Bank of Japan Working Paper Series

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No.16-E-17
November 2016

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Identifying Oil Price Shocks and Their Consequences: Role of Expectations and Financial Factors in the Crude Oil Market

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NOVEMBER 2016

Abstract

This paper proposes a simple but comprehensive structural vector autoregression (SVAR) model to examine the underlying factors of oil price dynamics by explicitly incorporating the role of expectations on future aggregate demand and oil supply as well as financial investors' role in the crude oil market. Our main findings are threefold. First, our empirical analysis shows that shocks on expectations and financial factors in the oil market explain more than 40 percent of historical oil price fluctuations. In particular, expected future oil supply shocks are more than twice as important as realized and expected aggregate demand shocks or financial factor shocks in accounting for the oil price developments. Second, focusing on a recent large drop in oil prices since 2014, the analysis reveals that expected future oil supply shocks were the dominant driver of oil price falls from January 2014 to January 2015, while expected and realized aggregate demand shocks played a major role in oil price falls from June 2015 to February 2016. Finally, we show that the influence of oil price shocks on global output varies by the nature of each shock.

JEL classification: C32, E44, G12, G15.

Keywords: Oil demand and supply, Oil price, Financial factor, Structural vector autoregressive model.

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* We are grateful for the helpful comments from the staff of the Bank of Japan. Currently, Jouchi Nakajima is at the Bank for International Settlements, and Yoichiro Tamanyu is at the University of Oxford. The views expressed herein are those of the authors alone and do not necessarily reflect those of the Bank of Japan or the Bank for International Settlements.

1. Introduction

The causes and consequences of oil price dynamics have attracted much attention among academics and policy makers as well as market practitioners. Recently, it is well acknowledged that we need to identify a number of economic and financial structural factors driving oil price fluctuations in order to better understand the oil price dynamics. In addition, each structural factor could have a significantly different impact on the real economy. However, the quantification of each structural factor behind the oil price fluctuations remains an open question. Regarding this issue, Arezki and Blanchard (2015) and World Bank (2015) raise and discuss several questions. The goal of this paper is to address two of them: "What are the respective roles of demand and supply factors?" and "What are the effects likely to be on the global economy?"

Among the literature regarding the oil price shocks and their influence on the economic activity, one of the most distinguished is Kilian (2009). He proposes a novel structural vector autoregression (SVAR) model to identify the three contributing factors in accounting for oil price fluctuations: flow demand shocks, flow supply shocks, and other factors involving *oil-specific demand*. The last component is designed to include *any* factors affecting swings in the real price of oil after controlling for oil supply and global demand shocks. He shows that those three shocks have considerably different effects on the oil price and the real economy.

Since this seminal work of Kilian (2009), a wide variety of extensions have been proposed. Among them, Ratti and Vespignani (2013) extend the SVAR model by incorporating a monetary factor such as global real money stocks. They point out that the global real money stocks have a statistically significant effect on oil prices, and that its historical impact is sizable in the phase of increase in oil prices from 2009 to 2011.

Kilian and Murphy (2014) and Kilian and Lee (2014) refine Kilian (2009) to allow for an explicit role of the speculative oil demand as well as of flow demand and supply, exploiting time series data on oil inventories. A key intuition of Kilian and Murphy (2014) is that there exist some factors which are not captured by realized (or flow) demand and supply shocks, and that one of them can be "any expectations of a shortfall of future oil supply relative to future oil demand." They show in their empirical study that the factor of future supply shock has a significant effect on the oil price.

According to Kilian (2014), the empirical studies following Kilian (2009) provide the evidence that oil demand shocks associated with the global business cycle explain a major component of oil price fluctuations, while oil supply shocks sometimes play a nonnegligible role. In addition to the demand and supply factors, financial factors of oil future trade provide an alternative transmission channel of expectations on oil price. Basak and Pavlova (2013) imply that the activity of financial investors in the oil future market amplifies earlier realized and expected shocks. The quantitative significance of this amplification mechanism is an open question according to Kilian (2014), however.

More recently, there is an increasing number of studies that focus on the causes and consequences of the large fall in oil prices from mid-2014 to 2016. World Bank (2015) raises the following four causes of sharp oil price drop: a trend of greater-than-anticipated supply and less-than-anticipated demand, changes in OPEC objectives, fading geopolitical concerns about supply disruptions, and US dollar appreciation. While this World Bank's address is qualitative, several studies have examined quantitative assessments. On one hand, Baumeister and Kilian (2015) show the evidence that more than half of the price decline from mid-2014 to 2016 was predictable as of June 2014, because it owes to the adverse shocks that hit the oil market prior to June 2014. On the other hand, Davig et al. (2015) decompose the oil price fluctuation with the technique of Kilian (2009) and find that *oil-specific* or *precautionary demand* shocks mostly drove the oil price decline.

The finding of Davig et al. (2015) clearly reveals the limitation of the methodology developed in Kilian (2009): it is not well defined to identify factors driving *oil-specific demand* shocks, although we assume that it potentially reflects changes in expectations and uncertainty about future oil supply and future global real activity as well as financial shocks. Since "not all oil price shocks are alike" as is pointed out in Kilian (2009), it would be difficult to better examine the causes and consequences of the recent declines in oil prices without identifying factors that involve the *oil-specific demand* shocks.

To address the limitation, this paper develops a simple but comprehensive methodology, studying the components of the *oil-specific demand* shocks.

Our model has two distinguishing features from the literature. First, we develop an extended SVAR model which incorporates the role of expectations on future global aggregate demand and future oil supply, in addition to the traditionally-used factors, realized aggregate demand and oil supply. Since it is widely accepted that swings in expectations about future real economic activity and future crude oil supply play an important role in accounting for the oil price development, it is quite straight-forward to develop a model for the quantification of these factors.[1] We identify expected aggregate demand shocks and expected future oil supply shocks, based on the revision of global economic growth by professional forecasters and on the changes in oil inventory respectively, in order to examine their impacts on the oil price in an endogenous manner.[2]

Second, we explicitly take account of the role of financial investors' positions as the driver of oil price fluctuations. Since oil future contracts are traded in public exchanges, not only the physical oil demand and supply but also the positions taken by financial investors can affect oil prices. Basak and Pavlova (2013) propose a model where the presence of financial investors amplifies the response of the real oil price to realized aggregate demand shocks. In the current paper, we address the impact of changes in the expectations of financial investors on oil price, using the net position of non-commercial investors in the crude oil future market, in addition to the transmission of any other structural shocks through the oil future market.

Using our ground-breaking model, we identify six oil price shocks, namely realized oil supply shock, realized aggregate demand shock, expected aggregate demand shock, expected future oil supply shock, financial factor shock from the crude oil future market, and oil-price specific shock. We then disclose the mechanism of the oil price development as well as these shocks' influence on the global industrial output.

