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# Oil currencies in the face of oil shocks: What can be learned from time-varying specifications?\*

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## Abstract

While the oil currency property is clearly established from a theoretical viewpoint, its existence is less clear-cut in the empirical literature. We investigate the reasons for this apparent puzzle by studying the time-varying nature of the relationship between real effective exchange rates of five oil exporters and the real price of oil in the aftermath of the oil price shocks of the last two decades. Accordingly, we rely on a time-varying parameter VAR specification which allows the responses of real exchange rates to different oil price shocks to evolve over time. We find that the reason of the mixed results obtained in the empirical literature is that oil currencies follow different hybrid models in the sense that oil countries' real exchange rates may be driven by one or several sources of oil price shocks that furthermore can vary over time. In addition to structural changes affecting oil countries, structural changes arising from the oil market itself through the various, time-varying sources of oil price shocks are found to be crucial.

**Keywords:** oil currencies, oil shocks, Time-Varying Parameter VAR model.

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## 1. Introduction

It is a widely accepted view that many commodity-exporting countries have commodity currencies, in that movements in real commodity prices can explain fluctuations in their real exchange rates (Chen and Rogoff, 2003; Cashin et al., 2004). Among those commodities, oil has been identified as a potential driver of currencies as movements in the real price of oil can also have significant influence on oil producers' real exchange rates (Korhonen and Juurikkala, 2009; Coudert et al., 2011).

On a theoretical level, two main arguments have been put forward to explain the existence of oil currencies. First, higher oil prices may bring about an appreciation of real exchange rates through mechanisms that have been identified by the literature on the Dutch disease (Corden, 1984) and on commodity currencies (Chen and Rogoff, 2003). Higher oil prices lead to an improvement in terms of trade which in turn increases oil export revenues. This effect, by raising the price of non-traded goods, may place appreciation pressures on the real exchange rate. Second, exchange rates of oil countries can also experience a 'wealth effect' through the specific impact of oil price changes on international portfolio decisions and trade balances (Krugman, 1983; Golub, 1983). According to this view, oil-exporting countries can encounter a wealth transfer driven by the improvement of their net foreign asset position if the price of oil rises.

The empirical literature has, however, provided mixed support for the assumed relationship between the price of oil and real exchange rates of oil-producing countries. Studies relying on panel data mostly find that real exchange rates of oil producers appreciate in the wake of increased oil prices, confirming the relevance of oil currencies (Korhonen and Juurikkala, 2009; Coudert et al., 2011). Country-by-country studies lead, however, to less clear-cut findings with some cross-country differences. For example, Habib and Kalamova (2007) do not find a long-run relationship between real effective exchange rates and oil prices for Norway and Saudi Arabia, while they report evidence for Russia. Mohammadi and Jahan-Parvar (2012) find significant long-run effects of oil prices on real exchange rates only in 3 economies (Bolivia, Mexico and Norway) over a sample of 13 oil-exporting countries. Figure 1, which depicts the evolution of the real price of oil and real effective exchange rates (REER) of five oil producers, illustrates those mixed empirical results. The oil price boom observed since 1999 has not been followed by an appreciating trend of the REER in all the five countries. The REER has only appreciated in Canada, Norway and Indonesia; it has even slightly depreciated in the United Kingdom, while remaining broadly constant in Saudi

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3 Arabia. This configuration also contrasts with the 1970s when rises in the price of oil, for the  
4 two latter countries, went hand in hand with an appreciating trend of their respective REER.  
5 Overall, trends do not indeed indicate any obvious relationship between the two variables.  
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10 **Figure 1.** Evolution of real effective exchange rates and real price of oil (1988=100)

11 *Insert Figure 1 about here*

12 Note: the black line represents the evolution of the REER (left scale) and the blue dashed line, the evolution of  
13 the real price of oil (right scale). See Section 3.1 for data sources.  
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17 Such empirical findings are puzzling with regard to the theoretical literature and the widely  
18 shared belief that the price of oil is an important driver of the major fluctuations observed in  
19 oil producers' real exchange rates. One interpretation is that the relationship between the price  
20 of oil and real exchange rates is somewhat weak. Coudert et al. (2011), reviewing the  
21 empirical studies on commodity and oil currencies, report and find a real exchange rate long-  
22 run elasticity with respect to the terms of trade lower for oil-exporting countries than for  
23 commodity-exporting economies. The authors explain this lower sensibility by (i) greater  
24 fluctuations in the price of oil than in other commodity prices, and (ii) the pegged exchange-  
25 rate regime adopted by many oil-exporting countries that dampens the adjustment of the real  
26 exchange rate to the oil price movements.  
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34 The other interpretation is that the common belief is not baseless, but the puzzle arises from  
35 the empirical approach used to estimate the relationship between oil prices and real exchange  
36 rates. Indeed, the literature investigating the macroeconomic effects of oil price shocks has  
37 recently highlighted the importance of identifying the sources of those shocks. In particular,  
38 there is some evidence that the sources of changes in oil prices vary over time. Several  
39 authors (see, e.g., Hamilton, 2003; Barsky and Kilian, 2004) have argued that in the most  
40 recent decades, major oil price fluctuations have been primarily demand-driven. As a  
41 consequence, a large body of research has shown that macroeconomic variables could respond  
42 differently to an oil price change depending on the nature of the underlying shock. Those  
43 findings also have important methodological implications. Indeed, estimates based on the  
44 economic effects of an average oil price shock determined by a combination of supply as well  
45 as demand factors, can seriously bias cross-country comparisons.  
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54 Aware of this methodological problem, some studies (Buetzer et al., 2012; Atems et al., 2015)  
55 have investigated the relationship between the price of oil and real effective exchange rates  
56 using the decomposition of oil market shocks provided by Kilian (2009). Overall, these  
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3 studies converge towards an univocal stylized fact: the underlying source of the oil price  
4 increase is crucial to determine the repercussions of oil shocks on exchange rates.  
5 Interestingly, while this finding might simply reflect structural changes experienced by the oil  
6 market itself through the increase in the relative importance of expansionary global shocks  
7 (Kilian, 2009; Baumeister and Peersman, 2013a), this literature offers complementary  
8 explanations that the effect of oil price shocks may also depend on some structural changes  
9 likely to influence the joint dynamics of the two macroeconomic variables (Buetzer et al.,  
10 2012; Peersman and Van Robays, 2012).

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16 Against this background, we examine how oil shocks are transmitted to real exchange rates  
17 over time and the driving forces behind the observed time variation. Accordingly, we take  
18 into account the different sources of oil price shocks usually highlighted by the literature  
19 (Kilian, 2009) by distinguishing (i) exogenous disruptions in oil supply, (ii) oil demand  
20 shocks driven by global economic activity, and (iii) oil market specific demand shocks caused  
21 by speculative or precautionary motives. We explore the time-varying dimension of the  
22 relationship between real exchange rates and oil prices by relying on a time-varying parameter  
23 VAR (henceforth TVP-VAR) specification. Indeed, the main advantage of the TVP-VAR is  
24 to allow oil shock effects and the transmission of oil price fluctuations to real exchange rates  
25 to vary over time; a property which is essential to capture the time-changing effects of shocks.  
26 Our contribution to the literature is twofold. First, we go beyond the previous studies on the  
27 effects of oil shocks which mainly (i) rely on structural VAR or panel specifications with  
28 fixed coefficients (Buetzer et al., 2012; Atems et al., 2015), or (ii) introduce a structural break  
29 in the relationship between the real price of oil and real exchange rates in the mid-1980s to  
30 further investigate changes in the relationship between these two variables (Peersman and  
31 Van Robays, 2012). Second, by identifying and estimating the effects of oil price shocks  
32 depending on their underlying source, our analysis provides an additional contribution to the  
33 literature on oil currencies which, despite outlining the existence of a non-linear relationship  
34 between real exchange rates and oil prices (Akram, 2004; Mohammadi and Jahan-Parvar,  
35 2012; Ahmad and Moran Hernandez, 2013; Beckmann and Czudaj, 2013), has the major  
36 disadvantage of assuming exogenous oil price shocks.

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Considering a sample of five oil exporters over the 1988Q1-2013Q2 period, our main findings  
give additional insights to the oil price – real exchange rate nexus. First, we observe  
significant time variation in the relationship between the price of oil and real exchange rates,  
whose identification enables us to add new contributions to the commodity currency  
literature. Second, we show that there are significant differences in those responses depending

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3 on the source of the oil shock. In particular, we find that (i) real exchange rates react  
4 significantly to oil demand and oil market specific shocks, in contrast to supply disturbances,  
5 and (ii) the respective importance of oil demand and oil market specific shocks evolves  
6 through time in all countries and tends to offset each other. Finally, depending on both the  
7 type of shocks and the time period considered, our analysis reveals significant evolutions and  
8 differences for a given country and across countries, meaning that there is no single model of  
9 oil currencies.  
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11 The rest of the paper is organized as follows. Section 2 presents the time-varying structural  
12 VAR model adopted in the paper. Results and related comments are displayed in Section 3.  
13 Section 4 summarizes our main findings and draws some concluding remarks.  
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## 15 **2. Empirical methodology**

16 We go further than the previous literature by aiming at better capturing the time-varying  
17 nature of the oil price-real exchange rate nexus. Specifically, we account simultaneously for  
18 two key characteristics of this relationship: the existence of abrupt movements and the  
19 presence of gradual changes, due to the persistence induced by some potential dampening  
20 factors (foreign reserves, adaptive learning behavior of agents...). To this end, we rely on the  
21 TVP-VAR model with sign restrictions.<sup>1</sup>  
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23 Such methodology is highly appealing for our purpose for two main reasons. First, it permits  
24 to model both the possible abrupt breaks and gradual evolution of the relationship between the  
25 variables of interest, but also to capture non-linearities. Indeed, the relationship between oil  
26 prices and the relevant macroeconomic variables might either be subject to structural changes<sup>2</sup>  
27 that come from economic events (e.g., the 2008 global crisis), economic policy decisions  
28 (OPEC decisions), political and social events (e.g., war and civilian unrest), fluctuations in the  
29 oil intensity of economic activity, changes in the regulation of oil and other energy markets,  
30 or present persistence due to adaptive learning behavior of agents (Primiceri, 2005). In  
31 addition, the transmission mechanism of oil price movements into macroeconomic variables  
32 might follow a non-linear process (Akram, 2004; Mohammadi and Jahan-Parvar, 2012;  
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49 <sup>1</sup> In the aftermath of the seminal paper by Kilian (2009)—arguing that changes in the real oil price-  
50 macroeconomic variables relationship over time are due to the time-varying nature of oil price shocks—TVP-  
51 VAR models with sign restrictions have been used, for instance, by Peersman and van Robays (2009), Hahn and  
52 Mestre (2011), and Baumeister and Peersman (2013a).  
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54 <sup>2</sup> Cashin et al. (2004) and Le and Chang (2013) in a time series context, and Chen and Chen (2007) in a panel  
55 framework provide a formal test. Chen et al. (2010) advanced the necessity of controlling for structural breaks  
56 and time-varying parameters to uncover (in-sample) causality from commodity prices to the exchange rate.  
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Ahmad and Moran Hernandez, 2013) with effects that can be different depending notably on the economic environment. Therefore, letting the data to determine whether the relationship between the real exchange rate and the price of oil either presents a structural break or is persistent, and capture possible non-linearities in the reaction of the exchange rate to oil price changes are valuable features of the TVP-VAR approach. Second, identifying structural shocks using the sign restriction methodology allows us to assess the responses of the real exchange rate following different sources of oil price fluctuations, namely oil supply, global oil demand and oil market specific shocks.

