Causes and Consequences of Oil Price Shocks on the UK Economy

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Abstract

In this paper, we assess the impact and repercussions of oil price fluctuations on the UK economy. We use an empirical strategy which allows us to decompose oil price changes from the underlying source of the shock. Our results show that the consequences of oil price changes on UK macroeconomic aggregates depend on different types of oil shocks. While increases in aggregate and oil market-specific demand do not depress the UK economy in the short run, shortfalls in crude oil supply cause an immediate fall in GDP growth. We also find that domestic inflation increases following a rise in the real oil price. Our variance decomposition shows that oil shocks play a non-negligible role in terms of variation in the main UK macroeconomic aggregates. In particular, aggregate and specific oil demand substantially contribute to changes in GDP growth, inflation, nominal interest rate and unemployment rate. Our study provides evidence that the Bank of England responds to the underlying sources of oil price shocks rather than oil price changes themselves. In particular, unanticipated booms in aggregate and specific oil demand cause an increase in the nominal interest rate whereas the opposite occurs in the case of unexpected oil supply disruptions.

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Keywords: Oil Price Shocks, Vector Autoregressions, UK Economy.

1. Introduction

Since the dramatic oil price spikes of the 1970's, and the consequent global recession, economists have analysed oil price fluctuations in order to understand their economic impact. In this regard, a large number of studies have investigated the macroeconomic effects of oil price shocks.[1]

Although these studies have found a negative correlation between oil price increases and economic performance, a strong divergence appeared in the analysis of the causes of oil price fluctuations. The assumption of the oil price as an exogenous driver to economic fundamentals, which did not distinguish between the different sources of oil price fluctuations, was shown inappropriate by Kilian (2009). In his study, Kilian (2009) suggested important evidences of a reverse causality from macroeconomic aggregates to oil prices and also showed that oil prices are driven by structural demand and supply shocks which have direct effects on the macroeconomy.

In this paper, we aim to analyse the impact of oil price changes on the UK economy. We use a structural Vector Autoregression (VAR) approach and adopt a two-stage method in order to identify and estimate our model. In the first stage, we assess the causes of oil price changes depending on the underlying source of the shock; that is, we investigate whether the oil price is driven by a supply or a demand disturbance. In the second stage, we examine the effects of the structural shocks estimated in stage 1 on a set of UK macroeconomic aggregates such as output growth, inflation, nominal interest rate and government deficit.

Our contribution with respect to previous economic literature is twofold. Firstly, we are able to assess the effects of different types of oil shocks on the UK economy. Using an impulse response analysis, we are able to show that

[1] See, for example, Hamilton (1983) and (2003); Burbidge and Harrison (1984); Bernanke et al. (1997); Papapetrou (2001); Lee and Ni (2002); Bernanke (2004); Barsky and Kilian (2004); Peersman (2005); Blanchard and Galí (2007); Kilian (2008) and (2009); Peersman and Van Robays (2009); Lombardi and Van Robays (2011); Mohaddes and Raissi (2013); Zhang and Yao (2016); Morana (2017).

unanticipated booms in oil demand have different effects than unexpected oil supply disruptions. Moreover, our variance decomposition analysis quantifies the contribution of these different types of oil shocks on the fluctuations in the main UK economic fundamentals. Secondly, our empirical model allows us to study the response of the Bank of England (BoE) to unexpected oil shocks. In particular, our findings show that the UK monetary policy is affected differently by changes in oil supply as well as variations in aggregate and specific oil demand. Interestingly, our results higlight the fact that the BoE responds to the underlying shocks in the oil market, whereas we find no evidence that the BoE responds directly to oil price shocks.

Our empirical strategy is in accordance with the approach of Kilian (2009), which endogenises the effects of oil price, and is fully consistent with the theoretical framework based on Dynamic Stochastic General Equilibrium (DSGE) models developed by Bodenstein et al. (2008), Nakov and Pescatori (2010), Nakov and Nuño (2011), Bodenstein et al. (2011), Bodenstein and Guerrieri (2011) and Bodenstein et al. (2012).[2] Our analysis also focuses on the demand side of the oil market. It is worth noting that the traditional emphasis on physical oil supply shocks in explaining oil price fluctuations is misplaced as provided by a large number of studies such as Barsky and Kilian (2002), Kilian (2008), Apergis and Miller (2009), Basher et al. (2012), Kilian and Murphy (2012) and (2014), Kilian and Hicks (2013), Baumeister and Peersman (2013).

Most of the papers analysing the relationship between oil and the macroeconomy have focused on the United States. There have also been several cross-country studies.[3] More recently, economic literature has focused on the oil-macroeconomy relationship considering the complex framework of global economic

[2] Using a DSGE model, Milani (2009) proposed an innovative approach in order to investigate the effects of oil prices on US macroeconomic aggregates. In particular, this author emphasized the changing effect that oil prices have on the formation of economic agents' expectations and the role of learning.

[3] See, for example, Berument et al. (2010); Baumeister et al. (2010); Peersman and Van Robays (2012); Aatstveit et al. (2015); Vespignani (2015); Vespignani and Ratti (2016).

interactions. For example, Cashin et al. (2014) have employed a Global VAR model (GVAR) to assess the effects of oil price shocks on a large number of countries. Esfahani et al. (2014) focused on nine major oil exporting countries and estimated the effects of oil revenue shocks on this set of countries. Mohaddes and Raissi (2015) have studied the consequences of the US shale oil boom for the global economy and, in particular, the Middle East and North Africa (MENA) region using a GVAR-Oil model. Mohaddes and Pesaran (2016) have analysed the economic impact of country specific oil supply shocks on real output, oil prices, interest rates, and real equity prices for 27 countries. In the same spirit, Mohaddes and Pesaran (2017) have used a GVAR approach to assess the effects of negative short-run oil price decreases on the US and the rest of the world economy. All these studies have a common point considering the direct effects of oil price shocks together with the indirect impact of oil price fluctuations through secondary and tertiary channels.

In contrast to the above literature, our paper focuses on the relationship between the UK macroeconomy and global oil price changes. We expect the United Kingdom to be a very interesting study case as it is one of the largest oil producers among the European countries. In particular, the recent Brexit vote could have profound implications since the European economy has not grown rapidly in recent years and a fracturing political system could affect negatively economic growth, putting pressure on oil demand.

Thus, we analyse how the effects of oil price fluctuations on the UK economy may depend on the nature of the underlying shock. Our structural VAR model distinguishes between oil price changes caused by exogenous disruptions in oil production, oil demand shocks driven by global real economic activity and oil market-specific demand shocks associated with the uncertainty about future supply. The sample of our analysis covers the period 1976-2014. In this regard, we estimate our VAR model with monthly data. Our empirical set up heavily relies on delay restrictions that are economically plausible only at monthly frequency.

As far as the causes of oil price shocks are concerned, our results confirm the findings of Kilian (2009) for the sample 1976-2007, adding the explanation of oil price variations in recent years. We find that, since the mid-1970's, most large and persistent fluctuations in the real price of oil have been associated with the cumulative effects of oil demand rather than oil supply shocks.

Turning to the consequences of oil price shocks on the UK economy, we find that oil supply disruptions induce an immediate fall in domestic GDP growth and cause a sustained increase in domestic inflation. Our impulse response analysis shows that increases in aggregate demand and oil market-specific demand, initially, have a negligible effect on the UK output growth but in the long term they tend to depress it. In addition, both these shocks induce a rise in the CPI inflation. We also quantify the contribution of oil shocks in terms of fluctuations of the main UK macroeconomic aggregates. Our variance decomposition analysis indicates that oil shocks played an important role in the UK economy. Among oil shocks, oil market specific-demand is definitely the most important concerning the variation in the real GDP growth and the unemployment rate, whereas aggregate demand shocks play a significant role in determining changes in the inflation and nominal interest rate. Focusing on the UK monetary policy, we find that the nominal interest rate increases after both aggregate demand shocks and oil market-specific demand shocks occur, whereas negative shocks to the oil supply induce the Bank of England to reduce its policy interest rate.

