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Oil price shocks and exchange rate movements☆

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ABSTRACT

This study investigates the effects of oil price shocks on exchange rate movements in five major oil-exporting countries: Russia, Brazil, Mexico, Canada, and Norway. The R^2 of the fundamental model doubles in Russia and Brazil, but increases slightly in Canada and Norway when oil prices are added to it. The volatility of exchange rates associated with oil price shocks is significant in Russia, Brazil, and Mexico, but weak in Norway and Canada. It takes much longer for the exchange rate to reach the initial equilibrium level in Russia, Brazil, and Mexico than in Norway and Canada. The asymmetric behavior of exchange rate volatility among countries seems to be related to the efficiency of financial markets rather than to the importance of oil revenues in the economy.

1. Introduction

The recent dramatic decrease in the prices of oil and the subsequent reduction in the value of the currencies of several oil-exporting countries have once again revived an interest in the interdependence between major commodity prices and exchange rates. The nearly 50% drop in the oil prices that occurred between June and December of 2014 was accompanied by a reduction in the value of the Russian ruble almost by half[1]; the Brazilian real lost about 20% of its value; the Mexican peso was trimmed over 15%. Oil exports are an important source of the government revenues of these countries, and the drop in the prices of oil puts a pressure on the countries' budgets, thus increasing the uncertainty about the ability of the countries to meet their spending obligations (see for example the December 26th, 2014 issue of the Wall Street Journal).

Oil prices can affect exchange rates through multiple channels. First, oil price fluctuations affect domestic economic activity such as GDP, inflation, and interest rates for both oil-exporting and oil-importing countries. Any change in market fundamentals amplifies the volatility of exchange rates. Second, the large portion of the international transactions of crude oil is denominated in U.S. dollars. Thus, oil price changes induce the inflow (or outflow) of oil dollars, which will directly affect the exchange rate of an oil-exporting or oil-importing country with the U.S. dollar. Oil prices are also heavily affected by the behavior of speculators (see Kaufmann & Ullman, 2009). Oil prices could be much more volatile than the prices of assets such as equities and bonds. International oil prices rose from $42 per barrel in early 2005 to $147 per barrel in July 2008, and many experts blamed such oil price

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[1] Note that the period is also associated with the sanctions that were placed on Russia by the United States and the European Union. It is likely that the drop in the value of the ruble is at least in part attributed to the geopolitical landscape.

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hikes on international speculations in crude oil. This kind of speculative behavior inevitably brings about wide fluctuations in exchange rates.

Several studies, including Aloui, Ben Aissa, and Nguyen (2013) and Chen, Choudhry, and Wu (2013) have discovered extreme co-movements between crude oil prices and dollar exchange rates on the basis of copula-distributional families. A close relationship between crude oil prices and dollar exchange rates makes it realistic to assume that the exchange rate depends on conditional volatility represented by the conditionally heteroskedastic variance.

To investigate the relation between oil price shocks and exchange rate movements, we focus on the monthly bilateral exchange rate between the U.S. dollar and the currencies of major oil-exporting countries that operate under a floating exchange rate system for the period of September 1998 to August 2012: Russia, Brazil, Mexico, Canada, and Norway. Out of 18 major oil-producing countries, only these five countries operate under a market-determined exchange rate system. On average, the proportion of oil revenues as a percentage of GDP in these countries is sizable. The ratio is 25.8% in Norway, 11.6% in Russia, 6.2% in Canada, 5.3% in Mexico, and 4.6% in Brazil. Thus, it is highly likely that the prices of oil play a crucial role in these economies, and their exchange rates. Furthermore, we observe that higher oil prices tend to appreciate the currency of an oil-exporting country, and lower oil prices tend to depreciate the currency, suggesting that exchange rate volatility may be asymmetric between increases and decreases in oil prices.

As a main analytical tool, we utilize a GARCH-M framework in which the mean equation includes the oil prices together with other fundamental determinants of exchange rates as explanatory variables, and the variance equation includes the oil prices. This framework used by Nam and Yuhn (2001) allows one to investigate the volatility of exchange rates conditional on the direction of oil price changes. Additionally, we use the VECM framework, utilizing the Toda and Yamamoto (1995) methodology to test for the causality between the exchange rates and the prices of oil.

Our main results are as follows: The behavior of exchange rates differs between advanced markets (Canada and Norway) and emerging markets (Russia, Brazil, and Mexico) in a model where oil prices are incorporated as an explanatory variable. The volatility of exchange rate (measured by the variance of exchange rates) associated with an oil price shock is significant in Russia, Brazil, and Mexico, but weak in Norway and Canada. Furthermore, it takes much longer for the exchange rate of Russia, Brazil, and Mexico to reach the initial equilibrium level following a shock to the oil prices than for the exchange rate of Norway and Canada.

The paper is organized as follows: Section 2 briefly reviews the related literature, Section 3 discusses the methodology employed. Section 4 presents the empirical results and their implications. Section 5 provides concluding remarks.

2. Literature review

The theories of exchange rate determination state that the equilibrium exchange rate is determined by fundamental macroeconomic variables such as the money supply, inflation, output, and interest rates. It is widely maintained, however, that empirical models based on market fundamentals have limited success in explaining exchange rate movements (see Cheung, Chinn, & Pascual, 2005; Meese & Rogoff, 1983). The main argument associated with this skeptical view is that since floating exchange rates between countries follow a random walk, fundamental variables do not help predict future changes in exchange rates (see Engel & West, 2005).

However, several studies have found that market-fundamental models with commodity prices added perform better. For instance, Golub (1983) develops a stock/flow model of the effect of oil price increases on exchange rates. The model focuses on the wealth transfer effects, which results from oil price increases, and on the implications of these wealth transfers for a portfolio equilibrium. Lizardo and Mollick (2010) add oil prices to the basic monetary model of exchange rate determination proposed by Rapach and Wohar (2002). They find that oil prices significantly explain movements in the value of the U.S. dollar against major currencies from 1970 to 2008. They report that an increase in real oil prices leads to a significant depreciation of the U.S. dollar in the developed net oil-producing countries.

The existing literature mainly focuses on examining the stationarity properties of commodity prices and exchange rates between major currencies. Amano and Van Norden (1998a, 1998b) find that the price of oil and the real effective U.S. exchange rate are cointegrated and that the price of oil Granger-causes the exchange rate, but not vice versa. Likewise, Chaudhuri and Daniel (1998) examine the effect of oil price movements on the nonstationary behavior of monthly real U.S. dollar producer price exchange rates with 16 OECD countries during the post-Bretton Woods period. They find that most of the real exchange rates and real oil prices are cointegrated and show that the direction of causality runs from real oil prices to real exchange rates. They also observe that the behavior of oil prices appears to be responsible for the nonstationary behavior of U.S. dollar real exchange rates during the sample period. Chen and Chen (2007) examine a sample of G7 countries for the period of 1972–2005 and use panel data techniques to test for cointegration of real exchange rates and oil prices. Using the Pedroni (2004) test, they find that there is a long-run equilibrium relationship between real oil prices and real exchange rates.