### 2.1. The TVP-VAR model

The structural VAR representation of a multivariate time series model with both time-varying coefficients and time-varying standard errors of structural innovations is defined as:

$$B_t Y_t = d_t + C_{1,t} Y_{t-1} + \dots + C_{p,t} Y_{t-p} + \Sigma_t v_t \quad (1)$$

where  $Y_t = [\Delta \ln(q_t), \Delta dc_t, \Delta \ln(p_{o,t}), \Delta \ln(reer_t)]'$  is an  $4 \times 1$  vector of endogenous variables, with  $\Delta$  denoting the first-difference operator.  $q_t$ ,  $dc_t$ ,  $p_{o,t}$  and  $reer_t$  respectively denote the world oil production, the dry-cargo index of Kilian (2009) used as a proxy of the global economic activity, the real price of oil, and the real effective exchange rate.<sup>3</sup>  $d_t$  is a vector of time-varying constants,  $C_{i,t}$  ( $i = 1, \dots, p$ ) are  $4 \times 4$  matrices of time-varying coefficients on the lags of the endogenous variables and  $v_t$  is a vector of structural innovations which are assumed to follow a multivariate standard normal distribution. As in Baumeister and Peersman (2013a), the lag length is set to  $p=4$  in order to fully capture delays in the transmission of oil shocks (see also Hamilton, 2008).

We assume that the matrix of time-varying contemporaneous coefficients  $B_t$  is lower triangular with one along its diagonal elements, whereas the matrix of time-varying standard errors  $\Sigma_t$  is diagonal:

$$B_t = \begin{pmatrix} 1 & 0 & \dots & 0 \\ b_{21,t} & 1 & \ddots & \vdots \\ b_{31,t} & b_{32,t} & 1 & 0 \\ b_{41,t} & b_{42,t} & b_{43,t} & 1 \end{pmatrix} \text{ and } \Sigma_t = \begin{pmatrix} \sigma_{1,t} & 0 & \dots & 0 \\ 0 & \sigma_{2,t} & \ddots & \vdots \\ \vdots & \ddots & \sigma_{3,t} & 0 \\ 0 & \dots & 0 & \sigma_{4,t} \end{pmatrix} \quad (2)$$

Time variation in the relationship between our considered variables might derive from changes in (i) the contemporaneous relationship, (ii) the propagation mechanism, and (iii) the size of the shock that hits the model. Thus, the time-varying property of the parameters of

<sup>3</sup> See Section 3.1 for details concerning data.

interest  $B_t$ ,  $C_{i,t}$  ( $i = 1, \dots, p$ ) and  $\sigma_{j,t}$  ( $j = 1, \dots, 4$ ) lets the data determining the nature of changes that affect the link between the considered variables.

The reduced-form representation of the structural model (1) is defined as follows:

$$Y_t = c_t + A_{1,t}Y_{t-1} + \dots + A_{p,t}Y_{t-p} + \varepsilon_t \quad (3)$$

where  $A_{i,t} = B_t^{-1}C_{i,t}$  ( $i = 1, \dots, p$ ) are matrices of lagged coefficients,  $c_t = B_t^{-1}d_t$  is the vector of time varying coefficients that multiply constant terms and  $\varepsilon_t = B_t^{-1}\Sigma_t v_t$  is the vector of the reduced-form residuals. Following the structure of the contemporaneous coefficients matrix  $B_t$  and that of the standard errors of the structural innovations matrix  $\Sigma_t$ , we can assume that the reduced-form residuals follow a multivariate normal distribution:

$$\varepsilon_t \sim \mathcal{N}(0, \Omega_t) \quad (4)$$

where  $\Omega_t$  is a symmetric and positive definite time-varying variance-covariance matrix that satisfies the following equality:

$$B_t \Omega_t B_t' = \Sigma_t \Sigma_t' \quad (5)$$

Allowing for such time-varying heteroskedasticity in the innovations is important for our purpose since it permits to account for changes in the size of shocks and their immediate impact.

The time paths for the parameters of interest are assumed to follow random walk processes without drift.<sup>4</sup> If we denote  $\alpha_t$  the column vector that contains the stacked columns of the matrix  $A_t = (c_t \ A_{1,t} \ \dots \ A_{p,t})$ ,  $b_t = (b_{21,t} \ b_{31,t} \ b_{32,t} \ b_{41,t} \ b_{42,t} \ b_{43,t})'$  the column vector that gathers the elements of the matrix of the contemporaneous relationship  $B_t$ , and  $h_t = \ln(\sigma_t)$  with  $\sigma_t = (\sigma_{1,t} \ \dots \ \sigma_{4,t})'$  being the column vector that contains the diagonal elements of the matrix of standard errors  $\Sigma_t$ , the parameters evolve according to:

$$\begin{aligned} \alpha_t &= \alpha_{t-1} + \omega_t \\ b_t &= b_{t-1} + \zeta_t \\ h_t &= h_{t-1} + \eta_t \end{aligned} \quad (6)$$

This random walk specification has two main advantages. First, it permits to model possible abrupt breaks in the evolution of parameters that might occur during the estimation period. Second, it also allows us to model gradual changes in the relationship between the variables as a result of an adaptive learning behavior of individuals. Therefore, unlike multivariate specifications used in the literature that model either structural breaks or persistence, the TVP-VAR model encompasses these two important features of the relationship between the

<sup>4</sup> Even though the dynamics of the parameters can be easily extended to a more general autoregressive specification, we consider a random walk process in order to capture possible permanent shifts and to reduce the curse of dimensionality.

considered variables that might occur at different periods in our sample. In turn, innovations in the reduced-form model are assumed to be jointly normally distributed:

$$\begin{pmatrix} v_t \\ \omega_t \\ \zeta_t \\ \eta_t \end{pmatrix} \sim \mathcal{N}(0, V) \text{ with } V = \begin{pmatrix} I_4 & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{pmatrix} \quad (7)$$

where the matrix  $V$  is block diagonal with  $I_4, Q, S$  and  $W$  corresponding to the covariance matrix of the structural innovations  $v_t$ , the innovations of lagged coefficients  $\omega_t$ , the innovations of contemporaneous coefficients  $\zeta_t$  and the innovations of (log) standard errors  $\eta_t$ , respectively. The covariance matrix  $S$  is assumed to be block diagonal, i.e. the blocks of  $S$ —corresponding to the contemporaneous coefficients of each individual equation in (1)—are supposed to be mutually independent.

We estimate our TVP-VAR model using Bayesian methods on quarterly data from 1988Q1 to 2013Q2. To strengthen inference about the true value of the parameters, we use prior information in addition to the sample data to evaluate the posterior distributions of the parameters of interest.<sup>5</sup> From this perspective, a critical step is to carefully choose these priors for the estimation over the actual sample period. The key priors are estimated using a time-invariant VAR process on the training sample, i.e. a small initial subsample of the dataset. To this end, we estimate a time-invariant VAR model for each studied country over the 1970Q1-1988Q1 period.<sup>6</sup> In other words, our whole sample covers the 1970Q1-2013Q2 period, but the first 19 years of data are used as the training sample to obtain the priors for the estimation beginning in 1988Q1.

## 2.2. Identification scheme

The recent literature on oil market has evidenced that different sources of shocks can drive oil price movements by identifying three types of oil shocks: (i) changes in the world oil production that result from political and social events (war, civil unrest, OPEC decisions, ...) and that affect the supply of oil, (ii) changes in the evolution of the global economic activity that affect the demand of commodities, including oil, and (iii) changes in the expectation of agents in oil market about the state of world oil production relative to global demand that

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<sup>5</sup> See Appendix for details.

<sup>6</sup> TVP-VAR models are data consuming, a property that explains why our country sample is relatively small in comparison with related studies that rely on more usual econometric methodologies.

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3 affect demand for oil inventories for speculative or precautionary motive.<sup>7</sup> Moreover, the  
4 response of oil prices to those three shocks has been well identified by the literature,  
5 depending on the underlying source of the oil price change. Thus, the difference of sign,  
6 magnitude and persistence of the response of oil prices to those shocks offers a reliable  
7 identification scheme for structural shocks in the oil market. The signs of the restricted  
8 responses that we impose are then relatively uncontroversial and consistent with the  
9 restrictions used in most studies of the oil literature (Baumeister and Peersman, 2010; Kilian  
10 and Murphy, 2012) and of related works (Buetzer et al., 2012; Peersman and Van Robays,  
11 2012). They can be summarized as follows. First, after a negative oil production shock, world  
12 production decreases while the price of oil increases. Second, after a positive oil demand  
13 shock triggered by an unexpected rise in world economic activity, world oil production is not  
14 affected at least on the impact (zero restriction) while the price of oil increases. Kilian (2009)  
15 found evidence that aggregate demand shocks increase oil production with a delay of six  
16 months. Indeed, changing oil production is costly and, thus, oil producers set their production  
17 on the basis of the expected trend growth rather than on variation in the world demand.  
18 Moreover, in line with the previous literature (Hamilton, 2003, 2008; Kilian, 2008;  
19 Baumeister and Peersman, 2013a), we consider that a rise in the price of oil holds four  
20 quarters following demand shocks. Third, oil market specific shocks do not affect world oil  
21 supply on the impact (zero restriction), decrease the global economic activity and raise the  
22 price of oil which also holds four quarters following oil market specific shocks. The main  
23 difference between the oil demand shocks driven by global economic activity and the  
24 speculative demand shock is that the latter have a recessionary impact on economic activity.  
25 Furthermore, the assumption that the world oil production does not react to physical and  
26 speculative demand shocks on the impact reflects the evidence that the oil supply curve is  
27 vertical in the short run (Kilian, 2009).