This paper contributes to the discussion regarding the causes and consequences of oil price decline from mid-2014 to 2016 by quantitatively identifying oil price shocks and their consequences. In the existing studies, a consensus that various factors including expected future oil demand and supply have contributed to the oil price decline seems to have been reached. There is, however, no consensus regarding the extent to which each of those factors has contributed quantitatively. In addition, there is intense discussion as to why the positive impact of oil price decline on the global economy has not yet clearly materialized. We contribute to these discussions by identifying the oil price shocks behind the recent oil price fall and quantitatively examining their impact on the real oil price as well as the global industrial output.

Our main findings are threefold:

[1] For example, see Bernanke (2016), and Davig et al. (2015).

[2] Kilian and Hicks (2013) examine the relationship between the revision of professional GDP growth forecasts and the oil price, using the model in which the revision of the growth rate is treated as an exogenous shock.

First, our analysis sheds new light on the effects of expectations on the oil market: *expected* future oil supply shocks and *expected* aggregate demand shocks have a significant effect, compared with the *realized* shocks. Our variance decomposition shows that the expected shocks account for about 36 percent of oil price variance at twelve months, although the realized shocks explain only about 5 percent. In addition, we find financial factors also play an important role. About 11 percent of the variance is contributed by the financial factors at twelve months. This implies that shocks on expectations and financial factors in the oil market explain more than 40 percent of oil price variance. In particular, expected future oil supply shocks are more than twice as important as realized and expected aggregate demand shocks or financial factor shocks.

Second, focusing on a recent large drop in oil prices, the analysis implies that expected future oil supply shocks were the dominant driver of oil price falls from January 2014 to January 2015, while expected and realized aggregate demand shocks played a major role in the episode of oil price falls from June 2015 to February 2016. In particular, although the oil price decreased in real terms by approximately 50 percent from January 2014 to January 2015, about 40 percentage points are attributed to the expected future oil supply shocks. On the other hand, when looking at real oil price declines by approximately 30 percent from June 2015 to February 2016, about 20 percentage points could be explained by the realized and expected aggregate demand shocks. In addition, financial factor shocks also played an important role in accounting for the declines: about 12 percentage points were devoted to the financial factor.

Finally, we show that the effects of oil price dynamics on the global economy depend on the factors behind it; for example, an unexpected increase of global oil supply will cause a small increase in the global output. Both realized and expected negative aggregate demand shocks bring the global output down. More interestingly, both positive expected future oil supply shocks and negative oil-price specific shocks initially push the global output down, probably reflecting the contractions in the upstream investments of the crude oil. Almost one year later, however, the global output increases. Financial factor shocks to lower the real price of oil bring a small but significant increase in the global output.

The remainder of this paper is organized as follows. Section 2 describes the methodology and the data to identify the structural shocks as key determinants of real oil price movements. In Section 3, we quantify their influence on the real oil price and assess which shocks contribute to drive the real price of oil. In addition, we discuss the influence of these structural shocks behind the fluctuations of real oil price on the global economy. Section 4 concludes.

2. Methodology and Data

This section presents our model of the oil market. In the next subsection, we briefly describe a novel methodology proposed in Kilian (2009) and discuss the limitation. To address it, we propose our simple method in the following subsection.

2.1 Kilian (2009)

Kilian (2009) proposes a novel structural vector autoregression (SVAR) model to identify underlying demand and supply shocks in the global oil market. Specifically, the representation can be expressed as

$$\mathrm{A}_0 \mathrm{z}_t = \alpha + \sum_{i=1}^{k} \mathrm{A}_i \mathrm{z}_{t-i} + \varepsilon_t, \tag{1}$$

where ε_t refers to the vector of serially and mutually uncorrelated structural innovations, and $\mathrm{z}_t = (\Delta \mathrm{prod}_t, \mathrm{rea}_t, \mathrm{rpo}_t)'$, where $\Delta\mathrm{prod}_t$ represents the percent change in global crude oil production, rea_t implies the index of real economic activity, and rpo_t denotes the real price of oil. Let e_t denote the reduced form VAR innovations such that $\mathrm{e}_t = \mathrm{A}_0^{-1}\varepsilon_t$. The structural innovations are derived from the reduced innovations by imposing recursive exclusion restrictions on A_0^{-1}.

The identification restrictions on A_0^{-1} are imposed as follows:

$$\mathrm{e}_t \equiv \begin{pmatrix} \mathrm{e}_t^{\Delta\mathrm{prod}} \\ \mathrm{e}_t^{\mathrm{rea}} \\ \mathrm{e}_t^{\mathrm{rpo}} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{\text{oil supply shock}} \\ \varepsilon_t^{\text{aggregate demand shock}} \\ \varepsilon_t^{\text{oil specific demand shock}} \end{pmatrix}.$$

Realized oil supply shocks are designed as unexpected innovations to global oil production. Innovations to global economic activity that cannot be explained by realized oil supply shocks refer to realized aggregate demand shocks. Finally, by construction, innovations to the real oil price could represent *any* factors having an impact on the real price of oil after controlling realized oil supply and aggregate demand shocks.

It is worth stressing that Kilian (2009) suffers from a limitation: there are many possible interpretations on the oil market specific shocks. That is, it is not well defined to identify factors driving oil-specific demand shocks. One possible explanation is that oil specific demand shocks may capture changes in the precautionary demand for oil, as mentioned by Davig et al. (2015) and Kilian (2009). We could assume that it potentially might reflect fluctuations in market expectations on availability of future supply or demand.[3] However, the method proposed in Kilian (2009) does not allow us to quantify the roles of expectations on future oil supply or aggregate demand in accounting for the effects and consequences of oil price fluctuations.

As is discussed in Kilian (2009), each structural shock should have a different dynamic impact on real oil prices and the real economy. In order to better quantify the causes and consequences of oil price fluctuations, it is required to disentangle each structural shock and properly separate the effects of each. In particular, it is well acknowledged that the main driver of recent declines in oil prices should be the oil specific demand shocks, as in Davig et al. (2015). This motivates us to identify the factors driving the oil specific demand shocks properly.

2.2 Our Methodology

To address the limitation, we extend the method proposed in Kilian (2009). Departing from it, we introduce three more variables into the VAR model (1): the revisions in professional forecasts about annual real GDP growth of the global economy for the next year, the percent change in the oil inventory, and the changes in net position of non-commercial traders. As is discussed below, this allows us to identify shocks to "expectations" on future demand and supply as well as financial factors.

