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

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Non-technical summary

Research Question

This paper investigates the impact of different types of oil price shocks on stock return volatility and on the covariance between oil price changes and stock returns using volatility impulse response analysis based on a bivariate GARCH model.

Contribution

The model allows to quantify the effects of each type of shock on stock return volatility and on the covariance between oil price changes and stock returns for a wide range of net oil-importing and oil-exporting countries. These results may provide important insights for risk management practices related to hedging and undertaking scenario analyses.

Results

We find that precautionary demand shocks and aggregate demand-side shocks have larger and more persistent effects on the conditional variances of stock returns than supply-side shocks for all countries. The covariances between oil price changes and stock returns, on the other hand, are shown to react mostly to precautionary demand shocks. These responses are positive for China, Norway and Russia and negative for all other countries.

Nichttechnische Zusammenfassung

Fragestellung

Dieser Artikel untersucht die Auswirkungen verschiedener Arten von Ölpreisschocks auf die Aktienrenditenvolatilität und die Kovarianz zwischen Ölpreisänderungen und Aktienrenditen unter Verwendung einer Impuls-Antwort-Analyse für Volatilitäten, die auf einem GARCH-Modell basiert.

Beitrag

Die Schätzung ermöglicht die Quantifizierung der Effekte der verschiedenen Arten von Schocks auf die Volatilität der Aktienrenditen und die Kovarianz zwischen Ölpreisänderungen und Aktienrenditen in ausgewählten ölimportierenden und -exportierenden Ländern. Diese können hilfreiche Informationen für Risikomanagementpraktiken im Zusammenhang mit Hedgegeschäften und Szenarioanalysen liefern.

Ergebnisse

Unsere Ergebnisse zeigen, dass sogenannte vorsorgliche Nachfrageschocks und aggregierte nachfrageseitige Schocks für alle Länder größere und anhaltendere Auswirkungen auf die bedingte Varianz der Aktienrenditen haben als angebotsseitige Schocks. Die Kovarianzen zwischen Ölpreisänderungen und Aktienrenditen reagieren dagegen vor allem auf vorsorgliche Nachfrageschocks. Diese Reaktionen sind für China, Norwegen und Russland positiv und für alle anderen Länder negativ.

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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 estimated from the bivariate GARCH-BEKK model to quantify the size and the persistence of different types of oil price shocks on stock return volatility and the covariance between oil price changes and stock returns for a wide range of net oil-importing and oil-exporting countries. We find that precautionary demand followed by aggregate demand-side shocks, compared to supply-side ones, have higher positive and persistent effects on the conditional variances of stock returns for all countries. Moreover, we show that precautionary demand shocks, unlike the other types of shocks, mostly affect the covariances between oil price changes and stock returns; their effects being negative for all countries except China, Norway and Russia, where they are positive.

Keywords: Oil price shocks, Stock returns, Volatility impulse response analysis

JEL classification: C32, Q43.

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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 followed Kilian (2009) by attributing 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) shocks which capture shifts in precautionary demand for crude oil in response to higher uncertainty about future oil supply shortfalls. This finding was confirmed by Filis, Degiannakis & Floros (2011), Degiannakis, Filis & Floros (2013) and Broadstock & Filis (2014), who analysed respectively six net oil-importing and oil-exporting countries, European industrial sector indices, and US and China aggregate and sectoral stock indices in a time-varying framework. Boldanov, Degiannakis & Filis (2016) further established that the correlations between the oil and stock market volatilities are time-varying and are responsive to major economic and geopolitical events. Foroni, Guérin & Marcellino (2017) also documented this time-variation in the relation between oil price and US equity returns and found that oil-specific demand shocks have had positive effects on the US stock market since 2009 as opposed to oil supply shocks, which have no large effects on stock returns. More recently, Ready (2018) classified oil price changes as supply or demand driven using information in asset prices and reported that demand shocks are strongly positively correlated with market returns and economic output whereas supply shocks have a strong negative correlation.

