

What Drives Long-term Oil Market Volatility? Fundamentals versus Speculation

Libo Yin and Yimin Zhou

Abstract

This paper explores the role of speculation and economy fundamentals in the oil market using a two-component GARCH-MIDAS model. Specifically, the authors highlight the different roles played by the changing oil shocks with respect to the short-term and long-term components regarding oil market volatility. The results indicate that a global demand shock is the only factor found not only to be positive but to also significantly increase long- and short-term oil volatility in the full sample. This is consistent with a classic host of research that advocates that global demand dominates the oil market. However, since 2004, impacts of other oil shocks have been significantly weakened or even reversed. For example, the speculative demand shock has helped to stabilize long-term oil volatility during the post-2004 period. The results also suggest the existence of asymmetric impacts on short-term oil volatility, particularly for shocks from oil supply, oil-specific demand and oil speculative demand.

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Keywords Oil shocks; economy fundamentals; speculation; long/short-term oil volatility; GARCH-MIDAS model

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1 Introduction

Given that crude oil price is one of the key variables in affecting macroeconomic aggregates (Hamilton, 2003; Jo, 2014; Dhaoui and Khraief, 2014; Arora, 2015), the volatility of crude oil prices has become the focus of many economists and decision makers. Although the question as to whether fundamental factors actually anticipate changes in oil market volatility dates back to the 1970s, the latest run-up in oil prices since 2004 has put this issue back into the spotlight. A recent example, a study by Kilian (2009), highlights that oil price shocks can have vastly different effects on the real price of oil depending on the origin of the shock, even though oil prices have historically been driven by demand factors. Empirical results indicate that oil supply shocks have little explanatory power for the real oil price and that aggregate demand shocks are the driving force of oil price movements. Since this contribution, an impressive list of empirical studies has investigated the effects of different types of oil shocks and supports Kilian's (2009) conclusion. See, among others, Lütkepohl and Netšunajev (2014), Kilian and Murphy (2014), Baumeister and Peersman (2013), Kilian and Park (2009), Lombardi and Van Robays (2011) and Peersman and Van Robays (2009, 2012). Because of the importance of global demand in driving oil volatility, Aastveit et al. (2014) take a further step to explicitly analyze the contribution of the demand of different geographical regions. Their results suggest that the demand from emerging economies is more than twice as important as the demand from developed countries in accounting for the fluctuations in the real oil price.

However, the developments in the oil market in the past decade have been so dramatic that growing flows of investments to commodity markets have coincided with an increase in the volatility of oil prices. Some researchers find evidence that index investments directly or indirectly impact volatility in oil prices (Einloth, 2009; Kaufmann and Ullman, 2009; Irwin et al., 2009; Cifarelli and Paladino, 2010; Sanders and Irwin, 2010; Irwin and Sanders, 2012a, 2012b; Hache and Lantz, 2013). According to Tang and Xiong (2012), this speculative component may have contributed to the recent boom in oil prices. Hamilton and Wu (2014) argue that speculation has changed the nature of risk premia in the crude oil futures market. More specifically, the compensation to the long position became smaller, on average, and more volatile.

However, recent studies that test for a bubble component or a strong global growth in oil prices are decidedly mixed (Phillips and Yu, 2011). Fattouh et al. (2013) find that the existing evidence is not supportive of an important role of speculation in driving the spot price of oil after 2003. Instead, they find strong evidence that the co-movement between spot and futures prices reflects common economy fundamentals. Manera et al. (2016) find that speculation presents a negative sign on volatility in oil futures markets, suggesting that it does not destabilize prices, a finding that is consistent with recent evidence. The robustness checks are enriched with alternative measures of speculation based on CFTC data, specifically the market share of non-commercial traders, the Working's speculative T-index, and the percentage of net long positions of non-commercial traders over total open interest in future markets. Juvenal and Petrella (2014) find that while global demand shocks account for the largest share of oil price fluctuations, speculative demand shocks are the second most important driver. These findings illustrate the acrimonious and heated nature of the public policy debate surrounding the role of index funds and economy fundamentals in the oil markets. Although more than eight years have passed since the 2008 peak in commodity prices, the controversy surrounding the speculation activity and the huge demand from emerging economies continues unabated. Thus, this has led to an intense research effort to assess the role of economy fundamentals and speculations as drivers of volatility in oil prices.

To explore these questions, this paper complements the existing literature by employing the GARCH-MIDAS framework suggested by Colacito et al. (2011) and Conrad and Loch (2014). This framework enables us to directly identify the role of speculation activity and economy fundamentals as drivers of the secular component of oil market volatility. As previous studies have mainly focused on only one aspect, studies that combine the two are limited. Consistent with Kilian and Murphy (2014), the roles of speculation activity and economy fundamentals are identified as different types of oil shocks, namely, oil supply, oil-specific demand, global demand and speculative shocks.

Our contributions are as follows. First, we provide a detailed exploration of the relationship between various oil shocks and the oil market in terms of volatility in a unified framework. To the best of our knowledge, this is the first paper to focus on the effect of various oil shocks with respect to volatility. Admittedly, the effects of oil shocks on the oil market in terms of return or price level have been studied

extensively, albeit with controversial results (Einloth 2009; Kaufmann, 2011). However, relatively little attention has been paid to the level of volatility.

Second, we jointly model the dynamic volatility structure of oil prices. By employing the GARCH-MIDAS framework, we decompose oil volatility into its short-term (conditional) and long-term (unconditional) components, where the latter are affected by oil shocks. This identification strategy, which is adopted to isolate the long- and short-term components of oil market volatility, is novel in the oil literature, as is the use of the GARCH-MIDAS model for this purpose. We also highlight the different roles played by changing oil shocks on short-term and long-term dynamics.

