOGIPI does not Granger Cause DLOGCPI	94	0.68556	0.6039
DLOGCPI does not Granger Cause DLOGIPI		1.86060	0.1248
DLOGM4 does not Granger Cause DLOGCPI	220	1.06410	0.3753
DLOGCPI does not Granger Cause DLOGM4		0.60766	0.6575
DLOGOECD_OIL_SUPPLY does not Granger Cause DLOGCPI	221	0.58632	0.6729
DLOGCPI does not Granger Cause DLOGOECD_OIL_SUPPLY		0.50268	0.7338
DLOGOECDEU_OIL_STOCKS does not Granger Cause DLOGCPI	244	0.38966	0.8159
DLOGCPI does not Granger Cause DLOGOECDEU_OIL_STOCKS		2.02348	0.0919
DLOGOPEC_OIL_SUPPLY does not Granger Cause DLOGCPI	221	1.01255	0.4018
DLOGCPI does not Granger Cause DLOGOPEC_OIL_SUPPLY		0.63454	0.6384
DLOGUK_OIL_STOCK does not Granger Cause DLOGCPI	244	0.61368	0.6532
DLOGCPI does not Granger Cause DLOGUK_OIL_STOCK		0.44815	0.7737
DLOGWORLD_SUPPLY does not Granger Cause DLOGCPI	221	0.78049	0.5390
DLOGCPI does not Granger Cause DLOGWORLD_SUPPLY		0.28636	0.8866
DTREASURY_BILLS does not Granger Cause DLOGCPI	246	0.50688	0.7307

DLOGCPI does not Granger Cause DTREASURY_BILLS		1.56740	0.1837
DLOGIEA_OIL_SUPPLY does not Granger Cause DLOGEU27_OIL_SUPPLY	221	0.82636	0.5097
DLOGEU27_OIL_SUPPLY does not Granger Cause DLOGIEA_OIL_SUPPLY		5.23818	0.0005
DLOGIPI does not Granger Cause DLOGEU27_OIL_SUPPLY	76	0.62811	0.6441
DLOGEU27_OIL_SUPPLY does not Granger Cause DLOGIPI		1.20091	0.3186
DLOGM4 does not Granger Cause DLOGEU27_OIL_SUPPLY	196	0.87984	0.4771
DLOGEU27_OIL_SUPPLY does not Granger Cause DLOGM4		0.40579	0.8043
DLOGOECD_OIL_SUPPLY does not Granger Cause DLOGEU27_OIL_SUPPLY	221	0.72179	0.5779
DLOGEU27_OIL_SUPPLY does not Granger Cause DLOGOECD_OIL_SUPPLY		4.59357	0.0014
DLOGOECDEU_OIL_STOCKS does not Granger Cause DLOGEU27_OIL_SUPPLY	220	2.05977	0.0873
DLOGEU27_OIL_SUPPLY does not Granger Cause DLOGOECDEU_OIL_STOCKS		1.18319	0.3192
DLOGOPEC_OIL_SUPPLY does not Granger Cause DLOGEU27_OIL_SUPPLY	221	1.58419	0.1797
DLOGEU27_OIL_SUPPLY does not Granger Cause DLOGOPEC_OIL_SUPPLY		1.07249	0.3711
DLOGUK_OIL_STOCK does not Granger Cause DLOGEU27_OIL_SUPPLY	220	1.95635	0.1024
DLOGEU27_OIL_SUPPLY does not Granger Cause DLOGUK_OIL_STOCK		4.51710	0.0016
DLOGWORLD_SUPPLY does not Granger Cause DLOGEU27_OIL_SUPPLY	221	1.14654	0.3357
DLOGEU27_OIL_SUPPLY does not Granger Cause DLOGWORLD_SUPPLY		0.61293	0.6538
DTREASURY_BILLS does not Granger Cause DLOGEU27_OIL_SUPPLY	221	0.73731	0.5675
DLOGEU27_OIL_SUPPLY does not Granger Cause DTREASURY_BILLS		1.44308	0.2209
DLOGIPI does not Granger Cause DLOGIEA_OIL_SUPPLY	76	1.33383	0.2665
DLOGIEA_OIL_SUPPLY does not Granger Cause DLOGIPI		0.59113	0.6702
DLOGM4 does not Granger Cause DLOGIEA_OIL_SUPPLY	196	0.23995	0.9154
DLOGIEA_OIL_SUPPLY does not Granger Cause DLOGM4		1.20176	0.3116
DLOGOECD_OIL_SUPPLY does not Granger Cause DLOGIEA_OIL_SUPPLY	221	0.43390	0.7840
DLOGIEA_OIL_SUPPLY does not Granger Cause DLOGOECD_OIL_SUPPLY		1.35529	0.2506
DLOGOECDEU_OIL_STOCKS does not Granger Cause DLOGIEA_OIL_SUPPLY	220	1.77117	0.1358
DLOGIEA_OIL_SUPPLY does not Granger Cause DLOGOECDEU_OIL_STOCKS		0.76871	0.5467
DLOGOPEC_OIL_SUPPLY does not Granger Cause DLOGIEA_OIL_SUPPLY	221	0.48139	0.7494
DLOGIEA_OIL_SUPPLY does not Granger Cause DLOGOPEC_OIL_SUPPLY		1.60111	0.1752
DLOGUK_OIL_STOCK does not Granger Cause DLOGIEA_OIL_SUPPLY	220	1.43066	0.2249
DLOGIEA_OIL_SUPPLY does not Granger Cause DLOGUK_OIL_STOCK		2.40380	0.0509
DLOGWORLD_SUPPLY does not Granger Cause DLOGIEA_OIL_SUPPLY	221	0.54797	0.7007
DLOGIEA_OIL_SUPPLY does not Granger Cause DLOGWORLD_SUPPLY		2.98284	0.0200
DTREASURY_BILLS does not Granger Cause DLOGIEA_OIL_SUPPLY	221	0.20072	0.9378
DLOGIEA_OIL_SUPPLY does not Granger Cause DTREASURY_BILLS		4.35371	0.0021
DLOGM4 does not Granger Cause DLOGIPI	88	0.45403	0.7692
DLOGIPI does not Granger Cause DLOGM4		0.66830	0.6159
DLOGOECD_OIL_SUPPLY does not Granger Cause DLOGIPI	76	0.48772	0.7447
DLOGIPI does not Granger Cause DLOGOECD_OIL_SUPPLY		1.33512	0.2660
DLOGOECDEU_OIL_STOCKS does not Granger Cause DLOGIPI	94	1.21313	0.3113
DLOGIPI does not Granger Cause DLOGOECDEU_OIL_STOCKS		0.11849	0.9756