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 prices depending on their origins (namely supply-side, aggregate demand-side and precautionary demand shocks as in Kilian (2009) and Kilian & Park (2009)) on stock return volatility and on the covariance between oil price changes and stock returns for a wide range of net oil-importing and oil-exporting countries. It follows that the adopted framework is flexible enough as it allows for volatility spillovers between oil price changes and stock returns, and more strikingly, for the identification of the dynamic responses of stock return volatility and its covariance with oil price changes to a specific type of historical oil price shock, since the response functions depend on the volatility state at the time when such shocks hit the markets. In this way, our paper builds upon many studies in the existing literature, e.g., by Filis et al. (2011), Degiannakis et al. (2013), Broadstock & Filis (2014) 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 Park & Ratti (2008), Apergis & Miller (2009), 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). All in all, knowledge of the response of stock return volatility and the covariance between oil price changes and stock returns to each type of oil price shocks may provide important practical insights for risk management practices related to hedging and undertaking scenario analyses as well as policy implications related to the regulatory capital required by financial institutions, since the volatility and covariance are used as input elements in the calculation of employed risk measures.

The paper is organised as follows. Section 2 describes the employed data on stock returns and oil price changes. Section 3 outlines the bivariate GARCH-BEKK model and volatility impulse response analysis to study the effects of oil price shocks on stock return volatility and the covariance between oil price changes and stock returns. Section 4 discusses the empirical results. Section 5 concludes.

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 $r_{s,t} = 100 * (s_t - s_{t-1})$. Figure 1 plots oil and stock market returns and volatilities (proxied by squared returns). 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,[1] we employ the GARCH-BEKK framework of Engle & Kroner (1995) for modelling the conditional variance-covariance matrix which takes the following form:

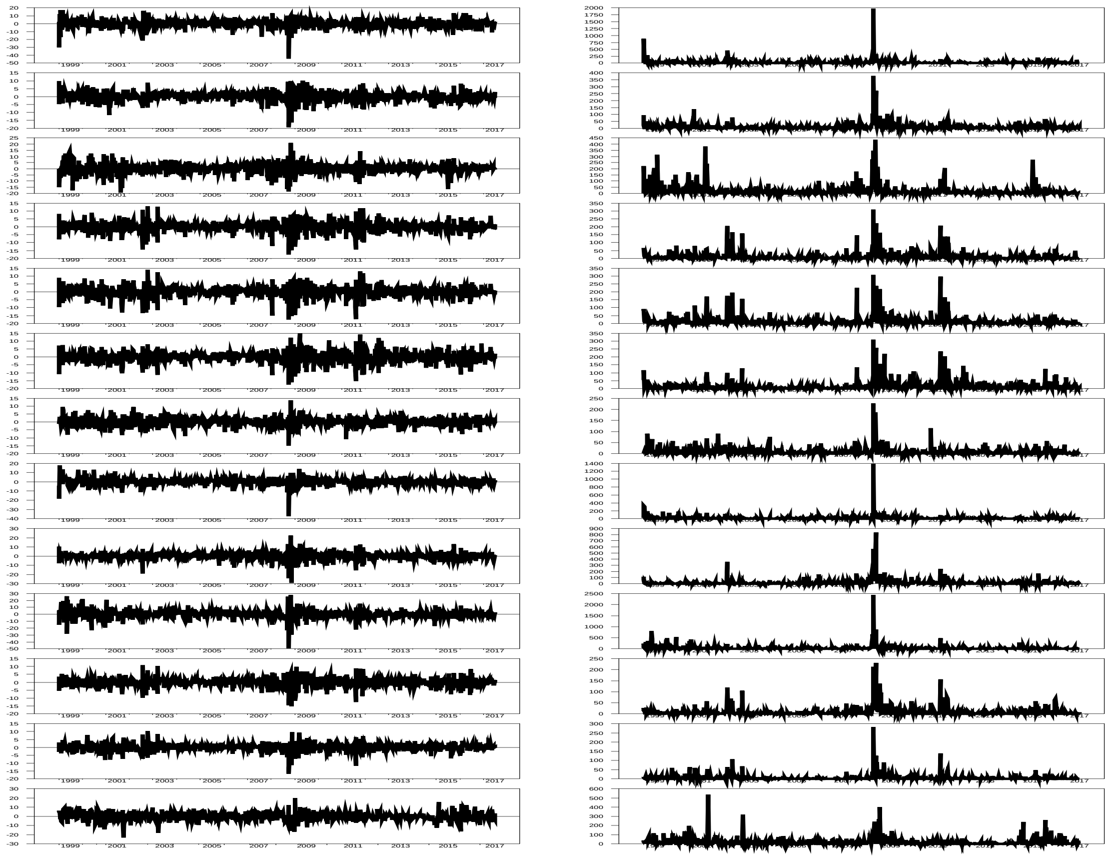
$$\boldsymbol{H_t} = \boldsymbol{C'C} + \boldsymbol{A'\epsilon_{t-1}\epsilon'_{t-1}A} + \boldsymbol{G'H_{t-1}G} \tag{1}$$