Several studies have recently argued that the relationship between the U.S. dollar and the price of oil is non-linear. A number of studies use vector autoregressive (VAR), vector error correction (VEC), and ARCH-family models to study the dynamic relationship between commodity prices and U.S. dollar exchange rates (Aloui et al., 2013; Amano & Van Norden, 1998a, 1998b; Basher, Haug, & Sadorsky, 2012; Golub, 1983; Wu, Chung, & Chang, 2012). These studies report conflicting results. Amano and Van Norden (1998a, 1998b) and Basher et al. (2012) show that the oil prices and the exchange rates exhibit a positive long-run equilibrium relationship, i.e., an increase (decrease) in the oil price is associated with the U.S. dollar appreciation (depreciation). Other studies, such as Akram (2009) and Lizardo and Mollick (2010), show a negative relationship between the price of oil and the U.S.

dollar. Aloui et al. (2013) employs copula-based GARCH models to show the dynamic dependence between the oil price and the exchange rate. Chen et al. (2013) constructs a flexible range-based volatility model to analyze the volatility and dependence between oil and the U.S. dollar exchange rate returns.

This study differs from the existing studies in several ways. Unlike the existing studies, this study primarily explores how the level and conditional volatility of exchange rates are affected by oil price shocks. This study is particularly concerned with asymmetry in exchange rate volatility by investigating whether there are any differences in the behavior of exchange rate volatility between developed and emerging oil-exporting countries.

3. The hypotheses and methodology

The mechanism through which the exchange rate between major energy-exporting countries and the United States moves is complicated by movements in energy prices. Movements in energy prices will necessarily affect futures and forward foreign exchange rate contracts, which will in turn affect spot exchange rates.

Our strategy to investigating the effects of oil price shocks on exchange rate movements involves three-tier tests. We first investigate whether oil prices affect the level and volatility (measured by the variance of exchange rates) of exchange rates using a GARCH-M framework. Next, we run causality tests using the Toda and Yamamoto (1995) approach to ensure the robustness of our results. Finally we explore how long it takes for the exchange rate in each country to gravitate toward its initial level after an oil price shock.

The oil price-exchange rate dynamics could be affected by two factors. First, the magnitude of the effect could depend on the size of the energy sector in an oil-producing country. If energy prices are more volatile and are slower to adjust to their long-run equilibrium, the exchange rate could depreciate or appreciate more in a country with a larger proportion of the energy sector in the economy than in a country with a smaller energy sector.

Second, if a country's financial and foreign exchange markets are efficient, then the market will absorb the effect of a shock to oil prices more rapidly. Thus, the magnitude of the effect could be larger in a country whose financial and foreign exchange markets are less efficient than in a country whose financial and foreign exchange markets function more efficiently. Thus, the hypotheses to be tested in this study are as follows:

Hypothesis 1. The effects of an oil price shock on the level and volatility of the exchange rate will be larger in a country where the size of the energy sector as a percentage of GDP is larger than in a country where the relative size of the energy sector is smaller.

Hypothesis 2. The effects of an oil price shock on the level and volatility of the exchange rate will be larger in a country whose financial and foreign exchange markets are less efficient than in a country whose financial and foreign exchange markets function more efficiently.

Hypothesis 3. The exchange rate will converge toward its initial level after an oil shock more rapidly in a country where the size of the energy sector as a percentage of GDP is larger than in a country where the size of the energy sector is relatively smaller.

Hypothesis 4. The exchange rate will converge toward its initial level after an oil price shock more rapidly in a country whose financial and foreign exchange markets are more efficient than in a country whose financial and foreign exchange markets function less efficiently.

3.1. The base-line model

The current exchange rate is the outcome of interactions of several factors: relative prices (PPP) in two countries in the long run, business cycles and trade balances in the medium run, and interest rate differentials between two countries in the short run. Changes in expected future values of market fundamentals contribute to volatile exchange rate movements in a system of market-determined exchange rates. The exchange rate can wander away further from the equilibrium value dictated by macroeconomic fundamentals because of self-fulfilling expectations, overreacting to changes in market fundamentals.

Although we recognize some problems with representing the exchange rates by using fundamentals as explanatory variables for the reason that a market fundamentals model might underperform a random walk model (see MacDonald, 1999; Meese & Rogoff, 1988), we first identify some relevant variables that affect the exchange rate between the United States and major oil-exporting countries on the basis of the market fundamentals model. The fundamental factors include interest rate differentials between two countries in the short run (*DINT*), income (or production) differentials (*DIND*) in the medium run, and inflation rate differentials (*DCPI*) in the long run. We exclude the money supply variable from the exchange rate determination model to avoid any possible multicollinearity between the money supply and the determining variables of the exchange rate. Since this study uses monthly data for the analysis of exchange rate movements, and since monthly GDP figures are not available, industrial production (*IND*) is used as a proxy for income. Thus, the base-line equation is expressed as

$$EXCH_t = \alpha + \beta_1 DINT_t + \beta_2 DIND_t + \beta_3 DCPI_t + \varepsilon_t, \tag{1}$$

where *EXCH* is the level of exchange rate between the local currency and the U.S. dollar expressed as the number of units of local currency needed to purchase one U.S. dollar; *DINT* is the difference in the short-run interest rates between a given country and the United States; *DIND* is the difference in the industrial production between a given country and the United States; *DCPI* is the difference in inflation between a given country and the United States.

As documented in the literature, the economic activity of the oil-exporting countries is heavily affected by fluctuations in oil production and prices (see Brown & Yucel, 2002; Gaddy & Ickles, 2005; Rautava, 2004; Tabata, 2009, among others). Thus, the model of exchange rate determination for oil-exporting countries is augmented to include these factors.

$$EXCH_t = \alpha + \beta_1 DINT_t + \beta_2 DIND_t + \beta_3 DCPI_t + \beta_4 OIL_t + \varepsilon_t \tag{2}$$

where *OIL* is the price for WTI oil expressed in U.S. dollars.

Model 2 controls for the oil prices in the determination of the exchange rate. If oil prices are an important factor that affects the exchange rate of a country examined, Model 1 is likely to suffer from an omitted-variable bias.

3.2. Volatility analysis

The primary purpose of this study is to analyze how the level and volatility of oil prices affect the exchange rates of oil-exporting countries. In order to investigate the level and volatility of the exchange rate in the oil prices-augmented model, we adopt three tests to obtain consistent results, thus ensuring robustness. First, we utilize a GARCH-M model and augment the variance equation to include oil prices, which enables one to examine whether the volatility of the exchange rate is conditional on changes in oil prices.

Second, after testing for unit roots and cointegration, we conduct causality tests using the Toda and Yamamoto (1995) approach. Finally, we examine the impulse response functions to investigate the long-run adjustment of the exchange rate after an oil price shock toward its equilibrium level.

3.2.1. Exchange rate volatility

In order to investigate the effects of an oil price shock on the level and variability of exchange rates, we utilize the following form of a GARCH(1)-in-mean model:

$$EXCH_t = \alpha + \beta_1 DINT_t + \beta_2 DIND_t + \beta_3 DINF_t + \beta_4 OIL_t + \gamma\sigma_t + \varepsilon_t \tag{3.1}$$

$$\sigma_t^2 = \phi_0 + \phi_1 \varepsilon_{t-1}^2 + \varphi_1 \sigma_{t-1}^2 + \delta OIL_t + v_t \tag{3.2}$$

This augmented GARCH-in-mean model is well suited for investigating the conditional volatility of exchange rates on oil price changes. The coefficient of σ_t in the mean equation measures the additional change in the exchange rate brought about by a one-standard-deviation change in the measure of conditional volatility. If the coefficient is significant, the evidence is that an additional change in the exchange rate is caused by exchange rate volatility in the market. If the sign of the coefficient is positive, exchange rate overshooting results in the depreciation of the local currency. If the sign of the coefficient is negative, exchange rate overshooting leads to the appreciation of the local currency. Exchange rate overshooting refers to a short-run overreaction of the exchange rate. In the GARCH-M framework, the mean Eq. (3.1) measures the effect of oil price changes on the level of exchange rates, and the variance Eq. (3.2) adopted by Nam and Yuhn (2001) and others is designed to capture the effect of oil price changes on the volatility of exchange rates.

