

Ji, Qiang; Shahzad, Syed Jawad Hussain; Bouri, Elie; Suleman, Muhammad Tahir

Article

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RESEARCH

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Dynamic structural impacts of oil shocks on exchange rates: lessons to learn

Qiang Ji^{1,2}, Syed Jawad Hussain Shahzad^{3,4*} , Elie Bouri⁵ and Muhammad Tahir Suleman⁶

*Correspondence:

j.syed@montpellier-bs.com

³ Montpellier Business

School, Montpellier, France

Full list of author information

is available at the end of the article

Abstract

This study explores the dynamic effects of different oil shocks on real exchange rates in net oil importers and exporters. Specifically, the connectedness measures are combined with the structural vector autoregressive model. The findings show that oil supply shocks have a larger depreciating influence on exchange rates in oil exporters than in importers. All countries are generally more sensitive to oil-specific demand shocks, and this sensitivity can lead to a significant appreciation in real exchange rates, except in Japan and the United Kingdom. Further, the spillover effect between oil shocks and exchange rates has strengthened after the global financial crisis of 2007–08. Our findings provide useful implications for the policy-makers and market risk managers to effectively avoid exchange rate risk induced by oil shocks.

Keywords: Oil shocks, Exchange rate, Connectedness, Spillover effect

1 Introduction

Oil's importance as an energy resource and influence in the global economic system has steadily increased.¹ Especially, the increasing oil trade has placed pressure on the current payment balance and led to exchange rate fluctuations (Bal and Rath 2015). Because oil price is a widely verified source of shock for exchange rates (Ji et al. 2015; Basher et al. 2016), investigating the underlying forces and transmission mechanisms of oil shocks to exchange provides useful information to market investors and holds important implications for policy-makers and central banks. Investors can incorporate any evidence of impacts of oil shocks on exchange rates in their investment and asset allocations decisions. As for policy-makers and central banks, who are concerned about the stability of exchange rates, they can improve their understanding of the vulnerability of exchange rates to oil price shocks so more appropriate policies and regulations can be formulated.

Within the related literature regarding the impact of oil prices on exchange rates, researchers apply various methodologies, such as cointegration and Granger causality (Huang and Tseng 2010), Markov-switching analysis (Beckmann and Czudaj 2013), vector autoregressive (VAR) models (Pershin et al. 2016a, b), GARCH jump models (Jawadi et al. 2016), multivariate GARCH-type models (Jain and Biswal 2016), wavelet models (Yang et al. 2017), copula models (Beckmann et al. 2016; Mensi et al. 2017), and

¹ According to BP (2017), one-third of the world's primary energy consumption is in form of oil. In 2016, 67.8% of oil consumption depended on international trade involving more than 200 countries.

multifractal detrended cross-correlation analysis, (Jiang and Gu 2016) to investigate the relationship between oil prices and exchange rates. Concurrently, the focus on the US dollar has shifted to encompassing other currencies, including those of emerging economies (Ji et al. 2015), African countries (Pershin et al. 2016a, b), OECD countries (Reboredo 2012) and oil exporters (Nusair 2016).

Importantly, three different sources by Kilian (2009) are typically used to categorise oil shocks, and several studies consider the impacts of disaggregated oil shocks on exchange rates and other financial and economic variables using the structural VAR (SVAR) model. Basher et al. (2012) study the dynamic interactions between oil prices, emerging stock prices and the US dollar. They conclude that oil shocks tend to depress the US dollar in the short run. Ji et al. (2015) analyse the impacts of different oil shocks on industrial production, real exchange rate and CPI. They found that the real exchange rates in BRICS countries have significant appreciation in response to the aggregate demand shock. Atems et al. (2015) apply Kilian's (2009) oil shock framework to the US dollar and six other bilateral exchange rates in OECD countries. Their results indicate the importance of global aggregate demand as well as oil-specific demand shocks in explaining the depreciation of the sampled currencies, whilst the role of oil supply shock is insignificant. Cunado et al. (2015) examine how the top four Asian oil importers react to structural oil shocks. They argue that the impact of oil supply shocks is marginal, whereas oil aggregate demand shocks have a significant impact in the sampled countries. Bai and Koong (2018) compare the differences in the impact of oil shocks on the exchange rates of China and the US. They show that oil shocks negatively impact the US dollar.

This study, against the growing literature on the interdependence between oil prices and exchange rates, examines the impact of oil shocks on the real exchange rates in both oil exporters and oil importers. It applies the SVAR model combined with the connectedness framework of Diebold and Yilmaz (2014). Such a time-varying aspect of modelling design captures the impacts of recent geopolitical unrest and financialisation of oil markets. It is expected that the increased financialisation of oil market and resulting speculative activities may have led to a higher connectedness between oil prices and exchange rates. Importantly, the methodological combination between the SVAR model and the connectedness framework of Diebold and Yilmaz (2014) generates at least two advantages for our analysis: (1) it allows us to categorise oil shocks as oil supply shock, aggregate demand shock, or oil-specific demand shock; (2) it grants us the ability to study time-varying connectedness and spillover effects between oil shocks and exchange rate returns.

Based on a sample of net oil exporters and net oil importers, our analyses conclude that there is a time-varying impact of oil shocks on exchange rate returns, whereas the spillover from oil supply shocks to real exchange rates is stronger in oil exporters than oil importers. Furthermore, the impacts of aggregate demand shock and oil-specific demand shock are more profound compared to oil supply shock. We also find that impacts of oil shocks on real exchange rates have gradually increased over time, more specifically after the global financial crisis (GFC) of 2008. Our findings can provide useful implications for the central bank to effectively stabilise its exchange rate, and for market investors and risk managers to well measure foreign exchange portfolio risk.

We organise the rest of this paper as follows. Section 2 overviews the related literature on the link between oil prices and exchange rate. In Sect. 3, we present and explain

our empirical. Section 4 provides the data and sources, and Sect. 5 presents and discusses the results and findings. Finally, Sect. 6 concludes the analysis with some policy formulations.

2 Research background and related studies

Existing literature generally confirms two channels to examine the link between crude oil prices and exchange rates. The ‘terms of trade channel’ (Amano and van Norden 1998a, b) feature crude oil as a major determinant of trade. Distinguishing the tradable sector from the non-tradable sector, Amano and van Norden (1998a, b) argue that higher oil prices lead to a real currency appreciation if the non-tradable sector, relative to the tradable sector, is more dependent on crude oil. Meanwhile, when the oil price increases if the tradable sector is more oil-intensive than the non-tradable sector, the domestic currency will experience a real depreciation. The second channel, the ‘wealth transmission channel’ (Krugman 1983; Golub 1983), points to a wealth transfer from oil importers to oil exporters with oil prices rise. Importers must pay more when oil prices rise, depreciating their currencies against the dollar.

Theoretically, Amano and van Norden (1998a, b) conclude that trade provisions affect the oil importers and exporters differently. For example, a positive shock to trade often leads to an increase in the non-tradeable foods and an appreciation of oil exporters’ real exchange rates. However, Fratzscher et al. (2014) find that local currency depreciates when the oil price rises as it may lead to a weakening of the trade balance in oil-importing countries. The difference between exporters and importers seems predominantly related when the transmission of oil shocks is considered through the wealth effect channel. The literature concludes that as oil prices increase, the wealth transfer from oil-importing countries to oil-exporting countries intensifies, leading to real appreciation (depreciation) of exchange rates in oil exporters (oil importers) through the portfolio allocation and current account differences [for example see, Fratzscher et al. (2014)]. Golub (1983) and Krugman (1983) formed the original theoretical framework for this channel.