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. Following Bollerslev (1987) 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 moreover, unlike the conventional impulse response analysis which captures the effect of specific shocks in oil price on the first moment of stock returns, it enables us to apply volatility impulse response analysis, which is introduced by Hafner & Herwartz (2006), to analyse the dynamic impact of an oil price shock on both stock return volatility and the covariance between oil price changes and stock returns.

[1] We increased the lag length to 2 in the conditional mean equation of stock returns for Russia to capture its required dynamics.

Figure 1: Oil and stock log returns and volatilities



Notes: The graphs plot the weekly oil and stock log returns (left column) and volatilities (proxied by squared returns, right column) over the period 1995:1:1−2017:6:30, presented from top to bottom for Brazil, Canada, China, France, Germany, Italy, Japan, Mexico, Norway, Russia, the UK and the US as well as the crude oil (brent).

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:[2]

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

where $\boldsymbol{\vartheta_t}$ is a three dimensional vector containing the responses of the conditional variances of oil and stock market returns, denoted by $\boldsymbol{\vartheta_{o,t}}$ and $\boldsymbol{\vartheta_{s,t}}$, on its first and third elements, respectively, while the second element $\boldsymbol{\vartheta_{os,t}}$ is the response function of the conditional covariance between the two market returns. Moreover, ν_0 and $\mathcal{F}_{-1}$ denote the volatility shock and the information set available up to the period -1, respectively, where the volatility shock ν_0 is specified as $\nu_0 = \boldsymbol{H_0^{-1/2}\epsilon_0}$.

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

[2]Note that the vech($\cdot$) operator stacks the lower triangular of an $N \times N$ matrix into a vector with $N^* = N(N+1)/2$ dimensions. In our bivariate case $N = 2$ and $N^* = 3$.

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 (2009) and Kilian & Park (2009) (see also Filis et al. (2011) and Degiannakis et al. (2013) for choice of some of these dates).

time $t = 0$, is obtained as

$$\boldsymbol{\vartheta_1} = \boldsymbol{A}^*\{\text{vech}(\boldsymbol{\epsilon_0\epsilon_0'}) - \text{vech}(\boldsymbol{H_0})\}, \tag{3}$$

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

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

with $\boldsymbol{A^*}$ and $\boldsymbol{G^*}$ being $N^* \times N^*$ parameter matrices expressed in the *vech* representation of the GARCH-BEKK model.[3] Comparing the VIRFs calculated in Eq. (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 shock.