Specifically, we estimate a SVAR model constructed with data for $\mathrm{z_t} = (\Delta\mathrm{prod_t}, \mathrm{rea_t}, \Delta\mathrm{CF_t}, \Delta\mathrm{Stock_t}, \Delta\mathrm{Net_t}, \mathrm{rpo_t})$, where $\Delta\mathrm{prod_t}$ is the percent change in global oil production, $\mathrm{rea_t}$ represents the global real aggregate demand, $\Delta\mathrm{CF_t}$ denotes the forecast revisions of the global aggregate demand, $\Delta\mathrm{Stock_t}$ is the percent change in the oil inventory, $\Delta\mathrm{Net_t}$ represents the revisions of net position of oil, and $\mathrm{rpo_t}$ refers to the real price of oil.[4] All data are monthly, and the sample period is

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[3] Davig et al. (2015) provide an example on this interpretation.

[4] We employ the index of industrial production as a proxy for the global aggregate demand, instead of using the BDI index as in Kilian (2009). This is because the BDI might include some factors such as weather factors and shipping shortages (or oversupply) that are not relevant to economic activity, as is pointed out in Beidas-Strom and Pescatori (2014). For example, the BDI swings relative to the IIP due to shipping shortages or oversupply. In addition, since the crude oils are storable and relatively homogeneous, any swings of market participants' expectation on future oil demand and supply may influence the demand and supply of cargo vessels and thus the BDI. With these respects, we consider that the global industrial production is the better proxy of the global aggregate demand for oil than the BDI.

from March 2005 to February 2016.[5] The detail of data is described in the appendix.

Based on (1), we have six structural shocks to be identified in the model as realized oil supply shocks, realized aggregate demand shocks, expected aggregate demand shocks, expected future oil supply shocks, financial factor shocks, and other oil-price specific shocks. Let $\mathrm{e_t}$ denote the reduced form VAR innovations such that $\mathrm{e_t} = \mathrm{A}_0^{-1}\varepsilon_\mathrm{t}$. The structural innovations are derived from the reduced innovations by imposing recursive exclusion restrictions on A_0^{-1}.[6] In particular, our identification restrictions on A_0^{-1} are imposed as follows:

$$\mathrm{e_t} = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} \end{bmatrix} \varepsilon_\mathrm{t},$$

$$\text{where } \mathrm{e_t} = \begin{pmatrix} \mathrm{e_t^{\Delta prod}} \\ \mathrm{e_t^{rea}} \\ \mathrm{e_t^{\Delta CF}} \\ \mathrm{e_t^{\Delta Stock}} \\ \mathrm{e_t^{\Delta Net}} \\ \mathrm{e_t^{rpo}} \end{pmatrix} \text{ and } \varepsilon_t = \begin{pmatrix} \varepsilon_\mathrm{t}^{\text{oil supply shock}} \\ \varepsilon_\mathrm{t}^{\text{aggregate demand shock}} \\ \varepsilon_\mathrm{t}^{\text{expected aggregate demand shock}} \\ \varepsilon_\mathrm{t}^{\text{expected future oil supply shock}} \\ \varepsilon_\mathrm{t}^{\text{financial factor shock}} \\ \varepsilon_\mathrm{t}^{\text{oil-price specific shock}} \end{pmatrix}.$$

The exclusion assumptions could be interpreted in the following way: *Realized* oil supply shocks are defined as unexpected innovations to global oil production as in Kilian (2009). Oil production is assumed not to respond to other shocks within the same month due to the adjusting cost of oil production and the uncertainty about the future state of the oil market. *Realized* aggregate demand shocks correspond to shocks to global industrial production that cannot be explained by realized oil supply shocks. The exclusion assumption implies that realized aggregate demands for crude oil are assumed not to respond to shocks on *expected* future demand and supply of crude oil and other below shocks in a month. This is also due to the uncertainty. *Expected* aggregate demand shocks are innovations to professional projection of global economic growth which cannot be explained by realized aggregate demand and oil supply. Expected future oil supply shocks are defined as innovations to the US oil inventory stocks which

[5] We choose March 2005 as the starting point of the sample, because the CUSUM structural break test identifies a break in the time-series of the real oil price in March 2005.

[6] We find that the empirical results with other different variable orderings are in line with those under our baseline ordering discussed in Section 3.

are attributable to neither realized aggregate demand, oil supply of crude oil, nor expected aggregate demand. Expected future oil shocks are considered as shocks on the expectation of oil supply in the coming months or years. Expected future oil supply is assumed not to respond to shocks to financial factor shocks or any other developments of the real oil price. Financial factor shocks are referred to as innovations to net positions of non-commercial traders. As is implied in Basak and Pavlova (2013), this kind of shocks captures those to the activity of financial investors in oil future market such as shocks to the risk appetite for the investors.

Lastly, other or *oil-price specific* shocks are defined as innovation to the development of real oil price after controlling the effects from the above-mentioned factors. That is, from the assumption on A_0^{-1}, the oil-price specific shocks represent any factors affecting the real price of oil after controlling the other preceding structural shocks explained above, such as those impacts stemming from the increased presence of pension funds in the oil market, or the shocks to changes in the risk appetite for the investors in any other financial markets.

3. Empirical Results

3.1 The Structural Shocks Behind the Oil Price Shocks and Their Influence

Figure 1 exhibits the historical evolution of structural shocks identified by our model, which shows that our identified structural shocks are consistent with some specific episodes.[7] The first panel shows that realized oil supply shocks are identified as positive in 2014 and 2015. This implies that the increase in oil supply might have contributed to the oil price plunge since mid-2014. Realized aggregate demand shocks become negative in 2008, representing the economic contraction after the Global Financial Crisis (GFC). From 2010 to 2014, realized aggregate demand shocks are positive, suggesting the demand pull for oil price in that period. Expected aggregate demand shocks are also positive from 2012 to 2014. Both realized and expected aggregate demand shocks turn negative in 2015, which implies that demand factors might contribute to the oil price decline. More interestingly, expected future oil supply shocks show a relatively large swing. It is negative in 2007, corresponding to the hike in oil price in the latter half of 2007, and becomes positive in 2014 and 2015, which suggests that an expected increase in future oil supply might drive the real oil price to plunge largely. Both financial factor shocks and oil-price specific shocks are negative in

[7] Structural shocks are expressed as annual averages for readability, as in Kilian (2009).

2014-2015, implying that those impacts on real variables are amplified in the crude oil market. As is highlighted in the following, we discuss the major episodes of oil price hikes and falls by referring to the respective cumulative contribution of six structural shocks based on the historical decomposition.

Figure 2 shows the responses of the real oil price to each of six structural shocks defined earlier. Note that all shocks are set to lower the real oil price. An unexpected increase of global oil supply causes a small but statistically significant decrease in the real oil price at the initial month, although its impact on oil price turns out to be insignificant afterward.[8] This result is consistent with the findings of Kilian (2009).