Third, previous analyses (e.g., Kilian and Murphy, 2014) of the relationship between oil returns and oil shocks are limited, for the most part, to monthly frequency data. However, the GARCH-MIDAS model delivers a flexible methodology that allows for jointly modeling the daily observations of oil returns with data on oil shocks recorded at a lower frequency, such as monthly, to examine directly the impacts of oil shocks on oil volatility.

The remainder of the paper is structured as follows. Section 2 describes the model and the estimation procedure. Section 3 reports the data and shocks identification strategy. We report the results of the study and of our robustness checks in Section 4, and Section 5 concludes the paper.

2 The GARCH-MIDAS model

To evaluate the role of different oil shocks on the long-term volatility of the spot oil price, we rely on the GARCH-MIDAS (mixed data sampling) model. The GARCH-MIDAS model combines the insights of Engle and Rangel (2008) and the work on mixed data sampling (MIDAS), as in, e.g., Ghysels et al. (2005).¹ The model uses a mean reverting unit daily GARCH process, similar to that used by Engle and Rangel (2008), and a MIDAS polynomial that applies to lower frequency macroeconomic or financial variables.

¹ More details are available in Engle et al. (2008).

In our case, this model enables us to incorporate the monthly measures of oil supply shocks and oil demand shocks, which includes demand driven by economic activity, oil-specific demand, and speculative oil demand shocks, directly into the specification of the long-term component of daily spot oil returns. A log version of the GARCH-MIDAS model is formally described as follows. Assume the spot oil return on day i in month t , as in the following process:

$$r_{i,t} = u + \sqrt{\tau_t} g_{i,t} \varepsilon_{i,t}, \quad (1)$$

$$\varepsilon_{i,t} | \phi_{i-1,t} \sim N(0,1), \quad (2)$$

where $t = 1, 2, \dots, T$ denotes the monthly period; $i = 1, 2, \dots, N_t$; N_t is the number of trading days in month t ; $\phi_{i-1,t}$ is the information set up for the $(i-1)th$ day of period t ; u is the daily expected returns. Equation (1) indicates that spot oil return volatility has at least two components, namely $g_{i,t}$, which accounts for daily fluctuations that are assumed short-lived, and a long-term component, τ_t .² The short-term component follows a mean-reverting GARCH(1,1) process:

$$g_{i,t} = (1 - \alpha - \beta - \gamma / 2) + (\alpha + \gamma \cdot 1_{\{r_{i-1,t} - u < 0\}}) \frac{(r_{i-1,t} - u)^2}{\tau_t} + \beta \cdot g_{i-1,t}, \quad (3)$$

where $\alpha > 0, \beta > 0$ and $\alpha + \beta + \gamma / 2 < 1$. The choice of parameters in Equation (3) should ensure that $E[g_{i,t}] = 1$. Note that the short-term component follows a mean-reverting asymmetric unit GARCH process in the model we use, and the parameter γ contains the information regarding the asymmetry. The value of $\frac{\alpha + \gamma \cdot 1_{\{r_{i-1,t} - u < 0\}}}{\theta} \triangleq \lambda$ is the measure of the impact of the oil shock on short-term oil volatility.³ Specifically, a significant and negative value of γ indicates that when the value of $r_{i,t}$ is larger than the fixed value u , the parameter $\frac{(r_{i-1,t} - u)^2}{\tau_t}$ in

²Contrary to that in Engle and Rangel (2008), the τ_t component in Equation (1) is assumed constant throughout the month for reasons of simplicity.

³ λ can provide information on the effects of the various oil price shocks on short-term volatility. Monthly structural shocks transmit their information into long-term volatility (τ_t). As specified in Equation 3, both $g_{i-1,t}$ and τ_t affect the short-term volatilities.

the value of $r_{i,t}$ is larger than the fixed value u , the parameter $\frac{(r_{i-1,t} - u)^2}{\tau_t}$ in Equation (3) is larger in magnitude when compared with the situation where the value of $r_{i,t}$ is less than the fixed value u .

With regard to the long-term component, following Engle et al. (2013), Asgharian et al. (2013) and Conrad and Loch (2014), we consider the alternative version of the MIDAS component τ_t , which involves the macroeconomic variable. In the empirical analysis, we focus on the version that directly incorporates monthly measures of oil shocks. In this version, we consider fixed span specifications and use a monthly frequency:

$$\log(\tau_t) = m + \theta_x \sum_{i=1}^{K_v} \varphi_i(w_1, w_2) X_{t-i}, \quad (4)$$

where X_{t-i} denotes the value of different oil shocks. To complete the model, we must specify the weighting scheme, which calls for Beta weights as in Equation (4) and as defined by Engle et al. (2013), that is,

$$\varphi_l(w_1, w_2) = \frac{\left(\frac{l}{K_v + 1}\right)^{w_1 - 1} \left(1 - \frac{l}{K_v + 1}\right)^{w_2 - 1}}{\sum_{j=1}^{K_v} \left(\frac{j}{K_v + 1}\right)^{w_1 - 1} \left(1 - \frac{j}{K_v + 1}\right)^{w_2 - 1}}, \quad (5)$$

The weight attached to past oil shocks depends on the parameters w_1 , w_2 and K_v . The latter determines the number of lagged oil shocks taken into account. The decay parameters w_1 and w_2 determine the weights attached to the past realized variances. In the case of $w_1 = w_2 = 1$, the past K_v receives an equal weight of $1/K_v$. In the likely case of $w_1, w_2 > 1$, past oil shocks gradually exhibit increasingly less weight.⁴

⁴ The Beta weighting scheme describes the weights of each lag l with fixed values of w_1 and w_2 . The hump-shaped weights are obtained from the function of $\varphi(l)$ rather than $\varphi(w_1, w_2)$.

3 Data and shocks identification

3.1 Identifying oil shocks using sign restrictions

The analysis in this paper builds on the structural oil shock, which is a vector of four oil price shocks, namely, supply-side shock, aggregate demand shock, specific demand shock and speculative demand shock. Consistent with Kilian (2009), Kilian and Murphy (2014) and Kilian and Lee (2014), the structural shocks are identified based on a combination of sign restrictions and bounds on the short-run price elasticities of oil demand and oil supply.