3.2.2. Cointegration and VECM

We next conduct unit root tests for each variable in Eq. (2) to find out whether the time series is stationary or not. Then we perform cointegration tests to investigate whether there is a long-run equilibrium relationship between the exchange rate and its determining variables. If the time series variables in the model contain a unit root, and they happen to be cointegrated, then it is appropriate to perform the VECM and the causality test proposed in Toda and Yamamoto (1995). We estimate the following model:

$$\begin{aligned}\Delta EXCH_t = {} & \alpha_1 + \alpha_1 \Delta EXCH_{t-1} + \ldots + \alpha_p \Delta EXCH_{t-p} + \beta_1 \Delta DINT_{t-1} + \ldots + \beta_p \Delta DINT_{t-p} + + \gamma_1 \Delta DIND_{t-1} + \ldots \\ & + \gamma_p \Delta DIND_{t-p} + \delta_1 \Delta DINF_{t-1} + \ldots + \delta_p \Delta DINF_{t-p} + \mu_1 \Delta OIL_{t-1} + \ldots + \mu_p \Delta OIL_{t-p} + \theta\varepsilon_{t-1} + v_t\end{aligned} \tag{4}$$

3.2.3. Impulse response functions

Finally, we consider impulse response processes. The IRF allows for decomposing the error variance by tracing the effect of the response of a shock (impulse) to, say, oil prices on the exchange rate. We can dynamically trace the effects of a one standard deviation shock to the oil price on the exchange rate using the impulse response function. The advantage of examining impulse response functions is that they show how big the size of the impact of the shock is and how long it takes for the adjustment to complete. From the analysis of IRFs, we can find out whether a currency appreciates or depreciates in response to a shock, and how long it will take for the exchange rate to reach its initial equilibrium level after the shock.

4. Empirical analysis

4.1. Data

The study uses monthly data of the exchange rates between the United States and the major oil-exporting countries for the period ranging from September 1998 to August 2012.

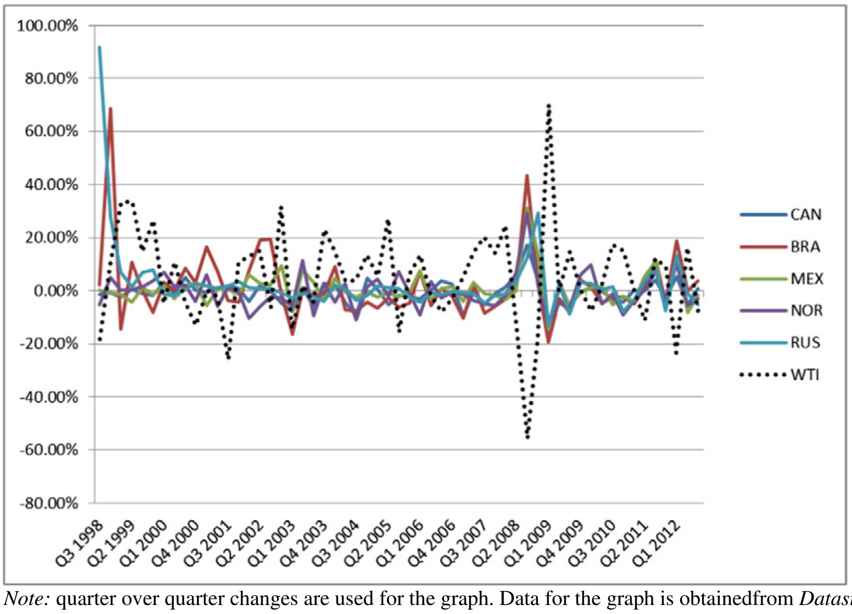
Throughout the tests used in the paper, the exchange rate for the given currencies is expressed as the number of units of local currency needed to purchase one U.S. dollar. The price of WTI oil brand, price of which is highly correlated with the prices for other brands of oil, is used to proxy for the oil prices. We have left out the period preceding the default of the Russian government obligations that caused a significant overnight devaluation of the Russian currency. The oil prices and exchange rate data are obtained from the *Datastream*, and the macroeconomic variables are taken from the OECD website.

4.2. Basic statistics

Fig. 1 illustrates the quarterly change in the exchange rates of the oil-producing countries and the quarterly change in the price of oil. A visual inspection of the graph reveals some evidence of an inverse relationship between the change in the oil price and the exchange rate of a given currency (i.e., an increase in the price of oil and a simultaneous appreciation of the local currency), specifically following the 2007 financial crisis.

The country-specific statistics, such as economic growth, oil revenues as a percentage of GDP, average annual U.S. dollar exchange rates, and the standard deviation of the exchange rates are presented in Table 1. The proportion of oil revenues as a percentage of GDP (average) is highest in Norway (25.8%), followed by Russia (10.1%), Canada (6.2%), Mexico (5.3%), and Brazil (4.6%) during the sample period. The average annual economic growth rate during the 1998–2012 period is 4.54% in Russia, 2.97% in Brazil, 2.60% in Mexico, 2.53% in Canada, and 1.82% in Norway. The average annual inflation rate is highest in Russia (18.25%) and lowest in Norway (1.99%). Mexico (6.42%) and Brazil (6.27%), together with Russia, can be characterized as volatile-price countries, while Canada (2.01%) and Norway (1.99%) can be classified as stable-price countries. Finally, Brazil's exchange rate is most volatile, and Russia's exchange rate is second most volatile in the five exchange ~~rates~~ regimes considered in the study. The standard deviation of the exchange rate divided by its mean value is 0.261 for Brazil, 0.200 for Russia, 0.170 for Canada, 0.165 for Norway, and 0.133 for Mexico.

As a preliminary step, we have examined the correlation between the oil price variable and other explanatory variables such as inflation, interest rates, and real GDP (market fundamental variables). Interestingly enough, we have found that there is a high



Note: quarter over quarter changes are used for the graph. Data for the graph is obtainedfrom *Datastream*.

Fig. 1. Changes in the price of oil and the exchange rates The quarter-by-quarter percentage change in USD exchange rates for the currencies of Russia, Brazil, Mexico, Canada, and Norway and the change in the price of WTI oil brand. *Note:* quarter over quarter changes are used for the graph. Data for the graph is obtained from *Datastream*.

Table 1
Country characteristics and exchange rates.