4 Empirical results

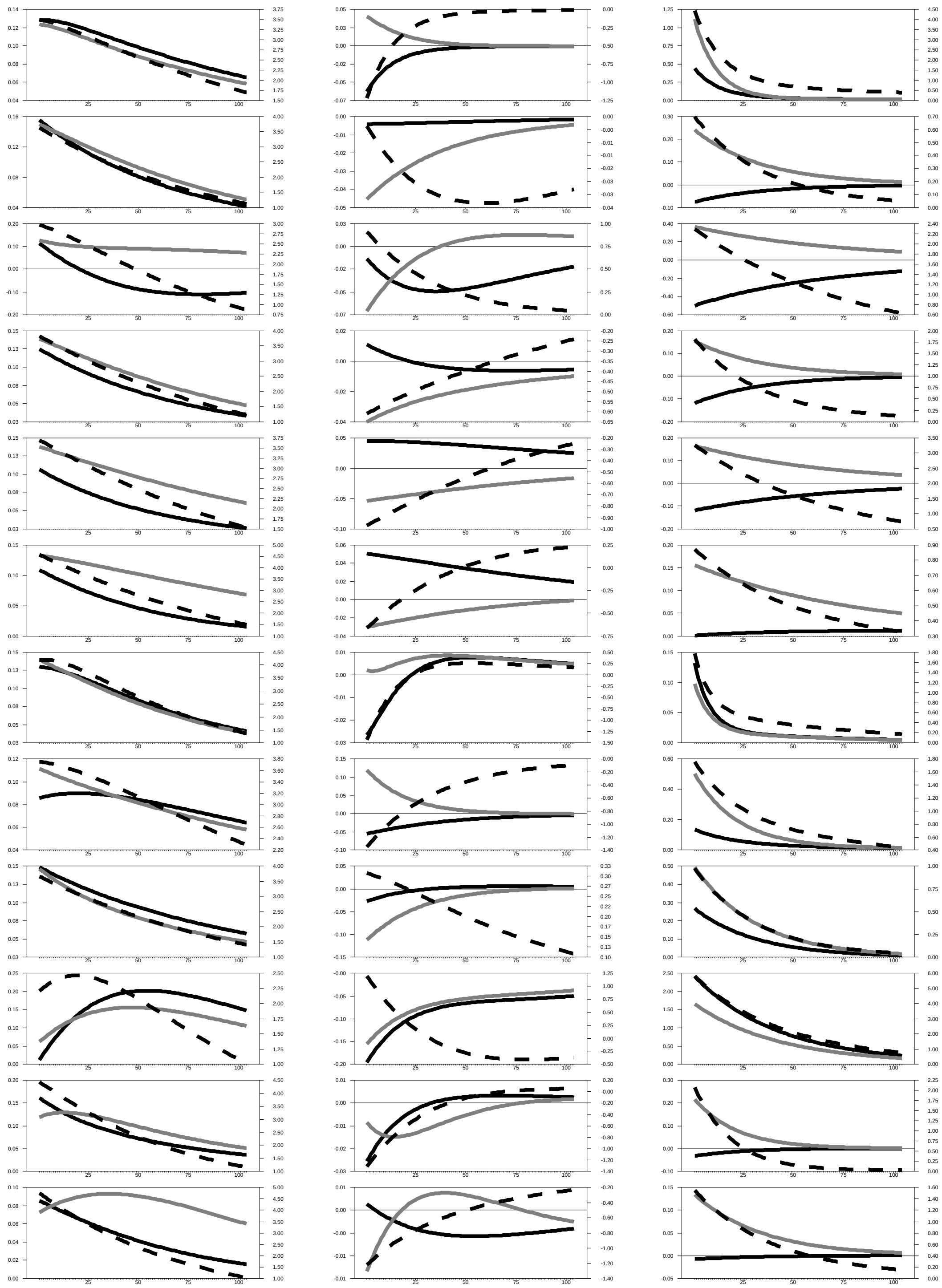
Figure 2 illustrates the average VIRFs of oil returns, the covariance between oil and stock returns and stock returns over periods which cover supply- and demand-side as well as precautionary demand shocks. A graphical inspection indicates that on average the expected conditional variances of stock returns exhibit a large positive response to pre-cautionary demand shocks compared to the other types of shocks (as seen by the scale on the right axis of the VIRF graphs in Figure 2). Yet, the effect sizes of such shocks are not the same for all countries. For example, while slowly decreasing to zero (e.g., taking about 100 weeks in most countries to disappear), their effects are the largest for Russia and Brazil (their one-step ahead expected conditional variances increase by around 570% and 450% respectively) reflecting the stronger dependency of such economies on oil exports whereas they are the smallest for Canada, Italy and Norway (their one-step ahead expected conditional variances increase by around 70%, 86% and 98% respectively).