The first three shocks were proposed in the earlier work of Kilian (2009), who proposed a model that allows for the identification of oil shocks and contributes to the understanding of their relative importance in determining the real price of oil. In their work, oil shocks are decomposed into three components, specifically crude oil supply shocks, shocks to the aggregate global demand for industrial commodities, and global demand shocks that are specific to the crude oil market. Supply-side shocks are associated with changes in the world oil production, e.g., overproduction or supply interruptions due to military conflicts or the destruction of oil facilities. Oil-specific demand shocks are associated with concerns about the future availability of oil, while aggregate demand shocks are associated with changes in global economic activity. A change in the demand for commodities from emerging economies shifts world economic activity, oil prices and oil production in the same direction. This strategy has also been widely used in Peersman and Van Robays (2009, 2012), Baumeister and Peersman (2013) and Kilian and Murphy (2014).

The fourth shock is the speculative demand shock. Since the financialization of commodity markets, the coincident increase in oil prices and speculators in the crude oil futures market have led to allegations that speculators drive crude oil prices. The works of Kilian and Murphy (2014) and Kilian and Lee (2014) refer to such a shock as a speculative demand shock in the spot market for crude oil, which is constructed by scaling US crude oil inventory data by the ratio of the OECD petroleum inventories over US petroleum inventories. This focus on above-ground crude oil inventories is consistent with conventional accounts of speculation involving the accumulation of oil inventories in oil-importing economies. Hamilton (2009) and Alquist and Kilian (2010) argue that any expectation of a shortfall in the future oil supply necessarily causes an increase in the demand for

above-ground oil inventories and, hence, in the real price of oil. Kilian and Lee (2014) also empirically observe that this proxy, which is based on readily available EIA data, is likely to be accurate. Therefore, to distinguish speculative demand shocks from other shocks, we follow Kilian and Lee (2014).

The key identifying assumptions are the set of restrictions on the signs of the impact responses of the four observables to each structural shock, as presented in Table 1. The sign restrictions are imposed to hold for the first month, and the sign restrictions are imposed to hold for the first month. To test the robustness of the results, the sign restrictions are also imposed to hold for the first three months (see Paustian, 2007) and for the first six months (Barsky and Kilian, 2004) after the occurrence of the shocks, which accounts for the delayed response of the oil market variables in the early period of our sample due to institutional arrangements. These restrictions have been widely applied by Peersman and Van Robays (2009, 2012), Kilian and Murphy (2012) and Baumeister and Peersman (2013).

Table 1 Identifying oil shocks using sign restrictions

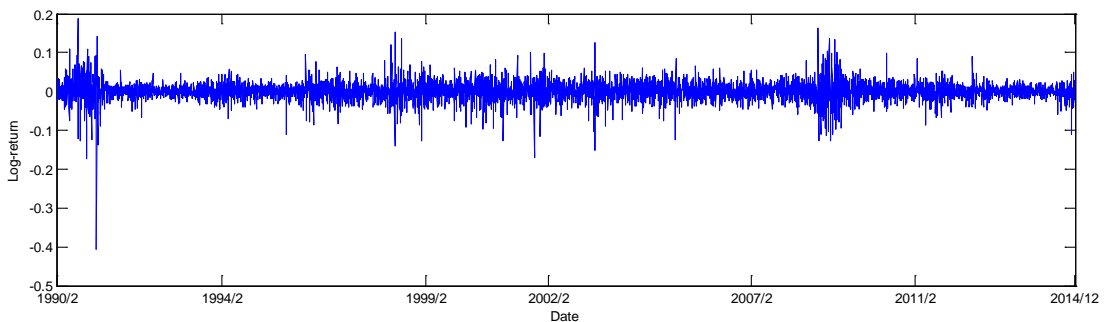
	Oil supply disruption	Aggregate demand shock	Oil-specific demand shock	Speculative demand shock
Oil production	–	+	+	+
Real activity	–	+	–	–
Real oil price	+	+	+	+
Inventories				+

3.2 Data

The spot price for crude oil (US dollars per barrel) is obtained from the Energy Information Administration (EIA). We employ daily data for the period from January 1988 to the end of year 2015. The log-returns of crude oil are displayed in Figure 1. Our measure of global real economic activity is the updated version of the index of global real economic activity in industrial commodity markets, as proposed in Kilian (2009), i.e., the monthly percent deviations from the trend for 1990.1 to 2014.12. The real price of oil is defined as the US refiners' acquisition

cost for imported crude oil, as reported by the EIA.⁵ The refiners' acquisition cost for imported crude oil has been argued to be a better proxy for the price of oil in global markets than the US price of domestic crude oil, which was regulated during the 1970s and early 1980s⁶ (Kilian, 2009) and has been used in the work of Baumeister and Kilian (2012), Peersman and Van Robays (2012) and Baumeister and Peersman (2013). With regard to data on crude oil inventories, we follow Hamilton (2009) and Kilian and Murphy (2012, 2014) and use the data for total US crude oil inventories provided by the EIA due to the lack of data for other countries. These data are scaled by the ratio of the OECD petroleum stocks over the US petroleum stocks for each time period.

Figure 1 Evolution of daily log-returns of crude oil



⁵ The Energy Information Administration (EIA) uses the imported refiner acquisition cost, the weighted average cost of all oil imported into the US, as its world oil price.

⁶ We choose it for two reasons. First, compared with the US price of domestic crude oil (WTI oil price), which was regulated during the 1980s, the RAC for imported crude oil is likely to be a better proxy for the price of oil in global markets. Supportive evidence can be found in Kilian (2009), Alhajji and Huettner (2000), Baumeister and Peersman (2013), and many others. Second, because the process to construct the oil shocks is based on the work of Kilian (2009), we follow Kilian and use the same variable.