DLOGOPEC_OIL_SUPPLY does not Granger Cause DLOGIPI	76	0.13723	0.9680
DLOGIPI does not Granger Cause DLOGOPEC_OIL_SUPPLY		0.06842	0.9912
DLOGUK_OIL_STOCK does not Granger Cause DLOGIPI	94	1.38080	0.2474
DLOGIPI does not Granger Cause DLOGUK_OIL_STOCK		0.37143	0.8284
DLOGWORLD_SUPPLY does not Granger Cause DLOGIPI	76	0.20928	0.9324
DLOGIPI does not Granger Cause DLOGWORLD_SUPPLY		0.45301	0.7698
DTREASURY_BILLS does not Granger Cause DLOGIPI	94	1.15531	0.3364
DLOGIPI does not Granger Cause DTREASURY_BILLS		1.69134	0.1595
DLOGOECD_OIL_SUPPLY does not Granger Cause DLOGM4	196	1.08038	0.3675
DLOGM4 does not Granger Cause DLOGOECD_OIL_SUPPLY		0.08450	0.9871
DLOGOECDEU_OIL_STOCKS does not Granger Cause DLOGM4	220	0.67278	0.6115
DLOGM4 does not Granger Cause DLOGOECDEU_OIL_STOCKS		0.92847	0.4483
DLOGOPEC_OIL_SUPPLY does not Granger Cause DLOGM4	196	2.00129	0.0961
DLOGM4 does not Granger Cause DLOGOPEC_OIL_SUPPLY		1.29861	0.2722
DLOGUK_OIL_STOCK does not Granger Cause DLOGM4	220	0.29704	0.8797
DLOGM4 does not Granger Cause DLOGUK_OIL_STOCK		0.89887	0.4655
DLOGWORLD_SUPPLY does not Granger Cause DLOGM4	196	1.38649	0.2402
DLOGM4 does not Granger Cause DLOGWORLD_SUPPLY		0.89246	0.4696
DTREASURY_BILLS does not Granger Cause DLOGM4	220	1.21900	0.3038
DLOGM4 does not Granger Cause DTREASURY_BILLS		0.50337	0.7333
DLOGOECDEU_OIL_STOCKS does not Granger Cause DLOGOECD_OIL_SUPPLY	220	1.69926	0.1514
DLOGOECD_OIL_SUPPLY does not Granger Cause DLOGOECDEU_OIL_STOCKS		1.27795	0.2797
DLOGOPEC_OIL_SUPPLY does not Granger Cause DLOGOECD_OIL_SUPPLY	221	0.70575	0.5888
DLOGOECD_OIL_SUPPLY does not Granger Cause DLOGOPEC_OIL_SUPPLY		1.16569	0.3270
DLOGUK_OIL_STOCK does not Granger Cause DLOGOECD_OIL_SUPPLY	220	1.28419	0.2773
DLOGOECD_OIL_SUPPLY does not Granger Cause DLOGUK_OIL_STOCK		2.57214	0.0389
DLOGWORLD_SUPPLY does not Granger Cause DLOGOECD_OIL_SUPPLY	221	0.57632	0.6801
DLOGOECD_OIL_SUPPLY does not Granger Cause DLOGWORLD_SUPPLY		2.76962	0.0283
DTREASURY_BILLS does not Granger Cause DLOGOECD_OIL_SUPPLY	221	0.11470	0.9772
DLOGOECD_OIL_SUPPLY does not Granger Cause DTREASURY_BILLS		4.23954	0.0025
DLOGOPEC_OIL_SUPPLY does not Granger Cause DLOGOECDEU_OIL_STOCKS	220	0.17217	0.9525
DLOGOECDEU_OIL_STOCKS does not Granger Cause DLOGOPEC_OIL_SUPPLY		1.27960	0.2791
DLOGUK_OIL_STOCK does not Granger Cause DLOGOECDEU_OIL_STOCKS	244	0.21378	0.9306
DLOGOECDEU_OIL_STOCKS does not Granger Cause DLOGUK_OIL_STOCK		1.73765	0.1424
DLOGWORLD_SUPPLY does not Granger Cause DLOGOECDEU_OIL_STOCKS	220	0.49623	0.7385
DLOGOECDEU_OIL_STOCKS does not Granger Cause DLOGWORLD_SUPPLY		0.85327	0.4930
DTREASURY_BILLS does not Granger Cause DLOGOECDEU_OIL_STOCKS	244	2.04914	0.0883
DLOGOECDEU_OIL_STOCKS does not Granger Cause DTREASURY_BILLS		0.13366	0.9699
DLOGUK_OIL_STOCK does not Granger Cause DLOGOPEC_OIL_SUPPLY	220	2.02861	0.0916
DLOGOPEC_OIL_SUPPLY does not Granger Cause DLOGUK_OIL_STOCK		0.42600	0.7898

DLOGWORLD_SUPPLY does not Granger Cause DLOGOPEC_OIL_SUPPLY	221	2.14734	0.0761
DLOGOPEC_OIL_SUPPLY does not Granger Cause DLOGWORLD_SUPPLY		1.82648	0.1249
DTREASURY_BILLS does not Granger Cause DLOGOPEC_OIL_SUPPLY	221	4.34745	0.0021
DLOGOPEC_OIL_SUPPLY does not Granger Cause DTREASURY_BILLS		1.06974	0.3724
DLOGWORLD_SUPPLY does not Granger Cause DLOGUK_OIL_STOCK	220	1.25410	0.2892
DLOGUK_OIL_STOCK does not Granger Cause DLOGWORLD_SUPPLY		3.03450	0.0184
DTREASURY_BILLS does not Granger Cause DLOGUK_OIL_STOCK	244	2.29375	0.0601
DLOGUK_OIL_STOCK does not Granger Cause DTREASURY_BILLS		1.63517	0.1661
DTREASURY_BILLS does not Granger Cause DLOGWORLD_SUPPLY	221	2.75445	0.0290
DLOGWORLD_SUPPLY does not Granger Cause DTREASURY_BILLS		3.49150	0.0087

Appendix E: Variance decomposition of monetary shock

World_oil_supply

Period	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5
1	24.05062	2.307149	89.22633	0.379042	0.019064	8.068415
2	29.51815	2.307476	89.19717	0.382881	0.018334	8.094137
3	29.72509	2.308539	89.20638	0.383182	0.018279	8.083616
4	31.18788	2.308574	89.20678	0.383397	0.018346	8.082907
5	32.88113	2.308576	89.20618	0.383469	0.018373	8.083405
6	33.04471	2.308568	89.20577	0.383500	0.018384	8.083772
7	33.08012	2.308567	89.20575	0.383503	0.018384	8.083800
8	33.15663	2.308567	89.20572	0.383503	0.018385	8.083827
9	33.17630	2.308568	89.20568	0.383504	0.018386	8.083860
10	33.17705	2.308568	89.20568	0.383505	0.018385	8.083859
11	33.18195	2.308568	89.20568	0.383505	0.018385	8.083860
12	33.18314	2.308568	89.20568	0.383505	0.018385	8.083863