Year	Russia					Brazil				
	Oil revenue percent of GDP	Economic growth rate	Inflation rate	Average exchange rate	Standard deviation of exchange rate	Oil revenue percent of GDP	Economic growth rate	Inflation rate	Average exchange rate	Standard deviation of exchange rate
1998	5.23%	-5.34	27.80	9.71	5.24	1.02%	0.05	3.20	1.16	0.03
1999	6.80%	6.35	85.70	24.62	1.37	1.58%	0.25	4.90	1.81	0.16
2000	9.67%	10.05	20.80	28.13	0.39	3.75%	4.28	7.00	1.83	0.07
2001	7.92%	5.09	21.50	29.17	0.50	2.90%	1.29	6.80	2.35	0.25
2002	7.80%	4.74	15.80	31.35	0.42	3.77%	2.64	8.50	2.92	0.55
2003	8.66%	7.25	13.70	30.69	0.72	4.97%	1.16	14.70	3.08	0.26
2004	11.06%	7.18	10.90	28.81	0.40	5.86%	5.71	6.60	2.93	0.12
2005	13.32%	6.38	12.70	28.28	0.41	7.29%	3.16	6.90	2.43	0.17
2006	12.34%	8.15	9.70	27.19	0.65	6.68%	3.93	4.20	2.18	0.06
2007	12.12%	8.54	9.00	25.58	0.64	6.12%	6.08	3.60	1.95	0.12
2008	12.94%	5.25	14.10	24.85	1.56	6.77%	5.17	5.70	1.83	0.27
2009	8.77%	−7.82	11.70	31.74	2.08	3.73%	−0.32	4.90	2.00	0.23
2010	10.44%	4.50	6.90	30.37	0.66	5.17%	7.55	5.00	1.76	0.05
2011	12.21%	4.29	8.40	29.38	1.44	4.91%	2.74	6.60	1.67	0.09
2012	11.57%	3.44	5.10	30.84	1.16	4.02%	0.87	5.40	1.95	0.12
Average	10.06%	4.54	18.25	27.38	1.17	4.57%	2.97	6.27	2.12	0.17
	Canada					Norway				
	Oil revenue percent of GDP	Economic growth rate	Inflation rate	Average exchange rate	Standard deviation of .exchange rate	Oil revenue percent of GDP	Economic growth rate	Inflation rate	Average exchange rate	Standard deviation of exchange rate
1998	2.43%	4.21	1.00	1.48	0.05	18.00%	2.68	2.30	7.55	0.12
1999	2.99%	5.17	1.70	1.49	0.02	22.17%	2.03	2.30	7.80	0.15
2000	4.52%	5.12	2.70	1.49	0.03	29.69%	3.25	3.10	8.80	0.43
2001	3.67%	1.74	2.50	1.55	0.03	24.26%	1.99	3.00	8.99	0.19
2002	3.74%	2.82	2.30	1.57	0.02	23.62%	1.50	1.30	7.99	0.66
2003	4.27%	1.99	2.80	1.40	0.08	25.43%	0.98	2.50	7.08	0.24
2004	5.27%	3.17	1.90	1.30	0.05	28.84%	3.96	0.50	6.74	0.28
2005	6.50%	3.11	2.20	1.21	0.03	32.13%	2.59	1.50	6.44	0.17
2006	7.45%	2.65	2.00	1.13	0.02	30.20%	2.30	2.30	6.42	0.22
2007	7.97%	2.09	2.10	1.07	0.07	28.49%	2.65	0.70	5.86	0.31
2008	9.79%	1.10	2.40	1.07	0.09	32.02%	0.07	3.80	5.65	0.71
2009	6.27%	−2.80	0.30	1.14	0.08	21.42%	−1.63	2.20	6.29	0.48
2010	7.85%	3.17	1.80	1.03	0.02	23.10%	0.48	2.40	6.05	0.23
2011	9.85%	2.57	2.90	0.99	0.03	25.37%	1.22	1.30	5.61	0.19
2012	10.04%	1.84	1.50	1.00	0.01	21.68%	3.17	0.70	5.82	0.16
Average	6.17%	2.53	2.01	1.26	0.04	25.76%	1.82	1.99	6.87	0.30

Year	Mexico				
	Oil revenue percent of GDP	Economic growth rate	Inflation rate	Average exchange rate	Standard deviation of exchange rate
1998	2.86%	5.01	15.90	9.15	0.72
1999	3.51%	3.56	16.60	9.55	0.27
2000	5.03%	5.97	9.50	9.45	0.16
2001	4.20%	−0.93	6.40	9.34	0.24
2002	4.08%	0.07	5.00	9.66	0.44
2003	4.66%	1.37	4.50	10.80	0.32
2004	5.71%	4.03	4.70	11.28	0.20
2005	6.95%	3.18	4.00	10.89	0.23
2006	7.00%	5.15	3.60	10.90	0.25
2007	6.67%	3.24	4.00	10.93	0.12
2008	7.44%	1.19	5.10	11.15	1.16
2009	4.50%	−5.99	5.30	13.50	0.60
2010	5.28%	5.31	4.20	12.63	0.26
2011	5.94%	3.92	3.40	12.43	0.81
2012	5.47%	3.95	4.10	13.15	0.39
Average	5.29%	2.60	6.42	10.99	0.41

Note: The data have been obtained from the OECD.

degree of positive correlation between the oil price variable and other fundamental variables in Russia and Brazil, but a negative correlation in Canada and Norway (see Table 2). This observation indicates that a higher oil price tends to move together with the market fundamental variables in the same direction in Russia and Brazil, but in the opposite direction in Canada and Norway. One

Table 2
Correlation matrix for variables used in the study.
EXCH is the level of exchange rate between the local currency and the U.S. dollar expressed as the number of units of local currency needed to purchase one U.S. dollar; *DINT* is the difference in the short-term interest rates between a given country and the United States; *DIND* is the difference in the industrial production between a given country and the United States; *DCPI* is the difference in inflation between a given country and the United States; *OIL* is the price for WTI oil expressed in U.S. dollars.

	EXCH	*OIL*	*DINT*	*DIND*	*DCPI*
Russia					
EXCH	1.00				
OIL	0.05	1.00			
DINT	−0.15	−0.37	1.00		
DIND	0.27	0.89	−0.36	1.00	
DCPI	0.36	0.88	−0.28	0.87	1.00
Mexico					
EXCH	1.00				
OIL	0.61	1.00			
DINT	−0.53	−0.58	1.00		
DIND	0.79	0.81	−0.43	1.00	
DCPI	0.86	0.81	−0.68	0.78	1.00
Norway					
EXCH	1.00				
OIL	−0.80	1.00			
DINT	0.16	−0.10	1.00		
DIND	0.79	−0.87	0.31	1.00	
DCPI	0.82	−0.88	0.29	0.72	1.00
Brazil					
EXCH	1.00				
OIL	−0.46	1.00			
DINT	0.31	−0.59	1.00		
DIND	−0.33	0.83	−0.55	1.00	
DCPI	−0.21	0.86	−0.52	0.79	1.00
Canada					
EXCH	1.00				
OIL	−0.90	1.00			
DINT	0.12	0.00	1.00		
DIND	0.82	−0.81	−0.02	1.00	
DCPI	0.88	−0.92	−0.04	0.78	1.00

possible explanation for this trend is that as the oil price goes up, economic agents in Russia and Brazil perceive the oil price hike as a positive signal for the economy, but economic agents in Canada and Norway perceive the oil price increase in the opposite way.

This high degree of correlation also signifies that any exchange rate determination model with the oil price variable omitted could suffer from an omitted-variable bias. More specifically, the marginal effects of the fundamental variables on the exchange rate could be upwardly biased in Russia and Brazil, and downwardly biased in Canada and Norway if the oil price variable were not included in the exchange rate determination model. These characteristics also seem to be related to the explanatory power of the exchange rate determination model. The value of R^2 in the exchange rate model doubles in Russia and Brazil, but changes marginally in Canada and Norway when the oil price variable is included. This issue will be further spelled out in the next section.

The strong correlation between the oil price variable and fundamental variables could lead to multicollinearity among the explanatory variables. Thus, we have investigated the variance inflation factor (VIF) using an independent OLS regression of the augmented baseline model (2) for each country. The VIFs are provided in Table 3. The VIFs are not worrisome levels in all counties

Table 3
Variance inflation factors
Variance Inflation Factor (VIF) using an independent OLS regressions of the augmented baseline model of the form $EXCH_t = \alpha + \beta_1 DINT_t + \beta_2 DIND_t + \beta_3 DCPI_t + \beta_4 OIL_t + \varepsilon_t$, where *EXCH* is the level of exchange rate between the local currency and the U.S. dollar expressed as the number of units of local currency needed to purchase one U.S. dollar; *DINT* is the difference in the short-term interest rates between a given country and the United States; *DIND* is the difference in the industrial production between a given country and the United States; *DCPI* is the difference in inflation between a given country and the United States; *OIL* is the price for WTI oil expressed in U.S. dollars, for each country.