4 Effects of oil shocks on the long-/short-term volatilities of oil prices

The analyses of the impacts of different types of oil shocks on oil market volatilities focus primarily on two factors. First, we investigate the long-term and short-term volatilities of the spot oil price and the effects of different oil shocks as exogenous shocks in the GARCH-MIDAS model. With respect to each of the four types of oil shock, we investigate how oil shocks affect long-/short-term oil volatilities in terms of magnitude, significance and asymmetry. Second, we compare the responses of long-/short-term oil volatilities to these oil shocks before and after 2004 when significant index investments began to flow into the commodity markets.

Empirical results are presented in Tables 2 to 5, and long-/short-term volatility components are presented in Figure 2. The responses of oil price volatility to different types of oil shocks are summarized in Table 6. We also report estimation results for parameters where X denotes the oil real price.

4.1 Effects of oil supply shock

Table 2 provides parameter estimates for the GARCH-MIDAS model with oil supply shocks. In each case, we set one, two and three years of lags, respectively. The results in Table 2 indicate that the parameters u and m are both insignificant in all cases, while the estimated α , β and γ parameters are highly significant. The sums of α , β and $\gamma/2$ are almost identical and always less than one,⁷ while in the standard GARCH model, the sum is typically 1. That is, in all specifications, the short-term volatility component is mean reverted to the long-term trend. The same finding is reported in Engle and Rangel (2008), Engle et al. (2013) and Conrad et al. (2014).

The most interesting parameter is the slope parameter θ in Equation (3), which represents the impact of oil shocks on long-term oil volatility. Consider,

⁷ Note that the parameters γ for the full sample and α for the 2004 to 2015 sample are insignificant in the results, as indicated in Table 2. The sum of α , β and $\gamma/2$ is calculated using only the significant values.

first, the parameter estimators in the sub-periods. For instance, take three years of lags where θ ranges from 3.438 for the pre-2004 (1990 to 2003) sample to -5.235 for the post-2004 (2004 to 2014) sample. Because the parameter θ is positive and significant in the pre-2004 period, it means that increased oil demand shocks lead to high stock market volatility. From Table 2, we find that the weighting function in Equation (5) where $w_1 = 20.576$ and $w_2 = 12.967$ results in 0.359 on the first lag

Table 2 Parameter estimates of GARCH-MIDAS with oil supply shocks

<i>Full sample</i>								
<i>Lags</i>	μ	α	β	γ	m	θ	ω_1	ω_2
12 month	0.0015 (0.0099)	0.0753*** (0.0213)	0.9177*** (0.0171)	-0.0014 (0.0169)	0.4093 (0.3495)	-2.0037 (1.628)	10.6115** (4.9276)	16.341* (10.015)
24 month	0.0024 (0.0099)	0.0744*** (0.02)	0.9208*** (0.0164)	-0.0029 (0.0165)	0.2002 (0.3336)	0.4101 (0.5204)	26.9977** (11.419)	55.2748** (24.437)
36 month	0.0015 (0.0099)	0.0753*** (0.0213)	0.9177*** (0.0171)	-0.0014 (0.0169)	0.4093 (0.3495)	-2.0037 (1.628)	10.6115** (4.9276)	16.341* (10.0145)
<i>Pre-2004 sample</i>								
<i>Lags</i>	μ	α	β	γ	m	θ	ω_1	ω_2
12 month	-0.0015 (0.0137)	0.1062*** (0.0321)	0.906*** (0.0243)	-0.0394 (0.025)	0.4313 (0.4013)	-0.3292 (0.3024)	22.8052 (38.6091)	2.5547 (5.5399)
24 month	-0.0003 (0.0135)	0.1145*** (0.032)	0.9002*** (0.0231)	-0.0437* (0.0258)	0.0694 (0.4431)	2.5613* (1.4968)	10.9831 (7.3359)	2.1366** (0.9362)
36 month	0.0006 (0.0136)	0.113*** (0.0331)	0.9026*** (0.0244)	-0.0451** (0.0258)	-0.0534 (0.46)	3.4375** (1.4952)	20.576** (9.9819)	12.9568* (7.8087)
<i>Post-2004 sample</i>								
<i>Lags</i>	μ	α	β	γ	m	θ	ω_1	ω_2
12 month	0.0067 (0.0145)	0.0172* (0.0092)	0.9602*** (0.0112)	0.043*** (0.0149)	0.0062 (0.302)	3.4231 (2.9467)	0.6661 (0.5768)	1.4116 (1.1)
24 month	-0.0044 (0.0152)	0.0161 (0.0129)	0.9357*** (0.0291)	0.0669*** (0.025)	0.0597 (0.2599)	-5.0848*** (1.3551)	3.0133 (2.8541)	1.802 (2.3429)
36 month	-0.0038 (0.0151)	0.0164 (0.0132)	0.9355*** (0.0291)	0.0655*** (0.0251)	0.0454 (0.2348)	-5.2345*** (1.2472)	5.5582 (3.6781)	7.2056 (5.5651)

Note: This table reports estimation results for parameters in Equations (3)–(5) with X being the oil supply shock; the value in parenthesis refers to the standard deviation. We take the lags for 1, 2, 3 years respectively. ***, ** and * indicate significance at 1%, 5% and 10% levels.

(the maximum weights) of the oil demand shock. If an oil demand shock occurred in the current month, we would see an increase of 2.429 in long-term oil volatility the following month.⁸ For the post-2004 sample, the weighting function where $w_1 = 5.558$ and $w_5 = 7.206$ results in 0.071 on the first lag and 0.095 on the fifth lag (the maximum weights) of the oil demand shock. Thus, an oil demand shock occurring in the current month would lead to a 0.309 decrease in oil volatility, while an oil demand shock occurring five months prior would have led to a 0.391 decrease in oil volatility. With respect to the upper panel of Table 2, all of the parameter estimates for θ are insignificant when we take one, two and three years of lags for the full sample. Furthermore, it is noted that the impact of oil demand shock on oil volatility behaves much differently and, even contrary, before and after the financialization of commodities.