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29 More technically, the structure of the variance-covariance matrix of the reduced-form  
30 residuals  $\Omega_t$  in (5) implies a Cholesky identification scheme, restricting the contemporaneous  
31 relationship matrix to be lower triangular. This is equivalent to an exclusion restriction in the  
32 oil price literature as in Kilian (2009). Hamilton (2003) in turn uses a counterfactual  
33 experiment to identify oil supply shocks. As previously mentioned, in the present paper, we

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<sup>7</sup> Changes in agents' expectation arise from (i) uncertainty surrounding world oil supply and global economic environment that affects demand for oil inventories without changing the level of demand and world oil production (Alquist and Kilian, 2010), (ii) revision to expected future level of world oil production, and (iii) revision to global demand of crude oil (Kilian and Murphy, 2013).

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3 rely on sign restrictions to identify different sources of oil price fluctuations such as oil  
4 supply, global demand and speculative demand shocks (Kilian, 2009; Kilian et al., 2009;  
5 Kilian and Murphy, 2012). The sign-restriction methodology we adopt here is the  
6 Householder Transformations of Fry and Pagan (2011) that is based on QR decomposition of  
7 randomly selected square matrices from a standard multivariate normal distribution.<sup>8</sup> Our sign  
8 restrictions are summarized in Table 1 below.  
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14 **Table 1.** Sign restrictions

15 *Insert Table 1 about here*  
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18 Note: this table reports the sign restrictions adopted to identify the different sources of oil price shocks (oil  
19 supply, global demand, speculative demand).  
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### 24 **3. Results**

#### 25 **3.1. Sample of countries and data**

26 We consider a sample of five oil exporters, namely Canada, Indonesia, Norway, Saudi Arabia,  
27 and the United Kingdom, over the 1988Q1-2013Q2 period. These oil producers account for  
28 about 25 percent of the world production on the whole period and differ in terms of the role of  
29 oil in the economy. Moreover, our panel of countries covers (i) developed with high income  
30 (Canada, Norway, the United Kingdom), developing with high income (Saudi Arabia), and  
31 developing with lower middle income (Indonesia) economies;<sup>9</sup> (ii) countries in hard peg  
32 regimes (Saudi Arabia) or in intermediate or managed floating regimes with a currency peg to  
33 the US dollar (Indonesia) or to the euro (Norway); (iii) non-inflation-targeting (Indonesia,  
34 Saudi Arabia) and inflation-targeting countries (Canada, Norway, the United Kingdom);<sup>10</sup> (iv)  
35 OPEC (Indonesia, Saudi Arabia) and non-OPEC countries (Canada, Norway, the United  
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46 <sup>8</sup> Moreover, as argued by Fry and Pagan (2011), the difference between Givens Matrices (GM) method and  
47 Householder Transformations (HT) method is simply a matter of computational speed. These two approaches are  
48 indeed equivalent, but HT is more efficient than GM in terms of computational speed when the size of the VAR  
49 specification grows.  
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52 <sup>9</sup> The classification between developed and developing economies reflects basic economic country conditions,  
53 while the categorization between high-income and lower middle-income developing economies refers to levels  
54 of development measured by gross national income per capita.  
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56 <sup>10</sup> We rely on Roger (2009) for the list of inflation targeting countries and their effective adoption date: Canada  
57 (1991), Norway (2001), United Kingdom (1992).  
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3 Kingdom). Thus, the sample is heterogeneous enough to capture changes in the relationship  
4 between the price of oil and real exchange rates that may be explained by countries'  
5 specificities.  
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8 Moreover, while the covered period differs from the mid and late 1970s in the nature of oil  
9 transactions,<sup>11</sup> it has been marked by oil price shocks of sign and magnitude comparable to  
10 those of the 1970s (Blanchard and Gali, 2007). In particular, the period has been characterized  
11 by two episodes of oil price increase—from 1999Q1 to 2000Q2 and from 2002Q1 to  
12 2008Q2—which obviously raise the issue of whether they have been a significant source of  
13 real exchange rate variations in oil-producing countries. It has also coincided with several  
14 exogenous shocks to the oil market induced by political events—the Persian Gulf war of  
15 1990-1991, the Venezuelan crisis of 2002, the Iraq war of 2003, and the Libyan uprising of  
16 2011 (Kilian, 2014)—and by many disruptions on foreign exchange markets caused by  
17 financial crises—the crisis of the European Monetary System of 1992-1993, the Asian crisis  
18 of 1997-1998, and the financial and economic crisis of 2008-2009.  
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21 Turning to the data and as stressed above, four variables are considered at the quarterly  
22 frequency.<sup>12</sup> Regarding the exchange rate series, we rely on the real effective exchange rate  
23 calculated as the weighted average of real bilateral exchange rates against each partner, and  
24 expressed in logarithmic terms. REER series are extracted from the JP Morgan effective  
25 exchange rates database.<sup>13</sup> The three other variables are the world crude oil production (in  
26 logarithm) taken from Datastream, the real price of oil (in logarithm), and the dry-cargo index  
27 of Kilian (2009). The real price of oil is defined as the average of the end-of-period nominal  
28 prices of WTI, Dubai and Brent (source: Datastream) deflated by the US consumer price  
29 index (source: Datastream).<sup>14</sup> The dry-cargo shipping rate index developed by Kilian  
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43 <sup>11</sup> Since the OPEC cartel collapse in 1985, oil transactions are mainly current marked based (Baumeister and  
44 Peersman, 2013b).

45 <sup>12</sup> The use of quarterly data deserves some comments since they are available on a monthly frequency. VAR-type  
46 estimations with monthly data generally require many lags, because changes in the variables following shocks  
47 often appear with a delay. In the case of TVP-VAR models, this issue is exacerbated by the important number of  
48 parameters to estimate. As a consequence, using monthly data is not recommended in the TVP-VAR models. We  
49 thus follow Baumeister and Peersman (2013a, 2013b) to utilize quarterly oil market data.  
50

51 <sup>13</sup> The effective exchange rates correspond to broad indices, which encompass not only major currencies, but  
52 also those of many emerging market economies. For more details, see Hargreaves and Strong (2003).  
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54 <sup>14</sup> As robustness checks, we have also considered two other oil price series. First, to investigate the sensitivity of  
55 our results to the price series itself, we have used the US refiners' acquisition cost of imported crude oil from the  
56 Energy Information Administration as a measure of the nominal price of oil, and expressed it in real terms using  
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(2009)—available on Lutz Kilian’s homepage—is a business cycle index which is designed to account for shifts in the global demand for industrial commodities. We use this index as a proxy for global economic activity, an idea that dates back to Isserlis (1938) and Tinbergen (1959). Finally, note that all those variables entering in our TVP-VAR model are stationary.<sup>15</sup>

### 3.2. Time-varying real exchange rate patterns

We start by investigating whether the response of REER to unexpected oil price shocks whatever their underlying source, has changed over time. Our interest here is then in detecting possible structural shifts in oil economies and in having a first insight regarding the potential of the time-varying oil-currency property for our selected oil-exporting countries. Figure 2 reports the dynamics of the contemporaneous relationship between the REER and the real price of oil.

**Figure 2.** Contemporaneous link between REER and real price of oil

*Insert Figure 2 about here*

Note: this figure displays the dynamics of the contemporaneous relationship between the real effective exchange rate and the real price of oil for each country.

Except for Saudi Arabia, positive changes in world oil prices trigger a contemporaneous appreciation of the REER. As shown in Figure 2, the positive relationship between the price of oil and REER is not necessarily explained by the prominence of the petroleum sector and dampened effects can indeed be at stake. For example, for long-standing US dollar peggers such as Saudi Arabia, studies evidence that this anchor seems to have delivered the expected benefits of this exchange rate regime, contributing to low inflation over the long term (Jadresic, 2002; Abed et al., 2003). This can then explain the remarkable stability of the real exchange rate and its observed resilience to oil price fluctuations across the time period under review. Except for the Saudi riyal, an increase in the price of oil is associated with a real appreciation of the effective exchange rate. The intensity of this co-movement however differs across currencies, being more intense for Canada, Indonesia and Norway, and less pronounced for the United Kingdom.

But, the most striking feature is the significant time variation in the contemporaneous responses of real exchange rates to oil price movements. More precisely, looking at Figure 2,

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US CPI as the deflator. Second, instead of considering oil price series expressed in real terms, we have implemented our analysis using the price of oil in nominal terms. In both cases, we obtained results similar to those reported in this paper (complete results are available upon request to the authors).

<sup>15</sup> Results of unit root tests are available upon request to the authors.

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3 we can identify at least two periods in the magnitude of real exchange rates' responses to an  
4 increase in the price of oil. The first spans from the beginning of our sample period to the  
5 world trade collapse (2008) where the transmission of oil price fluctuations to real exchange  
6 rates clearly varies over time, significantly increasing and reaching a peak in some countries  
7 (Canada, Indonesia, Norway) or decreasing in the United Kingdom. This period coincides  
8 with the increase in the non-OECD's oil consumption share in the world consumption,  
9 stemming mainly from a rise in China's and India's oil consumption (BP, 2014). The second  
10 period begins after the world trade collapse, where the sensibility of real exchange rates is  
11 broadly maintained at a constant level. Differences in the adjustment pattern between those  
12 two periods and within each period underline the fact that the relationship between the price  
13 of oil and real exchange rates is subject to change over time, suggesting that time-varying  
14 effects are a key issue when analyzing oil currencies. Moreover, as reactions of real exchange  
15 rates to the real price of oil are more fluctuating during the first period which coincides with  
16 the increase in the non-OECD's oil consumption, we should therefore expect to obtain more  
17 significant impulse responses when the increase in the price of oil is driven by a growing  
18 global demand. This confirms the relevance to investigate the origins of this time-varying  
19 dimension of the relationship between real exchange rates and the price of oil, by  
20 distinguishing the underlying sources of oil price shocks.  
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### 33. Do sources of oil price shocks matter?