Negative shocks in both realized and expected aggregate demand, i.e., global industrial production and revision of global economic growth, lead to immediate, large and statistically significant plunges in the real oil price. Positive shocks in expected future oil supply immediately cause a more persistent decrease in real oil prices than two demand shocks. Shifts in expected supply schedule triggered by, for example, exogenous political events, have materialized the more persistent effect on oil price development than realized aggregate demand shocks. Both effects from financial factor and oil-price specific shocks are also significant and persistent.

Table 1 presents the variance decomposition of the real oil price. At twelve months, oil-price specific shock explains nearly 50 percent of oil price variance, while another half of variance is attributable to other five structural shocks. Among contributions of 50 percentage points stemming from these five shocks, shocks on expectations and financial factors of oil future trade explain more than 40 percent. In particular, expected future oil supply shocks are more than twice as important as realized and expected aggregate demand shocks and financial factor shocks in explaining the oil price development. This decomposition clearly indicates the important roles of the expectations on future oil supply and aggregate demand, and the financial factors in accounting for oil price dynamics.

Figure 3 plots the respective cumulative contributions of each structural shock for real oil price, based on our SVAR. This points out that the contribution of realized oil supply shocks to the real oil price is small in comparison with those of other shocks. By contrast, realized and expected aggregate demand and expected future oil supply historically have larger effects on the real oil prices. In addition, financial factor shocks

[8] It is one hypothesis to explain this result that an unexpected increase of global oil supply causes an increase of oil inventory, leading to the expectation of decrease in future oil supply.

have a sizable contribution to the oil price development, while oil-price specific shocks have more considerable contribution than financial factor shocks, especially in 2008 and 2014-2015.

This historical decomposition of the real oil price illustrates the mechanism behind the major episodes of oil price fluctuations. For example, from 2007 to mid-2008, the West Texas Intermediate (WTI) hiked from 60 U.S. dollars per barrel to 140 U.S. dollars per barrel. In this period, there was a substantial positive contribution of expected future oil supply shocks, which represented the prevailing concern over the oil supply capacity in OPEC countries due to the earlier stagnation in upstream investments and the political uncertainty in Middle East countries. Realized aggregate demand shocks also pushed the oil price up, indicating the demand pull stemming from the unexpected rapid growth of emerging economies, especially China and India. Before the GFC, it was widely pointed out that many pension funds and hedge funds had increased their investments in the commodity markets including the crude oil market. We consider that this understanding is consistent with the large positive contribution of oil-price specific shocks in the first half of 2008.

In the second half of 2008, the WTI fell dramatically from 140 U.S. dollars per barrel to below 40 U.S. dollars per barrel. Our historical decomposition shows that realized aggregate demand shocks mainly drove this decline reflecting the economic recession just after the GFC. Expected aggregate demand shocks also contributed to the decline to some extent. From 2010 to early 2012, the WTI steadily increased from around 80 U.S. dollars per barrel to over 100 U.S. dollars per barrel. The main contributors were realized aggregate demand shocks and expected future oil supply shocks. The former represented the steady growth of emerging economy and the United States after the GFC. The latter captured the uncertainty on oil supply stemming from the social instability in the Middle East and North Africa before and after the so-called Arab Spring. From the second half of 2013 to the first half of 2014, expected future oil supply shocks positively contributed to an oil price hike, representing the increasing uncertainty over the Middle East (Syria, Iran and Iraq) and Ukraine/Russia affairs.

From mid-2014, all shocks turned to decrease and push the oil price down, though the timings and magnitudes varied. Figure 4 and Table 2 illustrate in detail the historical decomposition of the oil price plunge since January 2014.[9] From January 2014 to

[9] Note that the contributions of shocks in Figure 4 differ from those in Figure 3, because Figure 3 illustrates the contributions as the deviation from the average, while Figure 4 does as the cumulative change from January 2014.

January 2015, the real oil price plunged by 50.1 percent. About 40 percentage points could be explained by expected future oil supply shocks, which were interpreted as those influences of expected increase of the US shale oil, the recovery of Libyan oil production and, most importantly, the publicly announced intention of Saudi Arabia not to act as the "swing producer."[10] Decreases in financial factor shocks and realized aggregate demand shocks had also contributed to the decline by 11.2 and 8.4 percentage points respectively, while expected aggregate demand shocks have virtually no contribution.

In June 2015, the real oil price rebounded by 11.9 percent in January 2015. Our historical decomposition discloses that this recovery was mainly due to the swing back of financial factor shocks and that the contribution of other real factors was relatively small. From June 2015 to February 2016, the real oil price decreased again by 30.0 percent. At this stage, demand shocks played a major role, which was a clear distinction from the episode from January 2014 to January 2015. Expected and realized aggregate demand shocks pulled the real oil price down by 14.4 and 7.1 percentage points respectively, while expected future oil supply shocks and financial factor shocks contributed to this plunge by 2.1 and 11.8 percentage points respectively. It is also noteworthy that realized oil supply shocks had almost no influence at this stage.

3.2 Influence of Oil Price Shocks on the Global Output

We examine the dynamic effects of each structural shock on the global industrial output. Figure 5 shows the impulse responses of the global output to one-standard deviation of structural shocks. Note that all shocks are set to lower the real oil price. We point out four remarks. First, an unexpected increase of global oil supply causes a small but statistically significant increase in the global output at the initial two months but its impact on oil price turns out to be insignificant afterward. Second, realized and expected negative aggregate demand shocks bring the global output down significantly for almost one year. This finding means that if negative demand shocks emerge, not only the real oil price but also the global output will decrease simultaneously for certain periods. And third, both positive expected future oil supply shocks and negative oil-price specific shocks initially push the global output down, probably reflecting the

[10] Arezki and Blanchard (2015) point out that "The resulting shift by the swing producer (Saudi Arabia), however trigger a fundamental change in expectations about the future path of global oil supply, in turn explaining both the timing and the magnitude of the fall in oil prices, and bringing the latter closer to the level of a competitive market equilibrium."

contractions in the upstream investments of the crude oil. Almost one year after these shocks, however, the global output increases in a statistically-significant manner. This response of the global output is considered as the positive impact on the global economy through the increase of real income or the decrease of the production costs in oil-importer economies. Finally, with respect to the real oil price, financial factor shocks bring a small but significant (in most periods) increase in global output. As is shown in Figure 2, the negative shocks to financial factors decrease the oil price. Figure 5 shows that this has positive impacts on the global economy because a fall in oil prices increases the real income of oil importer economies or decreases the production costs pushing up the benefits for firms. All of these features clearly show that "not all oil price shocks are the same" in accounting for the development of the real oil price and the global output. Bearing these findings in mind, one has to identify the shocks behind an oil price decline when evaluating its consequences on the global output.