With respect to the impact of oil supply shock on short-term oil volatility,⁹ the most striking result is its asymmetry as the oil price moves up and down. The estimated parameter μ is insignificant while γ is negative, and in all but one case, the two are statistically significant. A quick computation reveals that the absolute value of the parameter λ is greater when the oil price increases ($\lambda = 0.033$) than when the oil price decreases ($\lambda = 0.020$). This finding indicates that an oil supply shock would have a greater effect on oil volatility when the oil price increases. For the post-2004 sample, the estimated parameter γ is positive, and in all cases, it is statistically significant such that the parameter λ is -0.003 or -0.016 depending on whether the oil price increases or decreases, respectively. This suggests that during the post-2004 period, the oil supply shock would decrease oil volatility more when the oil price decreases than when the oil price increases. Although Herrera et al. (2015) argue that there is little support for asymmetry in the response of economic activity to oil price increases and decreases, we provide evidence that oil price increases and decreases are important for the asymmetric impacts of economic factors on short-term oil volatility.

⁸As $\Delta \log \tau_t = \theta \rho_1(w_1, w_2) \Delta X_t$, the increase in oil volatility is calculated as $e^{\theta \rho_1(w_1, w_2) \Delta X_t} - 1$.

⁹It should be noted that the response of short-term volatility to different oil shocks is consistent with that of long-term volatility as the value of $\alpha + \gamma \cdot 1_{\{r_{t-1} - u < 0\}}$ remains positive in all cases.

4.2 Effects of speculative oil demand shock

The contribution of oil-specific demand shock to long-/short-term oil volatility is examined, and the estimation results are presented in Table 3.

We first focus on the impact on long-term oil volatility. The parameter θ is statistically significant both for the pre-2004 sample and the post-2004 sample.

Table 3 Parameter estimates of GARCH-MIDAS with oil speculative demand shocks

<i>Full sample</i>								
<i>Lags</i>	μ	α	β	γ	m	θ	ω_1	ω_2
12 month	0.0021 (0.0099)	0.0747*** (0.02)	0.9202*** (0.016)	-0.0024 (0.0167)	0.2161 (0.3321)	0.5764 (0.689)	16.704 (13.481)	8.1625** (3.3738)
24 month	0.0022 (0.0099)	0.0742*** (0.0198)	0.9208*** (0.0161)	-0.0024 (0.0166)	0.184 (0.336)	1.2367 (1.9551)	1.8408 (2.9639)	4.5859 (12.259)
36 month	0.0022 (0.0099)	0.0742*** (0.0197)	0.9208*** (0.0161)	-0.0024 (0.0166)	0.1862 (0.3295)	1.1773 (1.8049)	2.0953 (2.4529)	9.0113 (10.782)
<i>Pre-2004 sample</i>								
<i>Lags</i>	μ	α	β	γ	m	θ	ω_1	ω_2
12 month	-0.0007 (0.0137)	0.114*** (0.0326)	0.8989*** (0.0242)	-0.041 (0.026)	0.3187 (0.4006)	1.6125 (1.4808)	3.6964 (2.3913)	3.3915*** (1.2684)
24 month	-0.0002 (0.0136)	0.1122*** (0.0326)	0.9007*** (0.024)	-0.0405 (0.0263)	0.1045 (0.4257)	4.4994** (2.115)	2.2294 (2.3415)	2.5919** (1.2848)
36 month	-0.0005 (0.0136)	0.1129*** (0.033)	0.8983*** (0.0248)	-0.0386 (0.0261)	0.3293 (0.3987)	1.0133* (0.6051)	308.6306 (217.0418)	329.8625 (238.9528)
<i>Post-2004 sample</i>								
<i>Lags</i>	μ	α	β	γ	m	θ	ω_1	ω_2
12 month	0.0022 (0.0139)	0.0236** (0.0108)	0.9469*** (0.0191)	0.0464** (0.0214)	-0.0999 (0.2949)	-1.3837 (1.2946)	10.5853** (5.4872)	17.7481** (9.0129)
24 month	-0.0032 (0.0149)	0.0168 (0.0142)	0.9307*** (0.0279)	0.0673*** (0.0228)	-0.0092 (0.1892)	-10.6815*** (2.5051)	2.5273 (1.7415)	1.9956* (1.0318)
36 month	-0.0027 (0.015)	0.0176 (0.015)	0.9315*** (0.0322)	0.065*** (0.0235)	-0.0097 (0.2154)	-10.6964*** (2.9306)	4.876 (5.1818)	6.9634 (6.3862)

Note: This table reports estimation results for parameters in Equations (3)–(5) with X being the oil speculative demand shock; the value in parenthesis refers to the standard deviation. We take the lags for 1, 2, 3 years respectively. ***, ** and * indicate significance at 1%, 5% and 10% levels.

However, the value of θ is positive with a value of 1.0133 with Lags=3 years during the pre-2004 period and becomes negative with a value of -10.6964 after 2004. This suggests that speculative oil shock increases oil volatility before 2004, whereas it decreases the fluctuations after the financialization of the commodity markets. For the full sample, a significant effect of speculative demand shock is not observed, a result that is consistent with Irwin and Sanders (2012).

The speculative demand shock on short-term oil volatility behaves differently in the pre-2004 sample than it does in the post-2004 sample in terms of its asymmetry. Before 2004, there is no significant asymmetric effect on oil price increases and decreases. By contrast, the parameter γ is positive and significant with a value of 0.06 during the post-2004 period, suggesting that speculative oil demand shock more substantially decreases oil volatility when the oil price decreases.