Several other studies have considered the oil price–exchange rate nexus. Using monthly data covering the period from January 1974 to November 2011, Beckmann and Czudaj (2013) apply a Markov-switching model and reveal that a depreciation in the real value of the US dollar leads to higher oil prices, whereas a significant link is reported between higher real oil prices and real appreciation of the US dollar. Pershin et al. (2016a, b) use a VAR model and show mixed findings on the effect of oil price changes on exchange rates in three African countries (Botswana, Kenya and Tanzania). Focusing on the multifractal detrended cross-correlation analysis between oil prices and exchange rates, Jiang and Gu (2016) report evidence of a cross-correlation in the long run, which is found to be multifractal and asymmetric. Jawadi et al. (2016) consider the relationship between crude oil prices and euro/US dollar from August 2014 to January 2016 via GARCH jump models. They show that the US dollar depreciation versus the euro leads to lower oil prices. Furthermore, they indicate the significance of volatility transmission from the currency exchange rate to the crude oil market. Beckmann et al. (2016) use both static and dynamic copulas on daily data from September 2003 to September 2013. They report evidence of a stronger association between crude oil prices and the exchange rate of five oil exporters and seven oil

importers. Furthermore, Beckmann et al. (2016) show evidence of extreme tail dependency in most of the cases. However, when oil process increases, the currencies of oil-importing countries depreciate versus the US dollar whereas an appreciation against the US dollar is reported for the case oil exporters.

From the methodology side, previous studies dealing with the oil price–exchange rate nexus employ a wide range of econometric models, such as cointegration and Granger causality (Chaudhuri and Daniel 1998; Brahmasrene et al. 2014; Mensah et al. 2017; Jung et al. 2019), error–correction model (Amano and van Norden 1998a), GARCH-type models (Narayan et al. 2008; Fowowe 2014; Brayek et al. 2015), quantile regression model (Nusair and Olson 2019), VAR model (Pershin et al. 2016a, b) and panel models (Chen and Chen 2007; Nikbakht 2010). Some recent research focuses on investigating the nonlinear relationship between oil prices and exchange rates in the oil-importing and oil-exporting countries using various copula-based model and CoVaR measures (Reboredo 2012; Wu et al. 2012; Aloui and Aïssa 2016; Ji et al. 2019; Tiwari et al. 2019).

However, the above literature ignores to differentiate the shock sources of oil prices and therefore cannot provide strong evidence on the impact of specific oil shocks. Unlike most of prior studies, we categorise oil shocks according to Kilian (2009)’s approach and apply the connectedness measures of Diebold and Yilmaz (2014) with the aim of unravelling the different impacts of disaggregated oil shocks on real exchange rates. Our sample period includes three oil importers (India, Japan and South Korea) and three oil exporters [Canada, Norway and the United Kingdom (UK)]. It covers the period from February 1974 to December 2016, except for the case of South Korea, where data are only available from April 1981.

3 Methodology

Following Hoang et al. (2019), the response of real exchange rates to disentangled oil price shocks using impulse response functions derived from a structural VAR model is examined and then we apply the connectedness method of Diebold and Yilmaz (2014). In doing so, we construct a four-dimensional SVAR model involving three sources of oil shocks and exchange rates. In this way, the response of the exchange rates to different oil shocks can be examined. Next, we build the connectedness table of three types of oil shocks and exchange rates based on variance decomposition by the structural identification of the SVAR model. This link provides a novel way to estimate the connectedness measure, which is different from Diebold and Yilmaz’s (2014) approach.

3.1 SVAR model for oil shocks

Referring to Kilian and Park (2009), we disaggregate oil shocks into three types, that is, oil supply shock (SS), aggregated demand shocks (ADS) and oil-specific demand shock (OSS). Then, we construct a four-dimensional SVAR model by adding the exchange rate into the analysis framework. Therefore, the SVAR model is specified as follows:

$$A_0 y_t = C_0 + \sum_{i=1}^p A_i y_{t-i} + \varepsilon_t, \tag{1}$$

where y_t is a 4×1 vector that includes global crude oil production (pro_t), global real economic activity (rea_t), real oil prices (rop_t), and the country’s exchange rate (ex_t). C_0 is

the vector of constants, A_0 is the contemporaneous matrix, A_i is the i th lag coefficients matrix, $i = 1, \dots, p$. ε_t is the vector of structural disturbances.

Equation (1) can be transformed into a reduced form by multiplying A_0^{-1} by both sides of the equation as follows.

$$y_t = \alpha_0 + \sum_{i=1}^p B_i y_{t-i} + e_t. \tag{2}$$

The reduced error vector is $e_t = A_0^{-1} \varepsilon_t$ and the structural oil shocks can be estimated by imposing restrictions on matrix A_0^{-1} . According to Kilian and Park (2009), three contemporaneous assumptions are set as short-term restrictions: (1) oil supply is assumed not to respond contemporaneously to innovations in oil demand because of lagged response in oil producers to demand shocks, considering the adjusting costs of oil production changes and market state’s uncertainty (Ji et al. 2015). (2) ADS is an innovation measure to global real economic activity, which cannot be described by SS. In turn, innovations in the real oil prices that cannot be explained by SS and aggregate demand shock are measured as OSS. (3) The response of exchange rate returns to the aforementioned oil price shocks is contemporaneous.

Therefore, a lower triangular structure is imposed on A_0^{-1} :

$$\begin{bmatrix} e_{1,t}^{pro} \\ e_{2,t}^{rea} \\ e_{3,t}^{rop} \\ e_{4,t}^{ex} \end{bmatrix} = \begin{bmatrix} \alpha_{11} & 0 & 0 & 0 \\ \alpha_{21} & \alpha_{22} & 0 & 0 \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & 0 \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} \end{bmatrix} \times \begin{bmatrix} \varepsilon_{1,t}^{SS} \\ \varepsilon_{2,t}^{ADS} \\ \varepsilon_{3,t}^{OSS} \\ \varepsilon_{4,t}^{ERR} \end{bmatrix}, \tag{3}$$

where ERR denotes the exchange rate returns. We used the recursive-design wild bootstrap method, whilst computing the response functions of each variable to structural oil shocks, to construct the confidence intervals. Similarly, variance decomposition is further calculated to construct connectedness measures.

3.2 Connectedness measures

In this section, connectedness is measured by the variance decomposition based on structural identification, whilst in Diebold and Yilmaz’s (2014) framework, a generalised variance decomposition is employed. Therefore, a matrix $\phi(H) = [\phi_{ij}(H)]_{i,j=1,\dots,4}$, is calculated whose entry denotes the forecast error variance of variable i contributed by the shock of variable j . The own shock contributions of the variable i are measured through main diagonal elements, whilst the off-diagonal elements measure the magnitude explained by the other variables j of forecast error variance of variable i .