Table 3 is the variance decomposition of the global output. At twelve months, more than 90 percent of variance is explained by realized and expected aggregate demand shocks. The contribution of demand shocks decreases over the time horizon and at 60 months it becomes about 30 percent. On the other hand, the variance attributable to expected future oil supply, financial factor and oil-price specific shocks increases, reaching about 70 percentage points at 60 months. These results indicate that even if the real oil price plunges due to positive expected future oil supply shock and negative financial factor and oil-price specific shocks, it takes a relatively long time for the positive impact on the global output to emerge. This delayed response of the global output to these shocks partly explains the mediocre economic development since mid-2014 even under the oil price plunge.

4. Conclusion

This paper proposes a novel SVAR model of the real oil price to shed light on the role of expectations and the financial investors in the crude oil market. Our model enables us to quantitatively examine the respective importance of shocks on expectations of future aggregate demand and oil supply and financial factors in the oil market in addition to traditionally-used realized (or flow) aggregate demand and oil supply. We find that shocks on expectations and financial factors explain more than 40 percent of the oil price variance and that expected future oil supply shocks have the largest influence on the oil price among those shocks. The cumulative contribution of oil price shocks based on the historical decomposition reveals the mechanism behind major episodes of oil price hikes and falls. In particular, as for the recent oil price plunge since mid-2014, it is ascertained that expected future oil supply shocks were the dominant driver of oil price falls from January 2014 to January 2015, while expected and realized aggregate demand shocks played a major role in the episodes of oil price falls from June 2015 to February 2016. We also find that the influence of oil price shocks on global output varies by the nature of each shock, which confirms that it is important to understand the causes of oil price development in the evaluation of its macroeconomic influence.

The results in this paper have clear implications for the heterogeneities of the roles of structural shocks on the real economy. In particular, since the shocks to expectations and financial factors play the significant role in accounting for the fluctuations in oil prices in the past decade, it is important for policy makers to learn more about those heterogeneities. One possible caveat of our approach is that we do not explain the mechanism through which the structural shocks affect the real economy. A richer structural model is required in order to examine the potential link between the structural shocks and the real economy, which remains as a future work.

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Month	Realized Oil Supply Shock	Realized Aggregate Demand Shock	Expected Aggregate Demand Shock	Expected Future Oil Supply Shock	Financial Factor Shock	Oil-Price Specific Shock
1	0.73	1.96	6.56	11.36	21.22	58.17
2	0.32	3.54	9.02	19.47	15.88	51.78
3	0.18	5.01	9.45	22.36	13.15	49.85
4	0.13	5.83	9.84	23.22	11.76	49.22
5	0.12	6.15	10.12	23.93	11.03	48.64
6	0.11	6.22	10.28	24.45	10.68	48.26
7	0.11	6.14	10.33	24.82	10.50	48.10
8	0.11	5.97	10.30	25.13	10.42	48.06
9	0.11	5.77	10.21	25.39	10.41	48.11
10	0.11	5.56	10.07	25.62	10.45	48.19
11	0.11	5.36	9.91	25.81	10.51	48.30
12	0.11	5.19	9.74	25.97	10.59	48.40

TABLE 1: VARIANCE DECOMPOSITION OF THE REAL OIL PRICE

（%, %point）

Monthly Predictors:	Evaluation Period: Jan. 2014 - Jan. 2015	Jan. 2015 - Jun. 2015	Jun. 2015 - Feb. 2016	Jan. 2014 - Feb. 2016
Real Oil Price Change	▲50.1	11.9	▲30.0	▲68.2
Realized Oil Supply Shock	▲0.9	▲1.4	1.4	▲0.9
Realized Aggregate Demand Shock	▲8.4	▲1.0	▲7.1	▲16.5
Expected Aggregate Demand Shock	4.0	▲3.1	▲14.4	▲13.5
Expected Future Oil Supply Shock	▲38.3	▲4.8	▲2.1	▲45.2
Financial Factor Shock	▲11.2	12.2	▲11.8	▲10.8
Oil-Price Specific Shock	4.7	9.9	4.1	18.8

TABLE 2: HISTORICAL DECOMPOSITION OF THE OIL PRICE PLUNGE SINCE JANUARY 2014

Month	Realized Oil Supply Shock	Realized Aggregate Demand Shock	Expected Aggregate Demand Shock	Expected Future Oil Supply Shock	Financial Factor Shock	Oil-Price Specific Shock
1	2.07	97.93	0.00	0.00	0.00	0.00
2	1.30	87.28	8.30	0.57	0.15	2.40
3	0.66	78.14	15.02	1.35	0.51	4.32
4	0.41	72.26	19.73	1.87	0.35	5.38
5	0.29	68.69	22.90	2.26	0.24	5.62
6	0.23	66.72	25.03	2.40	0.20	5.41
7	0.21	65.76	26.52	2.32	0.22	4.98
8	0.19	65.34	27.57	2.15	0.28	4.48
9	0.19	65.17	28.26	1.95	0.40	4.03
10	0.19	65.03	28.64	1.80	0.60	3.75
11	0.19	64.75	28.71	1.76	0.87	3.73
12	0.19	64.19	28.48	1.88	1.23	4.03
24	0.23	42.76	18.05	11.03	6.87	21.06
36	0.25	31.90	12.96	15.97	9.36	29.57
48	0.26	26.98	10.47	18.21	10.62	33.46
60	0.26	23.86	8.91	19.63	11.41	35.94