Briefly, our results indicate that speculative activities may stabilize the oil price, which complements the existing evidence that supports the Masters Hypothesis,¹⁰ for the following reasons. First, the parameter θ in Table 3 is negative in the post-2004 period, indicating that speculative oil demand shocks directly stabilize oil volatilities. Second, speculative activities change the pattern of impacts of other oil shocks and indirectly affect oil volatilities, a results that indicates that the index investment in the commodity market may change the patterns of the impacts of oil supply shocks, speculative oil demand shocks and speculative oil shocks on oil volatilities. As evidenced in Tables 2 to 4, the effects of all of the oil shocks (with the expectation of the global demand shock) become negative in the post-2004 period, which means that oil shocks stabilize oil volatilities.

Compared with the oil supply shock, a noteworthy fact is that the impact of oil speculative demand shock on oil volatility is similar to that of supply shock, as discussed in Section 4.1. To explain this, we first turn to the definition of speculation. The most general economic definition of speculation is provided by Kilian and Murphy (2014), who note that anyone buying crude oil for future use rather than for current consumption is a speculator from an economic perspective.

¹⁰ The Masters Hypothesis is a short-hand label for the claim that unprecedented buying pressure in recent years from commodity index investors created massive bubbles in commodity futures prices, as argued by hedge fund manager Michael W. Masters (Irwin and Sanders, 2012).

Thus, oil speculative demand is expected to be closely associated with oil supply as speculative oil demand is driven by the poor supply of oil.¹¹ After 1973, when supply became restricted, the long-term relationships between oil inventories and the real price became a function of the flexibility of the oil supply (Dvir and Rogoff, 2014). Supportive evidence is also found in the work of Kilian and Lee (2014), who find that speculation may drive up the real price of crude oil in the physical market during times of instability with respect to oil supplies from the Middle East. This could be because speculation is conducted by oil producers who have the option of leaving oil below ground in anticipation of rising prices, and this accumulation of below-ground inventories would be equivalent to a reduction in flow supply.

4.3 Effects of oil-specific demand shock

In this section, the contribution of oil-specific demand shock to long-/short-term oil volatility is examined. The estimation results are shown in Table 4.

Focusing on long-term volatility, the impact of an oil specific demand shock behaves differently in the two sub-periods with respect to significance. For the post-2004 sample, an oil specific demand shock exhibits significant impact on long-term oil volatility. For example, parameter θ is statistically significant with a value of -4.5618 with one-year lags and -5.3157 with two-year lags. Note that θ is negative for the post-2004 sample, which suggests that an oil-specific demand shock would decrease oil volatility. In particular, an oil-specific demand shock in the current month would contribute to a -0.013 decrease in oil volatility in the next month. According to the top panel of Table 4, the impact is negative and significant for the full sample, and when examining the sub-samples, we determine that this is mainly due to the financialization of the commodity markets.

With respect to the impact of a global demand shock on short-term oil volatility, there is also a significant difference between the pre-2004 period and the post-2004 period with respect to the asymmetry of the impact. For the pre-2004 sample, the parameter γ is insignificant, which suggests that the impact on short-

¹¹ This phenomenon is consistent with the view that speculation activities in oil markets simply follow market trends set in motion by earlier shocks to economy fundamentals rather than creating market trends of their own.

term volatility is symmetric with decreases and increases in the oil price. However, for the post-2004 sample, the estimated parameter γ is positive and significant in all cases. The value of λ is -0.015 when the oil price decreases and -0.003 when the oil price increases. These results reveal that during this period, an oil-specific demand shock would decrease oil volatility when the oil price decreases.

Table 4 Parameter estimates of GARCH-MIDAS with oil specific demand shocks

<i>Full sample</i>								
<i>Lags</i>	μ	α	β	γ	m	θ	ω_1	ω_2
12 month	0.0019 (0.01)	0.07** (0.0218)	0.9256*** (0.0204)	-0.0018 (0.0159)	0.1611 (0.3414)	0.7607 (1.3392)	6.4427 (22.18)	8.1226 (19.461)
24 month	0.0028 (0.0099)	0.0742*** (0.0219)	0.9188*** (0.0181)	-0.0033 (0.017)	0.3557 (0.3079)	-1.8664** (0.8082)	16.7173** (8.4031)	19.4785* (10.082)
36 month	0.0028 (0.0099)	0.0742*** (0.0219)	0.9189*** (0.0181)	-0.0034 (0.017)	0.3543 (0.308)	-1.858** (0.8207)	21.5315* (11.543)	47.1864* (25.915)
<i>Pre-2004 sample</i>								
<i>Lags</i>	μ	α	β	γ	m	θ	ω_1	ω_2
12 month	-0.0016 (0.0138)	0.1033** (0.0322)	0.909*** (0.0261)	-0.0373 (0.0238)	0.1934 (0.4128)	1.3238 (0.9794)	7.4917 (7.4044)	9.3671 (7.6477)
24 month	-0.0017 (0.0139)	0.1036*** (0.0322)	0.9088*** (0.026)	-0.0374 (0.024)	0.1893 (0.4135)	1.3744 (1.0099)	8.721 (6.9709)	28.5892 (19.448)
36 month	-0.0004 (0.0136)	0.1101*** (0.0309)	0.9048*** (0.0231)	-0.0418* (0.0248)	0.1131 (0.4643)	2.1466 (1.9371)	22.3452 (14.9147)	23.1777 (18.065)
<i>Post-2004 sample</i>								
<i>Lags</i>	μ	α	β	γ	m	θ	ω_1	ω_2
12 month	-0.001 (0.014)	0.0129 (0.013)	0.9336*** (0.025)	0.0665*** (0.022)	-0.0932 (0.147)	-4.5618*** (1.137)	1.7925 (1.549)	1.3372** (0.680)
24 month	-0.0016 (0.0139)	0.0115 (0.0136)	0.9371*** (0.0249)	0.0656*** (0.0204)	-0.0651 (0.1602)	-5.3157*** (1.3837)	4.4555** (1.930)	6.6391*** (2.342)
36 month	-0.0009 (0.0147)	0.0230* (0.012)	0.9491*** (0.0213)	0.0467** (0.0204)	0.2053 (0.8468)	-1.5939 (1.1668)	61.243 (55.1086)	41.9226 (40.5779)

Note: This table reports estimation results for parameters in Equations (3)–(5) with X being the oil specific demand shock; the value in parenthesis refers to the standard deviation. We take the lags for 1, 2, 3 years respectively. ***, ** and * indicate significance at 1%, 5% and 10% levels.

