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THE REAL EXCHANGE RATE OF OIL EXPORTING COUNTRIES

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Abstract

This paper investigates whether the real oil price has an impact on the real exchange rates of three main oil-exporting countries: Norway, Russia and Saudi Arabia. We create our measure of the real effective exchange rates for Norway and Saudi Arabia (1980-2006) and for Russia (1995-2006), testing if real oil prices and productivity differentials against 15 OECD countries influence exchange rates. In the case of Russia it is possible to establish a positive long-run relationship between the real oil price and the real exchange rate. However, we find virtually no impact of the real oil price on the real exchange rates of Norway and Saudi Arabia. The diverse exchange rate regimes cannot help in explaining the different empirical results on the impact of oil prices across countries, which instead may be due to other policy responses, namely the accumulation of net foreign assets and their sterilisation, and specific institutional characteristics.

Keywords: Real exchange rate, oil price, purchasing power parity, terms of trade, oil exporting countries

JEL classification: F31, C22

Non-technical summary

The world economy still runs on oil. Sharp fluctuations in the oil price provoke significant shifts in the wealth of nations. The large increase in oil prices since the beginning of the new millennium has been associated with the emergence of large current account imbalances across the globe. As the current oil shock has proved to be more persistent than expected, oil exporters have emerged as the group of countries with the largest current account surplus. This has prompted renewed interest in the economies of these countries and, in particular, their exchange rates, since the latter, at least for some, could contribute to the adjustment of global imbalances.

In this study, we focus on the economies of three main oil exporting countries: Norway, Russia and Saudi Arabia. In 2005, oil exports accounted for around fifty percent of total exports in Norway and Russia and for more than eighty percent of total exports in Saudi Arabia. The contribution to domestic production of the oil sector ranges from around twenty percent of GDP in Russia, to around one quarter in Norway and more than forty percent of GDP in Saudi Arabia. In 2006, these three countries recorded a combined current account surplus of around USD 250 billion, which is around a half of the total current account surplus of oil exporting countries and almost one third of the current account deficit in the United States.

In particular, this paper investigates whether the real oil price has an impact on the real exchange rates of these three main oil exporting countries. Indeed, the economic literature identified the terms of trade – the relative price of exports to imports - as one of the potential determinants of the real exchange rate, which may explain long and persistent deviations from a simple Purchasing Power Parity (PPP) equilibrium. In oil exporting countries, the main driver of the terms of trade is the oil price. Here, therefore, we take the real oil price as a proxy of the terms of trade and examine whether oil price fluctuations affect the real effective exchange rate of these three countries. Using quarterly data over the period 1980 - 2006 for Norway and Saudi Arabia and 1995 – 2006 for Russia, we create our measure of the real effective exchange rates and, in addition to real oil prices, we control for the possible role of productivity differentials against 15 OECD countries in explaining exchange rate movements. Since these countries adopted different exchange rate regimes, we also try to understand whether the currency arrangement does matter.

Following the literature on time series analysis, we estimate three different models based on the different results concerning the order of integration of our time series, which indicates whether or not the series tend to revert to a long-term mean. Our empirical investigation shows that there is not a "one size fits all" model for the real exchange rate for our three countries and that only in Russia is it possible to identify a robust long-run relationship between the exchange rate and oil prices. This relationship is robust to the inclusion of the productivity differential as an explanatory variable, which appears to be an important determinant of the real exchange rate in Russia, a transition economy. Due to the relatively short sample for Russia, it is necessary to take this conclusion with some caution and possibly test it again over a longer time-span in the future. On

the contrary, we find no – or at best a very marginal – impact of the real oil price on the real exchange rates of Norway and Saudi Arabia.

Overall, it does not seem that the different exchange rate regimes help to explain whether or not the relationship between the real oil price and the real exchange rate holds in practice. Irrespective of the exchange rate regimes, other factors may interfere and neutralise the transmission of shocks to the real exchange rate. These include specific policy responses to volatile oil revenues, monetary policy interventions modifying the combination of changes in relative prices and the nominal exchange rate which are necessary to restore the equilibrium and other institutional features. In the case of Norway, the exchange rate regime underwent a number of modifications, with full exchange rate flexibility being introduced only over the last few years, thus complicating any possible interpretation of the impact of these regimes over the long-run. At the same time, over the past decade, Norway "sterilised" the impact of higher oil revenues on the domestic economy and the real exchange rate through a massive accumulation of net foreign assets. In Russia, the nominal flexibility of the rouble has been limited by the interventions of the monetary authorities in the foreign exchange market, which have been only partially sterilised contributing to a strong expansion of domestic money supply and persistent inflationary pressures. As a result, the absorption of the positive oil shock by the real exchange rate took place through changes in relative prices and not through an appreciation of the nominal exchange rate. Finally, in Saudi Arabia, the "sterilisation" of oil revenues, as well as the presence of flexible labour markets and price subsidies, may have played an important role in breaking the relationship between the oil price and the real exchange rate. In conclusion, the exchange rate regime may not matter, but other policies and institutional characteristics may account for the different reaction of the real exchange rate to oil price shocks.