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35 To account for the effects driven by the different sources of oil price shocks, we rely on the  
36 shocks' decomposition defined by Kilian (2009) and distinguish between oil price innovations  
37 caused by exogenous disruptions in oil supply, oil demand shocks driven by global economic  
38 activity and oil market specific demand shocks arising from speculative or precautionary  
39 motives.  
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43 We first rely on an impulse-response function (IRF) analysis to assess how the transmission  
44 of those three oil shocks to real exchange rates has changed over time. As the size of the  
45 innovations in our study is time-varying, the magnitude of impulse responses depends on the  
46 size of the shock hitting the model at each period. Therefore, the standard approach consisting  
47 in depicting the responses of the different variables following one-standard-deviation shock to  
48 one variable is not appropriate here. In order to make impulse-response functions comparable  
49 across periods, normalization is required. Thus, for each period, we consider negative oil  
50 supply and positive demand shocks of magnitude of 1%. For oil market specific shocks, we  
51 assume that they generate at each period a 10% increase in the price of oil. Moreover, as  
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3 argued by Hamilton (2008) and Baumeister and Peersman (2013a), the greatest response of  
4 macroeconomic variables to oil price shocks occurs with a delay of around one year.  
5 Therefore, we represent in Figures 3 to 5 the REER impulse-response functions (including  
6 confidence intervals) cumulated over four quarters after the considered shock.  
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11 **Figure 3.** REER impulse response following an oil production shortfall (horizon: 4 quarters)

12 *Insert Figure 3 about here*

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15 Note: this figure reports the impulse-response functions (in blue) of real effective exchange rates to a negative oil  
16 supply shock, with the 68 percent posterior credible sets by the shaded areas.  
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19 Figure 3 reports the impulse responses of real exchange rates to a negative oil supply shock.  
20 As shown, such a shock generates responses that oscillate moderately over time for all  
21 countries and an appreciation of the REER, except for Canada. However, for all countries—  
22 but Indonesia before 1997 and after 2008, and Norway after 2000—the change in the REER is  
23 non-significant. As a consequence, the oil currency effect driven by the supply shock is only  
24 found in the case of the Norwegian krone and the Indonesian rupiah. This result is consistent  
25 with the small historical contribution of oil supply shocks to the real price of oil. Indeed, as  
26 evidenced by Kilian (2009), oil supply disruptions had some effect on the real price of oil  
27 only in the early 1990s, but this influence was small. It therefore appears that the low  
28 sensitivity of the price of oil to oil supply shocks has then mitigated, in most countries of our  
29 sample, REER changes usually associated with oil price shocks.  
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40 **Figure 4.** REER impulse response following a world oil demand shock (horizon: 4 quarters)

41 *Insert Figure 4 about here*

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43 Note: this figure reports the impulse-response functions (in blue) of real effective exchange rates to a world oil  
44 demand shock, with the 68 percent posterior credible sets by the shaded areas.  
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48 In contrast, as reported by Figure 4, results evidence a more statistically significant and time-  
49 varying impact of a rise in the price of oil in the aftermath of an unexpected surge in global  
50 demand. This finding is consistent with results of previous studies that underline the sizeable  
51 impact of such shocks on oil prices, i.e. the endogenous nature of oil prices with respect to the  
52 macroeconomic environment, considering the demand channel as a primary source of price  
53 fluctuations (Barsky and Kilian, 2002, 2004; Kilian, 2008, 2009; Hamilton, 2009).  
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3 However, the oil demand shock is not significant for all countries and over the entire period:  
4 while the shock is found significant for all countries before 2003, this is no more the case for  
5 Norway and the United Kingdom after that date. Moreover, following the rise in oil prices,  
6 the REER is appreciating only in Canada and Indonesia. For this latter country, the time-  
7 changing oil price elasticity of the REER is not exclusively determined by the magnitude of  
8 demand disturbances affecting the oil market, but also by reversals in the exchange rate  
9 policy. The sizeable adjustment of the Indonesian rupiah in 1997, in the wake of the Asian  
10 crisis, has strongly amplified the response of the REER to an increase in oil prices and  
11 explains those large, oil price induced, observed shifts in the real exchange rate.<sup>16</sup> For these  
12 two countries exhibiting an appreciating trend following the oil demand shock, the oil price  
13 elasticity of real exchange rates is, however, decreasing over time. As a consequence, if the  
14 oil currency property holds for the Canadian dollar and the Indonesian rupiah, it weakens over  
15 time, suggesting that real exchange rates of these two countries are less and less sensitive to  
16 global oil demand shocks, although their impact remains significant. In contrast, other  
17 countries of our sample undergo a depreciation of their REER following a positive oil demand  
18 shock. Here again, the sensitivity of the real exchange rates to the rise in the price of oil  
19 following this shock is found to be time-varying; it weakens over time in Saudi Arabia, while  
20 becoming not significant in Norway and in the United Kingdom after 2003.  
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22 Therefore, while the oil currency property holds when demand disturbances affect the oil  
23 market, it appears however to be mainly confined to some countries and to become weaker  
24 over time, underlining the weight of domestic considerations and the time-varying nature of  
25 the oil currency effect in the oil demand shock transmission.  
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42 **Figure 5.** REER impulse response following an oil-specific demand shock

43 (horizon: 4 quarters)

44 *Insert Figure 5 about here*

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46 Note: this figure reports the impulse-response functions (in blue) of real effective exchange rates to an oil market  
47 specific shock, with the 68 percent posterior credible sets by the shaded areas.

48  
49 Finally, turning to oil market specific shocks, their impact on the REER is also time-varying,  
50 but those shocks are found to be the most significant as responses of real exchange rates are  
51 significant for all countries, except Indonesia before 1997 (Figure 5). As for the global oil  
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56 <sup>16</sup> In the wake of the Asian crisis—that began with the floating of the Thai baht in July 1997—the Indonesian  
57 rupiah floated and, by early October, it had depreciated by 30 percent.  
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3 demand shock, real exchange rates appreciate in the aftermath of the shock only in Canada  
4 and Indonesia, while they depreciate in the other countries of our sample. But, for all  
5 countries—except the peak in the Indonesian REER response in 1997—trends observed over  
6 time in the responses of REER after oil market specific shocks depart from those ascertained  
7 following an oil demand shock. This result supports the idea that the magnitude and the  
8 evolution of the relationship between real exchange rates and oil prices highly depend on the  
9 nature of the oil shock.  
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14 Our results evidence an amplified effect driven by oil market specific demand shocks  
15 following the Iraq war of 2003 and the global financial crisis of 2007-2008, especially for  
16 Canada, Norway and Saudi Arabia. Indeed, the response of the real exchange rate following  
17 an oil market specific shock has remained constant until 2008 in Canada and Saudi Arabia  
18 and since then has shown growing pressures to real appreciation for the Canadian dollar and  
19 decreasing pressures to real depreciation for the Saudi Arabian riyal. This latter pattern is also  
20 observed for the Norwegian REER, while beginning earlier, in the wake of the 2003 Iraq war.  
21 Two main reasons can be given in order to explain those time-varying responses induced by  
22 oil market specific shocks. First, expectations of a future increase in the price of oil driven by  
23 either political events or economic crises provide incentives to curb current oil consumption  
24 and stimulate additional oil production (Kilian, 2014), which in turn can affect the  
25 relationship between the REER and the price of oil. This is then not surprising that the REER  
26 response to such shocks has been mostly effective in Canada, Saudi Arabia and Norway that  
27 are important oil-producing countries, while being inexistent in smaller oil producers like  
28 Indonesia and the United Kingdom. Second, the increased financialization of oil futures  
29 markets can matter, even if there is no clear-cut evidence of the role of speculation in driving  
30 the spot price of oil after 2003 (Fattouh et al., 2013). In particular, this process of  
31 financialization may encourage volatility spillovers both within the oil market and with  
32 financial markets which in turn impact the reaction of oil currencies to prices through a wealth  
33 effect and the demand for assets (Coudert et al., 2015).  
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48 To sum up, as expected, higher responses of real exchange rates to oil price movements  
49 appear to be more particularly at stake when oil shocks that have been responsible for many  
50 major oil price changes over our sample period—oil demand and oil market specific shocks—  
51 prevail. In addition, interactions between the real exchange rate and the price of oil vary both  
52 over time and according to the nature of the oil price shock. Consequently, analyzing the  
53 effect of oil price shocks without distinguishing their underlying sources over time could be  
54 misleading. In particular, responses of real exchange rates to oil price movements evidence  
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the presence of offsetting factors that vary over time and that arise from compensating effects between the two oil demand shocks. Moreover, depending on both the type of shocks and the time period considered, we also observe, for a given country and across countries, significant evolutions and differences, as summarized in Table 2.

**Table 2.** Statistical significance and sign of impulse responses to oil shocks

*Insert Table 2 about here*

Note: this table reports for each country the period at which a shock had a significant effect on the REER, depending on its source (oil supply, global demand, oil-specific demand). The sign + (-) stands for a positive (negative) response of the REER to an increase in the real price of oil.

This heterogeneity between countries found over time and for each type of oil shock points to the importance of domestic considerations that also affect the dynamics of REER and the real price of oil.

### 3.4. Identifying drivers of real exchange rates over time

To understand the underlying mechanisms that have been driving real exchange rates' fluctuations in the considered oil-producing countries, we perform both historical (Figure 6) and variance (Figure 7) decompositions. These two complementary tools are used in order to analyze the evolution of the size of structural innovations and to measure the contribution of each innovation to the evolution of real exchange rates. While the Forecast Error Variance Decomposition (FEVD) consists in decomposing the variance of the forecast error of the real exchange rate  $h$  periods ahead, the historical decomposition consists in explaining the observed values of real exchange rates in terms of the structural shocks. As for the impulse responses, we allow the FEVD to vary over time, thus enabling for alternating dynamics in the composition of shocks that drive the variances.<sup>17</sup>

**Figure 6.** Historical decomposition of the REER

*Insert Figure 6 about here*

Note: this figure reports the historical decomposition of real effective exchange rates (REER) for each country according to the nature of the oil shock (Oil-Prod: oil supply shock, Oil-Demand: oil global demand shock, Oil-Price: oil-specific demand shock).

<sup>17</sup> The decompositions are calculated for a 30 quarters horizon, thus representing the medium-term impact of shocks.

**Figure 7.** Forecast Error Variance Decomposition of the REER

*Insert Figure 7 about here*

Note: this figure reports the forecast variance error decomposition of real effective exchange rates (REER) for each country according to the nature of the oil shock (Oil-Prod: oil supply shock, Oil-Demand: oil global demand shock, Oil-Price: oil-specific demand shock).