Exchange Rate	Russia	Brazil	Mexico	Canada	Norway
OIL	5.14	4.47	3.60	6.26	8.78
DINT	1.32	1.56	2.67	1.01	1.50
DIND	18.36	5.31	7.48	4.31	5.45
DCPI	18.16	6.16	9.00	9.34	5.28
Mean VIF	10.74	4.38	5.69	5.23	5.25

except for Russia. Even for Russia, where the mean VIF is 10.74, all the coefficients are significant at the conventional level of significance and have anticipated signs. Thus, multicollinearity does not seems to be a concerning issue, but the potential omitted-variable bias arising from the omission of the oil price variable in the baseline model could be a more serious problem.

4.3. Empirical results

4.3.1. The base-line model

It is reasonable to assume that the error terms in the base-line regression model are interrelated among countries through the co-movements of international funds and energy prices. Thus SUR (seemingly unrelated regression) appears to be a preferred estimation method. The estimation results for Model 1 and Model 2 are presented in Table 4.

The most striking difference between the base-line model (Model 1) and the model with oil prices added (Model 2) is that the R^2 increases dramatically for the countries that are considered emerging markets or developing economies. The value of the R^2 is more than doubled in Russia (from 0.226 to 0.513) and Brazil (0.158 to 0.367) in Model 2. By contrast, the R^2 increases by over three percentage points in Mexico, and by over four percentage points in Canada, but stays virtually unchanged in Norway. It is possible to infer that differences in the exchange rate movements among the countries are related to the differences in the behavior of the R^2. Thus, the differing behavior of R^2 offers some clue to why Russia and Brazil, on the one hand, and Canada and Norway, on the other hand, exhibit similar patterns in the behavior of exchange rate volatility.

We also find that the coefficients of all the fundamental variables are highly significant in most countries. Since the exchange rate is expressed as the number of the units of local currency that is exchanged for one U.S. dollar, a positive sign indicates depreciation of the local currency, and a negative sign signifies its appreciation. All the coefficients have the signs that are consistent with the theoretical predictions and with empirical results provided by previous studies. As the local income level proxied by industrial production increases relative to the U.S. income level, the exchange rate tends to fall, ceteris paribus, that is, the value of the local currency tends to rise. As the local inflation rate relative to the U.S. inflation rate rises, the exchange rate tends to rise, ceteris paribus, indicating depreciation of the local currency.

The net effect of the interest rate on the exchange rate is ambiguous. As the local interest rate relative to the U.S. interest rate rises, local bonds become more attractive to international investors than U.S. bonds, which puts upward pressure on the local currency. On the other hand, a relative rise in the local interest rate will have a negative effect on local stocks, which will make local stocks less attractive to international investors than U.S. stocks. This will put downward pressure on the local currency, ceteris paribus. Our estimation result shows that a rise in the local interest rate relative to the U.S. interest rate leads to a decrease in the exchange rate of Russia and Norway with the United States (i.e., appreciation of the local currency), and an increase in the interest rate relative to the U.S. interest rate leads to increase in the exchange rates of the three other countries (Brazil, Mexico, and Canada) with the United States (i.e. depreciation of the local currency).

Lastly, the coefficient of the oil price variable in Model 2 is highly significant in all five countries. This finding further corroborates the claim that the oil price variable is a relevant variable in the exchange rate determination model, especially for Russia and Brazil.

The performance of oil prices in the determination of the exchange rate seems to have little to do with the importance of oil revenues for an economy. Norway has the highest proportion of oil revenues as a percentage of GDP (25.8%), and Brazil has the lowest proportion (4.6%). Nonetheless, the value of R^2 for Norway remains almost unchanged with the introduction of oil prices into the model, whereas the value of R^2 for Brazil is more than doubled in the oil prices-augmented model. Russia has the second

Table 4

Baseline model – seemingly unrelated regression

This table reports the results for a seemingly unrelated regression model for each of the five countries examined with the fundamental determinants of the exchange rate (Equation (1): $EXCH_t = \alpha + \beta_1 DINT_t + \beta_2 DIND_t + \beta_3 DCPI_t + \varepsilon_t$) and with the fundamental determinants of the exchange rate and oil prices (Equation (2): $EXCH_t = \alpha + \beta_1 DINT_t + \beta_2 DIND_t + \beta_3 DCPI_t + \beta_4 OIL_t + \varepsilon_t$). *EXCH* is the exchange rate between the local currency and USD (expressed in terms of the local currency), *DINT* is the interest rate differential, *DIND* is the industrial production growth differential, *DCPI* is the differential of the inflation rate in a given country, *OIL* is the monthly average price of WTI oil brand in U.S dollars. A sample of monthly data covering a period of September 1998 – August 2012 is examined (168 observations).

Exchange Rate	Russia		Brazil		Mexico		Canada		Norway	
	1	2	1	2	1	2	1	2	1	2
Intercept	27.695***	34.593***	2.010***	2.984***	10.801***	11.420***	1.323***	1.473***	6.756***	7.872***
	101.76	55.55	25.54	19.40	95.03	65.85	155.40	74.98	123.87	40.89
DINT	−0.027	−0.076***	0.019***	0.010**	0.017	−0.001	0.028***	0.019***	−0.047***	−0.009
	−1.03	−3.28	3.89	2.05	1.31	−0.10	5.88	4.60	−2.86	−0.51
DIND	−0.314***	−0.179***	−0.025***	−0.015***	0.019	0.076***	0.009***	0.000	0.043***	0.012
	−8.36	−5.32	−5.03	−2.86	0.75	2.96	3.16	0.07	5.62	1.24
DCPI	0.157***	0.207***	0.009**	0.034***	0.134***	0.137***	0.075***	0.039***	0.216***	0.082***
	10.07	14.07	2.33	7.30	7.78	8.54	12.43	5.06	9.45	2.82
OIL		−0.127***		−0.015***		−0.013***		−0.004***		−0.020***
		−11.80		−7.40		−4.56		−8.83		−5.88
N	168	168	168	168	168	168	168	168	168	168
Adj. R-sq	0.2257	0.5136	0.1578	0.3643	0.7472	0.7778	0.8102	0.8511	0.694	0.7186

The subscripts *,**,*** represent significance at 10, 5, and 1% respectively. The value in parentheses represents the t-statistic associated with the coefficient reported.

highest ratio of oil revenues to GDP, and its R^2 is more than doubled. It is worth noting that Russia and Brazil which are volatile-price countries have a less efficient financial system than Canada and Norway which are stable-price countries. Hence, oil prices seem to be a crucial variable in the determination of the exchange rate in a country where the financial system is less efficient and more restrictions on the foreign exchange transactions are in place.

4.3.2. Volatility analysis

4.3.2.1. Movements in the mean and volatility of exchange rates. Table 5 presents the results of the estimation of the GARCH-M model. Since the coefficient of σ_t (one conditional standard deviation of the error term) measures the additional change in the exchange rate associated with conditional volatility, it can be construed as a measure of overshooting. The estimation of the GARCH-M model indicates that the exchange rates of Russia and Canada overreact to the conditional variance negatively. This outcome confirms the presence of short-run overshooting in the two countries. The negative reaction of the exchange rate implies that the volatility of the exchange rate increases in the direction of the appreciation of the currency.