1. Introduction

The world economy still runs on oil. Sharp fluctuations in the oil price provoke significant shifts in the wealth of nations. The large increase in oil prices since the beginning of the new millennium has been associated with the emergence of large current account imbalances across the globe. As the current oil shock has proved to be more persistent than expected, oil exporting countries have emerged as the group of countries with the largest current account surplus. This has prompted renewed interest in the economies of these countries and, in particular, their exchange rates, since the latter, at least for some, could contribute to the adjustment of global imbalances[1]. Whether the degree of nominal exchange rate flexibility of oil exporting countries is appropriate may well depend on the behaviour of the real exchange rate over the long run, considering the possibility that the latter may in turn be influenced by significant changes in the terms of trade. Indeed, the literature has identified the terms of trade as one of the potential determinants of the real exchange rate, which may explain long and persistent deviations from a simple Purchasing Power Parity (PPP) equilibrium. In oil exporting countries, the main driver of the terms of trade is the oil price. In this study, therefore, we take the real oil price as a proxy of the terms of trade and examine whether oil price fluctuations affect the real effective exchange rate of three countries: Norway, Russia and Saudi Arabia. Since these countries adopted different exchange rate regimes, we also try to understand whether the currency arrangement does matter.

Our empirical investigation is based on the theoretical framework of exchange rate determination developed by Cashin et al. (2004), which in turn builds on De Gregorio and Wolf (1994) and Obstfeld and Rogoff (1996). In this framework, an improvement in the terms of trade - the relative price of exports in terms of imports - produces an appreciation of the domestic currency. According to this model, the economy is composed of two different sectors: one producing an exportable good, and the other producing a non-traded good. In this context, a positive shock to the terms of trade leads to an increase in wages in the exporting sector. Similarly to the dynamics of the Balassa-Samuelson model of exchange rate, under the assumption of wage equalization across the two sectors, this translates into an increase in wages and prices in the non-traded goods sector and an appreciation of the real exchange rate.

Empirically, the relationship between the terms of trade and the real exchange rate has been tested and proven in a number of non-energy commodity exporters. Amano and van Norden (1995) find that – as expected - the non-energy commodity terms of trade has a positive impact on the real exchange rate of Canada, even though - unexpectedly - the energy component of the terms of trade has a negative impact in spite of Canada being a net energy exporter. Chen and Rogoff (2003) detect a strong and stable influence of the US dollar price of non-

[1] In April 2006, the statement of the Group of Seven (G7) explicitly mentioned oil exporting countries in the context of global imbalances. In particular, in the annex to the G7 communiqué, it was affirmed that "in oil-producing countries, accelerated investment in capacity, increased economic diversification, enhanced exchange rate flexibility in some cases […] will play a critical role as part of the multilateral adjustment process".

energy commodity exports on the real exchange rates in Australia and New Zealand. Cashin *et al.* (2004) extend this investigation to a set of 58 developing countries, which are commodity exporters. They find evidence of a long-run relationship between the real exchange rate and real commodity prices in around one third of the countries in their sample.

As mentioned, we take the real oil price as a proxy of the terms of trade in oil exporting countries. By definition, in these countries, oil exports account for a large share of total exports, thus dominating movements in their terms of trade. Baxter and Kouparitsas (2000) study the sources of fluctuations in the terms of trade identifying two components: "a goods price effect", which reflect the fact that a country exports and imports different baskets of goods, and "a country price effect" due to cross-country differences in the price of a particular class of goods. For oil producers, most of the terms of trade variation appears to origin in the goods-price effects (around 90 percent), confirming hence the enormous role of the price of the petroleum-good in these countries' relative export prices. However, in general, even in major industrialised countries, which have diversified import and export structures and are net importers of oil, both changes and volatility in the terms of trade are largely driven by changes and volatility in oil prices and quantities (see Backus and Crucini, 2000).