The total connectedness measure is defined as follows:

$$TS(H) = \frac{\sum_{i,j=1,i \neq j}^N \phi_{ij}(H)}{\sum_{i,j=1}^N \phi_{ij}(H)} \times 100 = \frac{\sum_{i,j=1,i \neq j}^N \phi_{ij}(H)}{N} \times 100. \tag{4}$$

Equation (4) helps in identifying directional spillover amongst different variables. We also calculate the directional measures of connectedness, namely “from others” and “to

others". The directional connectedness from all other variables j (from others) to variable i is calculated as:

$$DS_{i \leftarrow j}(H) = \frac{\sum_{j=1, j \neq i}^N \phi_{ij}(H)}{\sum_{i,j=1}^N \phi_{ij}(H)} \times 100 = \frac{\sum_{j=1, j \neq i}^N \phi_{ij}(H)}{N} \times 100. \tag{5}$$

In a similar way, the directional connectedness from a variable i to all other variables j (to others) is calculated as

$$DS_{i \rightarrow j}(H) = \frac{\sum_{j=1, j \neq i}^N \phi_{ji}(H)}{\sum_{i,j=1}^N \phi_{ji}(H)} \times 100 = \frac{\sum_{j=1, j \neq i}^N \phi_{ji}(H)}{N} \times 100. \tag{6}$$

The difference between Eqs. 6 and 5 is defined as the net total directional connectedness from variable i to the system.

$$NS_i(H) = DS_{i \rightarrow j}(H) - DS_{i \leftarrow j}(H) \tag{7}$$

Using the measure calculated in Eq. (7), one can identify the variable which is receiver or transmitter of the spillover in a system. This measure calculates the net contribution of each variable to the system. Finally, the pairwise (net) directional spillover of a variable i w.r.t to variable j is defined as

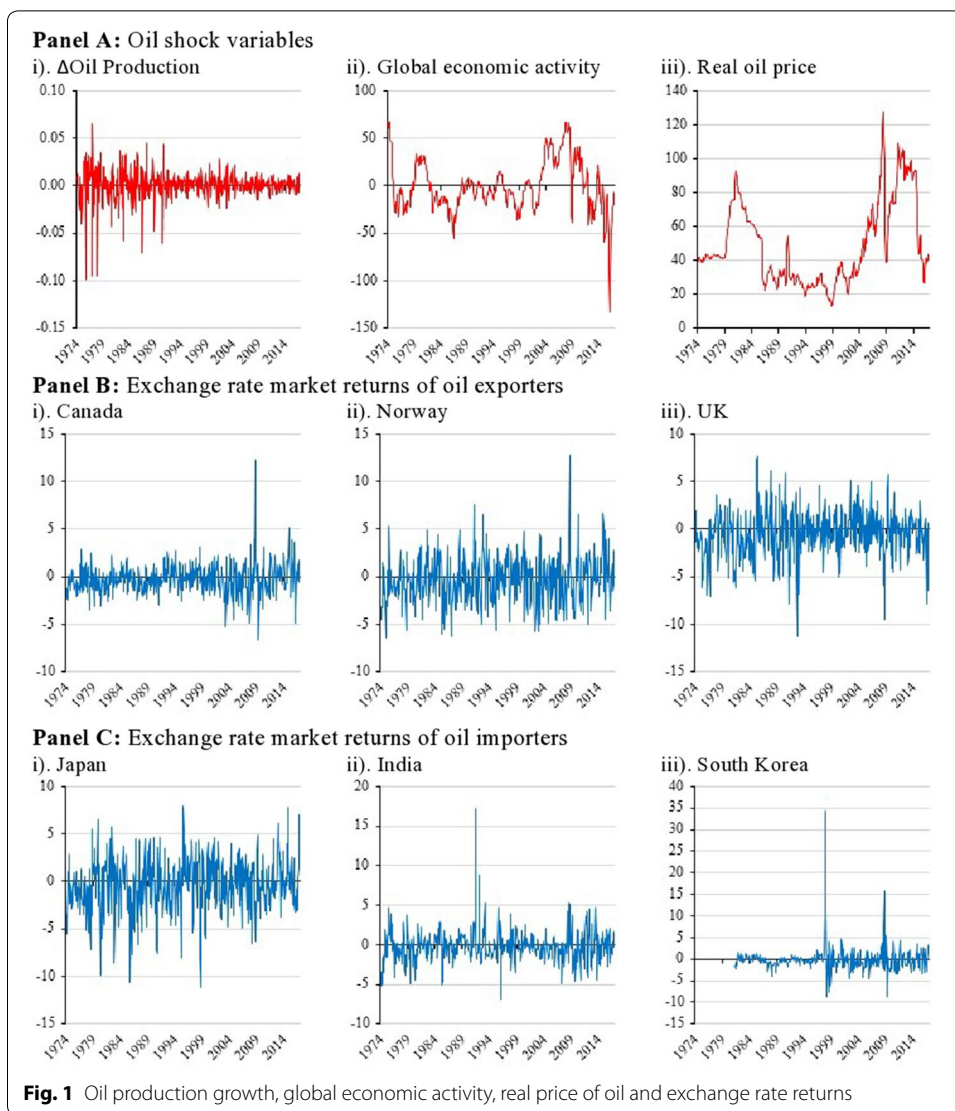
$$NPS_{i \rightarrow j}(H) = (\phi_{ji}(H) - \phi_{ij}(H)) \times 100. \tag{8}$$

4 Data description

We use monthly data on global crude oil production, the Kilian (2009) index of global real economic activity, real (US CPI deflated) oil prices and real (CPI deflated) exchange rates. Oil production data and real oil prices were extracted from the US EIA. We used the Kilian index, obtained from Kilian’s website, to measure global real economic activity. Nominal exchange rates and CPI data were extracted from DataStream. In this paper, we measure the bilateral exchange rates by the quantity of foreign currency per unit of the US dollar, which means that an increase of the bilateral exchange rate indicates its depreciation against the US dollar. Our data span from February 1974 to December 2016, except for the case of South Korea, where data are only available from April 1981. We include three oil exporters (Canada, Norway and the UK) and three oil importers (India, Japan and South Korea). In line with the existing literature (e.g., Basher et al. 2016), the choice of countries was influenced by data availability.²

Figure 1 depicts the data series over the full sample period, showing large fluctuations in most cases. In particular, the effect of the GFC is evident on oil prices and most of the real exchange rates. Large fluctuations in real exchange rates are apparent in Japan and South Korea in 1999, whereas currency depreciation is observed in India and South Korea in the early 1990s and in 1999, respectively.