Figures 6 and 7 show that oil shocks explain the main part of real exchange rate changes in all countries. Interestingly, this overall picture must be qualified as our countries exhibit diverging patterns over time. As expected, for economies where oil production significantly declined over time—Indonesia (since 1999) and the United Kingdom (since 1990)—our results emphasize a lower influence of oil shocks on real exchange rates particularly after 2000. These two countries shifted from a position of net oil exporters to net oil importers (since 2003 and 2004 respectively). In countries where oil represents a significant share of exports, Figures 6 and 7 suggest that time profiles differ more significantly. Canada is clearly the most “oil currency” country as not only oil shocks explain the main part of real exchange rate changes, but also their importance increases over time. At the opposite, Norway seems the least “oil currency” in the sense that the influence of oil shocks on REER accounts for the weakest part of real exchange rate changes over the studied period. However, the impact of oil shocks follows an increasing trend since 2000. Saudi Arabia is in an intermediate position insofar as oil shocks represent a higher (lower) share of real exchange rate changes than Norway (Canada).

Several explanations could be put forward to account for this heterogeneity between countries. Natural arguments can be sought in the importance of various dampening factors, clearly identified by the literature on oil-producing countries. This particularly holds for countries like Norway and Saudi Arabia which manage their oil revenues through an active policy to isolate their economy from sharp and erratic price movements that characterize the oil market. This policy mainly takes the form of an accumulation of exchange-rate reserves (Figure 8) and/or an increase in foreign assets through Sovereign Wealth Funds (SWFs). Specifically, while in Saudi Arabia, there is no separate wealth fund from the Saudi Arabian Monetary Agency to manage oil revenues, Norway owns such fund. According to the Norwegian Ministry of Finance, the market value of the Government Pension Fund Global has risen from 55 billion USD in 2001 to more than 879 billion in 2014. SWFs are especially important to the extent that they prevent a full conversion of oil revenues in domestic

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3 currency insofar as part of these revenues can be invested abroad. In other words, they act as a  
4 “quasi-sterilization” instrument for domestic authorities (Habib and Kalamova, 2007; Buetzer  
5 et al., 2012).<sup>18</sup> In those countries, the main transmission mechanism of oil price shocks should  
6 then be channeled through the fiscal policy rather than through the real exchange rate  
7 (Steigum and Thøgersen, 1995; El Anshasy and Bradley, 2011).  
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13 **Figure 8.** Foreign exchange reserves 1988-2013, in U.S. dollar billion

14 *Insert Figure 8 about here*

15 Source: International Monetary Fund, International Financial Statistics.  
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19 Similarly, we can expect that monetary authorities of inflation-targeting countries also raise  
20 interest rates in an effort to curb inflationary pressure, driven by a rise in world oil prices  
21 (Manera and Cologni, 2008). However, results for Canada suggest that the importance of  
22 monetary regimes must not be overestimated. Specifically, while this country has adopted an  
23 inflation-targeting regime, it does not rely on SWFs contrary to Saudi Arabia and Norway.<sup>19</sup>  
24 Regarding oil-producing countries that peg their currencies to the US dollar, if a rise in oil  
25 prices is absorbed by USD depreciation, the exchange rate policy may dampen the effect of  
26 oil prices on real exchanges rates (Reboredo, 2012). As a consequence, the experience of  
27 Norway (inflation-targeting country) and Saudi Arabia (conventional peg regime) suggests  
28 that the transmission of oil prices to real exchange rates can be dampened by an appropriate  
29 combination between monetary and fiscal policies.  
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37 Besides policy responses to oil price changes, structural factors can explain differences  
38 between Canada, Norway, and Saudi Arabia. As exhibited in Table 3, it is worth mentioning  
39 that Canada is characterized by some specific features compared to the other oil-exporting  
40 countries (Kilian et al., 2009): (i) it is a diversified country with manufactured goods exports  
41 representing about 54% of total exports, but is among the top ten oil exporters despite the  
42 quite limited oil share (19%) in its total exports; and (ii) it owns the third largest proved crude  
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51 <sup>18</sup> Various other factors can also dampen the contribution of oil prices to REER movements as the degree of  
52 financial integration and financial development (Kilian et al., 2009), and valuation effects (Kilian et al., 2009;  
53 Buetzer et al., 2012; Wang et al., 2013).  
54

55 <sup>19</sup> Up to 1983, 30 percent of the petroleum incomes were channeled into the fund (Alberta Heritage Savings  
56 Trust Fund created in 1976). This value was reduced to 15 percent during the 1984–87 period, before the  
57 payments into the fund went down to zero. Since then there have been no additional payments into the fund.  
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oil reserve after Saudi Arabia and Venezuela.<sup>20</sup> These specific characteristics confer to Canada a prominent role in the oil market, but do not entirely shelter the economy and especially the Canadian dollar from oil price volatility.

**Table 3.** Share of fuels and manufactured goods in GDP and trade (%)

*Insert Table 3 about here*

Sources: UNCTAD database and authors' calculations. Averages of annual data over the 1995-2013 period.

The previous trends about the influence of oil as a driver of real exchange rate fluctuations hide interesting differences concerning the contribution of the underlying sources of oil price shocks to REER innovations. The oil supply shock is the weakest driver of real exchange rates for all countries but Norway. In other words, differences in the degree of oil exports' concentration do not matter. Such finding is in line with the literature stressing the relative low influence of oil supply shocks on macroeconomic variables in oil-exporting countries. As shown in Figures 6 and 7, while real exchange rates tend to be mainly explained by oil demand shocks in the 1990s in Canada, Indonesia, Saudi Arabia and the United Kingdom, the influence of these shocks decreases in the 2000s. Indeed, over this latter sub-period, we identify a dramatic increase in the impact of oil specific shocks on the real exchange rate dynamics. Clearly, oil demand specific shocks are found to be the most significant ones in assessing real exchange rate changes across countries and over time. Historical and forecast error variance decompositions provide similar results, emphasizing the robustness of our findings.

#### **4. Conclusion**

This paper has investigated the time-varying property of the relationship between the real price of oil and real effective exchange rates for a sample of five oil exporters. Specifically, we account for time-changing effects of oil shocks and the evolving oil price transmission to real exchange rates through the estimation of a time-varying parameter VAR model. Acknowledging that different kinds of shocks may have distinct effects, we distinguish between three types of oil shocks: exogenous disruption in oil supply, oil demand shocks

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<sup>20</sup> According to the U.S. Energy Information Administration and the Oil & Gas Journal, the proved reserve of Canada amounts to 173 billion barrels while that of Venezuela and Saudi Arabia amounts to 297 and 278 billion of barrels, respectively.

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3 driven by global economic activity, and oil-specific demand shocks coming from speculative  
4 and precautionary motives.

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6 Considering the 1988Q1-2013Q2 period, we find evidence that the relationship between the  
7 real price of oil and real effective exchange rates has evolved through time and that the source  
8 of shocks strongly matters in explaining this time-varying property. Specifically, while oil  
9 supply shocks play a small role in explaining the relationship between oil prices and real  
10 exchange rates, when they lead to significant responses, the real exchange rate-oil price nexus  
11 appears to be remarkably constant. In contrast, oil demand shocks are shown to have a  
12 sizeable effect, over the 1988-2003 period. Indeed, those shocks cause time-varying  
13 relationships between real exchange rates and oil prices which, however, tend to offset each  
14 other. However, the appreciation of real exchanges rates following a demand-driven rise in  
15 the price of oil is only confined to some countries, suggesting that in addition to endogenous  
16 structural changes in the oil market, both economic policies and structural characteristics  
17 matter as driving forces behind the adjustment of real exchanges rates to oil price shocks.

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19 Our results thus provide additional insights on the gap between the theoretical literature and  
20 the empirical literature on oil currencies. Indeed, the result that the oil currency property in oil  
21 countries can be driven by different sources of oil price shocks changing over time gives a  
22 new picture of the oil currency phenomenon, compared to that delivered by the existing oil  
23 literature. The oil currency property cannot be considered as *the* oil producers' model but  
24 rather refers to different hybrid models in the sense that conditional to each country, oil  
25 currency may be driven by one or several sources of oil price shocks that furthermore can  
26 vary over time.  
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## Appendix

### A1. Bayesian inference

As in Cogley and Sargent (2005), the parameters of interest  $A_t$ ,  $B_t$  and  $\Sigma_t$  are expressed in a state-space representation. Based on (i) the reduced-form equation (3), (ii) the law of motion of parameters (4), and (iii) the normality assumption of innovations  $v_t$  and  $\omega_t$ , the lag coefficients  $A_t$  have a linear Gaussian state-space representation. In turn, the lower triangular, diagonality and bloc diagonality assumptions of  $B_t$ ,  $\Sigma_t$  and  $S$  ensure a linear Gaussian state-space representation of contemporaneous coefficients. Therefore, the joint posterior density for  $A_t$  and  $B_t$  is a product of independent normal distributions. However, the standard-error coefficients in  $\Sigma_t$  can be transformed into a linear state-space representation which is no longer Gaussian. Instead, they follow a  $\ln(\chi^2(1))$  distribution, which can be approximated by a mixture of 7 normal distributions as in Kim et al. (1998).

The entire sequence of the parameters of interest  $A_t$ ,  $B_t$  and  $\Sigma_t$  is generated *via* forward and backward recursion of Kalman filter using Gibbs sampler; estimates of parameters being obtained using Carter and Kohn (1994)'s simulation smoother.

### A2. Prior distribution

Our specifications of prior distributions follow Primiceri (2005). The initial values for the time-varying parameters and variance-covariance matrices are assumed to be mutually independent. An initial training sample of 80 observations is used to generate OLS point estimates of the parameters of interest. Priors of the initial values of the reduced-form VAR parameters  $A_0$ , the contemporaneous coefficients  $B_0$ , and the logarithm of volatilities  $\ln\Sigma_0$  are assumed to follow a normal distribution with mean equals to the corresponding OLS estimates of the parameters and variance equals to four times the corresponding OLS variances for  $A_0$  and  $B_0$ , and equals to the identity matrix for  $\ln\Sigma_0$ :

$$\begin{aligned}\alpha_0 &\sim \mathcal{N}(\hat{\alpha}_{ols}, 4.V(\hat{\alpha}_{ols})) \\ b_0 &\sim \mathcal{N}(\hat{b}_{ols}, 4.V(\hat{b}_{ols})) \\ h_0 &\sim \mathcal{N}(\hat{h}_{ols}, I_n)\end{aligned}\tag{A.1}$$

with  $n$  denoting the number of endogenous variables in the system ( $n = 4$ ).