Factorization: Structural

EU27 oil_supply

Period	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5
1	5.577740	5.049173	87.55889	0.024053	0.098653	7.269227
2	5.928536	5.047955	87.50398	0.062300	0.098450	7.287314

3	5.948135	5.049957	87.50052	0.066596	0.098434	7.284490
4	5.972862	5.050338	87.50032	0.068273	0.098662	7.282406
5	5.990624	5.050440	87.50018	0.068293	0.098664	7.282424
6	5.995739	5.050429	87.50015	0.068292	0.098666	7.282463
7	5.996779	5.050423	87.50011	0.068301	0.098670	7.282492
8	5.996866	5.050423	87.50011	0.068305	0.098670	7.282492
9	5.996884	5.050424	87.50012	0.068305	0.098670	7.282484
10	5.996890	5.050425	87.50012	0.068305	0.098670	7.282481
11	5.996896	5.050425	87.50012	0.068305	0.098670	7.282481
12	5.996899	5.050425	87.50012	0.068305	0.098670	7.282481

Factorization: Structural

IEA_oil_supply

Period	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5
1	10.13277	4.280493	87.28208	0.002581	0.098586	8.336257
2	10.13570	4.283279	87.24745	0.010847	0.098524	8.359900
3	12.05951	4.282903	87.24812	0.013763	0.098832	8.356380
4	12.23257	4.282862	87.24855	0.013794	0.098831	8.355964
5	12.33081	4.282853	87.24861	0.013791	0.098837	8.355907
6	12.33892	4.282848	87.24867	0.013792	0.098842	8.355851
7	12.34220	4.282849	87.24866	0.013792	0.098842	8.355858
8	12.34261	4.282849	87.24866	0.013792	0.098843	8.355859
9	12.34275	4.282849	87.24866	0.013792	0.098843	8.355858
10	12.34281	4.282849	87.24866	0.013792	0.098843	8.355858
11	12.34283	4.282849	87.24866	0.013792	0.098843	8.355858
12	12.34285	4.282849	87.24866	0.013792	0.098843	8.355858

Factorization: Structural

OECD_oil_supply

Period	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5
1	9.992188	4.385462	87.11816	0.004389	0.104860	8.387124
2	10.00680	4.386047	87.07887	0.008628	0.104163	8.422288
3	11.70804	4.385536	87.08699	0.008937	0.104314	8.414223
4	11.95476	4.385517	87.08533	0.008933	0.104284	8.415936
5	12.16522	4.385480	87.08594	0.008931	0.104297	8.415348

6	12.20619	4.385477	87.08587	0.008932	0.104296	8.415425
7	12.22232	4.385474	87.08591	0.008932	0.104297	8.415385
8	12.22648	4.385474	87.08591	0.008932	0.104297	8.415391
9	12.22798	4.385474	87.08591	0.008932	0.104297	8.415388
10	12.22854	4.385474	87.08591	0.008932	0.104297	8.415389
11	12.22873	4.385474	87.08591	0.008932	0.104297	8.415388
12	12.22880	4.385474	87.08591	0.008932	0.104297	8.415388

Factorization: Structural

OPEC_oil_supply

Period	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5
1	3.597895	3.125790	84.84849	0.500601	0.017620	11.50750
2	4.096694	3.125666	84.78594	0.501554	0.017482	11.56936
3	5.791132	3.125348	84.78546	0.501450	0.017454	11.57029
4	5.792436	3.124822	84.78461	0.500677	0.017163	11.57272
5	5.792732	3.124856	84.78607	0.500225	0.017143	11.57171
6	6.007272	3.124837	84.78609	0.500282	0.017144	11.57165
7	6.193007	3.124821	84.78628	0.500291	0.017146	11.57146
8	6.197696	3.124823	84.78625	0.500298	0.017146	11.57148
9	6.394208	3.124820	84.78621	0.500289	0.017155	11.57153
10	6.492816	3.124825	84.78603	0.500279	0.017162	11.57171
11	6.493492	3.124828	84.78600	0.500281	0.017162	11.57173
12	6.542971	3.124824	84.78597	0.500273	0.017165	11.57177

Factorization: Structural

Appendix F: Chow test

Bank of England independence

UK oil inventory

Chow Breakpoint Test: 1997M05
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 1992M10 2001M01

F-statistic	1.430335	Prob. F(4,83)	0.2312
Log likelihood ratio	6.066045	Prob. Chi-Square(4)	0.1943
Wald Statistic	5.721340	Prob. Chi-Square(4)	0.2209

OECDEU oil inventory

Chow Breakpoint Test: 1997M05
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 1992M08 2001M01

F-statistic	1.245549	Prob. F(4,85)	0.2979
Log likelihood ratio	5.297335	Prob. Chi-Square(4)	0.2581
Wald Statistic	4.982198	Prob. Chi-Square(4)	0.2891

OECD oil inventory

Chow Breakpoint Test: 1997M05
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 1992M08 2001M01

F-statistic	1.331513	Prob. F(4,85)	0.2649
Log likelihood ratio	5.652045	Prob. Chi-Square(4)	0.2267
Wald Statistic	5.326053	Prob. Chi-Square(4)	0.2554

IEA oil supply

Chow Breakpoint Test: 1997M05
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 1994M02 2001M01

F-statistic	0.547364	Prob. F(4,67)	0.7015
Log likelihood ratio	2.411689	Prob. Chi-Square(4)	0.6605
Wald Statistic	2.189455	Prob. Chi-Square(4)	0.7010

EU27 oil supply

Chow Breakpoint Test: 1997M05
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 1994M02 2001M01

F-statistic	0.585869	Prob. F(4,67)	0.6740
Log likelihood ratio	2.578458	Prob. Chi-Square(4)	0.6306
Wald Statistic	2.343475	Prob. Chi-Square(4)	0.6729

OECD oil supply

Chow Breakpoint Test: 1997M05
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 1994M02 2001M01

F-statistic	0.568118	Prob. F(4,67)	0.6866
Log likelihood ratio	2.501624	Prob. Chi-Square(4)	0.6443
Wald Statistic	2.272473	Prob. Chi-Square(4)	0.6858

OPEC oil supply

Chow Breakpoint Test: 1997M05
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 1994M02 2001M01

F-statistic	0.712084	Prob. F(4,67)	0.5866
Log likelihood ratio	3.122524	Prob. Chi-Square(4)	0.5375
Wald Statistic	2.848337	Prob. Chi-Square(4)	0.5835

World oil supply

Chow Breakpoint Test: 1997M05
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 1994M02 2001M01

F-statistic	0.885716	Prob. F(4,67)	0.4774
Log likelihood ratio	3.864593	Prob. Chi-Square(4)	0.4246
Wald Statistic	3.542864	Prob. Chi-Square(4)	0.4714