The rest of the paper is structured as follows. In the next section we discuss the specification and identification of our empirical model. Section 3 discusses the results distinguishing between the causes of oil price changes and the effects of oil price fluctuations on the UK economy. Section 4 reports the robustness analysis. Section 5 concludes suggesting improvements for future researches.

2. The Empirical Framework

We estimate the causes and consequences of oil price shocks in two distinct stages. Firstly, we use a structural VAR (SVAR) framework to capture supply and demand conditions in the oil market. Accordingly, we apply the identifying assumptions on the relationships between the world variables in order to recover three structural shocks affecting oil prices: oil supply shocks, aggregate demand shocks and oil market-specific demand shocks (or precautionary demand shocks). In particular, oil supply shocks are shocks respondent to current availability of crude oil. Aggregate demand shocks affect the current demand for crude oil coming from changes in the global business cycle. Oil market-specific demand shocks are those driven by shifts in the precautionary demand for oil; they come from the uncertainty about shortfalls of expected supply relative to expected demand. The latter shock includes the holdings of oil inventories as insurance against oil supply disruptions.

In stage 2, we assess the impact of structural innovations, estimated in stage 1, on several UK macroeconomic aggregates such as real GDP growth, CPI inflation, the nominal interest rate and the real government deficit. The use of two-stage procedure presents two advantages. Firstly, our approach enables us to keep the number of variables in our SVAR manageable (less than four) given the computational requirements associated with estimating larger VARs. Secondly, separating the process of identifying structural shocks in the oil market removes the need to employ further identification restrictions on the UK macroeconomic aggregates.

2.1. Modelling the Causes of Oil Price Shocks: a World SVAR

2.1.1. Data

We consider monthly data for the sample period 1976:1-2014:12.[4] In order to estimate the world structural VAR, we use the percentage change of global crude oil

[4] We use the sample period 1974:1-1975:12 as training sample for our estimates.

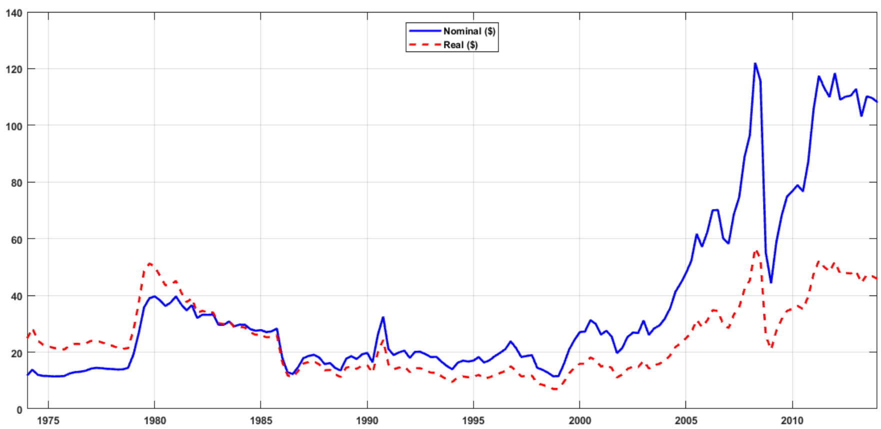
production ($\Delta prod_t$) obtained by the log differences of world crude oil production in millions per barrels pumped per day (averaged by month).[5]

The index of global real economic activity (rea_t) is a measure of the component of worldwide real economy activity which drives demand for industrial commodities in global markets (Kilian, 2009). This index is based on dry cargo single voyage ocean freight rates. As argued by Klovland (2004), world economic activity is the most important determinant of the demand for transport services. Thus, following the original idea of Kilian (2009), increases in freight rates are indicators of strong cumulative global demand pressures.

The real price of oil (rpo_t) is obtained from the series of the Europe Brent spot price FOB which is expressed in US dollars per barrel. The monthly series is taken from Datastream and deflated using the US consumer price index.

Here, we show the nominal and real oil price series at monthly frequency from the period January 1974 to December 2014 (Figure 1).

Figure 1: Real and Nominal Oil Prices (Europe Brent Spot Price)



Source: Datastream Database.

[5]See Appendix A for a detailed description of data sources and the construction of the series used to estimate the world SVAR.

As we can observe from the graph, the crude oil price rose persistently from the end of the 1970's to the mid-1980's. Except for the peak episodes observed in 1990-1991 and 1999-2000, the oil price remained fairly stable at around \$20 per barrel from 1986 until the end of 2001. Later that year, the path of oil price steepened sharply until the end of 2008, and this surge was followed by an even more spectacular collapse. In 2011, the oil price went back to the level achieved in 2007-2008. Finally, we observe a plunge in the oil price at the end of 2014.

2.1.2. Specification and Identification of the Model

As a benchmark specification for our model, we adopt a SVAR, whose reduced form is defined by the following dynamic equation:

$$\mathbf{B}_0 \mathbf{y}_t = \mathbf{c}_t + \sum_{l=1}^{24} \mathbf{B}_l \mathbf{y}_{t-l} + \mathbf{u}_t \tag{1}$$

where $\mathbf{y}_t = (\Delta prod_t, rea_t, rpo_t)'$ indicates the three-variable vector of variables specified above, $\mathbf{c}_t$ is a vector of constants and $\mathbf{u}_t$ denotes the vector of reduced-form innovations. As an identification strategy, we adopt a Cholesky factorization approach so as to recover the vector of structural shocks $\boldsymbol{\varepsilon}_t$ from the reduced-form error $\mathbf{u}_t$ in (1), according to the following scheme:

$$\boldsymbol{\varepsilon}_t = \begin{bmatrix} \varepsilon_t^{\Delta prod} \\ \varepsilon_t^{rea} \\ \varepsilon_t^{rpo} \end{bmatrix} = \begin{pmatrix} \alpha_{11} & 0 & 0 \\ \alpha_{21} & \alpha_{21} & 0 \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{pmatrix} \begin{bmatrix} u_t^{oil\ supply\ shock} \\ u_t^{aggregate\ demand\ shock} \\ u_t^{oil\ market\text{-}specific\ demand\ shock} \end{bmatrix} \tag{2}$$

The Cholesky ordering in (2) corresponds to assuming the following set of conditions. Firstly, crude oil supply shocks are defined as unpredictable innovations to global oil production, that is, oil demand shocks ($u_t^{aggregate\ demand\ shock}$ and $u_t^{oil\ market\text{-}specific\ demand\ shock}$) do not influence crude oil supply ($u_t^{oil\ supply\ shock}$) in the same month. This assumption is plausible since adjusting oil production is costly for oil producer countries and because the state of the crude oil market is difficult to forecast in the very short run. Hence, oil producer countries tend to respond slowly to oil demand shocks.

Secondly, shocks to global real economic activity that are not explained by oil supply shocks are identified as shocks to global demand for industrial commodities. We define these shocks as aggregate demand shocks. We assume that shocks to oil market-specific demand ($u_t^{oil\ market\text{-}specific\ demand\ shock}$) do not influence global real economic activity ($u_t^{aggregate\ demand\ shock}$) in the same month. In general, our assumption is reasonable because global real economic activity responds with a certain delay to oil price increases.

Finally, shocks to the real oil price that are not explained by oil supply shocks or aggregate demand shocks by construction reflect changes in the demand for oil in contrast to changes in the demand for all industrial commodities. We define these shocks as oil market-specific demand shocks. In particular, these shocks represent the fluctuations in precautionary demand for oil due to uncertain future oil supply.