TABLE 3: VARIANCE DECOMPOSITION OF THE GLOBAL OUTPUT

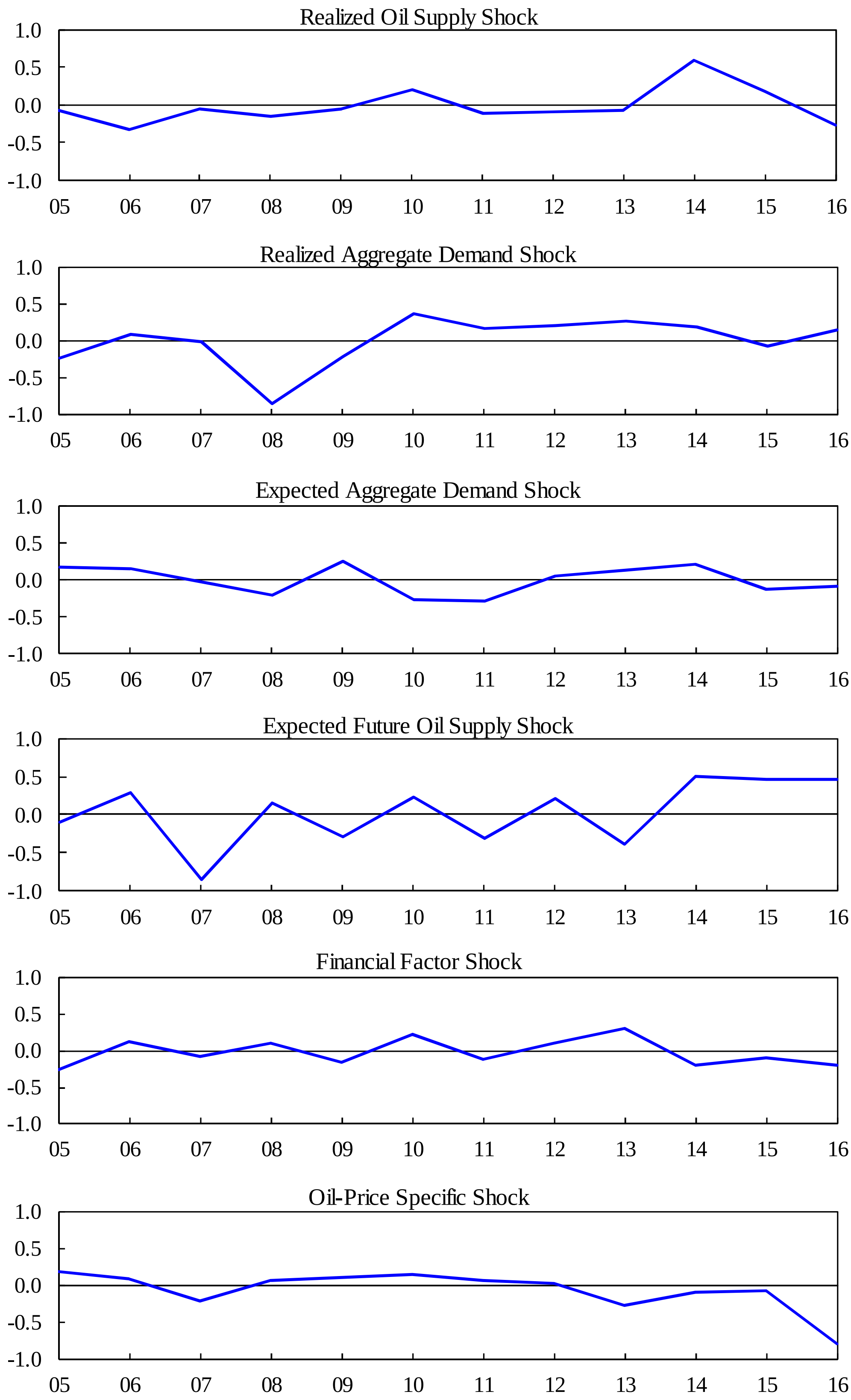


FIGURE 1: HISTORICAL EVOLUTION OF STRUCTURAL SHOCK

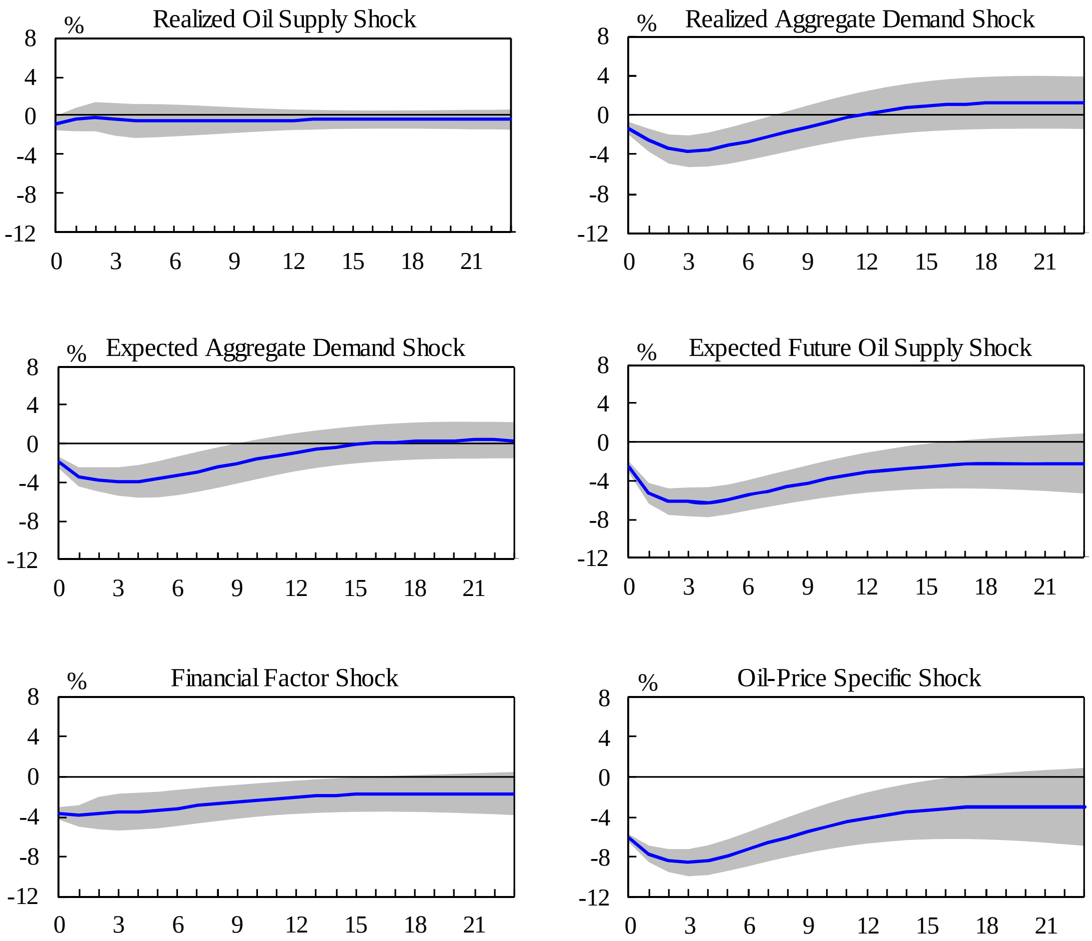


FIGURE 2: RESPONSES OF THE REAL OIL PRICE TO STRUCTURAL SHOCKS

(Point estimates with one-standard error bands. The x-axis refers to months from the shock.)