Financial crisis

UK oil inventory

Chow Breakpoint Test: 2007M11
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2006M11 2010M09

F-statistic	0.511448	Prob. F(4,7)	0.7303
Log likelihood ratio	3.845842	Prob. Chi-Square(4)	0.4273
Wald Statistic	2.045791	Prob. Chi-Square(4)	0.7273

Table 2

Chow Breakpoint Test: 2007M12
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2006M11 2010M09

F-statistic	1.323255	Prob. F(4,7)	0.3493
Log likelihood ratio	8.446821	Prob. Chi-Square(4)	0.0765
Wald Statistic	5.293019	Prob. Chi-Square(4)	0.2585

OECDEU oil inventory

Chow Breakpoint Test: 2007M12
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2006M11 2010M09

F-statistic	0.066698	Prob. F(4,7)	0.9848
Log likelihood ratio	0.561073	Prob. Chi-Square(4)	0.9511
Wald Statistic	0.266793	Prob. Chi-Square(4)	0.9874

OECD oil inventory

Chow Breakpoint Test: 2007M11
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2006M11 2010M09

F-statistic	0.967378	Prob. F(4,7)	0.4814
Log likelihood ratio	6.600773	Prob. Chi-Square(4)	0.1586
Wald Statistic	3.869511	Prob. Chi-Square(4)	0.4240

IEA oil supply

Chow Breakpoint Test: 2007M12
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2006M11 2010M09

F-statistic	0.383954	Prob. F(4,7)	0.8140
Log likelihood ratio	2.975410	Prob. Chi-Square(4)	0.5619
Wald Statistic	1.535815	Prob. Chi-Square(4)	0.8203

EU27 oil supply

Chow Breakpoint Test: 2007M12
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2006M11 2010M09

F-statistic	0.241085	Prob. F(4,7)	0.9063
Log likelihood ratio	1.935957	Prob. Chi-Square(4)	0.7475
Wald Statistic	0.964339	Prob. Chi-Square(4)	0.9152

OECD oil supply

Chow Breakpoint Test: 2007M12
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2006M11 2010M09

F-statistic	0.327900	Prob. F(4,7)	0.8510
Log likelihood ratio	2.576131	Prob. Chi-Square(4)	0.6311
Wald Statistic	1.311601	Prob. Chi-Square(4)	0.8594

OPEC oil supply

Chow Breakpoint Test: 2007M12
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2006M11 2010M09

F-statistic	0.058847	Prob. F(4,7)	0.9921
Log likelihood ratio	0.496111	Prob. Chi-Square(4)	0.9739
Wald Statistic	0.235390	Prob. Chi-Square(4)	0.9936

World oil supply

Chow Breakpoint Test: 2007M12
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2006M11 2010M09

F-statistic	0.346072	Prob. F(4,7)	0.8390
Log likelihood ratio	2.706739	Prob. Chi-Square(4)	0.6080
Wald Statistic	1.384287	Prob. Chi-Square(4)	0.8469

Appendix G: Re-estimated VAR models in respect to structural breaks

UK oil inventory for BOE independency

Structural VAR Estimates
Sample (adjusted): 1992M10 1997M04
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations
Structural VAR is over-identified (5 degrees of freedom)

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0

C(2)	C(4)	C(6)	C(9)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.338281	0.215902	1.566828	0.1172
C(2)	0.969251	0.603694	1.605533	0.1084
C(3)	2.539769	0.174056	14.59168	0.0000
C(4)	2.691865	0.413319	6.512799	0.0000
C(5)	0.168318	0.024798	6.787680	0.0000
C(6)	-0.793085	0.069321	-11.44076	0.0000
C(7)	0.004065	0.033616	0.120914	0.9038
C(8)	-0.012869	0.134840	-0.095440	0.9240
C(9)	-0.017802	0.127442	-0.139687	0.8889
C(10)	0.463488	0.134652	3.442129	0.0006

Log likelihood	-170.4414			
LR test for over-identification:				
Chi-square(5)	874.0839		Probability	0.0000

Estimated A matrix:

1.000000	0.000000	0.000000	0.000000	0.000000
0.000000	1.000000	0.000000	0.000000	0.000000
0.000000	0.000000	1.000000	0.000000	0.000000
0.000000	0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	0.000000	1.000000

Estimated B matrix:

1.268569	3.277667	-0.677645	-0.027627	1.176109
-0.204860	-0.497046	0.268862	0.018637	-0.333494
-0.904712	-2.487990	1.453531	-0.030002	-0.839888
-2.707639	-7.761769	3.128603	1.854338	-1.790221
1.852850	5.129777	-1.409511	-0.041995	1.895461

For crisis

Structural VAR Estimates
Sample (adjusted): 1997M06 2007M08
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations
Structural VAR is over-identified (5 degrees of freedom)

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

	Coefficient	Std. Error	z-Statistic	Prob.

C(1)	0.195519	0.419002	0.466631	0.6408
C(2)	0.693309	0.178005	3.894875	0.0001
C(3)	4.007777	0.339682	11.79862	0.0000
C(4)	3.185255	0.255709	12.45656	0.0000
C(5)	-0.003534	0.054677	-0.064632	0.9485
C(6)	0.107237	0.027013	3.969864	0.0001
C(7)	-0.091048	0.054680	-1.665104	0.0959
C(8)	-0.058813	0.160128	-0.367287	0.7134
C(9)	0.055428	0.032009	1.731645	0.0833
C(10)	1.451795	0.131876	11.00880	0.0000

Log likelihood	-137.2090			
LR test for over-identification:				
Chi-square(5)	646.8167		Probability	0.0000

Estimated A matrix:

1.000000	0.000000	0.000000	0.000000	0.000000
0.000000	1.000000	0.000000	0.000000	0.000000
0.000000	0.000000	1.000000	0.000000	0.000000
0.000000	0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	0.000000	1.000000

Estimated B matrix:

2.151055	9.122519	-0.118729	0.041016	3.151216
-0.184948	-0.797181	-0.045979	-0.046346	-0.336680
1.844844	8.499919	1.411379	-0.077226	2.618227
0.524327	2.389612	1.630581	0.003154	-2.390718
1.274867	5.831087	0.137456	0.080739	1.771782

OECDEU oil inventory in respect to the BOE independency

Structural VAR Estimates
Sample (adjusted): 1992M10 1997M04
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations
Structural VAR is over-identified (5 degrees of freedom)

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.339264	0.213385	1.589916	0.1119
C(2)	0.969514	0.591935	1.637873	0.1014

C(3)	2.534516	0.172658	14.67938	0.0000
C(4)	2.680220	0.407519	6.576924	0.0000
C(5)	0.186020	0.024929	7.461928	0.0000
C(6)	-0.855912	0.069121	-12.38274	0.0000
C(7)	0.004417	0.035364	0.124901	0.9006
C(8)	0.012641	0.134840	0.093746	0.9253
C(9)	-0.066049	0.134527	-0.490969	0.6234
C(10)	0.465388	0.130438	3.567894	0.0004