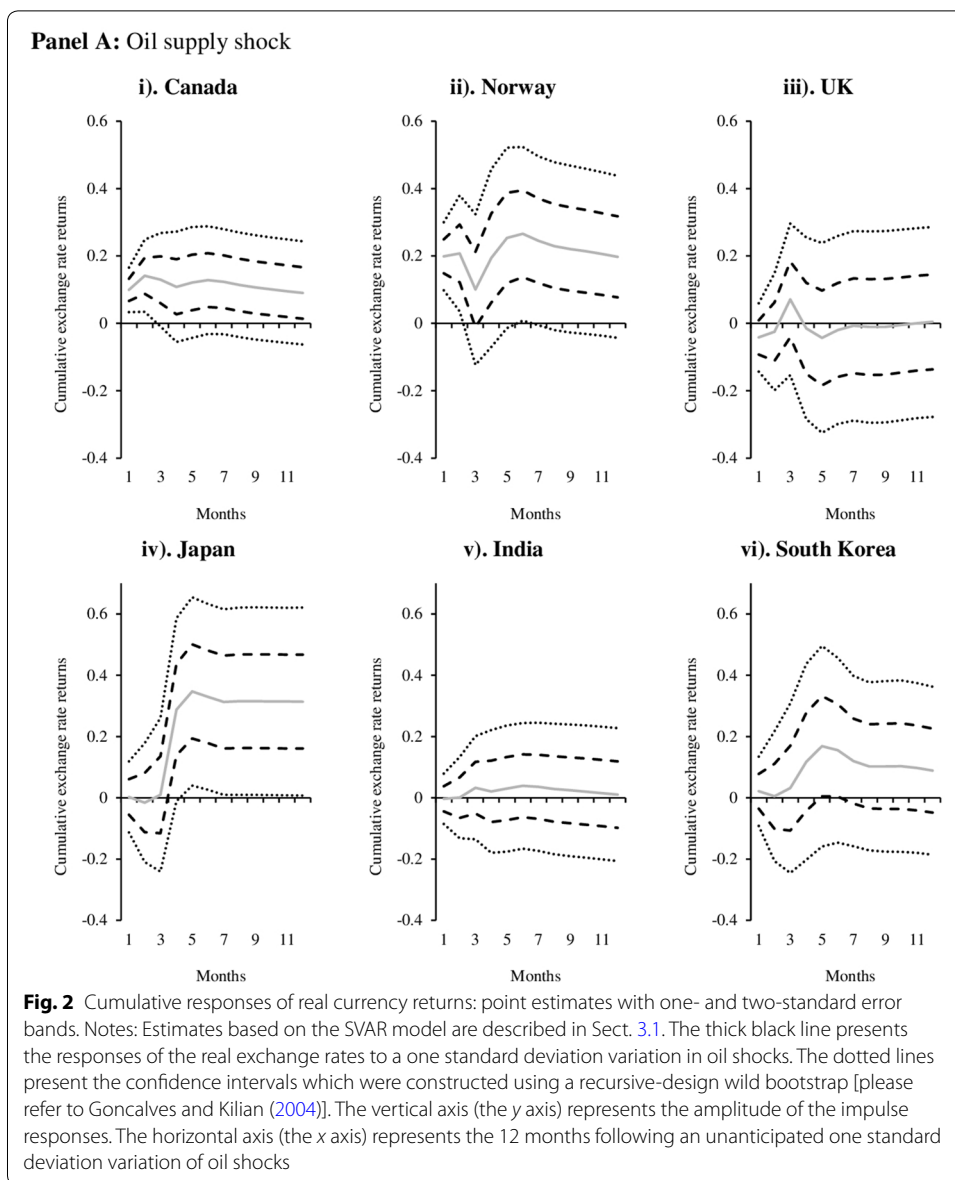
² We excluded oil exporters from the Gulf as they have fixed exchange rates. For the same reason, we excluded China, one of the largest oil importers, because China began to allow its currency to fluctuate within a narrow trading band since July 2005. The descriptive statistics and unit root results are not reported here; however, they are available from the corresponding author on request.



5 Results and discussion

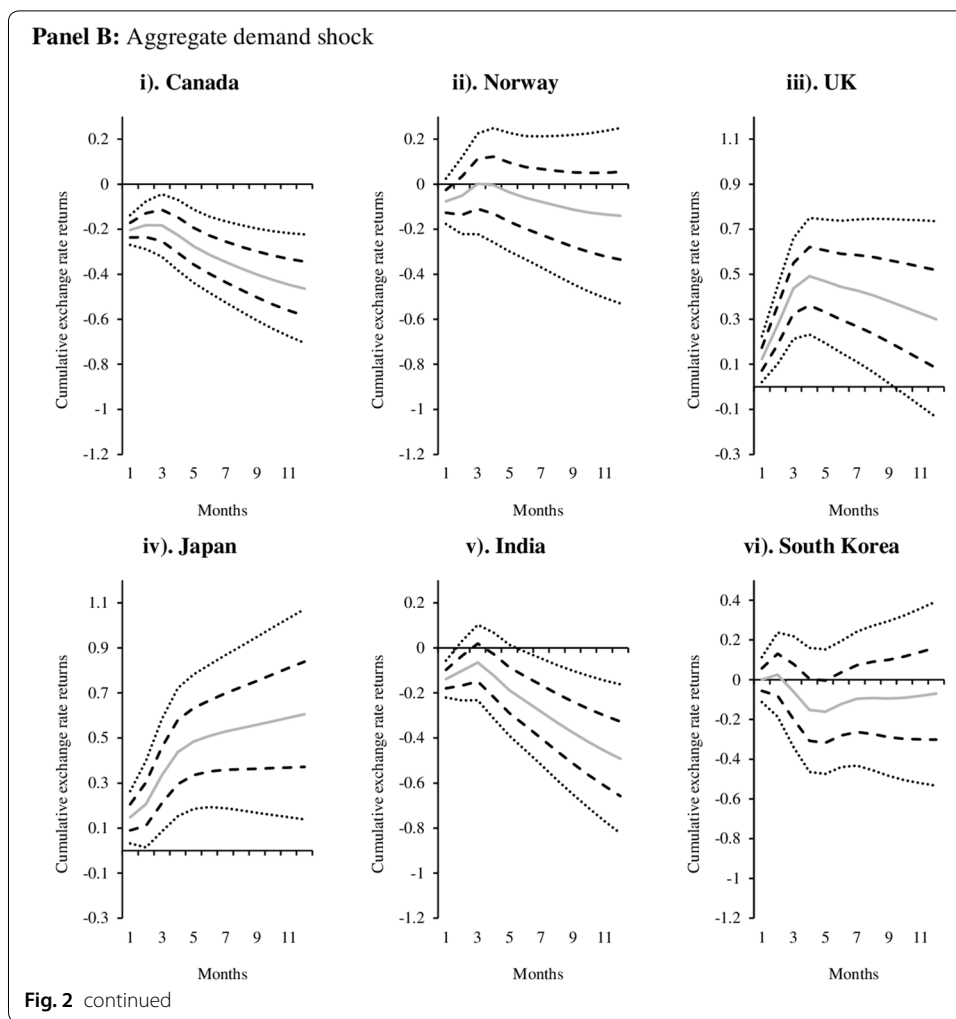
5.1 Full sample responses of real exchange rates and connectedness to structural oil shocks

Figure 2 details cumulative responses of real exchange rates to one standard deviation shock in oil supply, aggregate demand and oil-specific demand. Canada, Norway and Japan’s real exchange rates are all greatly influenced by oil supply shocks, implying that increase in oil supply has a depreciating effect on these currencies (see Fig. 2a). For Canada and Norway, the effects are statistically significant in the first month following the shock; in Japan, there is no observable impact until the third month. The responses of exchange rates to aggregate demand shocks and oil-specific demand shocks can be seen in Fig. 2b, c, respectively. The negative and statistically significant response of real exchange rates to aggregate demand shocks throughout the entire time span for Canada suggests that a shock in aggregate demand leads the Canadian dollar to appreciate. In