We estimate the VAR reduced-form equation (1) using least squares. The resulting estimates are used to construct the SVAR model. We adopt the inference method used by Gonçalves and Kilian (2004) which implies a recursive-design wild bootstrap with 2,000 replications.[6]

2.2. Modelling the Consequences of Oil Price Shocks on the UK Economy

Having identified the shocks and obtained the responses of our world variables to these shocks, we then estimate the impact of these structural innovations on the UK macroeconomic fundamentals. In particular, we use: growth rate of real GDP (Δy_t), CPI inflation (π_t) and the short-term nominal interest rate (Δr_t).[7] More specifically, we measure the effects of oil supply shocks, aggregate demand shocks

[6] This method is successful in dealing with conditional heteroskedasticity of unknown form in autoregressions. It is well known that there is evidence of conditional heteroskedasticity in the residuals of many estimated dynamic regression models involving monthly data and, in this case, standard residual-based bootstrap methods of inference for autoregressions are invalidated by conditional heteroskedasticity.

[7] Appendix A provides a detailed description of data sources and the construction of the series used to estimate the consequences of oil price shocks on the UK economy.

and oil specific demand shocks on these UK macroeconomic aggregates adopting the following regressions:[8]

$$\begin{aligned} \Delta y_t &= \alpha_j + \sum_{i=1}^{12} \gamma_{ji} \hat{\lambda}_{jt-i} + z_{jt} \\ with &: \ j = 1, 2, 3 \end{aligned} \tag{3}$$

$$\begin{aligned} \pi_t &= \delta_j + \sum_{i=1}^{12} \eta_{ji} \hat{\lambda}_{jt-i} + \upsilon_{jt} \\ with &: \ j = 1, 2, 3 \end{aligned} \tag{4}$$

and:

$$\begin{aligned} \Delta r_t &= \theta_j + \sum_{i=1}^{12} \iota_{ji} \hat{\lambda}_{jt-i} + s_{jt} \\ with &: \ j = 1, 2, 3 \end{aligned} \tag{5}$$

Our model is based on quarterly data for Δy_t, π_t and Δr_t, because some of the aggregate series of our analysis are not available at monthly frequency.[9] Our choice of using all the data series at quarterly frequency allows us to easily compare the estimated results of each macroeconomic aggregate.

Thus, in equations (3)-(5), $\hat{\lambda}_{jt}$ represents the measure of quarterly shocks estimated in model (1) and constructed by averaging the monthly structural innovations for each quarter:

$$\begin{aligned} \hat{\lambda}_{jt} &= \frac{1}{3} \sum_{i=1}^{3} \hat{u}_{j,t,1} \\ with &: \ j = 1, 2, 3 \end{aligned} \tag{6}$$

where $\hat{u}_{j,t,1}$ indicates the estimated residual for the $j-$th structural shock in the ith month of the tth quarter of the sample.[10] In equations (3)-(5) the impulse

[8] In equations (3)-(6), $j = 1, 2, 3$ represent the structural innovations of oil shocks estimated in the world SVAR: $j = 1$ denotes the structural innovations of global oil supply shocks, $j = 2$ stands for the structural innovations to aggregate demand shocks and $j = 3$ represents the structural innovations to oil market-specific demand shocks.

[9] We do not use interpolated data because interpolation is known to cause spurious dynamics.

[10] These quarterly averages are not exactly uncorrelated, but their correlation is so low that they can be treated as uncorrelated.

response coefficients correspond to γ_{ji}, η_{ji} and ι_{ji}, respectively. The number of lags is determined by the maximum horizon of the impulse response function, which is set to twelve quarters. Finally, in equations (3)-(5), z_{jt}, v_{jt} and s_{jt} are potentially serially correlated errors. In order to deal with possible serial correlation in the error term we use block bootstrap methods. Following the usual empirical strategy, all our estimated results are obtained with block size 4 and 20,000 bootstrap replications.

Our regression model (3)-(5) assumes that, within a given quarter, there is no feedback from Δy_t, π_t and Δr_t to $\hat{\lambda}_{jt}$, $j = 1, 2, 3$ such as we can assess their effects on UK macroeconomic aggregates. The assumption that oil supply shocks, aggregate demand shocks and oil market-specific demand shocks are exogenous to GDP growth, CPI inflation and nominal interest rate is based on the fact that the United Kingdom is "small" in the sense that movements in UK economic variables have no effect on world variables. In fact, although the United Kingdom produces oil, its average share of oil production in the period 1976-2014 was 3% with a peak of 5% from 1984 to 1986 and it was 1% in 2014 according to the statistics of US Energy Information Administration (Monthly Energy Review). Similarly, UK petroleum consumption has been on average 3% of world consumption during the period 1976-2014 (US Energy Information Administration - Monthly Energy Review).

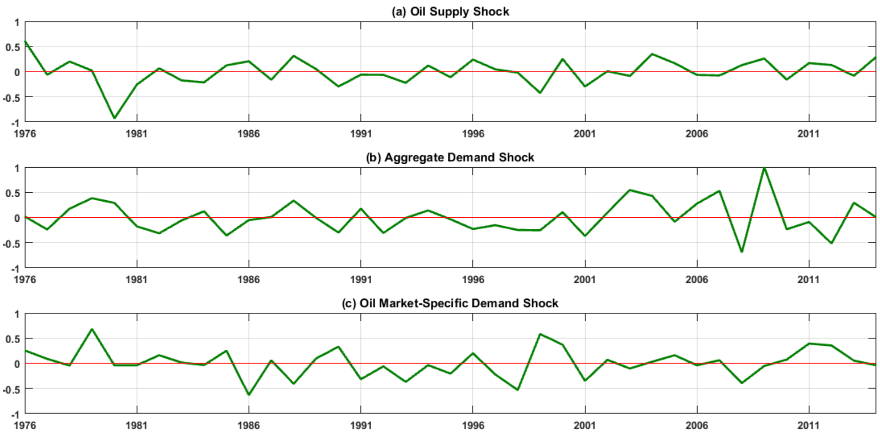
3. Results

In this section, we show the estimation results of our empirical model. We start by discussing the estimates concerning the causes of oil shocks.

3.1. Assessing the Causes of Oil Shocks

Figure 2 shows the historical evolution of the structural shocks considered in our model for the period 1976-2014. Our analysis focuses on the episodes associated with the major changes in the real oil price. Our estimated results confirm the findings of Kilian (2009) for the sample 1976-2007, although we are able to explain oil price variation in recent years (2008-2014).

Figure 2: Historical Evolution of Structural Shocks, 1976-2014



Note: Average of structural residuals implied by the SVAR model (1) at annual frequency.

From Graph (a), we do not observe any oil supply disruption corresponding to the Iranian Revolution occurring in 1978-1979. Accordingly, the reductions of oil supply due to the Iranian Revolution were more than offset by increases in production from other oil producer countries.

Differently, at the time of the Iran-Iraq War in 1980, we find evidence of a substantial shortfall in crude oil supply.

Graph (b) shows that repeated large positive shocks to global aggregate demand occurred in 1978, 1979 and 1980, while from Graph (c), we observe a large unanticipated increase of oil market-specific demand during 1979. Indeed, episodes of Iranian Revolution, the Iranian hostage crisis and the Soviet invasion of Afghanistan all created concern about the future availability of oil supply from the Middle East and induced a higher precautionary demand for oil.