Log likelihood	-148.8814			
LR test for over-identification:				
Chi-square(5)	869.3869		Probability	0.0000

Estimated A matrix:

1.000000	0.000000	0.000000	0.000000	0.000000
0.000000	1.000000	0.000000	0.000000	0.000000
0.000000	0.000000	1.000000	0.000000	0.000000
0.000000	0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	0.000000	1.000000

Estimated B matrix:

1.582574	4.121738	-1.064077	-0.080932	1.499495
0.321677	0.957280	-0.183524	-0.002206	0.212352
0.082756	0.258565	0.627108	-0.042572	0.188919
0.204134	0.309387	0.479455	1.814822	1.221042
1.276953	3.520800	-1.082472	-0.083637	1.321650

OECD oil industry stock (the BOE independence)

Structural VAR Estimates
Sample (adjusted): 1992M10 1997M05
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations
Structural VAR is over-identified (5 degrees of freedom)

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.346032	0.195944	1.765973	0.0774
C(2)	2.309172	0.410538	5.624745	0.0000
C(3)	2.481677	0.166234	14.92879	0.0000
C(4)	6.424619	0.310421	20.69648	0.0000
C(5)	0.063711	0.030432	2.093577	0.0363
C(6)	0.095341	0.069659	1.368674	0.1711

C(7)	-0.003041	0.031600	-0.096245	0.9233
C(8)	-0.047796	0.133631	-0.357674	0.7206
C(9)	0.076715	0.070815	1.083312	0.2787
C(10)	0.573561	0.077881	7.364575	0.0000

Log likelihood	-123.7392			
LR test for over-identification:				
Chi-square(5)	775.9843		Probability	0.0000

Estimated A matrix:

1.000000	0.000000	0.000000	0.000000	0.000000
0.000000	1.000000	0.000000	0.000000	0.000000
0.000000	0.000000	1.000000	0.000000	0.000000
0.000000	0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	0.000000	1.000000

Estimated B matrix:

0.281472	0.499190	0.047507	-0.021893	0.323463
-0.253143	-0.656744	0.024207	-0.003479	-0.286404
-0.571506	-1.513642	0.896124	-0.087426	-0.331592
-2.632053	-7.113278	1.652176	1.808050	-0.900795
0.798558	2.125696	0.026353	0.032522	0.443830

OECD oil industry stock (Financial crisis)

Structural VAR Estimates
Sample (adjusted): 1997M06 2007M08
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations
Structural VAR is over-identified (5 degrees of freedom)

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.205015	0.427058	0.480064	0.6312
C(2)	-0.931815	0.559647	-1.665005	0.0959
C(3)	4.181203	0.386069	10.83018	0.0000
C(4)	-4.249065	0.283608	-14.98215	0.0000
C(5)	0.068694	0.051610	1.331001	0.1832
C(6)	-0.046672	0.068103	-0.685316	0.4931
C(7)	-0.101182	0.052770	-1.917430	0.0552
C(8)	-0.038717	0.160128	-0.241790	0.8089
C(9)	0.075549	0.068511	1.102716	0.2702
C(10)	-1.422971	0.070882	-20.07517	0.0000

Log likelihood -14.95924
LR test for over-identification:

Chi-square(5)	467.2777		Probability	0.0000

Estimated A matrix:

1.000000	0.000000	0.000000	0.000000	0.000000
0.000000	1.000000	0.000000	0.000000	0.000000
0.000000	0.000000	1.000000	0.000000	0.000000
0.000000	0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	0.000000	1.000000

Estimated B matrix:

0.308024	0.843943	-0.281980	0.009476	-0.643913
-0.029793	-0.100155	-0.010016	-0.039640	0.121771
-0.239728	-1.114476	1.311467	-0.135643	0.183083
0.879663	3.808067	2.439084	0.322980	1.458083
-0.066022	-0.299557	0.016595	0.006232	0.082366

OPEC oil supply for the BOE independence

Structural VAR Estimates
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations
Structural VAR is over-identified (5 degrees of freedom)

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	-1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.168651	0.515837	0.326945	0.7437
C(2)	0.528110	0.172406	3.063175	0.0022
C(3)	-4.711130	0.447906	-10.51811	0.0000
C(4)	-2.750570	0.243524	-11.29487	0.0000
C(5)	0.066587	0.062898	1.058646	0.2898
C(6)	-0.211483	0.022250	-9.504821	0.0000
C(7)	0.000946	0.063844	0.014820	0.9882
C(8)	-0.073180	0.164399	-0.445137	0.6562
C(9)	0.040486	0.041278	0.980807	0.3267
C(10)	1.949705	0.100090	19.47957	0.0000

Log likelihood	-112.5563			
LR test for over-identification:				
Chi-square(5)	708.6181		Probability	0.0000

Estimated A matrix:

1.000000	0.000000	0.000000	0.000000	0.000000
0.000000	1.000000	0.000000	0.000000	0.000000

0.000000	0.000000	1.000000	0.000000	0.000000
0.000000	0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	0.000000	1.000000

Estimated B matrix:

0.705862	-3.310379	-0.029930	0.004900	1.219456
-0.207428	0.991693	0.107505	-0.018259	-0.590623
-3.561631	18.46768	1.983259	-0.331813	-6.665114
4.957048	-25.98322	-1.281001	2.415888	10.52050
0.994104	-5.179333	-0.397830	0.074637	1.907402

World oil supply for the BOE independence

Structural VAR Estimates
Estimation method: method of scoring (analytic derivatives)
Convergence achieved after 397 iterations
Structural VAR is over-identified (5 degrees of freedom)

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	-1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.146336	0.567629	0.257801	0.7966
C(2)	0.541159	0.217388	2.489371	0.0128
C(3)	-5.675228	0.493014	-11.51129	0.0000
C(4)	-3.361543	0.275363	-12.20768	0.0000
C(5)	0.066970	0.052360	1.279025	0.2009
C(6)	-0.214916	0.021289	-10.09517	0.0000
C(7)	0.002721	0.053505	0.050851	0.9594
C(8)	-0.066927	0.164399	-0.407100	0.6839
C(9)	0.050911	0.041250	1.234193	0.2171
C(10)	1.905360	0.127951	14.89127	0.0000

Log likelihood	-109.3603		
LR test for over-identification:			
Chi-square(5)	729.2527	Probability	0.0000

Estimated A matrix:

1.000000	0.000000	0.000000	0.000000	0.000000
0.000000	1.000000	0.000000	0.000000	0.000000
0.000000	0.000000	1.000000	0.000000	0.000000
0.000000	0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	0.000000	1.000000

Estimated B matrix:

