Oil price shocks and stock return volatility: new evidence based on volatility impulse response analysis

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Oil Price Shocks and Stock Return Volatility: New Evidence Based on Volatility Impulse Response Analysis[☆]

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Abstract

We use volatility impulse response analysis to quantify the size and the persistence of different types of oil price shocks on oil and stock return volatility dynamics. Our results show that precautionary demand followed by aggregate demand-side shocks, compared to supply-side ones, have higher positive and persistent effects on stock return volatility whereas the correlations between the two variables are mostly affected by the former shocks.

Keywords: Oil price shocks, Stock returns, Volatility impulse response analysis
JEL classification: C32, Q43

1. Introduction

The dynamic impact of oil price shocks on stock market returns has attracted considerable attention in the recent literature. In an influential paper, Kilian & Park (2009) found that the response of US aggregate stock returns to oil price shocks greatly depends on the cause of such shocks, when they attributed fluctuations in the real oil price to structural shocks associated with (i) the global supply of crude oil, (ii) the global demand for commodities driven by global real economic activity, and (iii) oil-market specific demand (or precautionary demand) shock which captures shifts in precautionary demand for crude oil in response to higher uncertainty about future oil supply shortfalls.

Considering the recent evidence on oil price shock effects on stock returns, this paper uses volatility impulse response functions, estimated from the bivariate GARCH-BEKK model and developed by Hafner & Herwartz (2006), as an alternative way to quantify the size and the persistence of different historical shocks in oil price depending on their origins (namely supply-side, aggregate demand-side and precautionary demand shocks as in Kilian & Park (2009)) on stock return volatility and on the correlation between oil price changes and stock returns for a wide range of net oil-importing and oil-exporting countries. In this way, our paper builds upon many studies in the existing literature, e.g., by Filis et al. (2011), Degiannakis et al. (2013) and Boldanov et al. (2016), who analyse instead the sign and magnitude of the correlations between oil price changes and stock returns during each type of oil price shocks using empirical specifications which ignore volatility spillovers between the two markets, and by Kilian & Park (2009), Foroni et al. (2017) and Ready (2018) among others, who mainly focus on the dynamic impact of oil price shocks on the mean of stock returns (i.e., the first moment). The paper is organised as follows. Section 2 describes the employed data on stock returns and oil price changes. Section 3 outlines the employed bivariate GARCH-BEKK model and volatility impulse response analysis, as well as the hypotheses tested. Section 4 discusses the empirical results. Section 5 concludes.

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2. Data description

In our analysis we use weekly (Wednesday to Wednesday) prices of oil and the stock markets, because daily or intra-daily data are impacted by noise and anomalies such as day-of the-week effects, while monthly data may be inadequate to trace the short-run evolution of capital across international financial markets. We consider a wide range of net oil-importing countries (Brazil, China, France, Germany, Italy, Japan, the UK and the US) and oil-exporting ones (Canada, Mexico, Norway and Russia) over the period from January 1995 to June 2017. The stock prices used are those of the MSCI indices in US dollars, while the oil price is the crude oil brent price in US dollars per barrel. The oil and stock prices are given in logarithms and denoted by the variables o_t and s_t, respectively. Hence, log returns of oil and stocks are expressed in percentages and calculated respectively as $r_{o,t} = 100{*}(o_t - o_{t-1})$ and $r_{s,t} = 100{*}(s_t - s_{t-1})$. All time series data have been downloaded from Thomson DataStream.

3. Econometric methodology

We adopt a bivariate AR(1)-GARCH(1,1)-BEKK model for our estimations. While the conditional mean equations are specified as simple AR(1) models, we employ the bivariate GARCH-BEKK framework of Engle & Kroner (1995) for modelling the conditional variances which takes the following form:

$$\boldsymbol{H_t} = \boldsymbol{C'C} + \boldsymbol{A'\epsilon_{t-1}\epsilon'_{t-1}A} + \boldsymbol{G'H_{t-1}G} \qquad (1)$$

where $\boldsymbol{H_t}$ is the conditional variance-covariance matrix, $\boldsymbol{C}$ is a lower triangular matrix and $\boldsymbol{A}$ and $\boldsymbol{G}$ are 2×2 parameter matrices. Given the nature of the data, we assume t-distributed innovations, such that $\epsilon_t \sim t(\nu)$ with ν being the degrees of freedom.