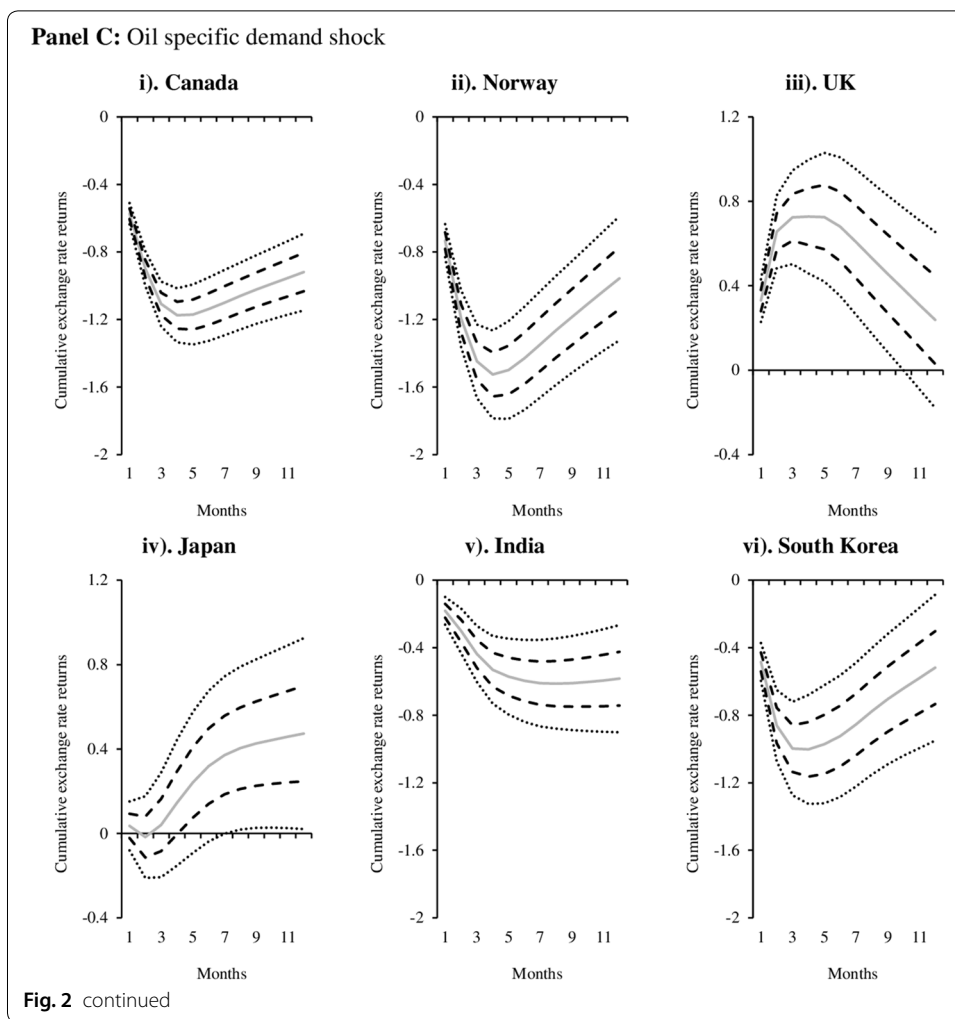
the first month and in months 6 and following, India also exhibits a negative response. In contrast, in Japan, an aggregate demand shock shifted the real exchange rates upward in months 1 through 12, and the effect is statistically significant. This means that an aggregate demand shock can lead to a slight depreciation in the real exchange rate in Japan. For the entire response period in the UK,³ the aggregate demand shock causes appreciation in the real exchange rates. Figure 2c shows that the response of exchange rates to oil-specific demand shocks is statistically significant, and such shocks lead to significant appreciation in the real exchange rates in Canada, Norway, UK, India, and South Korea.

³ In this study, we have followed the conventional quotation. Accordingly, and unlike the other currencies under study, the UK pound is the base currency against the USD, i.e., it is quoted in indirect form. Therefore, a negative and significant shock for the case of UK exchange rates (e.g., Fig. 2b, c) implies a currency depreciation rather than appreciation, as was the case for the other currencies under study.



In Japan, once again oil-specific demand shock depreciates the real exchange rate, and the effect is statistically significant. Our results align with prior studies highlighting the fact that demand-side oil shocks are more important than supply-side shocks (Ji et al. 2015; Basher et al. 2016).

Next, Table 1 shows the full sample-based total connectedness measures. Results show that the total connectedness ranges between 5.12% (Japan) and 10.77% (Canada). On average (because these results are based on full sample analysis and rolling window-based sub-sample analysis will follow), all the exchange rates are net receivers, except for India, where the net impact is marginal. Interestingly, oil exporters generally receive more information flow from the three oil shocks than importers, which has the relatively large net directional connectedness. There is no exception in all the sampled countries that oil-specific demand shock contributes most to the oil–exchange rate system relative to the other two oil shocks. Specifically, the UK, Japan, India and South Korea contribute more than 10% information inflow to their oil–exchange rate system, whilst Canada and Norway contribute more than 20% information inflow to their system. In the meantime, the net directional connectedness of oil-specific demand shock for all the countries is



positive, verifying its important role as an information transmitter. Generally, this finding is in line with our expectations and is also consistent with the existing conclusions found by previous studies (Ji et al. 2015; Atems et al. 2015; Yin and Ma 2018). One of the most reasonable explanations is that entering the twenty-first century, oil price behaviour goes beyond what the supply and demand framework can explain and starts to more reflect financial attributes due to the increase of oil futures derivatives and the large inflows of index investment by financial investors in the energy markets (Zhang and Ji 2019). Geopolitical risks, political turmoil in the Middle East and some unexpected Black Swan events have become the main driving force of oil price volatility. Under this high uncertain market conditions, macroeconomic variables such as exchange rates are inevitably more sensitive to oil-specific demand shock induced by unexpected events than to the other shocks.

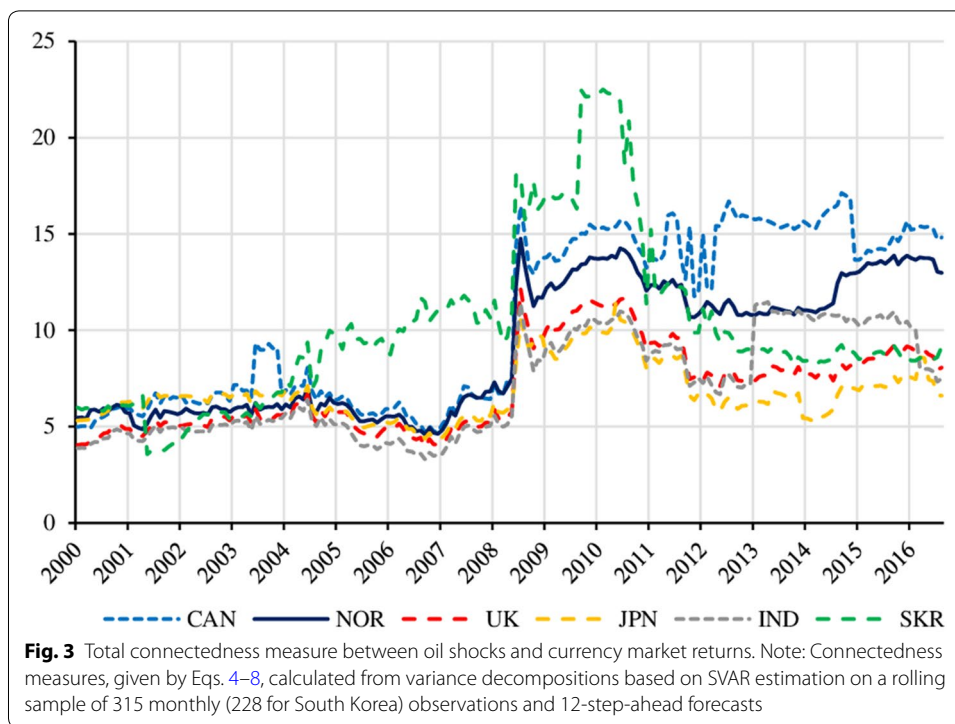
The impact of oil supply shock on the exchange rates is mixed because supply shocks behave like an information transmitter in oil-exporting countries and like an information receiver in oil-importing countries. This result is consistent with the petroleum attributes of various countries. In oil exporters, the income of these

Table 1 Connectedness between oil shocks and exchange rate markets' returns over the full sample