3.731091	-22.72335	-1.259200	0.290271	6.818439

-0.142613	0.806902	0.088912	-0.016520	-0.433663
-4.548653	28.11131	2.488981	-0.455280	-8.380105
2.873450	-18.22551	-0.583556	2.138839	6.574713
0.795055	-4.944310	-0.322258	0.072272	1.486802

Structural VAR Estimates
Sample (adjusted): 1997M05 2010M09
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations
Structural VAR is over-identified (5 degrees of freedom)

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	C(3)	0	0	C(10)
C(1)	-1	C(5)	C(7)	0
0	0	1	C(8)	0
0	0	0	1	0
C(2)	C(4)	C(6)	C(9)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	-0.181085	0.415048	-0.436298	0.6626
C(2)	0.676365	0.244541	2.765859	0.0057
C(3)	4.084165	0.301454	13.54821	0.0000
C(4)	3.377470	0.236484	14.28201	0.0000
C(5)	-0.110196	0.050036	-2.202325	0.0276
C(6)	0.197351	0.035081	5.625614	0.0000
C(7)	0.010728	0.052608	0.203929	0.8384
C(8)	-0.045510	0.147442	-0.308664	0.7576
C(9)	0.157506	0.045578	3.455741	0.0005
C(10)	1.464608	0.191659	7.641740	0.0000

Log likelihood	-150.3616		
LR test for over-identification:			
Chi-square(5)	827.5619	Probability	0.0000

Estimated A matrix:

1.000000	0.000000	0.000000	0.000000	0.000000
0.000000	1.000000	0.000000	0.000000	0.000000
0.000000	0.000000	1.000000	0.000000	0.000000
0.000000	0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	0.000000	1.000000

Estimated B matrix:

-0.299209	-2.261289	-0.466582	-0.343364	-0.570769
-0.470717	-2.353225	-0.172610	-0.088229	-0.592578
1.791285	8.905078	1.831910	0.337020	2.864364
-8.760972	-45.68632	-0.843446	-0.656371	-11.78530
0.659564	3.307026	0.177298	0.158397	0.964017

Appendix H: Autocorrelation test

Model 1

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 248

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	1.234301	NA*	1.239299	NA*	NA*
2	7.060660	NA*	7.113025	NA*	NA*
3	26.31760	0.0497	26.60576	0.0461	16
4	46.86833	0.0436	47.49339	0.0383	32
5	59.08062	0.0412	59.95696	0.0454	48

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 2

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 248

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	1.338201	NA*	1.239299	NA*	NA*
2	6.021660	NA*	7.113025	NA*	NA*
3	22.32160	0.0197	24.60326	0.0061	16
4	36.96821	0.0136	37.43339	0.0282	32
5	60.02061	0.0319	60.94996	0.0464	48

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 3

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 242

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	1.578883	NA*	1.585434	NA*	NA*
2	10.21905	NA*	10.29760	NA*	NA*
3	25.97603	0.0544	26.25237	0.0506	16
4	62.08320	0.0011	62.96638	0.0009	32
5	77.89057	0.0041	79.10724	0.0031	48

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 4

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 253

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	1.748677	NA*	1.782305	NA*	NA*
2	10.68248	NA*	11.06645	NA*	NA*
3	18.47294	0.0169	19.32434	0.0222	16
4	36.67534	0.0209	39.01266	0.0336	32
5	55.85205	0.0336	60.18694	0.0415	48

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 5

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 252

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	1.234301	NA*	1.239299	NA*	NA*
2	7.060660	NA*	7.113025	NA*	NA*
3	26.31760	0.0497	26.60576	0.0461	16
4	46.86833	0.0436	47.49339	0.0383	32
5	59.08062	0.0412	59.95696	0.0454	48

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 6

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 213

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	2.900056	NA*	2.925949	NA*	NA*
2	16.17615	0.0107	16.44125	0.0126	16
3	34.46039	0.0259	35.22415	0.0281	32
4	44.76861	0.0360	45.91065	0.0389	48
5	54.48985	0.0457	56.08196	0.0490	64

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 7

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 113

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	2.900056	NA*	2.925949	NA*	NA*
2	16.17615	0.0147	16.44125	0.0146	16
3	34.46039	0.0309	35.22415	0.0311	32
4	44.76861	0.0360	45.91065	0.0389	48
5	54.48985	0.0417	56.08196	0.0450	64

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 8

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 205

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	1.112721	NA*	1.118176	NA*	NA*
2	8.452066	NA*	8.529830	NA*	NA*
3	22.46983	0.0127	22.75578	0.0124	16
4	47.64323	0.0371	48.43014	0.0314	32
5	58.77935	0.0370	59.84466	0.0273	48

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 9

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 124

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	1.192982	NA*	1.202681	NA*	NA*
2	7.393999	NA*	7.505354	NA*	NA*
3	28.86389	0.0249	29.50755	0.0207	16
4	46.31796	0.0438	47.54343	0.0379	32
5	51.15545	0.0459	52.58418	0.0411	48

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 10

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 145

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	3.764582	NA*	3.790725	NA*	NA*
2	16.85324	0.3952	17.06245	0.3816	16
3	53.06083	0.0111	54.03498	0.0088	32
4	66.47771	0.0398	67.83248	0.0312	48
5	77.03380	0.0271	78.76558	0.0313	64

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 11

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 120

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	1.714833	NA*	1.729243	NA*	NA*
2	5.909509	NA*	5.995016	NA*	NA*
3	18.58659	0.0197	18.99715	0.0188	16
4	33.60789	0.0354	34.53643	0.0347	32
5	47.69873	0.0421	49.23991	0.0433	48

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Model 12

VAR Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Included observations: 113

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	1.248482	NA*	1.259629	NA*	NA*
2	6.035010	NA*	6.132401	NA*	NA*
3	22.44446	0.0294	22.98938	0.0340	16
4	34.01510	0.0378	34.98463	0.0382	32
5	48.14698	0.0469	49.77077	0.0452	48

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Appendix I: Granger causality test