Focusing on the most recent years (2002 to mid-2008), the large increase in the real oil price was driven by a series of positive aggregate demand shocks associated with shifts in global real economic activity. Interestingly, during the same period, we find that oil supply shocks played a negligible role in oil price fluctuations. We also observe that, at the end of 2008, the plunge in the real price of oil reflected the falls of aggregate demand and oil market-specific demand, respectively.

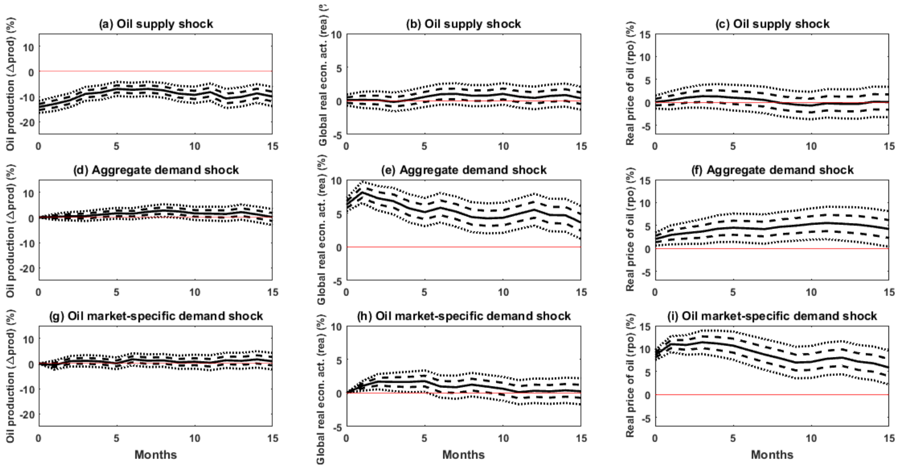
The last episode that we analyse concerns the surge in the oil price that occurred from 2011 to mid-2014. As we can see from Graph (c), there is evidence of a series of positive oil market-specific demand shocks. Indeed, serious concerns about political instability in the Middle East have emerged with protests taking place in Tunisia and Egypt. Some signs of civil unrest have also appeared in Lebanon, Algeria and Yemen. All these events have created concerns about future oil shortages in the Middle East. As Barrell et al. (2011) have argued, the repeated oil market-specific demand shocks which occurred in this period can also be explained by the sharp rise in investors' demand as the financial crisis unfolded, with investors pulling out of complex financial assets in search of a safer haven.

Figure 3 shows the impulse response analysis of global oil production, global real economic activity and the real price of oil to one-standard deviation structural shocks. We consider all the three shocks (oil supply, aggregate demand and oil market-specific demand) and we normalize their signs in order to induce an increase in the oil price to be consistent in their comparison.

Graph (a) shows that an unanticipated oil supply disruption implies an immediate strong reduction of global oil production. After five months, we observe a partial recovery of global oil production. This result is generally explained with the evidence that in the presence of a negative oil production shock in one region, producer countries of other areas in the world increase their production. From Graphs (b) and (c), we note that an unanticipated oil supply disruption does not significantly affect global real economy activity, while it causes a small and partially significant increase in the real price from second to fifth month.

We observe that an unexpected increase in aggregate demand implies an expansion of global oil production, that becomes significant five months after the shock occurs, a significant increase in the global real economic activity and a sharp, very persistent and statistically significant, increase in the real oil price.

Figure 3: Impulse Response Analysis to One St. Dev. Shocks



Note: Solid red lines: point estimates; dash and dotted blue lines: one and two standard error bands, respectively. The estimates are based on the SVAR model (1).

While an unanticipated expansion of oil market-specific demand does not influence global oil production, it causes a temporary increase in the global real economic activity, that is significant until the tenth month, and an immediate large increase in the real oil price. The last effect is very persistent and highly significant.

Our results confirm the findings of Kilian (2009) and Alquist and Kilian (2010). In particular, the most important result emerging from our IRF is that shortfalls in oil supply have small and partially significant effects on oil price changes. As argued above, oil supply disruptions in one region are compensated by increases of endogenous oil supply from other regions of the world. Accordingly, the question that arises is: how can one explain the large increases in the real oil price following the major political events in the Middle East? Figure 3 shows that the answer coincides with the sharp increases of precautionary demand for oil. These changes in precautionary demand are caused by shifts in expectations of future oil supply. Such expectations respond on impact to exogenous political events in the Middle East and cause a large increase in the oil price.

The cumulative effects of oil demand and supply shocks on the real price of oil are shown in Figure 4. These results confirm the previous findings that oil supply shocks have played a small role in terms of determination of oil price, while aggregate demand shocks and oil market-specific shocks explain most of the variation in the oil price.

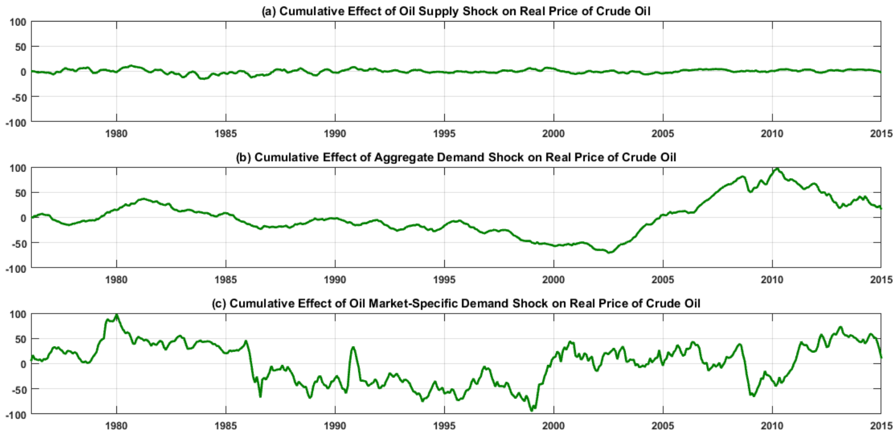
In particular, Graphs (c) shows that the surge in the oil price in 1980 was caused by the increase in precautionary demand for oil. From Graph (b) we note that, during the 1980-1982 period, aggregate demand grew continuously, causing the rise in the oil price. Therefore, the increase in the oil price that occurred in late 1979, which continued until 1985, was mainly caused by demand shocks, while during this period, oil supply shocks did not influence substantially oil price variation.

From Graph (a), we observe that the fall in the real price of oil that occurred in 1986 was mainly associated with the fall in oil market-specific demand. The increase of Saudi Arabia oil production following the fall of OPEC cartel in the late 1985 did not imply the drop in the oil price in 1986.

In 1990-1991, we note a large increase in the oil market-specific demand that caused a sharp increase in the oil price (i.e., precautionary demand for oil) in response to expected shortfalls in oil supply due to the Kuwait Invasion. The latter episode also caused a physical disruption in oil supply. Again, oil market-specific demand shock was the main cause of the oil price surge of 1999-2000.

Turning to more recent episodes of oil price fluctuations, we find that the increase in the oil price during the 2002-2008 period coincided with a very large swing in global real economic activity. Indeed, during this period, there was sustained global demand pressure and the oil price increased more than other commodity prices. The latter effect occurred because the supply of crude oil supply stagnated between 2002 and 2008. At the end of 2008, the drop in oil price was associated with the fall in oil market-specific demand.

Figure 4: Historical Decomposition of Real Oil Price



Note: Estimation results obtained from the SVAR model (1).

We know that between 2011 and mid-2014 there was a sustained increase in oil market-specific demand that pushed up the oil price and that this increase in precautionary demand for oil was associated with social and political instability in the Middle East and North African regions. In particular, the unrest sweeping through Tunisia in early 2011 rapidly spread over into many surrounding countries, including major oil producers, such as Algeria and, most significantly, Libya. Clearly, instability in the region automatically raised worries of supply disruptions and possible oil shortage. Moreover, between 2011 and mid-2014, the worsening of the financial crisis tended to increase precautionary demand for oil (Barrell et al., 2011).