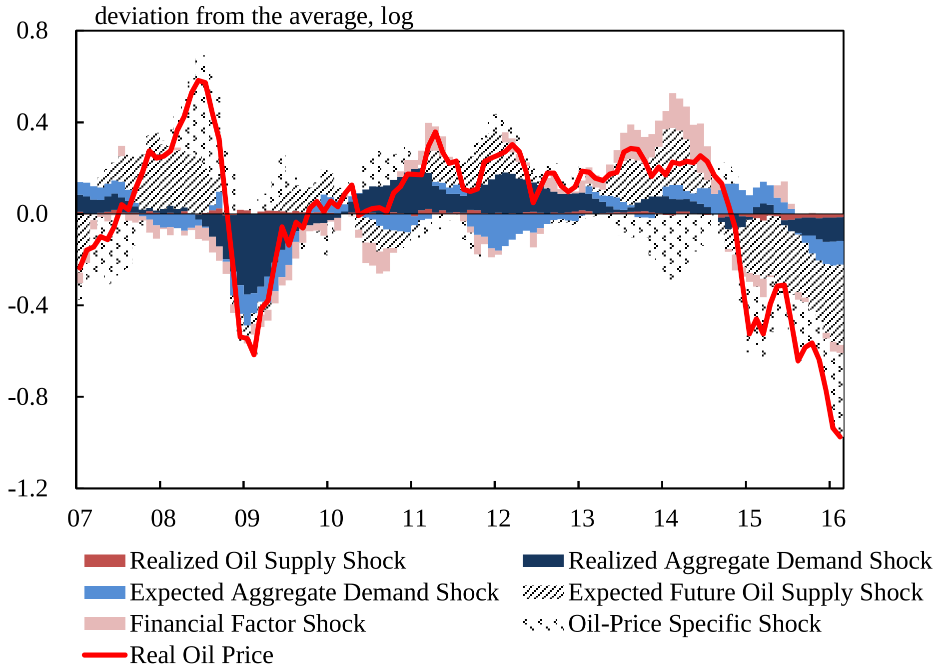


FIGURE 3: HISTORICAL DECOMPOSITION OF THE REAL OIL PRICE

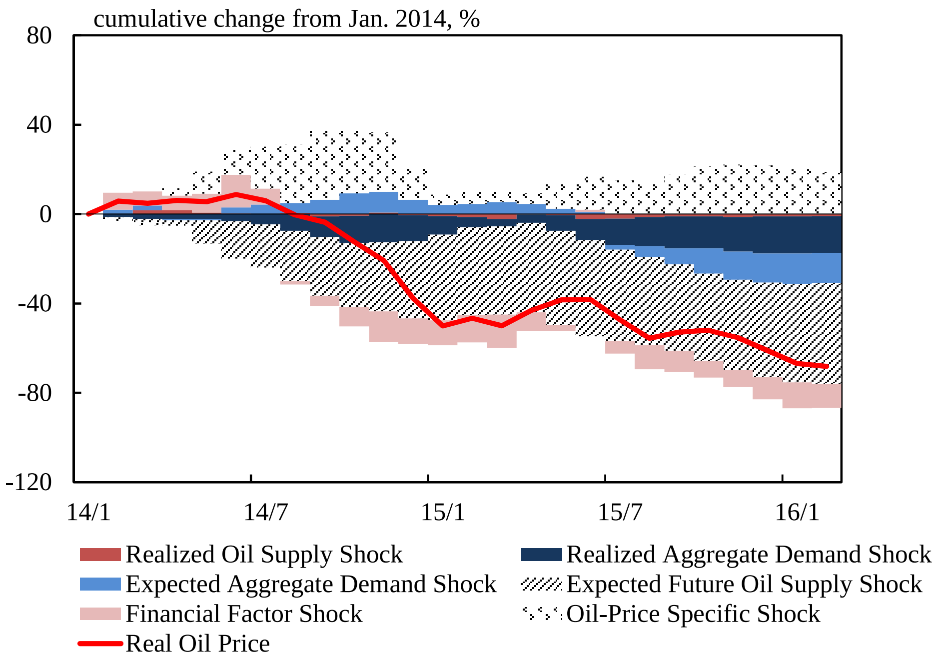


FIGURE 4: HISTORICAL DECOMPOSITION OF THE OIL PRICE PLUNGE SINCE JANUARY 2014

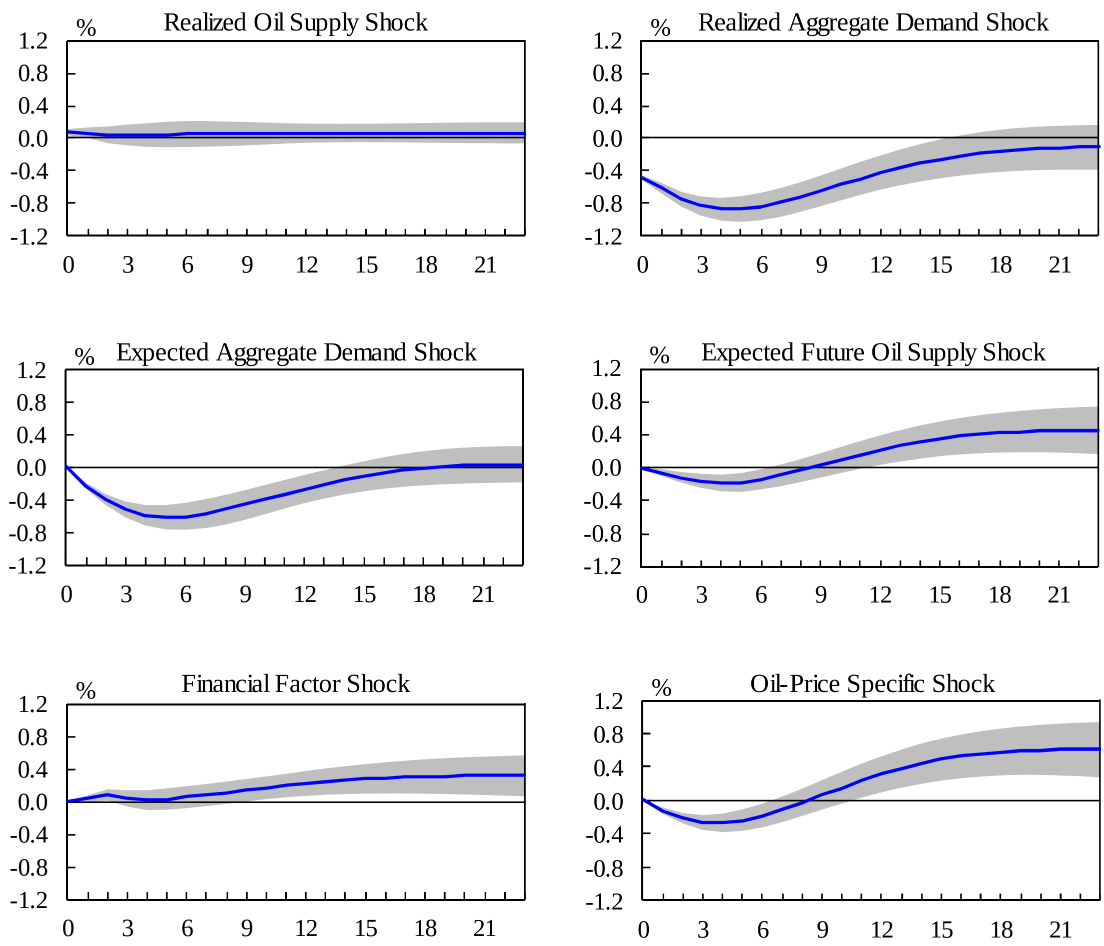


FIGURE 5: RESPONSES OF THE GLOBAL OUTPUT TO STRUCTURAL SHOCKS

(Point estimates with one-standard error bands. The x-axis refers to months from the shock.)