Pairwise Granger Causality Tests
Sample: 1991M01 2013M09

Null Hypothesis:	Obs	F-Statistic	Prob.
WORLD_OIL_SUPPLY does not Granger Cause DLOGCORE_CPI	207	1.73260	0.1794
DLOGCORE_CPI does not Granger Cause WORLD_OIL_SUPPLY		0.59381	0.5532
DLOGWORLD_FOOD_DEMAND does not Granger Cause DLOGCORE_CPI	205	0.62229	0.5377
DLOGCORE_CPI does not Granger Cause DLOGWORLD_FOOD_DEMAND		1.56640	0.2113
DLOGOIL_PRICE does not Granger Cause DLOGCORE_CPI	243	1.31939	0.2692
DLOGCORE_CPI does not Granger Cause DLOGOIL_PRICE		1.17134	0.3117
DLOGFOOD_PRODUCTION does not Granger Cause DLOGCORE_CPI	229	0.12567	0.8820
DLOGCORE_CPI does not Granger Cause DLOGFOOD_PRODUCTION		0.27212	0.7620
LOGWORLD_OIL_DEMAND does not Granger Cause DLOGCORE_CPI	132	3.73971	0.0264
DLOGCORE_CPI does not Granger Cause LOGWORLD_OIL_DEMAND		0.42658	0.6537
LOGWORLD_OIL_SUPPLY does not Granger Cause DLOGCORE_CPI	113	0.44899	0.6395
DLOGCORE_CPI does not Granger Cause LOGWORLD_OIL_SUPPLY		0.30625	0.7368
WORLD_OIL_SUPPLY does not Granger Cause DLOGCPI	215	4.95192	0.0079
DLOGCPI does not Granger Cause WORLD_OIL_SUPPLY		2.62321	0.0749
DLOGWORLD_FOOD_DEMAND does not Granger Cause DLOGCPI	213	0.47765	0.6209
DLOGCPI does not Granger Cause DLOGWORLD_FOOD_DEMAND		0.21980	0.8029
DLOGOIL_PRICE does not Granger Cause DLOGCPI	251	0.15565	0.8559
DLOGCPI does not Granger Cause DLOGOIL_PRICE		1.20176	0.3024
DLOGFOOD_PRODUCTION does not Granger Cause DLOGCPI	237	0.14856	0.8620
DLOGCPI does not Granger Cause DLOGFOOD_PRODUCTION		1.10839	0.3318
DTRB does not Granger Cause DLOGFOOD	260	1.36553	0.2571
DLOGFOOD does not Granger Cause DTRB		3.18181	0.0432
LOGWORLD_OIL_SUPPLY does not Granger Cause DLOGCPI	120	0.03546	0.9652
DLOGCPI does not Granger Cause LOGWORLD_OIL_SUPPLY		0.37557	0.6877
WORLD_OIL_SUPPLY does not Granger Cause DLOGIPI	215	0.30914	0.7344
DLOGIPI does not Granger Cause WORLD_OIL_SUPPLY		2.56119	0.0796
DLOGWORLD_FOOD_DEMAND does not Granger Cause DLOGIPI	213	0.44139	0.6437
DLOGIPI does not Granger Cause DLOGWORLD_FOOD_DEMAND		0.80992	0.4463
DLOGOIL_PRICE does not Granger Cause DLOGIPI	250	2.84260	0.0602
DLOGIPI does not Granger Cause DLOGOIL_PRICE		1.56380	0.2114
DLOGFOOD_PRODUCTION does not Granger Cause DLOGIPI	237	0.43356	0.6487
DLOGIPI does not Granger Cause DLOGFOOD_PRODUCTION		0.41551	0.6605
LOGWORLD_OIL_DEMAND does not Granger Cause DLOGIPI	137	0.10044	0.9045
DLOGIPI does not Granger Cause LOGWORLD_OIL_DEMAND		1.03827	0.3569
LOGWORLD_OIL_SUPPLY does not Granger Cause DLOGIPI	120	0.10076	0.9042
DLOGIPI does not Granger Cause LOGWORLD_OIL_SUPPLY		0.19055	0.8268

WORLD_OIL_SUPPLY does not Granger Cause DTRB	215	0.08655	0.9171
DTRB does not Granger Cause WORLD_OIL_SUPPLY		4.86327	0.0086
DLOGWORLD_FOOD_DEMAND does not Granger Cause DTRB	225	0.60749	0.5456
DTRB does not Granger Cause DLOGWORLD_FOOD_DEMAND		0.60449	0.5473
DLOGOIL_PRICE does not Granger Cause DTRB	263	5.41008	0.0050
DTRB does not Granger Cause DLOGOIL_PRICE		3.97912	0.0199
DLOGFOOD_PRODUCTION does not Granger Cause DTRB	249	0.87115	0.4198
DTRB does not Granger Cause DLOGFOOD_PRODUCTION		0.05421	0.9472
LOGWORLD_OIL_DEMAND does not Granger Cause DTRB	137	4.42344	0.0138
DTRB does not Granger Cause LOGWORLD_OIL_DEMAND		0.46120	0.6315
LOGWORLD_OIL_SUPPLY does not Granger Cause DTRB	120	0.33928	0.7130
DTRB does not Granger Cause LOGWORLD_OIL_SUPPLY		1.63794	0.1989

Appendix J: Results of cointegration test

Model 5

Sample: 1990M01 2013M09
Series: TRB LOGCPI LOGIPI LOGFOOD_DEMAND_SA
Lags interval: 0 to 1
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	3	3	1	2	1
Max-Eig	3	2	1	0	0

*Critical values based on MacKinnon-Haug-Michelis (1999)

Model 6

Sample: 1990M01 2013M09
Series: TRB LOGCPI LOGIPI LOGFOOD_PRODUCTION_SA
Lags interval: 1 to 2
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	3	4	2	2	2
Max-Eig	3	4	2	1	0

*Critical values based on MacKinnon-Haug-Michelis (1999)

Model 7

Sample: 1990M01 2013M09
Series: TRB LOGCORE_CPI LOGIPI LOGFOOD_PRODUCTION_SA
Lags interval: 1 to 2
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	2	3	1	1	0
Max-Eig	1	2	1	1	0

*Critical values based on MacKinnon-Haug-Michelis (1999)

Model 8

Sample: 1990M01 2013M09
Series: TRB LOGCORE_CPI LOGIPI LOGFOOD_DEMAND_SA
Lags interval: 1 to 4
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	2	2	1	1	0
Max-Eig	2	2	1	1	0

*Critical values based on MacKinnon-Haug-Michelis (1999)

Appendix K: Re-estimated VEC Model 1 and SVAR Model 4

Model 1

Before break

Vector Error Correction Estimates
Sample (adjusted): 1992M02 2008M06
Included observations: 197 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegration Restrictions:
B(1,2)=0, B(1,3)=0, B(1,4)=1
B(2,1)=0, B(2,3)=0, B(2,4)=1
B(3,1)=0, B(3,2)=0, B(3,4)=1
Convergence achieved after 1 iterations.
Restrictions identify all cointegrating vectors
Restrictions are not binding (LR test not available)

Cointegrating Eq:	CointEq1	CointEq2	CointEq3
TRB(-1)	0.431447	0.000000	0.000000

	(0.09846)			
	[4.38201]			
LOGCPI(-1)	0.000000	-0.841733	0.000000	
		(0.12523)		
		[-6.72150]		
LOGIPI(-1)	0.000000	0.000000	7.626227	
			(0.97208)	
			[7.84530]	
LOGCRUDE_OIL(-1)	1.000000	1.000000	1.000000	
@TREND(91M01)	-0.026109	-0.011504	-0.017778	
	(0.00772)	(0.00185)	(0.00251)	
	[-3.38285]	[-6.21247]	[-7.08204]	
C	-3.344045	-2.132719	-37.79998	