It follows that the adopted framework allows for volatility spillovers between oil price changes and stock returns and also enables us to analyse the dynamic impact of an oil price shock on both stock return volatility and the correlation between oil price changes and stock returns, in the spirit of Hafner & Herwartz (2006). More specifically, volatility impulse response functions (VIRFs) are defined as the difference between the expected volatilities conditional on the initial shock and the available information set and on such information set only:

$$\boldsymbol{\vartheta_t} = E[\text{vech}(\boldsymbol{H_t})|\nu_0, \mathcal{F}_{t-1}] - E[\text{vech}(\boldsymbol{H_t})|\mathcal{F}_{t-1}], \qquad (2)$$

where $\boldsymbol{\vartheta_t} = [\vartheta_{o,t}, \vartheta_{os,t}, \vartheta_{s,t}]'$ is a three dimensional vector containing the responses of the conditional variances of oil and stock market returns on its first and third elements, respectively, while the second element is the response function of the conditional covariance between the two market returns. Moreover, ν_0 and $\mathcal{F}_{t-1}$ denote the volatility shock and the information set available up to the period $t-1$, respectively, where ν_0 is specified as $\nu_0 = \boldsymbol{H_t^{-1/2}\epsilon_t}$.

Consequently, the initial response, which is the impact of a shock at time $t = 1$ is obtained as

$$\boldsymbol{\vartheta_1} = \boldsymbol{A^*}\{\text{vech}(\boldsymbol{\epsilon_t\epsilon'_t}) - \text{vech}(\boldsymbol{H_t})\}, \qquad (3)$$

whereas the response function for any $t \geq 2$ is calculated as

$$\boldsymbol{\vartheta_t} = (\boldsymbol{A^*} + \boldsymbol{G^*})\boldsymbol{\vartheta_{t-1}} \qquad (4)$$

with $\boldsymbol{A^*}$ and $\boldsymbol{G^*}$ being $N^* \times N^*$ parameter matrices expressed in the *vech* representation of the GARCH-BEKK model. Comparing the VIRFs calculated in Eqs. (3) and (4) with the impulse response functions (IRFs) from a conventional impulse response analysis of conditional mean models, Hafner & Herwartz (2006) emphasise that the VIRFs have various distinctive features, since they (i) are symmetric functions of the shock with $\vartheta_t(\nu_0) = \vartheta_t(-\nu_0)$, (ii) are not a homogeneous function of the shocks, and (iii) do depend on the history through the initial volatility state at the time when the shock hits the system.

Finally, we calculate the average VIRFs over periods covering different types of historical oil price shocks which are summarised in Table 1. Therefore $\boldsymbol{\vartheta_{i,j}}$ for $i = o, os, s$ and $j = SS, DS, PD$ denote the average response functions to each type of oil price shocks.

4. Empirical results

Figure 1 illustrates the average VIRFs of oil returns, the correlation between oil and stock returns and stock returns over periods which cover