Table 1 summarises the actual dates of the main (positive and negative) oil shocks as identified by our model.

Our analysis is in accordance with the results of Barsky and Kilian (2002) and Kilian (2009), which show that most large and persistent fluctuations in the real price of oil since the mid-1970's have been associated with the cumulative effects of oil demand rather than oil supply shocks. Moreover, our analysis contrasts with the traditional studies that suggest that all major fluctuations in the price of oil can be attributed to disruptions of oil supply triggered by political events occurred in the Middle East (Hamilton, 1983, 2003 and 2009).

Table 1: Major Oil Price Episodes

Date	Episode	Cause
1978-1979	Iranian Revolution	Aggregate Dem. & Oil Market-Specific Dem.
1980	Iran-Iraq War	Aggregate Demand & Oil Supply
1986	Fall of OPEC Cartel	Oil Supply
1990-1991	Iraq-Kuwait War	Oil Market-Specific Demand & Oil Supply
1999-2000	OPEC Supply Constraints	Oil Market-Specific Demand
2000-2008	Emerging Economies Growth	Aggregate Demand
End of 2008	Great Recession	Oil Market-Specific Demand
2011-2014	Arab Spring	Oil Market-Specific Demand

Notes: The several episodes are associated with the main causes as identified by our model.

The fact that flow supply disruptions have had small effects on the real oil price does not mean that political events in the Middle East do not matter. These events have affected the real oil price by shifting expectations about future shortages of oil supply relative to oil demand. As we explained above, in our model these expectations are captured by shocks to precautionary demand for oil, showing that oil market-specific demand shocks cause large fluctuations in the real oil price even when oil supply is unchanged.

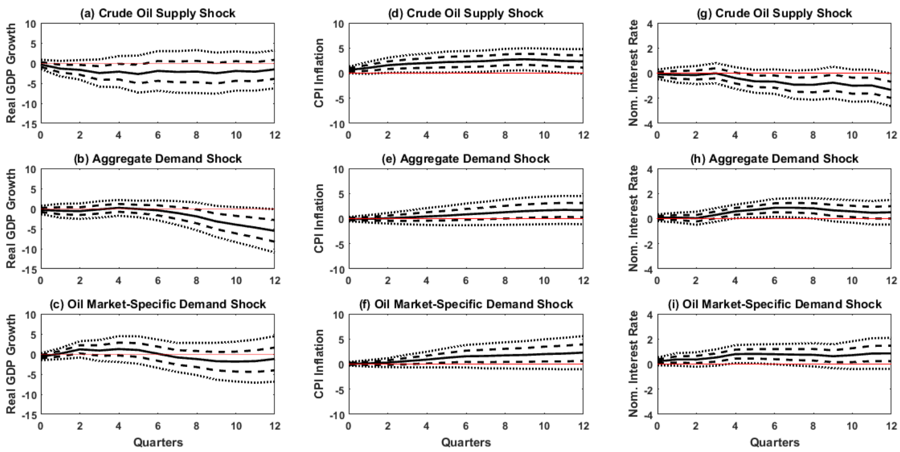
3.2. Assessing the Consequences of Oil Shocks on the UK Economy

Now we focus on the consequences of oil shocks on the UK economy. Firstly, we use separate bivariate VARs to assess the effects of different oil shocks on the UK real GDP growth, CPI inflation and nominal interest rate, respectively. Secondly, we estimate three distinct multivariate VARs including each single oil shock and four UK macroeconomic variables together (i.e., unemployment rate, real GDP growth, CPI inflation and nominal interest rate).

3.2.1. Benchmark VAR Approach

Figure 5 shows the responses of domestic GDP growth, CPI inflation and nominal interest rate to oil shocks obtained estimating our model according to equations (3)-(5).

Figure 5: IRFs of the UK Real GDP Growth, CPI Inflation and Nominal Interest Rate to Each Structural Shock



Note: Solid blue lines: point estimates; dash and dotted blue lines: one and two standard error bands, respectively. The IRFs are obtained estimating our model according to equations (3)-(5).

From Graph (a) we observe that the response of GDP growth to oil supply disruptions is negative throughout all quarters. However, the one-standard error confidence intervals indicate that the negative response is significant only for the first five quarters. Graph (b) shows that the immediate response of GDP growth to aggregate demand is not statistically significant. Six quarters after the shock occurs, it turns to negative and it becomes significant from the second year onwards. Instead, one-standard error confidence intervals, displayed in Graph (c), indicate that the response of GDP growth to oil market-specific demand shock is not statistically significant for the time frame analysed. There is only some evidence of a decline in GDP growth rate six quarters after the shock occurs.

Inspecting the inflation responses, from Graph (d) we note that negative oil supply shocks lead to statistically significant increases in CPI inflation throughout all quarters. Graph (e) shows the impact of increases in aggregate demand on the UK consumer price level is positive and statistically significant from the first year onwards. The maximum is reached three years after the shock occurs. Lastly, Graph (f) shows that the impact of expansions of oil market-specific demand on UK inflation is positive and significant from the fourth period onwards.

Turning to the BoE responses to oil shocks, Graph (g) shows that the nominal interest rate progressively falls in response to oil supply disruptions. One-standard error confidence intervals indicate that the response of the UK nominal interest rate to this shock is statistically significant starting from the fourth quarter. Graph (h) provides evidence that the increase in aggregate demand induces a positive nominal interest rate, statistically significant from the third quarter onwards. Finally, from Graph (i) we note that positive oil specific-market demand shocks cause a significant increase in the nominal interest rate throughout all quarters.

Overall, our results are in accordance with the findings of Millard and Shakir (2013) for the UK economy.[11] In particular, oil supply disruptions induce an immediate fall in GDP growth and cause a sustained increase in inflation. We find that increases in aggregate demand initially have a negligible effect on UK output growth, but in the long run they tend to depress it, in accordance with the

[11] Millard and Shakir (2013) have employed an empirical framework with time-varying parameters in order to understand how the impact of oil price shocks on the UK economy may have developed over time. However, as argued by Kilian (2014), the idea of analysing the responses of several macroeconomic aggregates to oil demand and supply shocks within a time-varying parameter VAR is not practical. Time-varying parameter VARs do not provide an efficient estimation since they consider samples that are not long enough in order to have a sufficient variation in oil demand and oil supply shocks. Moreover, our identifying assumptions hold only using data at monthly frequency. However, it is well documented that, although time-varying parameter VARs work well with quarterly data, they are computationally infeasible when using monthly data.

findings of Kilian (2009) for the US economy. This last result can be explained as follows. On impact, positive unexpected global economic shocks stimulate UK real GDP growth and offset the growth-retarding effects of a higher real price of oil. However, as this stimulus disappears over time, the response of UK GDP growth becomes negative. The most relevant example in this concern is the "Great Surge" in the real price of oil between 2002 and mid-2008. During this period, the UK economy did not experience any severe recession because the oil price surge was mainly driven by unexpectedly strong demand for oil from emerging Asia which offset the negative effects of higher oil prices and other imported commodities.

Similarly to the results of Peersman and Van Robays (2012), we find that positive precautionary demand shocks have a very small impact on GDP growth. This finding can be explained by the fact that the UK is an oil producing country. That is, the UK economy has been less affected by changes in inventory holdings compared to typical oil importing countries because it had the possibility to increase its own oil production in order to self-insure against interruptions to foreign oil supply instead of drawing upon inventory holdings.