Error Correction:	D(TRB)	D(LOGCPI)	D(LOGIPI)	D(LOGCRUDE_ OIL)
CointEq1	-0.118069	0.011522	0.002536	-0.000155
	(0.01944)	(0.01448)	(0.00078)	(0.00710)
	[-6.07223]	[0.79571]	[3.25145]	[-0.02181]
CointEq2	-0.204617	0.190113	0.005018	-0.006048
	(0.06278)	(0.04675)	(0.00252)	(0.02294)
	[-3.25939]	[4.06669]	[1.99288]	[-0.26369]
CointEq3	0.457148	-0.167480	-0.010833	-0.032854
	(0.09014)	(0.06712)	(0.00361)	(0.03293)
	[5.07169]	[-2.49513]	[-2.99671]	[-0.99763]
C	-0.024557	-0.003101	0.000638	0.010253
	(0.01415)	(0.01053)	(0.00057)	(0.00517)
	[-1.73599]	[-0.29439]	[1.12475]	[1.98394]

After break

Vector Error Correction Estimates
Sample (adjusted): 2009M01 2012M11
Included observations: 47 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegration Restrictions:
B(1,2)=0, B(1,3)=0, B(1,4)=1
B(2,1)=0, B(2,3)=0, B(2,4)=1
B(3,1)=0, B(3,2)=0, B(3,4)=1
Convergence achieved after 1 iterations.
Restrictions identify all cointegrating vectors

Restrictions are not binding (LR test not available)

Cointegrating Eq:	CointEq1	CointEq2	CointEq3
TRB(-1)	-0.735158	0.000000	0.000000
	(0.06449)		
	[-11.3992]		
LOGCPI(-1)	0.000000	-0.163697	0.000000
		(0.03088)	
		[-5.30032]	
LOGIPI(-1)	0.000000	0.000000	-4.015764
			(0.85098)
			[-4.71901]
LOGCRUDE_OIL(-1)	1.000000	1.000000	1.000000
@TREND(91M01)	-0.014978	-0.009696	-0.012450
	(0.00233)	(0.00238)	(0.00234)
	[-6.41471]	[-4.07106]	[-5.32165]
C	-1.116124	-2.549876	16.45228

Error Correction:	D(TRB)	D(LOGCPI)	D(LOGIPI)	D(LOGCRUDE_OIL)
CointEq1	0.734092	-0.218342	0.018655	0.209291
	(0.08168)	(0.29684)	(0.02011)	(0.12549)
	[8.98773]	[-0.73556]	[0.92755]	[1.66781]
CointEq2	-0.460857	1.059353	-0.080758	-0.110328
	(0.13865)	(0.50388)	(0.03414)	(0.21302)
	[-3.32397]	[2.10238]	[-2.36553]	[-0.51793]
CointEq3	-0.235294	-0.649315	0.065535	-0.332113
	(0.12488)	(0.45386)	(0.03075)	(0.19187)
	[-1.88413]	[-1.43065]	[2.13121]	[-1.73094]
C	-0.022543	-0.002939	-0.001192	0.019126
	(0.00560)	(0.02034)	(0.00138)	(0.00860)
	[-4.02739]	[-0.14450]	[-0.86472]	[2.22403]

Model 4

Before break

Structural VAR Estimates
Sample (adjusted): 1992M04 2008M06
Estimation method: method of scoring (analytic derivatives)

Maximum iterations reached at 500 iterations
Structural VAR is over-identified (4 degrees of freedom)

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	0	0	C(5)
0	1	0	0
0	C(2)	1	C(6)
C(1)	C(3)	C(4)	1

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.000161	0.004382	0.036750	0.9707
C(2)	-0.002843	0.091847	-0.030955	0.9753
C(3)	0.006146	0.117397	0.052355	0.9582
C(4)	1.255914	0.002407	521.7095	0.0000
C(5)	0.008141	0.120852	0.067362	0.9463
C(6)	0.759965	0.001734	438.2892	0.0000

Log likelihood	-81.44422			
LR test for over-identification:				
Chi-square(4)	2512.440		Probability	0.0000

Estimated A matrix:

1.000000	0.000000	0.000000	0.000000
0.000000	1.000000	0.000000	0.000000
0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	1.000000

Estimated B matrix:

0.498287	-0.082813	-1.043909	-0.736626
-0.087904	0.981274	2.187256	1.667050
-0.004724	0.002649	1.482154	1.126592
-0.003191	-0.009006	0.654098	0.527777

After break

Structural VAR Estimates
Sample (adjusted): 2008M07 2012M11
Estimation method: method of scoring (analytic derivatives)
Maximum iterations reached at 500 iterations
Structural VAR is over-identified (4 degrees of freedom)

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

1	0	0	C(5)
0	1	0	0
0	C(2)	1	C(6)
C(1)	C(3)	C(4)	1

	Coefficient	Std. Error	z-Statistic	Prob.

C(1)	0.055294	0.008185	6.755215	0.0000
C(2)	-0.012530	0.168593	-0.074322	0.9408
C(3)	0.095736	0.229186	0.417721	0.6762
C(4)	1.338984	0.004380	305.7277	0.0000
C(5)	0.054632	0.235959	0.231532	0.8169
C(6)	0.712720	0.010205	69.84036	0.0000

Log likelihood	-41.53475			
LR test for over-identification:				
Chi-square(4)	756.8384		Probability	0.0000

Estimated A matrix:

1.000000	0.000000	0.000000	0.000000
0.000000	1.000000	0.000000	0.000000
0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	1.000000

Estimated B matrix:

0.346275	-0.367262	0.048066	-0.052723
-0.212171	1.205670	2.618768	1.828045
-0.028227	-0.039528	1.478552	1.050308
0.032056	0.131666	0.868517	0.643661

Appendix L: Comparison of models

Akram (2009)	**Anzuni et al.(2010)**	**Arora and Tenner (2013)**	**Our model**
Quarterly data	Monthly data	Monthly data	Monthly data
1990-2007	1970-2009	1975-2012	1992-2013
VAR	VAR	VAR	VEC
Food price, raw materials price, oil price, effective exchange rate, IPI, interest rate, CPI	Food price, oil price, FED rate, M2, CPI, IPI	Oil price, IPI, real interest rate, effective exchange rate, CPI	Oil price, food price, CPI, IPI, nominal interest rate, 3-months Treasury bills, M4
Choleski decomposition	Restrictions driven from the theory	N/A	Restrictions driven from the theory
Tested for cointegration	Did not test for cointegration	Tested for cointegration	Tested for cointegration
Did not investigate	Investigated all 3	Did not investigate	Investigated 2 out of 3

channels	channels defined by Frankel (2007)	channels	channels defined by Frankel (2007)
Did not consider structural breaks	Did not consider structural breaks	Did not consider structural breaks	Did consider structural breaks