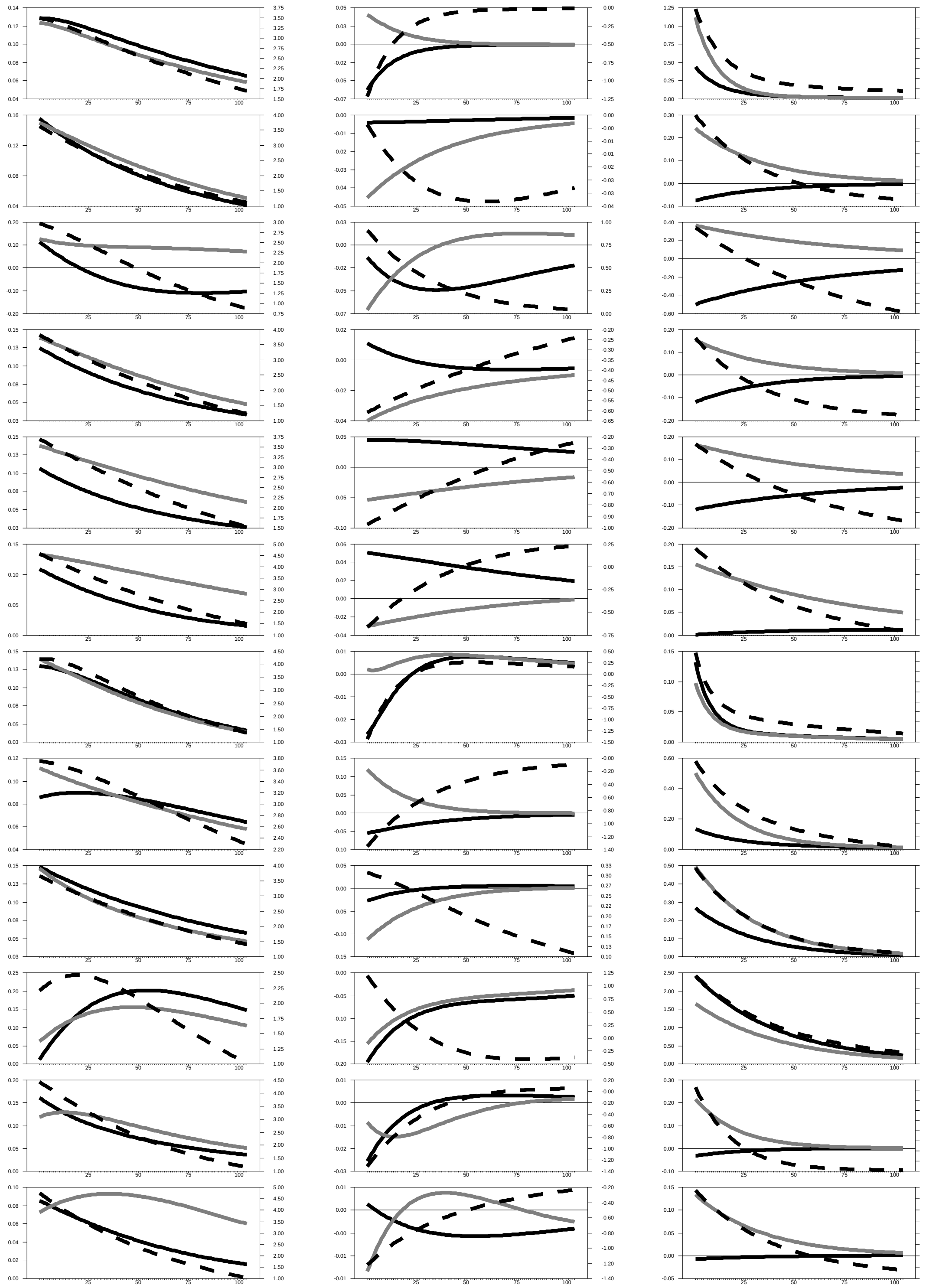

Figure 1: Volatility impulse response functions: The graphs plot average responses of oil and stock returns ($\boldsymbol{\vartheta_{o,j}}$ and $\boldsymbol{\vartheta_{s,j}}$) as well as of their correlation ($\boldsymbol{\vartheta_{os,j}}$) (left, right and middle columns, respectively) to different types of oil price shocks (supply shock ($\boldsymbol{\vartheta_{i,SS}}$): black line, left axis, demand shock ($\boldsymbol{\vartheta_{i,DS}}$): grey line, left axis, precautionary demand shock ($\boldsymbol{\vartheta_{i,PD}}$): black dashed line, right axis), presented from top to bottom for Brazil, Canada, China, France, Germany, Italy, Japan, Mexico, Norway, Russia, the UK and the US.