In turn, the priors of different blocks of the variance-covariance matrix  $V$  are assumed to be independent and to follow an inverted Wishart ( $\mathcal{IW}$ ) distribution:

$$\begin{aligned}
Q &\sim \mathcal{IW}(k_Q^2 \cdot 80 \cdot V(\hat{b}_{ols}), 80) \\
S_{[i]} &\sim \mathcal{IW}(k_S^2 \cdot (i+1) \cdot V(\hat{b}_{ols}), (i+1)) \\
W &\sim \mathcal{IW}(k_W^2 \cdot (n+1) \cdot I_n, (n+1))
\end{aligned} \tag{A.2}$$

where  $k_Q^2 = 0.01$ ,  $k_S^2 = 0.1$ ,  $k_W^2 = 0.01$ ,  $n = 4$ , and  $S_{[i]}$  corresponds to the  $i^{\text{th}}$  block of the matrix  $S$ . It should be noticed that these priors assumptions together with the random walk hypothesis in (6) imply normal priors on the entire sequences of  $A_t$ ,  $B_t$  and  $\Sigma_t$  conditional on  $Q$ ,  $S$  and  $W$ . Using this setting, the priors are not flat but sufficiently diffuse and uninformative to let the data determine the best estimates of parameters.

### A3. Posterior distribution

Given that the state-space model of parameters of interest are linear and Gaussian, the posterior distributions of the state variables  $\alpha_t | Y_t, B_t, \Sigma_t, S$ ,  $b_t | Y_t, \alpha_t, \Sigma_t, S$  and  $h_t | Y_t, \alpha_t, B_t, W$  are generated using forward and backward recursion of Kalman filter. Variance-covariance matrices  $Q$ ,  $S$  and  $W$  are generated from their respective independent posterior distributions which are assumed to follow an inverted Wishart distribution:

$$\begin{aligned}
Q | Y_t, A_t, B_t, \Sigma_t &\sim \mathcal{IW}\left(\left(\sum_{t=p+1}^T \omega_t \omega_t' + \underline{Q}\right), (T - p + \underline{q})\right) \\
S_{[i]} | Y_t, A_t, B_t, \Sigma_t &\sim \mathcal{IW}\left(\left(\sum_{t=p+1}^T \zeta_{[i]t} \zeta_{[i]t}' + \underline{S}_{[i]}\right), (T - p + \underline{s}_{[i]})\right) \\
W | Y_t, A_t, B_t, \Sigma_t &\sim \mathcal{IW}\left(\left(\sum_{t=p+1}^T \eta_t \eta_t' + \underline{W}\right), (T - p + \underline{w})\right)
\end{aligned} \tag{A.3}$$

where  $\underline{Q}$ ,  $\underline{S}_{[i]}$  and  $\underline{W}$  are positive definite scale matrices from the inverted Wishart prior distributions of  $Q$ , block matrix  $S_{[i]}$  of  $S$  and  $W$ ;  $\underline{q}$ ,  $\underline{s}_{[i]}$ ,  $\underline{w}$  being their respective degrees of freedom.

#### A4. Markov Chain Monte Carlo (MCMC) algorithm

The implementation procedure of the Markov Chain Monte Carlo (MCMC) algorithm can be summarized as follows:

1. Specify the initial sequence of  $A_t, B_t, \Sigma_t, D_t$  and  $V$ ,
2. Generate the states  $\alpha_t$  conditional on  $Y_t, B_t, \Sigma_t$  and  $Q$  using Kalman filter for  $t = 1, \dots, T$ ,
3. Generate off-diagonal elements  $b_t$  of the contemporaneous matrix  $B_t$  conditional on  $Y_t, \alpha_t, \Sigma_t$  and  $S$ , using Kalman filter for  $t = 1, \dots, T$ ,
4. Generate volatilities  $\sigma_t$  conditional on  $Y_t, \alpha_t, b_t, D_t$  and  $W$  using Kalman filter for  $t = 1, \dots, T$ ,
5. Generate a new selection matrix  $D_t$  by sampling from  $P(d_{it} = k | Y_{it}^{**}, h_{it})$  conditional on  $Y_t, \alpha_t, b_t, \sigma_t$  for  $t = 1, \dots, T$ ,
6. Generate variance-covariance matrix  $V$  by sampling from independent inverted Wishart distribution,
7. Check for stationarity of the VAR, and if and only if it is the case, store parameters of interest,
8. Go to step 2.

It is worth noting that step 7 is implemented in order to ensure that realizations of the VAR are stationary; only stationary draws being accepted and stored.

**Table 1.** Sign restrictions

	Supply shock	Global demand shock	Speculative demand shock
Oil production	-	0	0
Global activity	.	+	-
Real price of oil	+	+(for 4 horizons)	+(for 4 horizons)

Note: this table reports the sign restrictions adopted to identify the different sources of oil price shocks (oil supply, global demand, speculative demand).

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**Table 2.** Statistical significance and sign of impulse responses to oil shocks

	Supply shock	Global demand shock	Specific demand shock
Canada		1988-2013 (+)	1988-2013 (+)
Indonesia	1988-1997; 2008-2011 (+)	1988-2012 (+)	1997-2013 (+)
Norway	2000-2013 (+)	1988-2003 (-)	1988-2013 (-)
Saudi Arabia		1988-2013 (-)	1988-2013 (-)
United Kingdom		1988-2003 (-)	1988-2013 (-)

Note: this table reports for each country the period at which a shock had a significant effect on the REER, depending on its source (oil supply, global demand, oil-specific demand). The sign + (-) stands for a positive (negative) response of the REER to an increase in the real oil price.

**Table 3.** Share of fuels and manufactured goods in GDP and trade (%)

Exports	Canada	Indonesia	Norway	Saudi Arabia	United Kingdom
Fuels / Total exports	19.2	28.5	64.0	85.1	9.7
Manufactured goods / Total exports	54.4	42.2	18.8	12.8	70.5
Fuels / GDP	5.7	7.5	20.6	41.1	1.7
Manufactured goods / GDP	16.1	11.1%	6.1	6.2	12.3
Imports	Canada	Indonesia	Norway	Saudi Arabia	United Kingdom
Fuels / Total imports	8.4	19.5	4.9	0.2	8.4
Manufactured goods / Total imports	78.0	63.6	77.8	70.8	69.0
Fuels / GDP	2.3	4.4	0.9	0.04	2.0
Manufactured goods / GDP	21.4	14.3	14.8	14.0	16.1

Sources: UNCTAD database and authors' calculations. Averages of annual data over the 1995-2013 period.

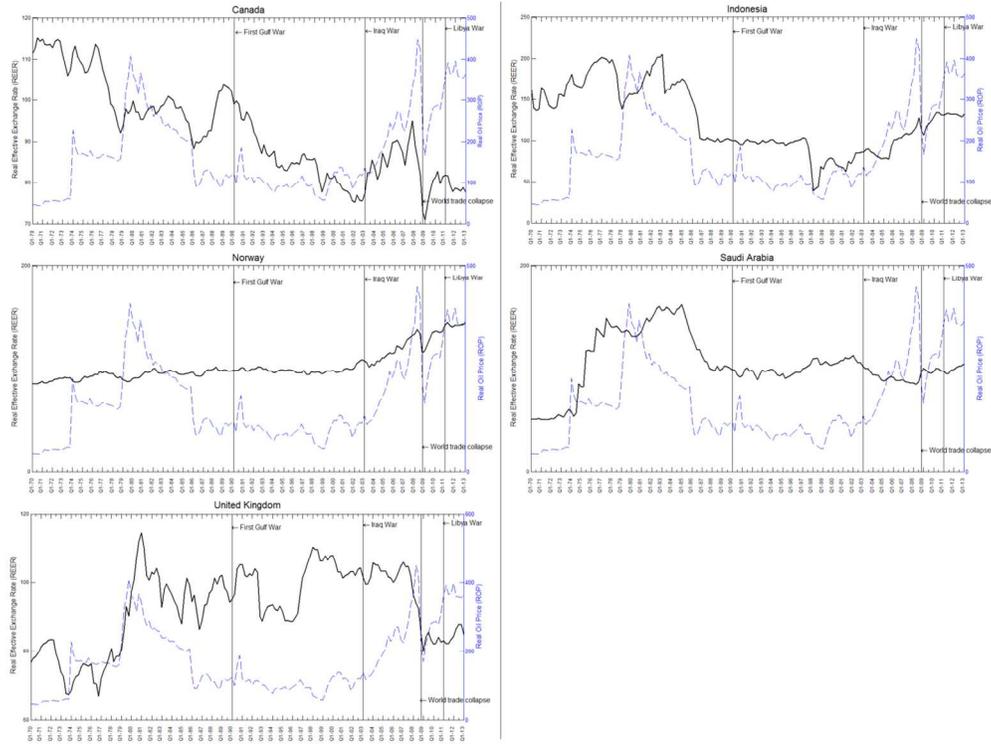


Figure 1. Evolution of real effective exchange rates and real price of oil (1988=100). Note: the black line represents the evolution of the REER (left scale) and the blue dashed line, the evolution of the real price of oil (right scale). See Section 3.1 for data sources.