Focusing on the UK monetary policy, we deduce that the BoE responds differently to oil price fluctuations associated with unanticipated booms in oil demand with respect to oil price changes due to unexpected oil supply disruptions. This result is consistent with the findings of Peersman and Van Robays (2012). Evidently, these different responses of the monetary authority relate to the corresponding effects of oil demand shocks and oil supply shocks on the UK economy.

For example, as we have shown in Figure 5, an unexpected demand boom driven by the global business cycle does not depress the UK economy in the short run. Conversely, an unanticipated oil supply disruption reduces immediately the UK real output growth. This implies different reactions of the UK monetary authority which depend on the composition of the oil demand and oil supply shocks underlying the oil price shock.

In particular, the evidence shows that the nominal interest rate increases after both an aggregate demand shock and an oil market-specific demand shock. In this regard, the positive response to aggregate demand shocks is consistent with the Bank of England's decision to raise interest rates before the oil price shock of 1978-1980. Indeed, looking at the 3 Month Treasury Bills series, it is evident that the Bank of England had been steadily raising interest rates from mid-1977 to the end of 1980.

Figure 5 also shows that negative shocks to oil supply induce the BoE to decrease the nominal interest rate. This result is in line with the findings of Kilian and Lewis (2011) about the behaviour of the Federal Reserve in the case of negative oil supply shocks. The negative response of the nominal interest rate to unanticipated oil supply disruptions is consistent with the view that the BoE considers the resulting oil price increases as adverse demand shocks.

3.2.2. Extended VAR Approach

In order to quantify the importance of different oil shocks with respect to other types of domestic shocks responsible for macroeconomic fluctuations in the UK economy, we extend the second stage of our empirical strategy including a VAR model in the spirit of Cover and Mallick (2012). In particular, we estimate three different five-variable structural VARs considering the effects of oil shocks (as identified in Section 3.1) on the UK unemployment rate (un_t), the growth rate of real GDP (Δy_t), the CPI (π_t) inflation and the short-term nominal interest rate (Δr_t).

In order to identify these three VARs, we use similar restrictions as in Cover and Mallick (2012) except for the fact that we do not include the UK exchange rate. More specifically, we assume the following Cholesky ordering: $\hat{\lambda}_{jt}$ (with $j = 1, 2, 3$), un_t, Δy_t, π_t and Δr_t. Our main assumption is that the oil shocks are predetermined with respect to the UK GDP growth, unemployment rate, CPI inflation and nominal interest rate. As we explained above, this assumption is plausible because the UK macroeconomic aggregates are not able to affect global oil market variables. Our remaining restrictions are as in Cover and Mallick (2012). Moreover, as in in Cover and Mallick (2012) and since lag lengths tests gave us mixed results, we decided to estimate our VARs with three lags.

In Appendix B, Figures B1-B3 show the impulse responses of unemployment rate, real GDP growth rate, CPI inflation and nominal interest rate to global oil supply, global aggregate demand and oil market-specific demand shocks, respectively. Overall, comparing these results with those of our benchmark model we note several similarities. For example, we find that aggregate and specific oil demand shocks do not reduce the real GDP growth in the short-run. However, in the long-run, in response to these shocks the real GDP tends to fall. In addition, crude oil supply, aggregate demand and specific oil demand shocks cause a strong and persistent increase in the CPI inflation. Finally, as in the benchmark model, the response of nominal interest rate tends to be positive in the presence of aggregate and specific demand shocks.

Now, we turn to the contribution of different oil shocks in terms of UK economy fluctuations. Tables 2-4 report the variance decompositions of the four UK macroeconomic fundamentals for our models including crude oil supply, aggregate demand and oil market-specific demand shocks. In addition, Tables 2-4 present the shares of the forecast-error variance explained by the UK technology, UK demand (IS), UK aggregate supply (AS) and UK monetary policy (MP) shocks as defined by Cover and Mallick (2012). We show the results for different forecast periods: 1 quarter, 5 quarters, 12 quarters and 30 quarters.

Table 2: Variance Decomposition

(Model including Crude Oil Supply)

Variable	Forecast	Structural Shock				
	Period	Crude Oil Supply	UK Technology	UK IS	UK AS	UK MP
un_t	1	0.09	99.91	0.00	0.00	0.00
	5	0.98	79.35	9.58	4.05	6.03
	12	2.21	65.60	9.14	10.05	12.99
	30	2.26	63.46	10.33	12.43	12.51
Δy_t	1	0.66	8.67	90.67	0.00	0.00
	5	4.13	13.56	72.14	1.11	9.06
	12	4.33	13.15	70.04	1.80	10.67
	30	4.32	13.12	69.96	1.97	10.63
π_t	1	2.11	4.10	0.07	93.72	0.00
	5	5.88	2.70	12.57	72.25	6.60
	12	5.11	2.03	18.91	68.52	5.43
	30	4.77	1.84	21.11	67.39	4.90
Δr_t	1	0.20	1.73	0.75	4.39	92.92
	5	2.50	5.64	2.95	4.36	84.56
	12	2.58	5.65	3.24	4.54	83.99
	30	2.58	5.65	3.27	4.47	83.93

Notes: Percentages of forecast-error variance explained by each structural shock. In the above table, un_t represents the change in unemployment, Δy_t the growth rate of real GDP, π_t the inflation and Δr_t the change in T-Bills. Results are obtained estimating a VAR model similar to Cover and Mallick (2012).

Our findings are in line with those obtained by Cover and Mallick (2012) in terms of technology, IS, AS and MP shocks. In the long-run, technology and IS shocks contribute for most of the variation in the real GDP growth (between 83% and 84% in the three different models). Moreover, after 30 quarters, the variance of the change in the unemployment rate is mostly affected by the technology shock (between 58% and 63%). Our results also show that the aggregate supply shock has the main impact on inflation explaining between the 65% and 67% of its long-run variance. As expected, the monetary policy shock mainly affects the variation of the nominal interest rate in the long-run (between 77% and 84%).

Table 3: Variance Decomposition
(Model including Global Aggregate Demand)

Variable	Forecast	Structural Shock				
	Period	Global Agg. Dem.	UK Technology	UK IS	UK AS	UK MP
un_t	1	0.37	99.63	0.00	0.00	0.00
	5	3.57	78.13	9.79	3.46	5.05
	12	7.56	64.62	9.11	9.98	8.73
	30	8.10	61.28	9.96	12.28	8.38
Δy_t	1	1.59	7.59	90.82	0.00	0.00
	5	2.63	12.39	76.06	1.37	7.55
	12	4.82	11.94	72.75	2.23	8.25
	30	4.87	11.89	72.58	2.44	8.22
π_t	1	1.03	3.35	0.21	95.41	0.00
	5	7.41	2.73	13.05	72.60	4.22
	12	9.21	1.99	17.97	67.50	3.33
	30	9.12	1.82	19.82	66.22	3.03
Δr_t	1	6.48	1.38	0.30	3.13	88.70
	5	11.49	4.02	2.54	3.59	78.36
	12	11.80	4.11	2.69	3.87	77.53
	30	11.82	4.10	2.73	3.86	77.39

Notes: Percentages of forecast-error variance explained by each structural shock. In the above table, un_t represents the change in unemployment, Δy_t the growth rate of real GDP, π_t the inflation and Δr_t the change in T-Bills. Results are obtained estimating a VAR model similar to Cover and Mallick (2012).

With respect to Cover and Mallick (2012), we are able to quantify the importance of different oil shocks on the variation of the main UK macroeconomic aggregates. In particular, we find that, after 30 quarters, the crude oil supply shock contributes for the 2% of the variation of the change in the unemployment rate, the 4% in the GDP growth, the 5% in inflation and the 3% in the nominal interest rate. From Table 3 we see that in the long-run the aggregate demand shock explains the 8% of the fluctuation in the unemployment rate, the 5% in the GDP growth, the 9% percent in inflation and the 12% in the nominal interest rate. Our results indicate that after 30 periods the oil market-specific demand shock accounts for the 12% of the variance of the change in the unemployment rate, the 5% in the GDP growth rate, the 6% in the inflation and the 3% in the nominal interest rate.