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 pre-cautionary demand (as seen by the scale on the left axis of the VIRF graphs in Figure 2). The effects of such shocks are larger for Russia followed by Brazil and then Mexico and Norway (the one-step ahead expected conditional variances for Russia and Brazil increase respectively by about 158% and 115% whereas those for both Mexico and Norway increase by about 50%), but they are the smallest for Japan and 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 countries.

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 pre-cautionary 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 (as seen by the scale on the left axis of the VIRF graphs in Figure 2). 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.

[3] The reader is referred to Engle & Kroner (1995) and Hafner & Herwartz (2006) for the transition between *vec* and BEKK representations.

Figure 2: Volatility impulse response functions



Notes: The graphs plot average responses of oil and stock return volatility ($\boldsymbol{\vartheta_{o,j}}$ and $\boldsymbol{\vartheta_{s,j}}$) as well as of their covariance ($\boldsymbol{\vartheta_{os,j}}$) (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.

As far as the persistence of the shocks is concerned, aggregate demand-side shocks are shown to be more persistent, compared to the other types of shocks, for all countries except Brazil, Japan and Mexico where precautionary-demand shocks have greater persistence. The persistence of the supply-side shocks, on the other hand, is relatively weak for most countries except China, Norway and Russia, where it is greater.

The results in Figure 2, however, suggest that the effects of each type of shock on the covariances 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 pre-cautionary demand shocks on the covariances 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 (where the expected conditional covariance declines by around 19%).

To sum up our results, the effects of oil price shocks on the covariances are somehow country-specific and they are relatively smaller especially those related to aggregate demand- and supply-side ones. On the other hand, the effects of such shocks on stock return volatility are greater and also vary depending on the origin of such shocks. In specific, unlike supply-side shocks, events of global impact such as world financial turmoil, economic recessions and US military actions in the Middle East seem to have significant and persistent effects on stock return volatility. By contrast, the covariances seem mostly to react to the US military actions in the Middle East among other precautionary demand shocks. Our findings complement those of Kilian & Park (2009) among others, who only considered the impact of different types of oil price shocks on the mean of stock returns (i.e., first moment), and are broadly consistent with those of Filis et al. (2011) and Boldanov et al. (2016), who analysed instead the sign and magnitude of the correlations between stock returns and oil price changes during each type of shocks. However, compared to these studies we provide clear-cut evidence of the impact of oil price shocks on the dynamics of stock return volatility (i.e., second moment) and the covariances; more specifically, 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 covariances to oil price shocks are relatively smaller, compared to those of stock return volatility, for most countries, and, moreover, such covariances 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.

Finally, we have also checked the robustness of our results in the following ways. First, we specified the conditional mean equation as a VAR model and estimated the VIRFs from bivariate VAR-GARCH-BEKK models. Second, we used a bivariate specification of Engle (2002)'s DCC-GARCH framework instead of the BEKK specification. Third, to capture global risk aversion we incorporated the VIX volatility index in its first difference into the conditional mean equations as well as the conditional variance equations of the GARCH-BEKK model. Overall, our findings remained unchanged during these robustness checks.

5 Concluding remarks

This paper investigates the impact of different oil price shocks on stock return volatility and the covariance between oil price changes and stock returns using volatility impulse response analysis estimated from the bivariate GARCH-BEKK model. The estimation allows to quantify the size and the persistence of each type of shocks on stock return volatility and the covariance between oil price changes and stock returns for a wide range of net oil-importing and oil-exporting countries. We find that precautionary demand followed by aggregate demand-side shocks, compared to supply-side ones, have higher positive and persistent effects on the conditional variances of stock returns for all countries. The responses of the covariances between oil price changes and stock returns, on the other hand, are shown to be relatively smaller in magnitude, compared to those of stock return volatility, for most countries, and, moreover, such covariances 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. These results are of paramount interest to (i) investors and risk managers in terms of portfolio diversification and their risk exposure to the different types of oil price shocks, and to (ii) 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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