Figure 1  
161x121mm (220 x 220 DPI)

view

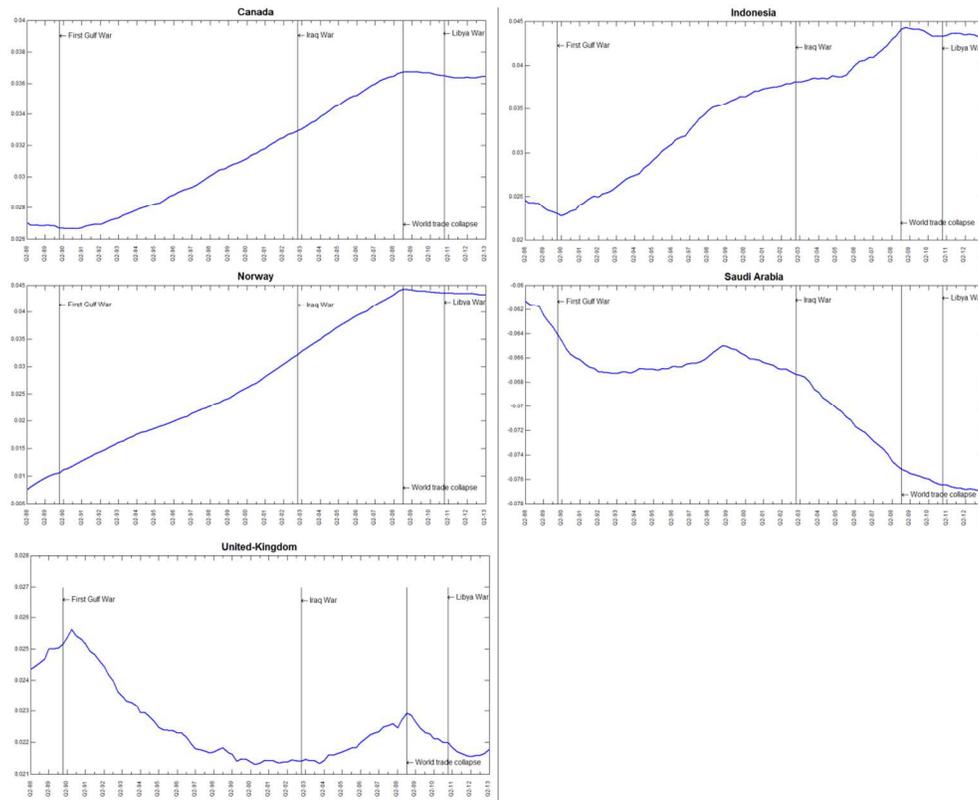


Figure 2. Contemporaneous link between REER and real price of oil. Note: this figure displays the dynamics of the contemporaneous relationship between the real effective exchange rate and the real price of oil for each country.

Figure 2  
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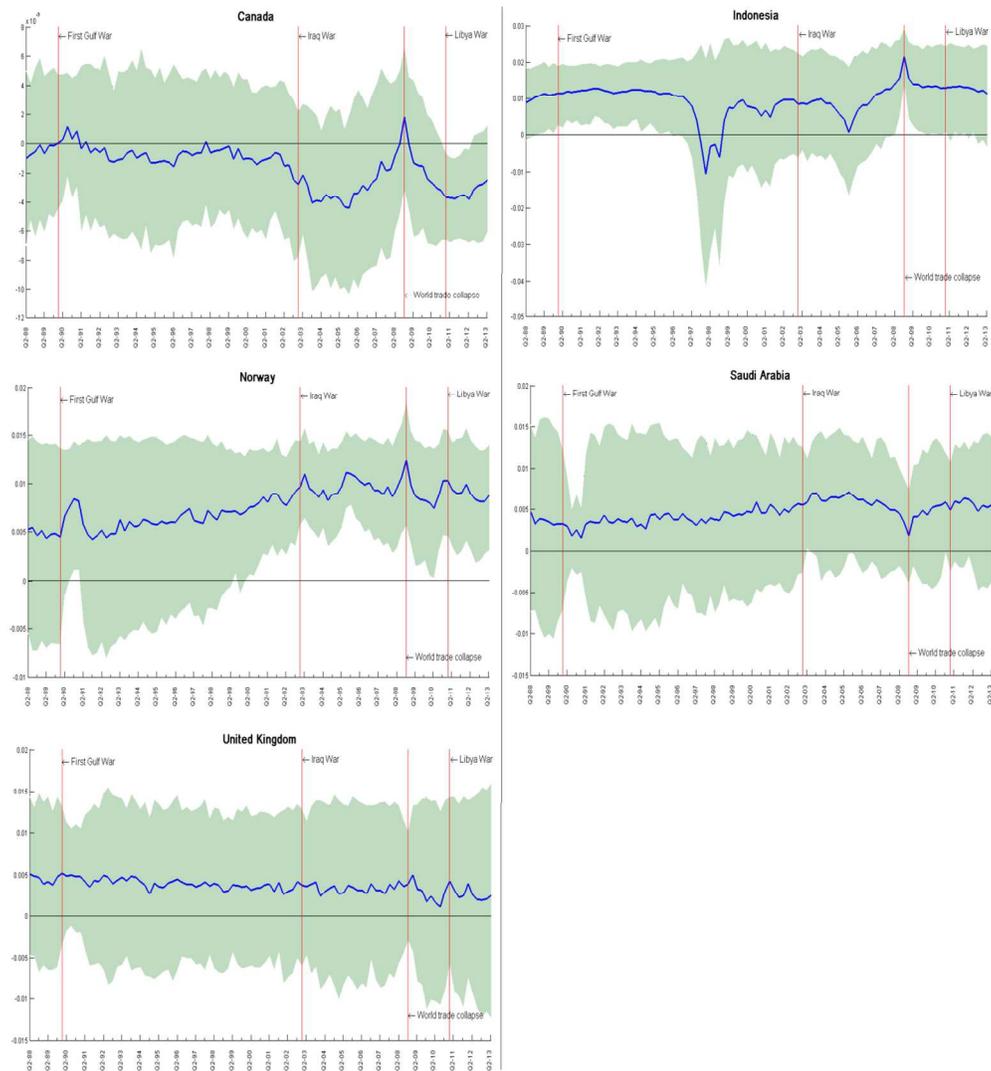


Figure 3. REER impulse response following an oil production shortfall (horizon: 4 quarters). Note: this figure reports the impulse-response functions (in blue) of real effective exchange rates to a negative oil supply shock, with the 68 percent posterior credible sets by the shaded areas.

Figure 3  
167x184mm (220 x 220 DPI)

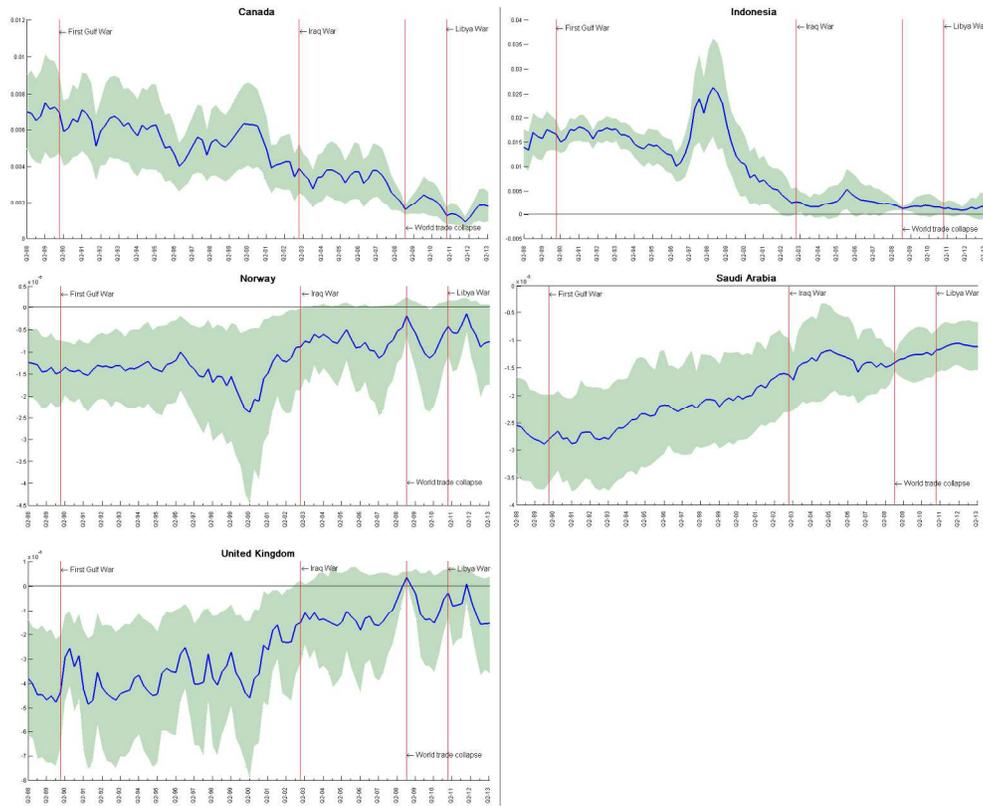


Figure 4. REER impulse response following a world oil demand shock (horizon: 4 quarters). Note: this figure reports the impulse-response functions (in blue) of real effective exchange rates to a world oil demand shock, with the 68 percent posterior credible sets by the shaded areas.

Figure 4  
249x204mm (220 x 220 DPI)

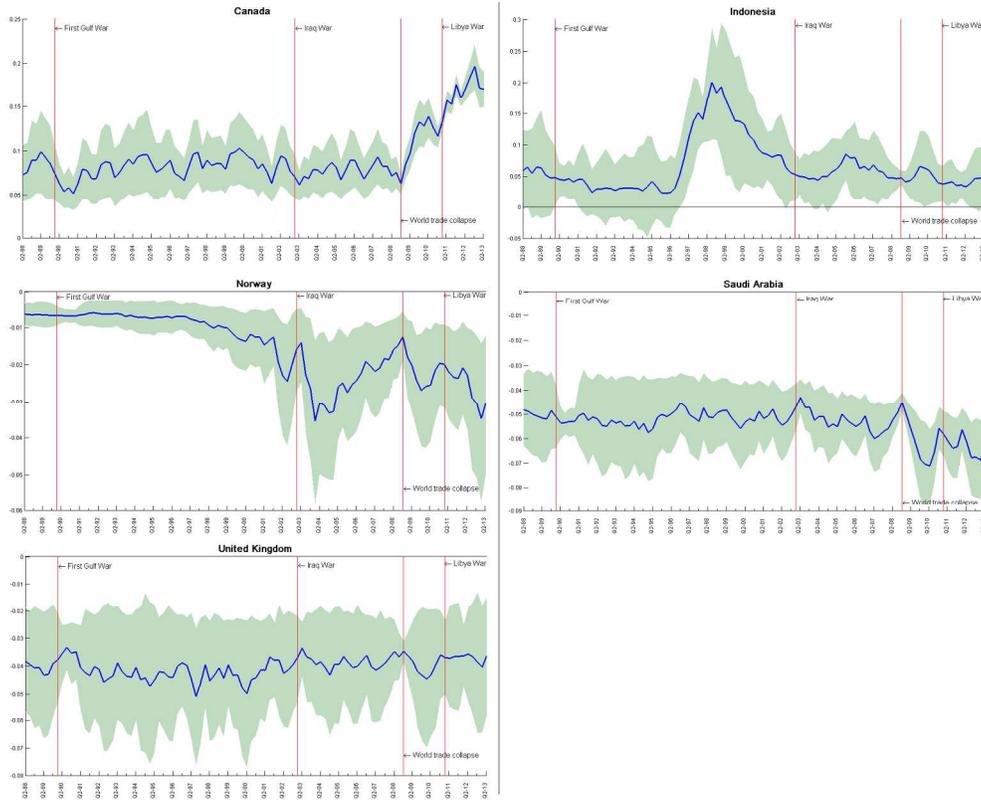


Figure 5. REER impulse response following an oil-specific demand shock (horizon: 4 quarters). Note: this figure reports the impulse-response functions (in blue) of real effective exchange rates to an oil market specific shock, with the 68 percent posterior credible sets by the shaded areas.