What is of particular interest to us is the behavior of the exchange rate in response to an oil price shock. First, we have found that the level of the exchange rate is negatively related to an oil price change in all oil-exporting countries. The coefficient of oil prices in the exchange rate mean equation is negative and highly significant in all countries. This means that the currency of each of the oil-exporting countries tends to appreciate in response to an oil price increase. However, as far as the variance of the exchange rate is concerned, we have a quite different story. The coefficient of oil prices in the exchange rate variance equation is significant only in three emerging markets: Russia, Brazil, and Mexico. Although the coefficient is also significant in Canada, the size of the coefficient is small enough to be ignored (−0.00003). The size of the variance of the Canadian exchange rate is only 0.2% of that of the Russian variance. The coefficient is negative in Russia and Brazil, indicating that as oil prices fall, the volatility of the exchange rate increases, and as oil prices rise, the volatility of the exchange rate decreases. This finding is in accordance with what has been happening in Russia and Brazil recently.

Why does the conditional volatility of the exchange rate behave differently among countries, especially between emerging markets such as Russia and Brazil and advanced economies such as Norway and Canada? As we noted, the importance of oil revenues to the economy does not seem to provide an answer to this question. The proportion of oil revenues in GDP is 25.8% in Norway and 6.2% in Canada, whereas it is 10.1% in Russia and 4.6% in Brazil. We have observed that the R^2 of the regression model is significantly higher for Russia and Brazil when oil prices are added to the model as an explanatory variable, but it increases by a small magnitude for Norway and Canada. We also observe that Russia and Brazil are volatile-price countries, whereas Norway and Canada are stable-price countries.

Table 5
GARCH-M model with augmented variance equation
This table reports the results for GARCH-M models for each of the five countries examined with the fundamental determinants of the exchange rate and the oil prices for the month incorporated in the main Equation (3.1) $EXCH_t = \alpha + \beta_1 OIL_t + \beta_2 DINT_t + \beta_3 DIND_t + \beta_3 DCPI_t + \gamma\sigma_t + \varepsilon_t$, and the monthly return on oil incorporated in the variance Equation (3.2) $\sigma_t^2 = \phi_0 + \phi_1 \sigma_{t-1}^2 + \phi_2 \varepsilon_{t-1}^2 + \phi_3 OIL_t + v_t$. *EXCH* is the monthly level on the exchange rate between the local currency and USD, *OIL* is the monthly average price of WTI oil brand, *DINT* is the interest rate differential, *DIND* is the industrial production growth differential, *DCPI* is the differential of the inflation rate in a given country, σ_t is the standard deviation of the residual. A sample of monthly data covering a period of September 1998 to August 2012 is examined.

	Russia	Brazil	Mexico	Canada	Norway
Main equation					
Intercept	35.682***	2.541***	11.193***	1.342***	7.124***
	30.09	24.05	76.91	25.18	49.66
OIL	−0.118***	−0.010***	−0.008***	−0.004***	−0.010***
	−9.45	−10.81	−2.97	−7.17	−4.21
DINT	0.064**	0.021***	0.035***	0.027***	0.001
	2.07	3.71	6.08	4.61	0.06
DIND	−0.248***	−0.023***	−0.009	0.012***	0.019**
	−9.13	−9.36	−0.56	5.19	2.42
DCPI	0.180***	0.023***	0.191***	0.027***	0.100***
	17.55	9.02	18.72	5.13	5.11
σ_t	−2.349***	−0.010	0.041	−0.036***	0.015
	−3.18	−1.16	0.96	−2.89	0.89
Variance equation					
Intercept	1.974***	0.052***	−0.010	0.003***	0.061**
	4.16	2.71	−0.49	5.16	2.22
σ^2_{t-1}	0.136*	−0.133**	0.169	0.537***	−0.136
	1.95	−2.44	0.82	11.12	−1.35
ε^2_{t-1}	0.349***	0.981***	0.639**	0.163	0.838***
	3.40	5.11	2.50	1.63	3.02
OIL	−0.0133***	−0.0004**	0.0013*	−0.00003***	−0.0001
	−4.47	−2.54	1.88	−5.23	−0.20
N	168	168	168	168	168
Adj. R-sq	0.631	0.254	0.753	0.877	0.636

Subscripts *,**,*** present significance at 10, 5, and 1% respectively. The value below the reported coefficient is the z-statistic associated with the coefficient.

These results suggest that the behavior of exchange rate volatility appears to be related to expected inflation. When there is an external shock, economic agents in Russia and Brazil perceive this as a signal for another bout of higher inflation, which could increase the volatility of the exchange rate and result in the depreciation of the local currency. However, economic agents in Norway and Canada are used to low inflation, and they are less likely to link an external shock to higher inflation. It needs to be emphasized that the Russian and Brazilian exchange rates exhibit the highest volatility, while the Norwegian exchange rate is the least volatile and the Canadian exchange rate is the second least volatile among the five countries examined in this study.

In sum, Hypothesis 2 is supported by the empirical results and our empirical evidence is not consistent with Hypothesis 1.

4.3.2.2. Cointegration and VECM. As part of the analysis of exchange rate volatility, we conduct unit-root tests for the time series variables using the Phillips-Perron test. We find that all the time series variables we used in Model 2 contain a unit root, indicating that they are nonstationary. As the next step, we perform cointegration tests using the Johansen method to find out whether the exchange rate is cointegrated with its determining variables. We confirm the cointegration of the exchange rate with its determinants in each country. The cointegration test results are reported in Table 6. On the basis of these findings, we have conducted VECM tests and the augmented causality tests as proposed in Toda and Yamamoto (1995).

The VECM and the causality test results are reported in Table 7. Our AIC indicates that a model with two lagged terms is the most appropriate representation of the VECM. They demonstrate that the causality from oil prices to exchange rates is confirmed in all countries, and the feedback effect from exchange rates to oil prices is not present. Any causality between other variables and their feedback effects are either absent or weak, and we can only draw an unambiguous conclusion on the causal relationship from oil prices to exchange rates. Thus as far as the causality from oil prices to exchange rates is concerned, there is no difference in the behavior of exchange rates between advanced markets and emerging markets and between oil-exporting countries with a higher proportion of oil revenues and oil-exporting countries with a lower proportion of oil revenues. This evidence is also consistent with our base-line results. The VECM result provides further evidence on the causality from oil prices to exchange rates for Russia, Brazil, and Norway. The coefficient of the error-correction term is highly significant in these countries.

4.3.2.3. Impulse response functions. The VECM results can be viewed as short-run evidence on the relationship between oil price shocks and exchange rate movements. We have examined how rapidly the exchange rate converges to its equilibrium level after an innovation in oil prices occurs. The IRF graphs (Fig. 2) show that an innovation (a one-standard-deviation increase) in oil prices causes all the currencies to appreciate after the shock and then to move gradually toward their initial levels. However, the speed of adjustment back to their initial levels substantially differs among countries. It takes more than eight months for the exchange rate of Russia and Brazil to reach the initial level, and about six months for the exchange rate of Mexico to reach the initial level, but less than four months for the exchange rate of Canada and Norway to reach the initial level.

In sum, these findings lend support to Hypothesis 4, and Hypothesis 3 is not supported by our empirical evidence.

5. Concluding remarks

The purpose of this study is to investigate how oil prices affect the level and volatility of dollar exchange rates between the United States and major oil-exporting countries that operate under a floating exchange rate system. We have examined the behavior of the exchange rates of Russia, Brazil, Mexico, Canada, and Norway with the United States using monthly data from September 1998 to August 2012.