To(i)	Canada					Norway				
	From					From				
	SS	ADS	OSS	ERR	From others	SS	ADS	OSS	ERR	From others
SS	98.93	0.23	0.31	0.54	1.07	98.90	0.25	0.29	0.56	1.10
ADS	0.45	85.29	10.81	3.44	14.71	0.35	89.13	10.07	0.45	10.87
OSS	0.30	4.89	94.79	0.02	5.21	0.42	4.36	95.06	0.15	4.94
ERR	0.50	2.05	19.55	77.89	22.11	1.05	0.20	14.05	84.70	15.30
To others	1.26	7.17	30.67	4.00	Total = 10.77%	1.82	4.81	24.41	1.16	Total = 8.05%
Net	0.19	-7.54	25.46	-18.11		0.73	-6.06	19.47	-14.14	
To(i)	UK					Japan				
	From					From				
	SS	ADS	OSS	ERR	From others	SS	ADS	OSS	ERR	From others
SS	98.62	0.22	0.26	0.90	1.38	99.00	0.22	0.29	0.49	1.00
ADS	0.36	89.10	10.47	0.06	10.90	0.24	87.64	10.49	1.63	12.36
OSS	0.42	4.45	95.01	0.13	4.99	0.44	4.39	95.15	0.02	4.85
ERR	0.32	1.15	4.07	94.45	5.55	1.05	0.72	0.49	97.73	2.27
To others	1.10	5.82	14.81	1.10	Total = 5.71%	1.73	5.33	11.28	2.14	Total = 5.12%
Net	-0.28	-5.08	9.81	-4.45		0.73	-7.03	6.43	-0.13	
To(i)	India					South Korea				
	From					From				
	SS	ADS	OSS	ERR	From others	SS	ADS	OSS	ERR	From others
SS	98.57	0.41	0.24	0.78	1.43	98.17	0.23	0.34	1.26	1.83
ADS	0.16	89.09	7.85	2.89	10.91	0.05	86.83	11.74	1.38	13.17
OSS	1.15	4.76	92.19	1.89	7.81	0.78	2.95	94.67	1.59	5.33
ERR	0.41	2.44	2.36	94.79	5.21	0.18	0.25	5.67	93.91	6.09
To others	1.72	7.62	10.45	5.57	Total = 6.34%	1.01	3.44	17.75	4.23	Total = 6.60%
Net	0.29	-3.29	2.65	0.35		-0.83	-9.73	12.42	-1.87	

This table presents the connectedness measures, given by Eqs. 4–8, calculated from variance decompositions based on 12-step-ahead forecasts. The column sums ('To others') and row sums ('From others') of off-diagonal elements indicate the directional connectedness measures 'to' and 'from' others for each variable, respectively. The row 'Net' of each variable means the gap between its 'To others' and 'From others', which measures its net contribution. The value of 'Total' is the average of either the row sums or the column sums and measures total connectedness in the system)

countries mainly depends on oil exportations. In case of oil supply interruption, it will have a significant impact on the economy of oil-exporting countries, such as Iran's oil embargo. Therefore, there will be information spillover from oil exporters' supply shock to their exchange rates. In addition, oil aggregate demand shock is always an information receiver in the system confirmed by the negative net directional connectedness. We also observed higher forecast ability of oil-specific demand shocks for real exchange rates in oil exporters than in oil importers. Furthermore, a low level of connectedness is observed between oil supply shocks and real exchange rates.



5.2 Time-varying impacts of structural oil shocks on real exchange rates

The results from Table 1, which summarise the net connectedness over the full sample period, do not account for any time variation in the overall connectedness in the SVAR variables. Given that the connectedness might be affected by several economic, financial, and geopolitical events, it becomes necessary to examine the time-varying connectedness measures by re-estimating the models based on the generalised VAR framework developed by Diebold and Yilmaz (2014), using a 315-month (228 for South Korea) rolling window and 12-step-ahead forecasts.⁴ As expected, the total connectedness between exchange rates and oil shocks varies across time and countries (Fig. 3). The total connectedness varies between 4 and 22%, suggesting time-varying behaviour. A spike in connectedness can be observed around the onset of the 2008 GFC in both oil-exporting and oil-importing countries. This is in line with prior studies, which generally shows a spike in the levels of spillover and connectedness during stressful periods. The total connectedness, after a slight decline from its spike in all cases during 2011, resumed its upward trend, especially in the oil exporters. This finding signifies that the full sample base estimates not only undermine (as it provides an average estimate) the overall degree of connectedness, but also indicate that the impact of oil shocks may significantly vary over the sample period and thus requires a more thorough examination. Khalifa et al. (2015) find that the spillover between oil and currency markets is generally governed by the significant asymmetries and hence a more appropriate framework should be utilised to fully uncover the dynamic relationships between these markets.

⁴ We have also estimated the connectedness using a fixed width rolling window of 120 months for all countries. Our findings are robust to different rolling window lengths.

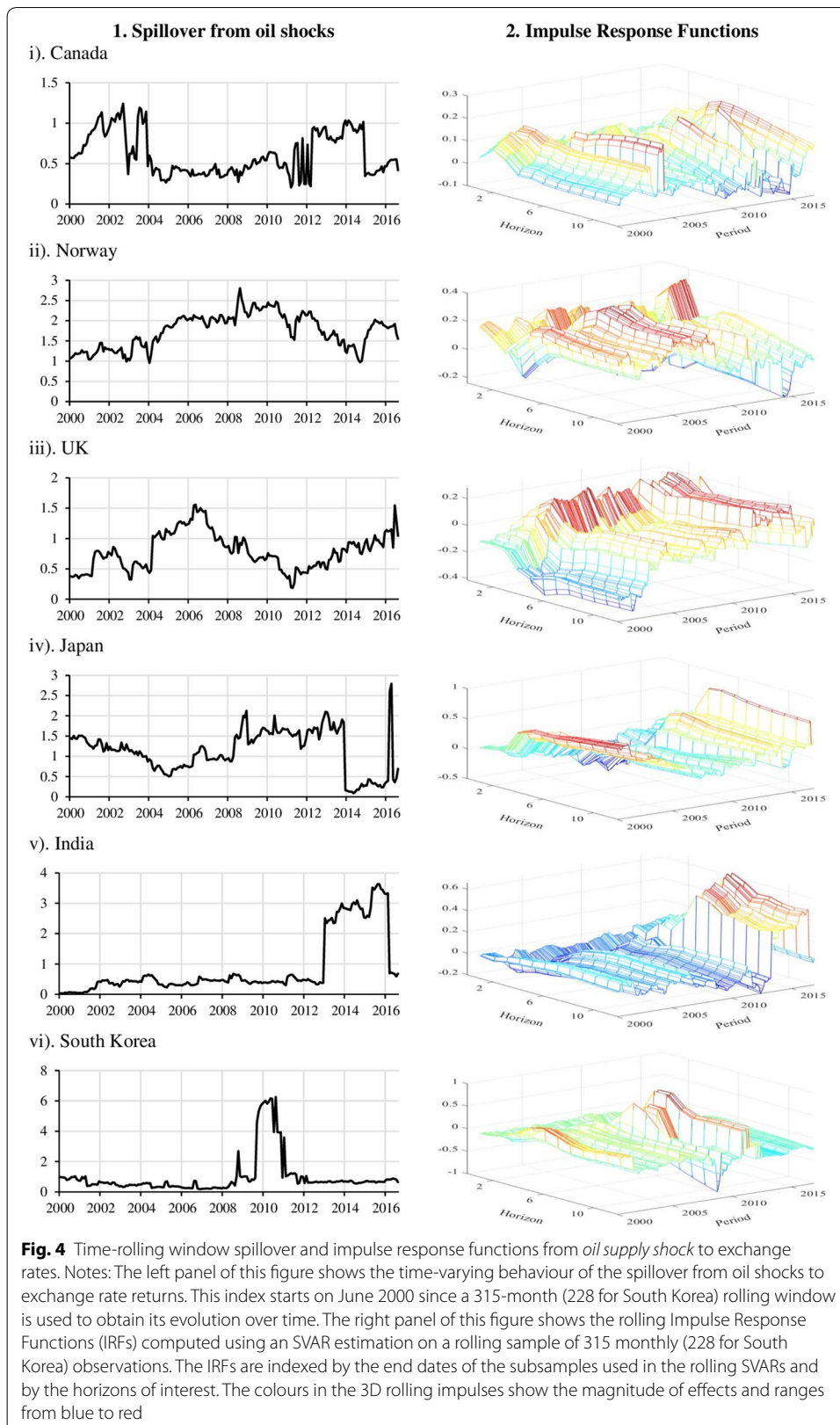
Our findings add to this debate and show that the spillover from oil shocks to currency exchange markets is time-varying and that the impact of oil shocks on currencies has increased in the post-GFC period. This finding is also strongly supported by Chen et al. (2016) and Malik and Umar (2019) who show that the uncertain market environment after the GFC has increased the investment liquidity and adjust speed of portfolio by investors which necessarily leads to higher connectedness.