Furthermore, it is noted that the empirical results for oil-specific shocks are similar to those of oil supply shocks and speculative oil demand shocks. Evidence indicates that these oil shocks enhanced oil volatility during the pre-2004 period. Moreover, the empirical results suggest that the three oil shocks tend to decrease more short-term oil volatility when the oil price decreases compared to when the oil price increases.

4.4 Effects of oil global demand shock

Table 5 provides parameter estimates for GARCH-MIDAS with a global oil demand shock. Two observations can be derived from the estimation results presented in Table 5.

First, and most importantly, contrary to other oil shocks, the impact of a global demand shock on long-/short-term volatility remains positive and statistically significant for both the pre-2004 period and the post-2004 period. This result is consistent with Kilian and Murphy (2014), who found that the 2003 to 2008 oil price surges were caused primarily by unexpected increases in world oil consumption driven by the global business cycle. For example, considering three years of lags, θ ranges from 7.047 for the pre-2004 (1990–2003) sample to 3.803 for the post-2004 (2004–2014) sample. However, this impact becomes much weaker after the financialization of the commodity markets. In the pre-2004 sample, a global oil demand shock occurring in the current month would lead to a 0.338 increase in long-term oil volatility in the subsequent month. However, in the post-2004 period, this same shock only results in a 0.118 increase in long-term volatility in the subsequent month.

Second, with respect to the asymmetry of the impact of a global demand shock on short-term oil volatility, the parameter γ is insignificant for the pre-2004 sample and for the full sample, but it is significant for the post-2004 sample. Focusing on the results in the bottom panel of Table 5, the estimated parameter γ is positive, and they are statistically significant in all cases. Considering the specification where Lags=3 years, for example, the value of λ is 0.022, denoting an oil price decrease, and 0.003, denoting an oil price increase. Accordingly, the results indicate that in the post-2004 period a significant asymmetric impact of a global demand shock on short-term oil volatility exists only during the post-2004 period. This suggests that the impact of a global demand shock on short-term

volatility would be greater when oil prices decrease rather than when oil prices increase.

Table 5 Parameter estimates of GARCH-MIDAS with global demand shocks

<i>Full sample</i>								
<i>Lags</i>	μ	α	β	γ	m	θ	ω_1	ω_2
12 month	0.0024 (0.0098)	0.0766*** (0.021)	0.9156*** (0.0161)	0.0001 (0.0175)	0.0077 (0.3548)	1.7986*** (0.6789)	7.8826** (3.7444)	2.8069** (1.2300)
24 month	0.0023 (0.0098)	0.0766*** (0.0209)	0.9155*** (0.016)	0.0004 (0.0175)	0.002 (0.3594)	1.8996** (0.749)	19.4501* (12.105)	28.7975* (17.628)
36 month	0.0023 (0.0098)	0.0767*** (0.0209)	0.9155*** (0.016)	0.0004 (0.0175)	0.0007 (0.3599)	1.9196** (0.7579)	22.6071* (14.07)	59.8713* (36.981)
<i>Pre-2004 sample</i>								
<i>Lags</i>	μ	α	β	γ	m	θ	ω_1	ω_2
12 month	-0.0011 (0.0137)	0.1098*** (0.0343)	0.9006*** (0.0264)	-0.0358 (0.0261)	0.3653 (0.422)	1.6636 (1.1504)	1.7332 (1.9365)	9.1048* (5.009)
24 month	-0.001 (0.0137)	0.1068** (0.0341)	0.9036*** (0.0264)	-0.036 (0.0258)	0.3562 (0.4123)	6.8745* (3.8953)	36.4847 (27.1774)	17.5175 (16.2746)
36 month	-0.001 (0.0137)	0.1066** (0.0339)	0.9038*** (0.0263)	-0.0359 (0.0256)	0.3553 (0.4123)	7.0473* (3.9216)	60.5962 (38.7786)	71.7431 (53.3899)
<i>Post-2004 sample</i>								
<i>Lags</i>	μ	α	β	γ	m	θ	ω_1	ω_2
12 month	-0.0007 (0.0139)	0.0137 (0.0136)	0.9359*** (0.0225)	0.0647*** (0.02)	-0.9485*** (0.210)	2.7227*** (0.604)	2.0147 (2.0834)	1.2373** (0.697)
24 month	-0.0006 (0.0139)	0.0128 (0.0129)	0.9286*** (0.023)	0.073*** (0.0201)	-1.1577*** (0.2534)	3.4778*** (0.9045)	4.4551* (2.7139)	5.4195 (3.8464)
36 month	-0.0013 (0.0139)	0.0112 (0.0132)	0.93*** (0.0232)	0.0742*** (0.0196)	-1.2306*** (0.3200)	3.8027*** (1.2356)	3.8986 (3.5797)	7.5089 (9.3704)

Note: This table reports estimation results for parameters in Equations (3)–(5) with X being the global demand shock; the value in parenthesis refers to the standard deviation. We take the lags for 1, 2, 3 years respectively. ***, ** and * indicate significance at 1%, 5% and 10% levels.

4.5 Discussion

Consistent with Kilian (2009), the results presented herein confirm the varied impacts of the different types of oil shocks on oil market volatility. The summarized results are presented in Table 6 and Figure 2.