There is not much difference in the effects of oil prices on the mean exchange rate among the five countries. The coefficient of the oil price variable is highly significant in all five countries. This finding suggests that a model of exchange rate determination without oil prices incorporated could suffer from an omitted-variable bias. We first compare the performance of the regression between a model with oil prices incorporated (oil prices-augmented model) and a model without oil prices. The most noticeable difference between these two models is that the R^2 increased dramatically for the countries that are generally classified as emerging markets or developing economies. The value of the R^2 in the exchange rate model with the oil price variable incorporated was more than doubled in Russia (from 0.226 to 0.513) and Brazil (0.158 to 0.367), but it increased slightly in Canada and stayed virtually unchanged in Norway. The R^2 for Mexico increased by over three percentage points.

Table 6
Cointegration
The table presents the results of the cointegration tests for the variables used in the study using the Johansen test.

Hypothesized No. of CE(s)	Critical Value at 5%	Russia		Brazil		Mexico		Canada		Norway	
		Trace Statistic	Prob.	Trace Statistic	Prob.	Trace Statistic	Prob.	Trace Statistic	Prob.	Trace Statistic	Prob.
None	69.82	97.64	0.0001***	153.58	0.0000***	70.38	0.0451**	46.29	0.7870	88.24	0.0009***
At most 1	47.856	48.050	0.0479**	56.565	0.0062***	41.039	0.1874	26.784	0.8623	41.092	0.1858
At most 2	29.797	17.719	0.5868	16.927	0.6454	20.510	0.3889	15.992	0.7128	15.733	0.7309
At most 3	15.494	7.860	0.4804	4.355	0.8729	7.228	0.5512	7.351	0.5371	5.345	0.7711
At most 4	3.841	0.210	0.6465	0.986	0.3205	0.233	0.6292	1.041	0.3075	0.801	0.3707

Subscripts *,**,*** present significance at 10, 5, and 1% respectively.

Table 7
VECM and granger causality tests
Panel A reports the results for the VEC model using two lags of the variables used in the study (see Eq. (4)). The use of two lags is justified by the Akaike Information Criterion. We only report the VECM results for the exchange rate variable and omit reporting the rest of the equations to preserve space.
Panel B reports the results for causality tests, which are performed using the methodology introduced in Toda and Yamamoto (1995).

Panel A. VECM

ΔEXCH	Russia	Brazil	Mexico	Canada	Norway
Intercept	0.263***	0.018	0.039	−0.003	−0.010
	2.93	1.22	1.28	−1.13	−0.57
$\Delta EXCH_{t-1}$	0.198***	−0.126	0.048	−0.052	0.001
	2.77	−1.51	0.59	−0.60	0.02
$\Delta EXCH_{t-2}$	−0.195***	0.048	−0.130	−0.066	−0.032
	−2.70	0.59	−1.50	−0.74	−0.39
ΔOIL_{t-1}	−0.010	−0.005**	−0.014***	−0.001	−0.008***
	−1.15	−2.48	−2.82	−1.61	−2.62
ΔOIL_{t-2}	−0.026***	−0.001	−0.012***	−0.001*	−0.004
	−2.90	−0.65	−2.60	−1.89	−1.34
$\Delta DINT_{t-1}$	0.026	−0.009	−0.018	−0.013	0.032
	1.52	−1.32	−0.94	−1.60	0.68
$\Delta DINT_{t-2}$	0.033**	−0.024***	0.000	0.015*	0.033
	2.08	−3.40	−0.01	1.87	0.69
$\Delta DIND_{t-1}$	0.036	−0.010**	−0.001	0.003	−0.009
	1.20	−1.96	−0.05	1.15	−1.31
$\Delta DIND_{t-2}$	0.028	−0.005	0.032	0.002	−0.010
	0.95	−0.94	1.13	0.82	−1.61
$\Delta DCPI_{t-1}$	0.027	−0.042	−0.036	0.007	−0.008
	0.28	−1.53	−0.60	0.80	−0.25
$\Delta DCPI_{t-2}$	−0.243**	−0.001	0.003	−0.007	−0.007
	−2.58	−0.05	0.05	−0.82	−0.20
e_{t-1}	−0.155***	0.050**	−0.018	0.006	−0.072***
	−6.87	2.45	−0.57	0.19	−4.21
Adj. R-sq	0.366	0.094	0.055	0.020	0.082

Panel B. VEC Causality using the Toda and Yamamoto (1995) methodology

ΔEXCH	Russia	Brazil	Mexico	Canada	Norway
ΔOIL	9.023**	6.255**	12.677***	5.692**	7.551**
	(0.011)	(0.044)	(0.002)	(0.058)	(0.023)
ΔDINT	4.856*	17.285***	0.984	4.540	1.814
	(0.088)	(0.000)	(0.611)	(0.103)	(0.404)
ΔDIND	1.879	3.915	1.392	1.583	3.096
	(0.391)	(0.141)	(0.498)	(0.453)	(0.213)
ΔDCPI	7.927**	2.962	0.488	1.465	0.106
	(0.019)	(0.227)	(0.783)	(0.481)	(0.948)
All	24.200***	27.022***	18.310**	14.194*	11.025
	(0.002)	(0.001)	(0.019)	(0.077)	(0.200)

Subscripts *,**,*** present significance at 10, 5, and 1% respectively. The value in parenthesis below the reported coefficient is the *p*-value associated with the coefficient.

Our empirical analysis based on the GARCH-M model further shows that an increase in oil prices leads to the appreciation of the local currency (that is, a fall in the dollar exchange rate) in all countries, ceteris paribus.

However, if we focus on the conditional volatility of the exchange rate, some differences in the behavior of the exchange rate are conspicuous among the countries, especially between emerging markets such as Russia and Brazil, and advanced economies such as Canada and Norway.

More specifically, our empirical results on the volatility of exchange rates associated with an oil price shock in the GARCH-M variance equation provides evidence on the asymmetric volatility between the advanced markets and emerging markets. The coefficient of an oil price shock in the variance equation is significant in Russia, Brazil and Mexico, which indicates that the volatility of exchange rates is conditional on oil price changes. In particular, the sign of the coefficient is negative in Russia and Brazil, implying that a fall in oil prices increases the volatility of the currency in these countries. Although the coefficient is positive and significant in Canada, the size is sufficiently small to be ignored. The coefficient is not significant in Norway at any reasonable level of significance.

The importance of oil revenues in an economy does not seem to provide adequate explanations for this pronounced difference. The different behavior of exchange rate volatility appears to be related to expected inflation. Russia and Brazil are volatile-price countries, whereas Canada and Norway are stable-price countries. We also observe that the Russian and Brazilian exchange rates are most volatile, whereas the Norwegian and Canadian exchange rates are the least volatile among the five countries. In a volatile price country, a change in oil prices is the dominant influence on the exchange rate with the U.S. dollar, and an oil price shock in a volatile-price country leads to more volatile movements of the exchange rate than in a stable-price country. In