Table 1: Summary of different types of oil price shocks

Shock	Event	Period	in weeks
Supply-side			
SS_1	Oil production cuts by OPEC countries (known as the 1998 oil crisis)	1998.03.01 − 1998.12.31	44
SS_2	Venezuela general strike of 2002−2003	2002.12.01 − 2003.02.08	13
SS_3	Libya's unrest and the subsequent NATO intervention and Saudi Arabia's increase of its oil production	2011.01.10 − 2011.05.27	20
SS_4	OPEC and non-OPEC producers reached their first deal since 2001 to curtail oil output jointly	2016.12.01 − 2016.12.31	4
SS_5	OPEC and non-OPEC members agree to extend production cuts for nine months	2017.05.22 − 2017.06.23	5
Aggregate demand-side			
DS_1	The Asian financial crisis	1997.06.30 − 1998.10.02	66
DS_2	The increase of Chinese oil demand	2006.01.02 − 2007.07.06	79
DS_3	The global financial crisis of 2007−2008	2008.09.15 − 2010.01.01	68
DS_4	The downgrade of the US debt status in August 2011	2011.08.08 − 2011.09.02	4
DS_5	The European sovereign debt crisis	2012.04.30 − 2012.06.29	9
DS_6	Robust global production exceeded	2014.07.14 − 2015.01.15	27
Precautionary demand			
PD_1	The terrorist attacks of September 11, 2001	2001.09.10 − 2001.09.28	3
PD_2	The Iraq invasion in March 2003	2003.03.17 − 2003.03.28	2
PD_3	The US missile strike of Syria's Shayrat Airbase	2017.04.07 − 2017.04.14	1

Notes: This table lists the historical periods dominated by each type of oil price shocks depending on its origin as in Kilian & Park (2009) (see also Filis et al. (2011) and Degiannakis et al. (2013) for choice of some of these dates).

supply- and demand-side as well as precautionary demand shocks. A graphical inspection indicates that on average the expected conditional variances of stock returns exhibit a large positive response to precautionary demand shocks compared to the other types of shocks. Yet, the effect sizes of such shocks are not the same for all countries. For example, while slowly decreasing to zero, their effects are the largest for Russia and Brazil reflecting the stronger dependency of such economies on oil exports whereas they are the smallest for Canada, Italy and Norway.

Aggregate demand-side shocks also have a positive impact on the expected conditional variances for all countries, albeit they are relatively smaller in magnitude compared to those of precautionary demand. The effects of such shocks are larger for Russia followed by Brazil and then Mexico and Norway, but they are the smallest for Japan, the US, France, Germany and Italy. Therefore, the expected conditional variances of stock returns for net oil-exporting countries exhibit a relatively larger positive response to aggregate demand-side shocks compared with those of net oil-importing ones.

As for the supply-side shocks, their effects are country-specific compared to the other types of shocks and smaller in magnitude relative to, at least, those of precautionary demand; for instance, they are positive (negative) for Brazil, Japan, Mexico, Norway and Russia (Canada, China, France, and Germany) and slowly dampening to zero whereas they are almost negligible for Italy, the UK, and the US. This implies that that the expected conditional variances of stock returns for most net oil-exporting countries also exhibit a relatively positive response to such shocks.

The results in Figure 1, however, suggest that the effects of each type of shocks on the correlations between oil price changes and stock returns are relatively smaller in magnitude, compared to those on stock return volatility, for all countries. Moreover, it is evident that the effects of precautionary demand shocks on the correlations are greater compared to the other types of shocks for all countries, although such effects are negative for all cases except China, Norway and Russia, where they show a positive response, and Canada where the effects are insignificant but turn into negative in the following weeks. The effects of aggregate demand-side shocks, by contrast, are shown to be small and negative for all countries except Brazil and Mexico where effects are positive, and Japan where they are insignificant. Finally, the effects of supply-side shocks are positive (negative) for France, Germany, Italy and the US (the rest of the countries); nonetheless, such effects are almost negligible for all countries except Russia.

5. Concluding remarks

Compared to related studies, such as Kilian & Park (2009), Filis et al. (2011) and Boldanov et al. (2016) among others, we show that (i) stock return volatility exhibits a greater response to precautionary demand followed by aggregate demand-side shocks, compared to supply-side ones, albeit the size of the impact and/or the degree of persistence of each type of shocks varies across countries, and that (ii) the responses of the correlations to oil price shocks are relatively smaller, compared to those of stock return volatility, for most countries, and, moreover, such correlations mostly react to precautionary demand shocks, compared to the other types of shocks, where the responses are negative for all countries except China, Norway and Russia, which are positive. Our findings are of paramount interest to investors and risk managers in terms of portfolio diversification and their risk exposure to the different types of oil price shocks, and to regulators as they shed light on the extent to which such shocks have effects and persistence on the dynamics of stock return volatility and its linkages with that of oil price changes.

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