Table 4: Variance Decomposition (Model including Oil Market-Specific Demand)

Variable	Forecast	Structural Shock				
	Period	Oil Spec. Dem.	UK Technology	UK IS	UK AS	UK MP
un_t	1	0.00	100.00	0.00	0.00	0.00
	5	6.44	76.07	9.46	2.62	2.62
	12	12.07	60.40	8.04	6.36	6.36
	30	12.04	58.00	8.85	8.19	8.19
Δy_t	1	0.01	6.38	93.61	0.00	0.00
	5	3.61	10.25	76.44	1.01	1.01
	12	5.10	9.88	72.84	1.45	1.45
	30	5.11	9.84	72.70	1.64	1.64
π_t	1	1.45	3.44	0.18	94.93	94.93
	5	6.83	2.27	14.02	70.87	70.87
	12	6.85	1.67	20.01	66.14	66.14
	30	6.47	1.54	22.07	65.06	65.06
Δr_t	1	1.11	2.14	0.52	4.03	4.03
	5	2.17	5.38	2.98	4.24	4.24
	12	2.76	5.37	3.24	4.31	4.31
	30	2.77	5.37	3.26	4.35	4.35

Notes: Percentages of forecast-error variance explained by each structural shock. In the above table, un_t represents the change in unemployment, Δy_t the growth rate of real GDP, π_t the inflation and Δr_t the change in T-Bills. Results are obtained estimating a VAR model similar to Cover and Mallick (2012).

In general, our findings show that oil shocks play a non-negligible role in terms of variations in the main UK macroeconomic aggregates. In particular, comparing between different oil shocks we observe that oil market-specific demand shocks are the most important in explaining the real GDP growth rate and change in unemployment rate. On the contrary, inflation and nominal interest rate are mostly affected by the aggregate demand shock. Therefore, these findings confirm the relative importance of oil demand shocks with respect to oil supply shocks in the case of the UK economy.

4. Robustness Analysis

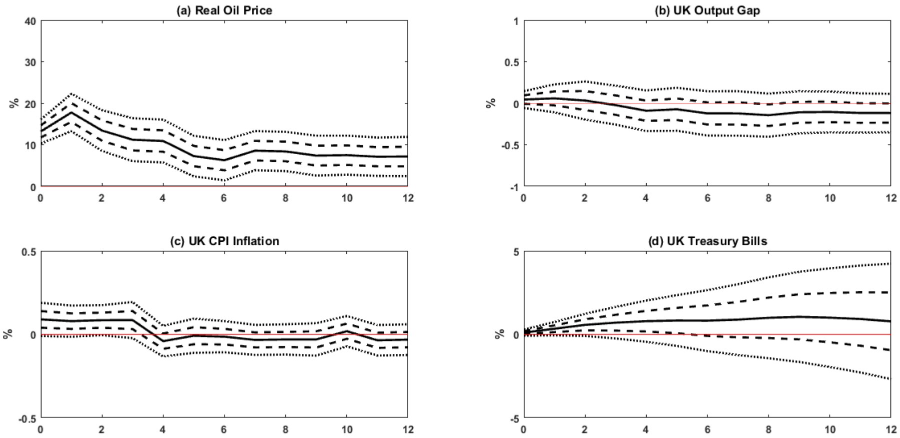
In the previous sections we have found that the UK monetary policy responds differently to the underlying sources of oil price shocks. In what follows, we show that there is no evidence of the UK monetary policy response to exogenous oil price shocks. More specifically, we estimate a VAR model including four variables: the percentage change in the real oil price (Δrpo_t), a measure of the UK output gap (y_t^{gap}), CPI inflation (π_t) and 3 Month Treasury Bills (r_t).[12] The identification of the VAR model is based on a recursive ordering. The variables order is the following: Δrpo_t, y_t^{gap}, π_t and r_t. This ordering corresponds to the conventional assumption that oil prices are predetermined with respect to domestic macroeconomic aggregates. The main question of interest is how the BoE responds to an oil price shock. We consider one standard deviation increase in the real oil price. Figure 6 shows the impulse responses of UK output gap, CPI inflation and treasury bills to such a shock.

The oil price shock is associated with a persistent increase in the real price of oil. CPI inflation increases for the first three quarters. However, such response is not significant from the 4^{th} period onwards. Following the rise in inflation, the nominal interest rate increases and remains significant for four quarters. The response of output gap is not significant for all the periods considered. These results suggest that there is no evidence of the BoE response to exogenous oil price shocks. This finding is confirmed by the historical decomposition reported in Figure 7. As a matter of fact, this figure plots the actual (detrended) data for output gap, CPI inflation and treasury bills and the fluctuations in the same variables explained by the direct effect of oil price shocks. From Figure 7, we note that the cumulative

[12] Our data are quarterly for the sample period 1975:Q1-2015:Q1. Appendix A provides a detailed description of the series used for the estimation.

contribution of oil price shocks on output gap and inflation is negligible through time. Similarly, we see that oil price shocks had a very small impact on treasury bills over the entire sample.

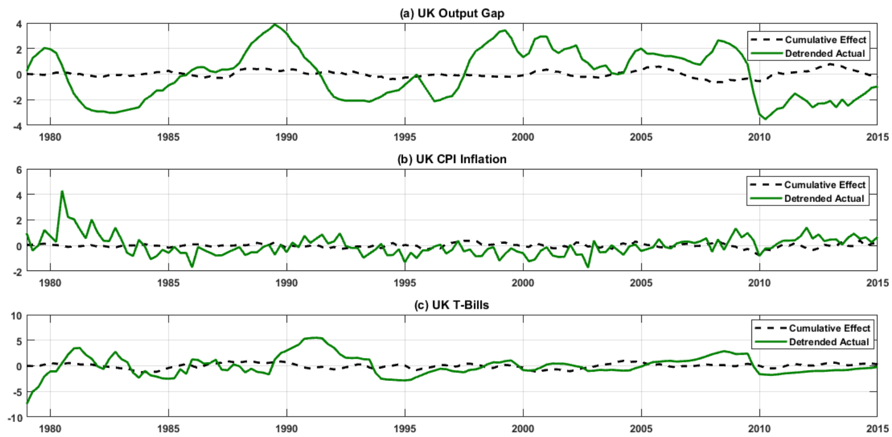
Figure 6: Responses to Real Oil Price Shock



Notes: estimates based on a recursively identified VAR (12) model for the percentage change in the real oil price, UK output gap, consumer price index inflation and 3-month treasury bills. Solid black lines: point estimates; dash and dotted black lines: one and two standard error bands, respectively.

Overall, these results confirm our approach. The reason why the conventional monetary policy reaction model fails to explain large fluctuations in UK macroeconomic aggregates is related to the fact that the sources of oil price shocks are different. As we have shown in Figure 5, the BoE responds differently to unexpected shocks to oil demand and supply. In particular, global oil production shocks induce a negative response of GDP growth whereas this is not the case for aggregate and specific demand shocks. Moreover, we have seen that the BoE increases its policy rate in the presence of unanticipated booms in aggregate and specific oil demand whereas the nominal interest rate drops due to unexpected oil supply disruptions.

Figure 7: Cumulative Effects of Real Oil Price Shocks on UK Output Gap, Inflation and Nominal Interest Rate



Notes: Historical decompositions constructed from the model underlying Figure 6.