However, this phenomenon is not found when only the real oil price is used, as illustrated in Table 7, which raises the question, “Why are oil shocks better indicators of oil volatility?” Many important studies (e.g., Hamilton, 2003; Blanchard and Riggie, 2010; Chiang et al., 2015) note that the nature of the relationship between oil prices and economic activity is nonlinear, time-varying, and difficult to attribute to any single source. Nonetheless, we believe that the combination of the set of oil shocks delivers relatively accurate information regarding economic activity. Moreover, traditional wisdom views oil prices as exceptionally informative with respect to future economic activities and volatilities. In addition, oil production, oil inventories and real activity are also found to provide valuable information about oil prices and volatilities (e.g., Hong and Yogo, 2012; Szakmary et al. 2010). Oil shocks, based on the indicators mentioned herein, can summarize the information of oil markets and may better capture oil volatilities. Given this line of reasoning, it is interesting that oil price shocks can have vastly different effects on the real price of oil depending on the origin of the shocks.

Table 6 The response of oil price volatility to different types of oil shocks.

	Long/short-term volatility		
	Full period	Pre-2004	Post-2004
Oil supply shock		+	-
Speculative demand shock		+	-
Specific oil demand shock	-		-
Global demand shock	+	++	+

Note: This table is extracted from the results of the response of oil price volatility to different types of oil shocks as shown in Table 2–5. The “+” indicates that oil shock would increase oil price volatility. The “-” indicates that oil shock tends to stabilize oil price. The “++” indicates that global demand shock has a larger impact for the pre-2004 period than other periods.

Figure 2 Long and short run volatilities under different oil shocks

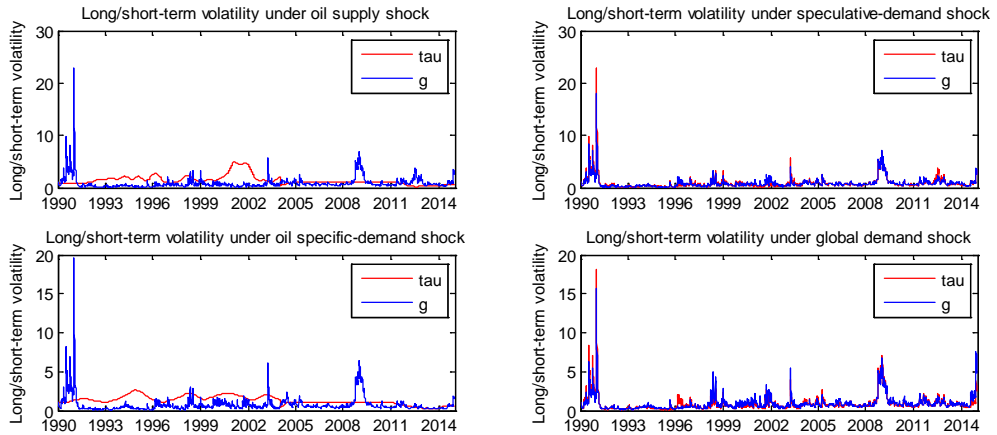


Table 7 Parameter estimates of GARCH-MIDAS with oil real price

μ	α	β	γ	m	θ	ω_1	ω_2
<i>Full Sample (Maximized LLF: -8071.93)</i>							
0.0035	0.0428**	0.9380***	-0.0237**	0.5335*	-0.0213*	14.9797	6.7311
(0.0103)	(0.0142)	(0.0147)	(0.0121)	(0.3142)	(0.011)	(13.3327)	(10.422)
<i>Pre-2004 sample (Maximized LLF: -4260.96)</i>							
0.0035**	0.0665**	0.9252**	-0.0092**	2.5499	-0.1990***	8.3156*	2.7801**
(0.0143)	(0.023)	(0.021)	(0.0191)	(0.6798)	(0.0473)	(4.6111)	(1.2532)
<i>Post-2004 sample (Maximized LLF: -3805.61)</i>							
-0.0183	0.0201*	0.9645***	0.0380**	1.3606	-0.1611**	4.3731***	2.4999***
(0.0172)	(0.0104)	(0.0095)	(0.0132)	(0.8523)	(0.0662)	(0.994)	(0.5573)

Note: This table reports estimation results for parameters in Equations (3)–(5) with X being the oil real price; the value in parenthesis refers to the standard deviation. We take the lags for 3 years respectively. ***, ** and * indicate significance at 1%, 5% and 10% levels.

5 Conclusion

In this paper, we aimed to assess the role of economy fundamentals and speculations as drivers of volatility in oil prices, a subject of considerable controversy, by employing the GARCH-MIDAS framework. In particular, because Kilian (2009) highlights that oil price shocks can have varying effects on the real price of oil depending on the origin of the shocks, we examine the impacts of different types of oil shocks on oil market volatility before and after the year 2004. Several conclusions are derived based on the results of this study.

First, with respect to the impacts of different types of shocks, the global demand shock is the only one found to be positive and to significantly affect long-/short-term oil volatility in all of the sample periods analyzed herein. These results indicate that a global oil demand shock would markedly increase oil volatility, which supports the findings of Kilian (2009), Juvenal et al. (2014) and others with respect to the importance of global demand in explaining oil price fluctuations.

Second, when comparing the results of the pre-2004 period with those of the post-2004 period, it is found that the results regarding the impacts of oil shocks for the two periods are reversed. According to our empirical results, all of the oil shocks except the oil-specific demand shock significantly exacerbated oil volatility during the pre-2004 period, while the impacts on oil volatility were significantly reduced (for global demand shock) and were even reversed (for oil supply shock, oil-specific demand shock and speculative shock) after 2004 when significant index investments began to flow into the commodity markets.

In addition, our results also suggest the existence of asymmetric impacts on short-term oil volatility, particularly for shocks from oil supply and oil-specific speculative demand. This asymmetry assumes that oil shocks tend to have a greater impact on short-term oil volatility when oil prices decrease rather than when oil prices increase. This result provides evidence for the argument that oil price increases are much more important than oil price decreases.

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