Figure 5  
249x203mm (220 x 220 DPI)

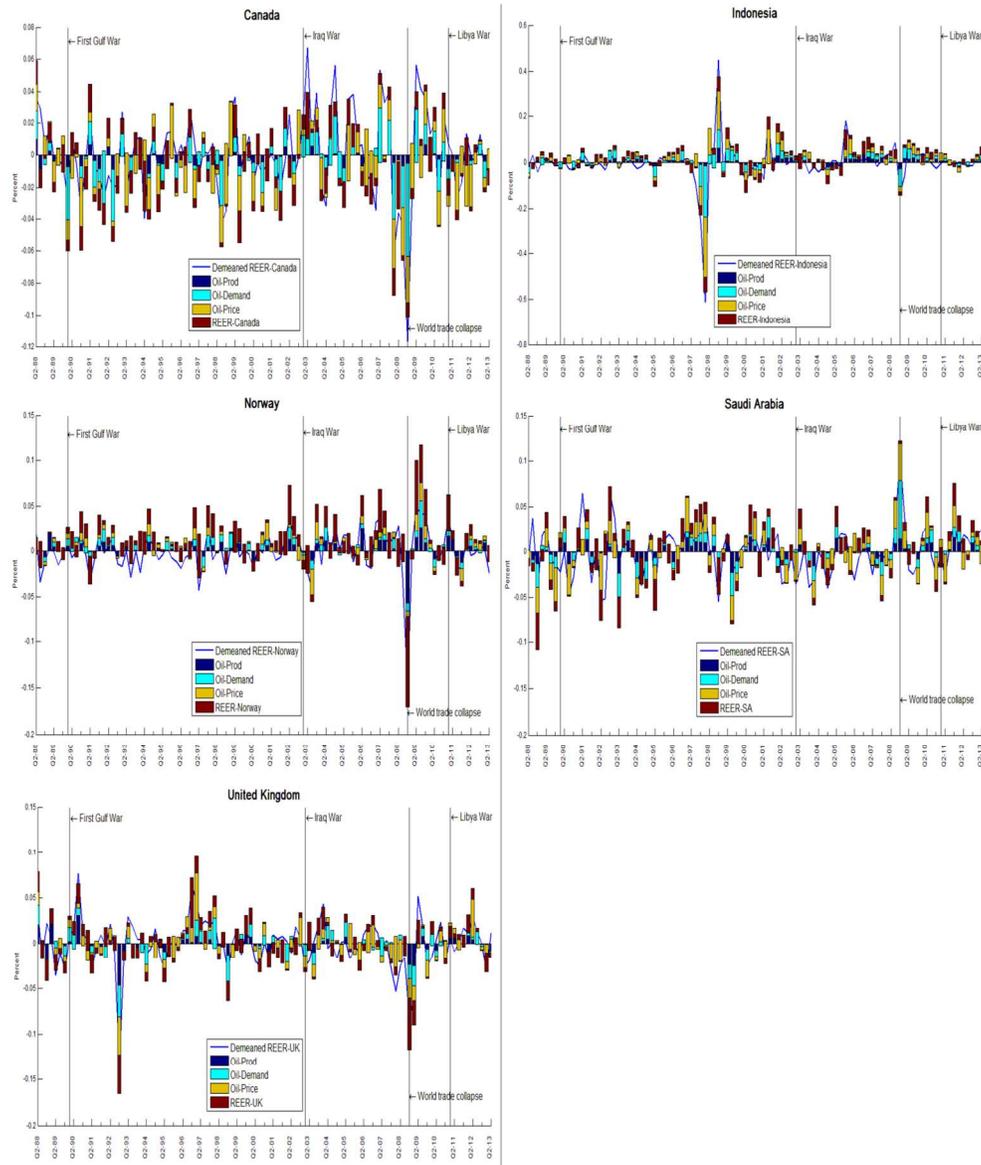


Figure 6. Historical decomposition of the REER. Note: this figure reports the historical decomposition of real effective exchange rates (REER) for each country according to the nature of the oil shock (Oil-Prod: oil supply shock, Oil-Demand: oil global demand shock, Oil-Price: oil-specific demand shock).

Figure 6  
170x200mm (220 x 220 DPI)

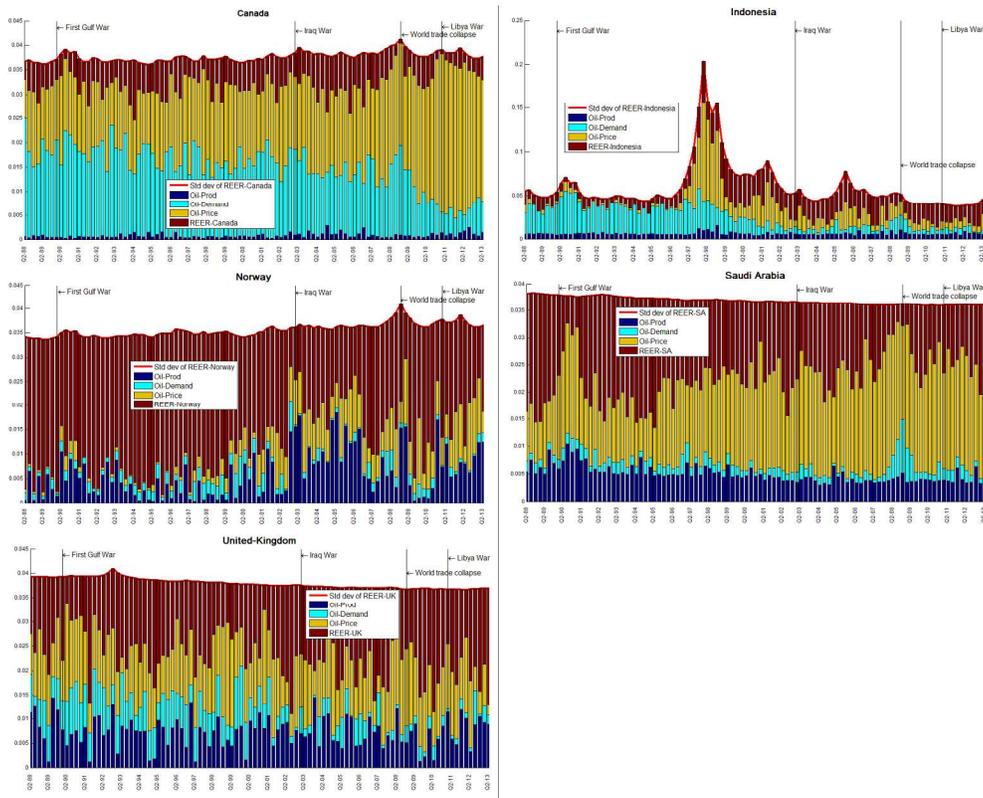


Figure 7. Forecast Error Variance Decomposition of the REER. Note: this figure reports the forecast variance error decomposition of real effective exchange rates (REER) for each country according to the nature of the oil shock (Oil-Prod: oil supply shock, Oil-Demand: oil global demand shock, Oil-Price: oil-specific demand shock).

Figure 7  
250x202mm (220 x 220 DPI)

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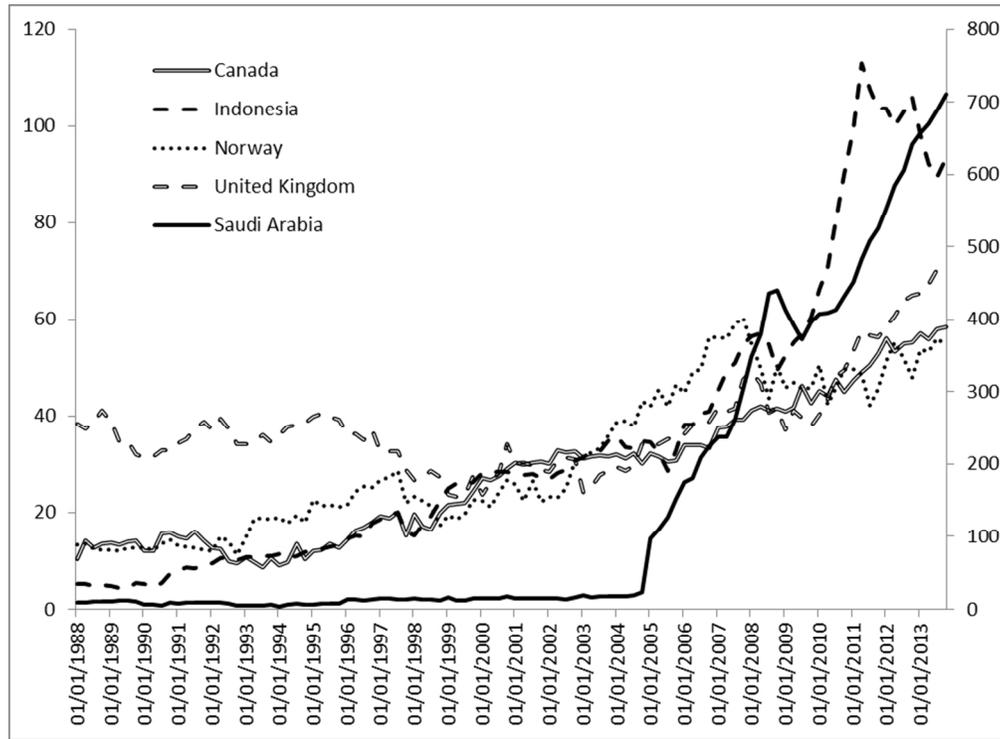


Figure 8. Foreign exchange reserves 1988-2013, in U.S. dollar billion. Source: International Monetary Fund, International Financial Statistics.

Figure 8

163x121mm (150 x 150 DPI)