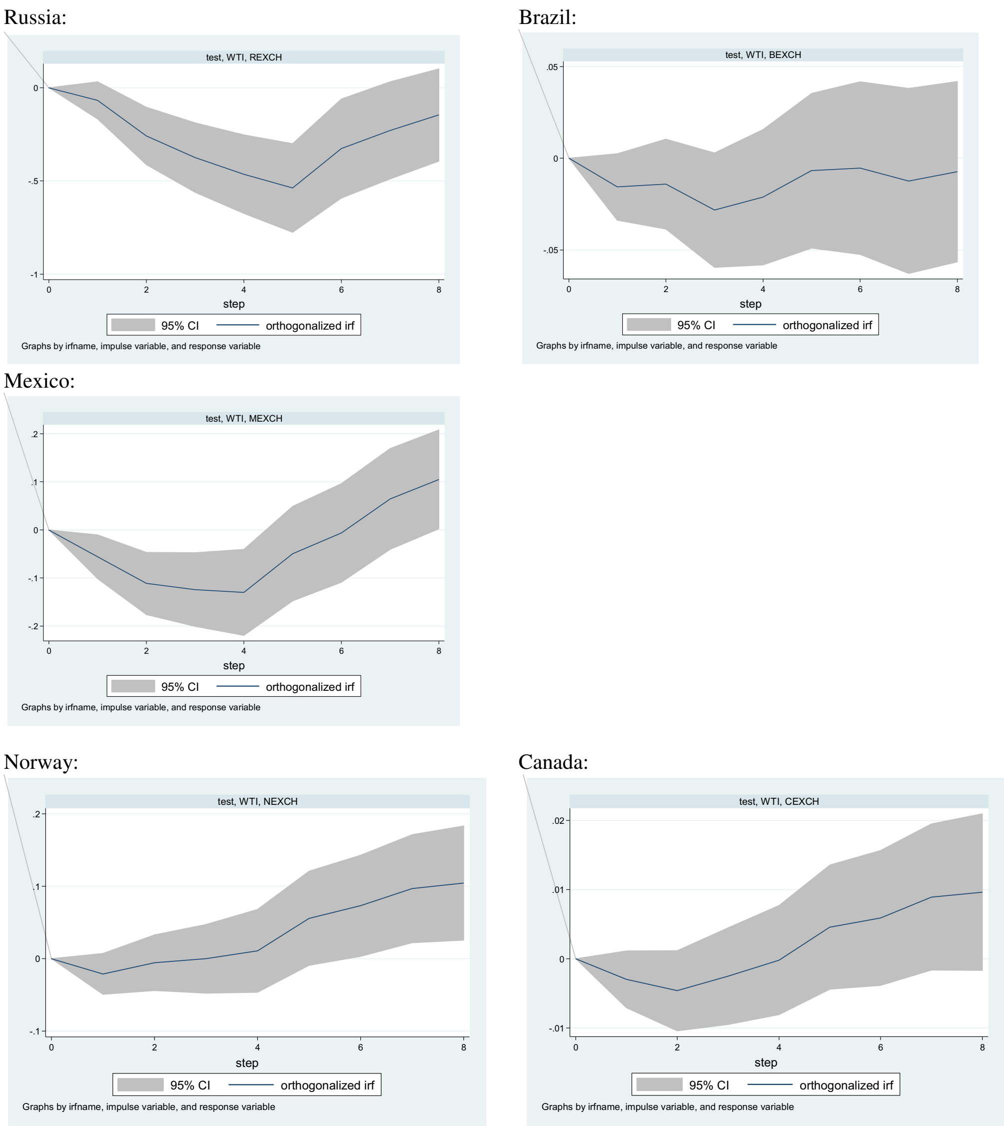


Fig. 2. Impulse response function The graphs report the impulse response functions with WTI oil price being the impulse and the exchange rate of a given country being the response.

general, volatile-price countries tend to have less efficient financial and foreign exchange markets than stable-price countries. Thus, the efficiency of financial and foreign exchange markets is a key factor in the behavior of exchange rate volatility.

Our IRF graphs also illustrate asymmetry in the dynamics of the long-run adjustment of the exchange rate in response to a one standard-deviation increase in oil prices. The speed of adjustment of the exchange rate toward its long-run equilibrium level is differentiated between volatile-price countries and stable price countries. It takes much longer for the exchange rate of Russia, Brazil, and Mexico to reach the initial equilibrium level than for the exchange rate of Canada and Norway.

References

Akram, Q. F. (2009). Commodity prices, interest rates and the dollar. *Energy Economics*, *31*, 838–851.
Aloui, R., Ben Aissa, M. S., & Nguyen, D. K. (2013). Conditional dependence structure between oil prices and exchange rates: A copula-GARCH approach. *Journal of International Money and Finance*, *32*, 719–738.
Amano, R., & Van Norden, S. (1998a). Exchange rates and oil price. *Review of International Economics*, *6*, 683–694.
Amano, R., & Van Norden, S. (1998b). Oil prices and the rise and fall of the US real exchange rate. *Journal of International Money and Finance*, *17*, 299–316.
Basher, S. A., Haug, A. A., & Sadorsky, P. (2012). Oil prices, exchange rates and emerging stock markets. *Energy Economics*, *34*, 227–240.
Brown, S. P. A., & Yucel, M. K. (2002). Energy prices and aggregate economic activity: An interpretive survey. *The Quarterly Review of Economics and Finance*, *42*, 193–208.
Chaudhuri, K., & Daniel, B. (1998). Long-run equilibrium real exchange rates and oil prices. *Economics Letters*, *58*, 231–238.

Chen, S. S., & Chen, H. -C. (2007). Oil prices and real exchange rates. *Energy Economics*, *29*, 390–404.

Chen, W. -P., Choudhry, T., & Wu, C. -C. (2013). The extreme value in crude oil and US dollar markets. *Journal of International Money and Finance*, *36*, 191–210.

Cheung, Y. -W., Chinn, M. D., & Pascual, A. G. (2005). Empirical exchange rate models of the nineties: Are any fit to survive? *Journal of International Money and Finance*, *24*, 1150–1175.

Engel, C., & West, K. (2005). Exchange rate fundamentals. *Journal of Political Economy*, *113*, 485–517.

Gaddy, C., & Ickles, B. (2005). Resource rents and Russian economy. *Eurasian Geography and Economics*, *46*, 559–583.

Golub, S. (1983). Oil prices and exchange rates. *Economic Journal*, *93*, 576–593.

Kaufmann, R., & Ullman, B. (2009). Oil prices, speculation, and fundamentals: Interpreting causal relations among spot and futures prices. *Energy Economics*, *31*, 550–558.

Lizardo, R. A., & Mollick, A. V. (2010). Oil price fluctuations and US dollar exchange rate. *Energy Economics*, *322010*, 399–408.

MacDonald, R. (1999). Exchange rate behavior: Are fundamentals important? *The Economic Journal*, *1999*, 673–691.

Meese, R., & Rogoff, K. S. (1983). Exchange rate models of the seventies. Do they fit out of sample? *Journal of International Economics*, *14*, 3–24.

Meese, R., & Rogoff, K. S. (1988). Was it real? The exchange rate-interest differential relation over the modern floating rate period. *Journal of Finance*, *43*, 923–948.

Nam, J. H., & Yuhn, K. -H. (2001). Volatility spillover effects from the U.S. market to the Korean stock market. *Review of International Economics*, *7*, 23–45.

Pedroni, P. (2004). Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric Theory*, 597–625.

Rapach, D., & Wohar, M. (2002). Testing the monetary model of exchange rate determination: New evidence from a century of data. *Journal of International Economics*, *58*, 359–385.

Rautava, J. (2004). The role of oil prices and the real exchange rate in Russia's economy – A cointegration approach. *Journal of Comparative Economics*, *32*, 315–327.

Tabata, S. (2009). The influence of high oil prices on the Russian economy: A comparison with Saudi Arabia. *Eurasian Geography and Economics*, *50*, 75–92.

Toda, H. Y., & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Econometrics*, *66*(1), 225–250.

Wu, C. -C., Chung, H., & Chang, Y. -H. (2012). The economic value of co-movement between oil price and exchange rate using copula-based GARCH models. *Energy Economics*, *34*, 270–282.