Appendix: Data Description

The sample period is from March 2005 to February 2016. The date set is constructed as follows. Appendix Figure 1 shows time series of the data used in our SVAR model.

Real Price of Oil:

We use the West Texas Intermediate (WTI) oil price as the nominal oil price. Following Kilian (2009), the original series is deflated by the US CPI; and the resulting real price of oil is expressed in log-levels.

Oil Production:

We use data on the global oil production provided in the *Monthly Energy Review* of the Energy Information Administration (EIA). We take the log differences of seasonally adjusted, world oil production in millions of barrels pumped per day.

Global Real Economic Activity:

Our measure of global real economic activity is the index of industrial production (IIP). We aggregate the IIP series for OECD countries and emerging countries, based on the PPP weights. For OECD countries, we follow the aggregated data provided by OECD. For emerging economies such as Brazil, China, India, Indonesia, Russia and South Africa, we aggregate the individual IIP series for each country provided by CEIC. After aggregating the IIP, we take deviation from its linear trend to obtain a gap measure.

Revision of Forecast on Global Real Economic Activity:

Following Kilian and Hicks (2013), we use the forecasts of annual real GDP growth for the next year and define the revisions of the forecast by taking differences from the forecast delivered in the previous period.

Specifically, let $CF_{i,j,t}$ denote the forecast of annual real GDP growth for the next year at month j in year t, for country i. We use the series of the Consensus Forecast provided by Consensus Economics Inc. We focus on the one-year forecast horizon because one-year forecasts are more reliable and watched more closely by market participants than longer-horizon forecasts. The revisions of forecasts on global real activity for a country i is defined as

$$\Delta CF_{i,j,t} = CF_{i,j,t} - CF_{i,j-1,t}.$$

Then, we take the weighted average for the aggregated revisions of the forecasts at month j in year t. That is, the aggregated revision $\Delta CF_{j,t}$ is defined as

$$\Delta CF_{j,t} = \sum_i \omega_{i,t} \Delta CF_{i,j,t},$$

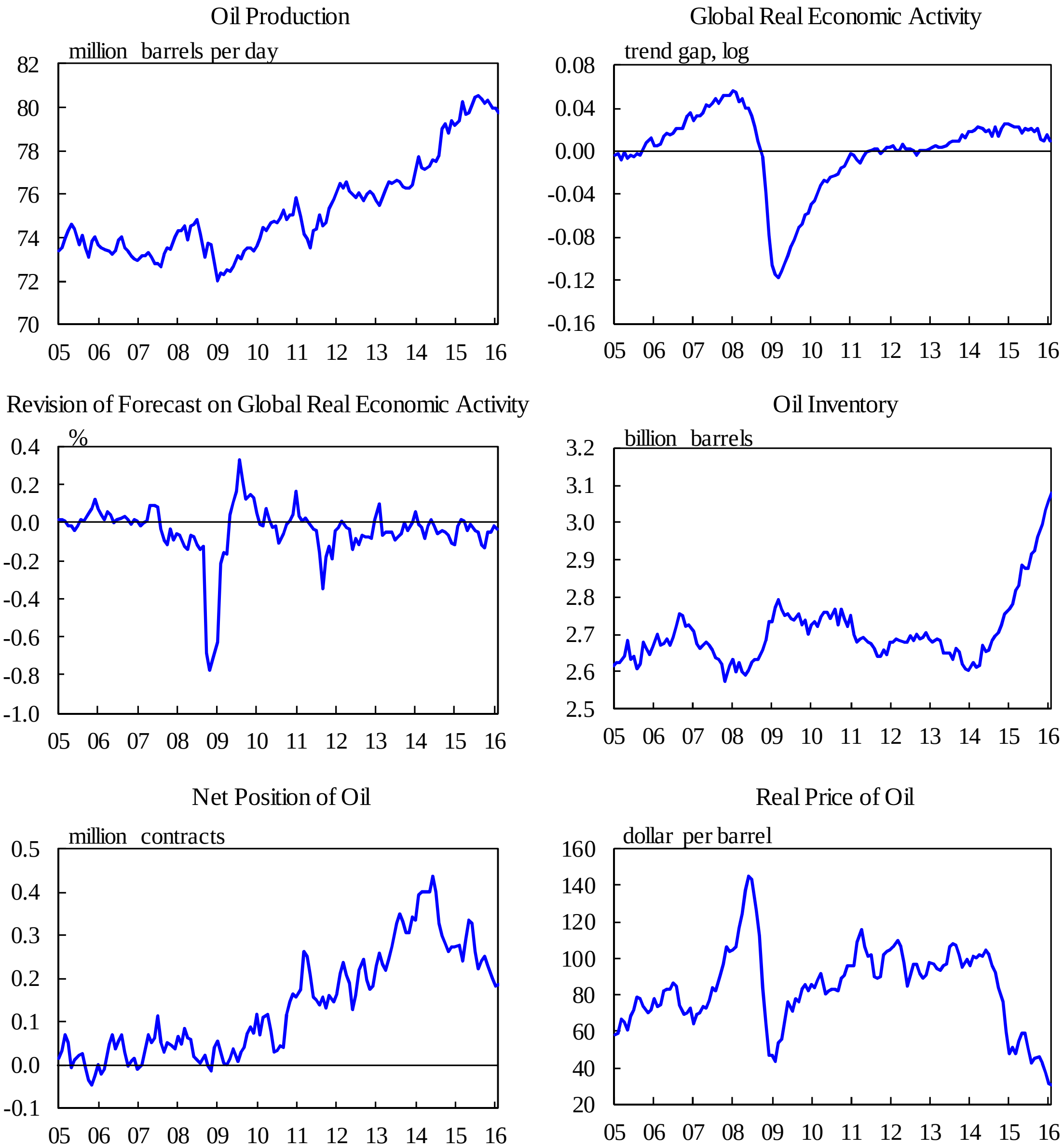
where $\omega_{i,t}$ denotes the PPP weights for country i in year t.

Oil Inventory:

Following Kilian and Murphy (2014), we treat the OECD industry petroleum stocks as a proxy for global petroleum inventories. The series is provided by the EIA. We take the log differences of seasonally adjusted series.

Net Position of Oil:

We use data on the WTI Crude Oil Financial Net Non-Commercial Futures Positions provided by New York Mercantile Exchange. We take the differences of the original series.



Appendix FIGURE 1: TIME SERIES OF DATA