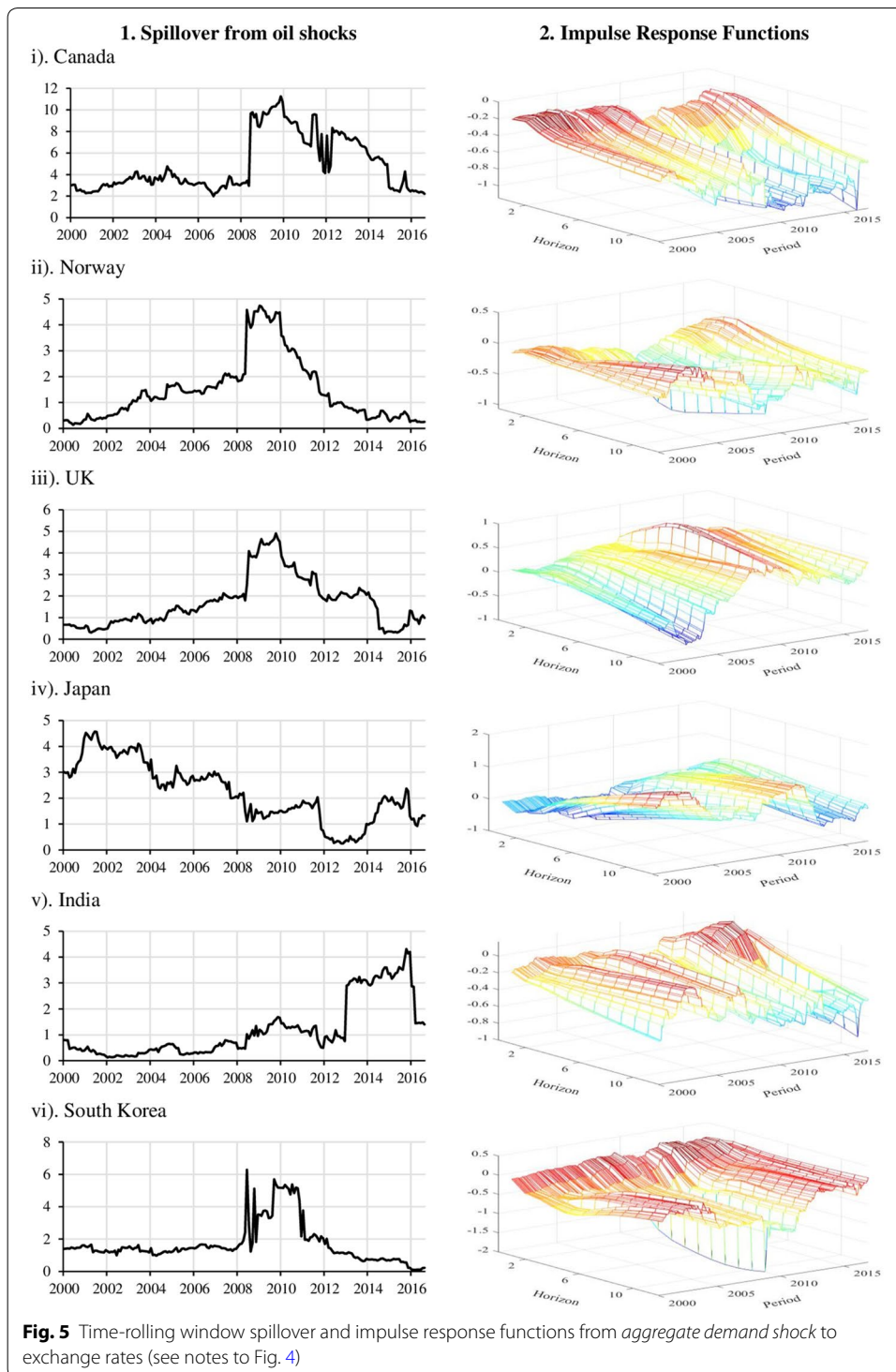
We further sought to disentangle the spillover and impact of oil shocks on selected real exchange rates. Accordingly, we consider the time-varying directional connectedness and cumulative responses of currency exchange rates to oil shocks (Figs. 4, 5, 6) using a 315-month (228 for South Korea) rolling window. Higher values of directional spillover, at some time period, indicate that the corresponding oil shocks have more explanatory power of exchange rate returns.

In Fig. 4, we report the dynamic directional spillovers and responses of real exchange rates to oil supply shocks. Figures indicate a time variation in the responses of exchange rates to oil supply shocks in all cases. They also show that the spillover from oil supply shocks to exchange rates is country-specific. The rolling window cumulative responses from the time-varying parameter model also confirm this finding and show a positive impact (currency depreciation) of oil supply shocks during periods of higher spillover. Specifically, oil supply shocks led to a depreciation of Canadian real exchange rates in earlier (up to 2004) and later points of the sample period, whereas the same shock has a lesser effect on real exchange rates during the rest of the period. For Norway, the depreciation in real exchange rate was stronger during the middle period ranging from 2004 till 2014. For UK, the impact is generally very low, close to zero. The effect on Japan is more profound at the end of the sample period, leading to depreciation. Similar patterns can be seen for India. For South Korea, the effect was positive and very higher during the GFC sub-sample.