5. Conclusions

In this paper, we have studied the causes and the consequences of oil price fluctuations on the UK economy. Our empirical approach assumes that the real oil price is endogenous with respect to macroeconomic fundamentals and identifies the causes and consequences of oil price shocks by a two-stage method. In the first stage, we identified shocks to the world oil price due to oil supply, aggregate demand and oil market-specific demand. In the second stage, we assessed the impact of structural innovations estimated in the first stage on several UK macroeconomic aggregates.

Several important insights emerge from our analysis. We find that, since the mid-1970's, shortfalls in oil supply have had small effects on oil price changes. Therefore, our results contrast with the view that major oil price changes are caused by disruptions in oil supply triggered by exogenous political events occurring in the Middle East. Instead, we find that major fluctuations in the real oil price coincide with shifts in precautionary demand for oil.

Our IRFs show different responses of UK macroeconomic aggregates depending on the underlying shock affecting oil price. More specifically, GDP growth goes down immediately in response to negative oil supply shocks whereas increases in aggregate and specific oil demand, initially, have small effects on domestic output growth but, in the long run, they tend to reduce it. In general, our estimated responses show that oil shocks cause a sustained increase in UK inflation.

We also quantify the effects of different types of oil shocks on the variation in the main UK economic fundamentals. Comparing between oil shocks we find that aggregate demand shocks are important in explaining changes in inflation and interest rate, whereas oil market-specific demand shocks substantially contribute to fluctuations in GDP growth and unemployment rate.

Focusing on UK monetary policy, we find no evidence of a direct response of the BoE to oil price shocks. On the contrary, the BoE responds to the different sources of oil price shocks. In particular, the nominal interest rate increases after both aggregate demand shocks and oil market-specific demand shocks. The opposite occurs in the case of negative shocks to oil supply.

To conclude, we believe that the empirical approach presented in this paper provides a useful framework in order to understand the causes and the consequences of oil price shocks on the UK economy. Given the promising results of this paper, we consider as a sound extension of this work the development of a DSGE model which is able to distinguish between several causes of fluctuations in the global demand for industrial commodities and to estimate the impact of alternative policy choices. We leave this area of investigation for future research.

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Appendix A: Data

$\Delta prod_t$: as we described in the main body of the paper, this is the percentage change of global crude oil production. This series is obtained by the log differences of world crude oil production in millions per barrels pumped per day (averaged by month). The source is the US Department of Energy.

rea_t : as we described in the main body of the paper, this is the index of the global real economic activity. The source of this series is Kilian website: http://www-personal.umich.edu/~lkilian/reaupdate.txt.

Kilian (2009) provides a clear explanation in order to obtain rea_t. In particular, the data series to construct this index are taken from representative single-voyage freight rates available in the monthly report on "Shipping Statistics and Economics" published by Drewry Shipping Consultants Ltd. These data series relate to various bulk dry cargoes consisting of grain, oilseeds, coal, iron ore, fertilizer and scrap metal. In order to eliminate the fixed effects for different routes, commodities and ship sizes, Kilian adopts two steps. Firstly, he computes the period-to-period growth rates for each series. Secondly, he takes the equal-weighted average of these growth rates and cumulates the average growth rate. The final series is deflated by the US CPI and linearly detrended. The base month is January 1986. Kilian also provides evidence that this index based on industrial commodity markets well represents the level of global real economic activity.

rpo_t : as we described in the main body of the paper, this is the real price of oil and it is expressed in log terms. This series is obtained from Europe Brent spot price FOB. The source is DataStream database. The nominal series of oil price is deflated by the US CPI. The source is the US Bureau of Economic Analysis.

Δy_t : it is the growth rate of UK real GDP. This series is obtained by the log differences of real UK GDP: "gross domestic product, chained volume measures, seasonally adjusted (£m)". The source is Office for National Statistics (code ABMI in Quarterly National Accounts).

π_t : it is the UK CPI inflation. This series is obtained by the log differences of UK consumption expenditure deflator: "final consumption expenditure by household and NPISH deflator, seasonally adjusted (base period: 2011)". The source is Office for National Statistics (code YBFS in Quarterly National Accounts).

Δr_t : it is the UK short-term nominal interest rate. This series is obtained by the 3 month treasury bills: "quarterly average rate of discount, 3 month treasury bills (Sterling)". The source is Bank of England (code IUQAAJNB in Statistical Interactive Database).

un_t : it is the UK unemployment rate. This series is obtained by the "unemployment rate (aged 16 and over, seasonally adjusted) %". The source is Office for National Statistics (code MGSX in Labour Market Statistics).

y_t^{gap} : it is the UK output gap. This series is obtained by the "OBR central estimate of the output gap (per cent of potential output)". The source is the Office for Budget Responsibility (March 2017 Economic and Fiscal Outlook: Economy supplementary tables - Table 1.20).

Appendix B: IRFs of the Extended VAR

The following IRFs are obtained estimating a VAR model similar to Cover and Mallick (2012). The solid black lines represent point estimates whereas the dash and dotted black lines denote one and two standard error bands, respectively.

Figure B1: Responses to Crude Oil Supply Shock

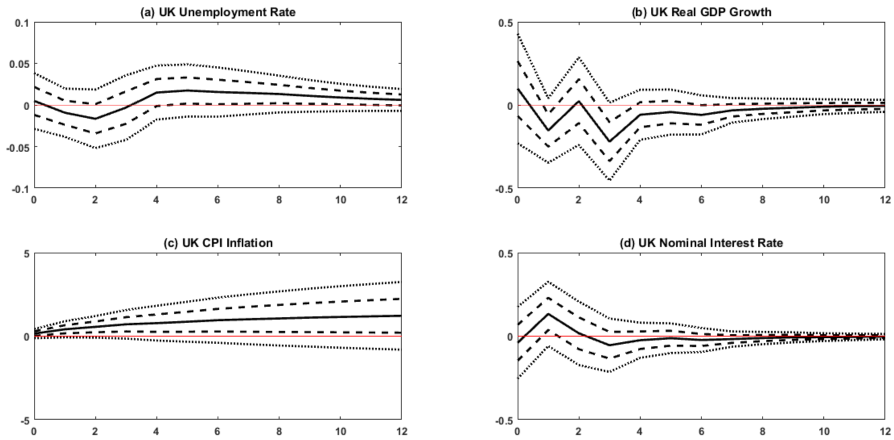

Figure B2: Responses to Aggregate Demand Shock

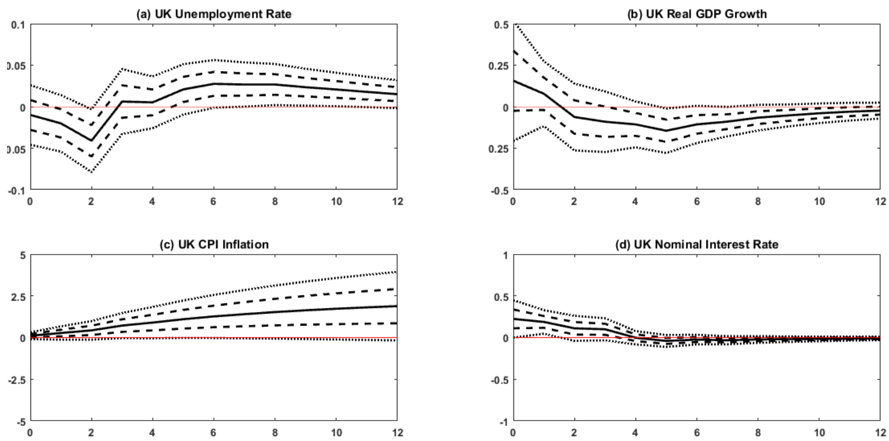

Figure B3: Responses to Oil Market-Specific Demand Shock