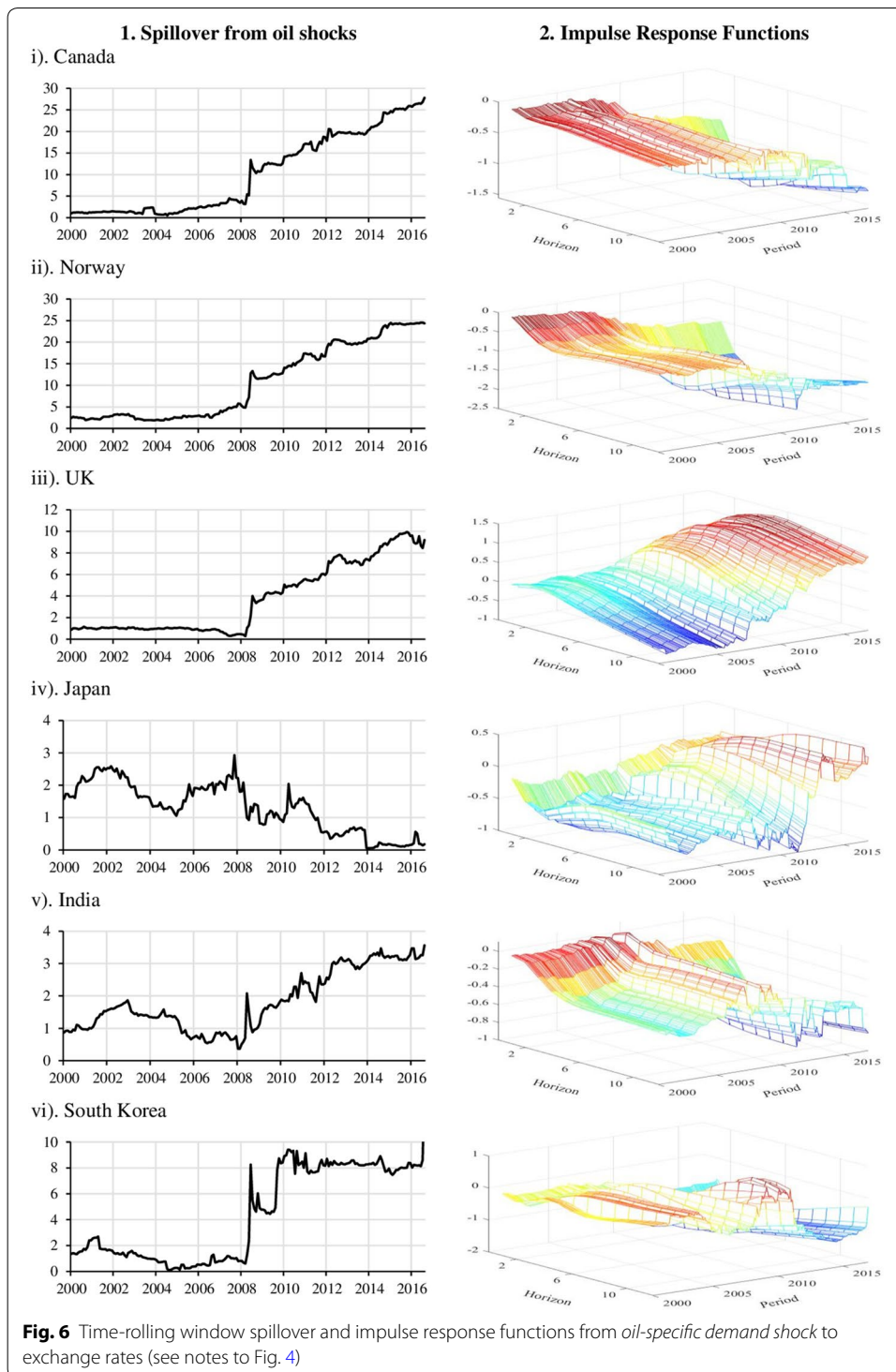
Figure 5 shows the time-varying impacts of aggregate demand shocks on real exchange rates. The appreciating impact of aggregate demand shocks is higher on the currencies of Canada, Norway, the UK and South Korea during GFC sub-sample. Indian currency appreciates in response to aggregate demand shocks only during the end of the study period. However, Japan is an exception because the impact of aggregate demand shocks gradually decreases over the sample period. Finally, Fig. 6 exhibits the directional spillover from oil-specific demand shocks to real exchange rates. Interestingly, the appreciating effect [see dynamic Impulse Response Functions (IRFs)] of oil-specific demand shocks increases from the onset of GFC and keeps increasing until the end of 2016, except for Japan, where once again this impact decreases towards the end of the study period.

These results support the conclusion that the negative effects of oil-specific demand shocks on real exchange rates are much stronger than those of aggregate demand shocks, and that currencies appreciate with the decrease in oil prices. At the same time, the effects of aggregate demand shocks on real exchange rates seem to be larger than those of oil supply shocks (Basher et al. 2016). Furthermore, the effects in most cases were higher during and after the GFC. It is important to note that the post-GFC period is marketed by the Arab Spring (from January 2011 till December 2012). The Arab





spring is a geopolitical event, due to the uncertainty caused in the oil production levels of the affected countries, which had its role in the oil market. Furthermore, this post-GFC period also includes the sharp fall in oil prices (from June 2014 till December 2015)



which also triggered (or accompanied) the slowdown of many major economies and the decision of OPEC’s members to main the usual levels of oil production. All these major oil-related events have potentially enhanced the oil–currencies relationships.

6 Conclusions and policy implications

Utilising both the SVAR model and the connectedness measures of Diebold and Yilmaz (2014), we examine how different oil shocks impact real exchange rates in oil importers and exporters. Our findings are summarised as follows. Real exchange rates' responses to oil price shocks are country-specific and shock-type-specific. Notably, oil exporters' exchange rates are more sensitive to oil supply shocks than exchange rates in oil-importers. Oil-specific demand shocks seem to impact all exchange rates. Generally, oil supply shocks can lead to a significant depreciation in the real exchange rates of oil exporters. Oil-specific demand shock can lead to a significant appreciation in the real exchange rates in both oil importers and exporters. The rolling window results show that the responses of exchange rates to oil price shocks are not consistent over time, and also indicate a general increase in the influences of oil price shocks on exchange rates during and after GFC.

In conclusion, we have created a novel framework to analyse the spillover effects from oil shocks to exchange rates in different countries. The comparison of results suggests that exchange rates in oil importers and exporters respond differently only to oil supply shocks, which can be reflected in their different trading strategies. Another implication is that oil-specific demand shock appreciates currencies of both importing and exporting countries, which deserves the attention of players in currency markets and policy-makers. Our findings can help different countries to better understand the influence path of oil shocks on exchange rate and effectively adjust its monetary policies to stabilise the exchange rate market. Finally, different responses of exchange rates in oil importers and exporters to oil shocks and spillover effects provide abundant information and practical implications to measure exchange rate risk of portfolios. Especially, it can help investors to optimise their portfolio investment and hedging strategy involving exchange rates whilst considering of the movement of disaggregated oil price shocks. Moreover, the increasing influence of disaggregated oil price shocks on exchange rates during some crisis periods further indicates the need for portfolio managers who combine oil and exchange rate in their investment basket to find effective risk-reducing tools and other safe-haven assets to manage the risk of their portfolios. Further studies can consider the effect of disaggregated oil price shocks on sovereign risk of net oil-exporting counties. Another area for future research involves the market state-specific impact of oil shocks on different financial markets.

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Authors' contributions

The work is the original contribution by the authors. All authors read and approved the final manuscript.

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Availability of data and materials

Data will be shared upon request by the readers.

Competing interests

There are no competing interests to declare.

Author details

¹ Institutes of Science and Development, Chinese Academy of Sciences, Beijing 100190, China. ² School of Public Policy and Management, University of Chinese Academy of Sciences, Beijing 100049, China. ³ Montpellier Business School,

Montpellier, France. ⁴ South Ural State University, Chelyabinsk, Russian Federation. ⁵ USEK Business School, Holy Spirit University of Kaslik, Jounieh, Lebanon. ⁶ Otago Business School, University of Otago, Dunedin, New Zealand.

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