The potential role of oil shocks in driving terms of trade movements and impacting on exchange rates has already received much attention in the literature. Several studies claim the existence of a relationship between oil prices and exchange rates in both developed oil importing and oil exporting countries. From a theoretical perspective, Krugman (1983) and Golub (1983) were the first to develop models in which shifts in oil prices generate wealth transfer effects and portfolio reallocations, leading to adjustments in exchange rates to clear asset markets. As regards the bilateral exchange rates between two or more oil importing countries, the relative propensity to import oil and their respective bilateral trade deficits against oil producing countries are the key variables in explaining whether a rise in the oil price will lead to an appreciation or depreciation of the currency. Amano and van Norden (1998a and 1998b) test empirically the Krugman-Golub hypothesis and find evidence of a long-run stable relationship between the real effective exchange rate of the US dollar and the oil price deflated by the US consumer price index over the post-Bretton Woods period. Chaudhuri and Daniel (1998) note that both exchange rates and oil prices appear non-stationary over the post-Bretton Woods period, but stationary over the very long run. They also find evidence of cointegration between these two variables – deflated by producer price indices – over the post Bretton-Woods period, concluding that the non-stationarity of the US dollar over this period is due to the non-stationarity of the real price of oil. More recently, Chen and Chen (2006) have confirmed and extended these results testing for cointegration in a panel of G7 countries.

Other empirical studies focused on the exchange rates of oil "exporting" countries, where a positive oil shock, in theory, is expected to generate an appreciation of the currency over the long-run. Indeed, many empirical studies find a significant and positive relationship between the oil price and the real exchange rate of oil exporting countries. Koranchelian (2005) and Zalduendo

(2006) find that oil prices - as well as productivity differentials - play a significant role in determining the equilibrium real effective exchange rate in the case of Algeria and Venezuela, respectively. As regards the three countries which are studied in this paper, there are a number of studies on Norway and only few studies investigating Russia and Saudi Arabia. Evidence concerning the Norwegian krone is mixed. Akram (2004) finds a non-linear asymmetric relationship between the "nominal" exchange rate of the krone and oil prices. In particular, he finds that declines in the oil price lead to a depreciation of the krone when oil prices are below a certain threshold. Bergvall (2004) examines the determinants of the real exchange rates in Norway and other Nordic countries, finding that exogenous terms of trade (real oil price) shocks and supply side (productivity) shocks explain most of the long-run variance of the real exchange rate in the case of Norway and also Denmark. Spatafora and Stavrev (2003) estimate the equilibrium real exchange rate for Russia and find a positive role for both the *nominal* oil price and the productivity differentials. Dibooglu and Aleisa (2004) run a vector autoregressive model in first differences for the Saudi Arabian economy and show that the Saudi Arabian price level, real exchange rate and output are vulnerable to exogenous terms of trade shocks. Finally, Korhonen and Juurikkala (2007) estimate the real exchange rate in a panel of nine OPEC countries by adopting the empirical methodology in Chen and Chen (2007), finding a statistically significant effect of the real price of oil on exchange rates.

This paper contributes to the existing literature on the determinants of real exchange rates in a number of different ways. First, we focus on the three major oil exporting countries in terms of their current account surplus[2], which are therefore relevant for the adjustment of global imbalances. So far, as mentioned above, only the case of Norway has been broadly investigated, with mixed results, whereas to our knowledge there exist no studies like ours that run a thorough analysis of the real exchange rates in these three countries, using a consistent and coherent single-equation time-series approach and testing for the potential impact of real oil prices. Second, from a methodological perspective, we build our measures of the real effective exchange rates and productivity differentials against the 15 OECD main trading partners, thus controlling also for the so-called Balassa-Samuelson effect and including productivity differentials as a potential explanatory variable of the real exchange rate. Third, as most exchange rates are near unit–root, we use a strict procedure for testing their stationarity and allow for both I(0) and I(1) processes when the results are not unequivocal, following Chen and Rogoff (2003). Fourth, as the three countries adopted different exchange rate regimes, we try to understand whether these arrangements may account for potential differences in the relationship between the real oil price and the real exchange rate. In particular, one would expect the relationship between oil prices and the real exchange rate to hold in countries where the nominal exchange rate is allowed to absorb potential exogenous oil shocks.

In a preview of our main findings, we conclude that only in the case of Russia it is possible to establish a positive long-run relationship between the real

[2] According to the IMF World Economic Outlook (2006), Russia and Saudi Arabia are the two countries with the largest current account, trade balance and oil balance surplus in US dollars among the oil exporting countries. Norway has the third largest current account and trade surplus and the seventh largest oil surplus.

oil price and the real exchange rate. However, we find no – or at best a very marginal – impact of the real oil price on the real exchange rates of Norway and Saudi Arabia. The adoption of different exchange rate regimes in these countries does not help to explain the divergence in these results. The paper is organized as follows. In section 2, we describe the statistical characteristics of our data. Section 3 reports the empirical results. We account for our findings in section 4. Section 5 concludes.

2. Data analysis

2.1. Background

The economies of Norway, Russia and Saudi Arabia are highly dependent on oil revenues. In 2005, oil exports accounted for around fifty percent of total exports in Norway and Russia and for more than eighty percent of total exports in Saudi Arabia. The contribution to domestic production of the oil sector ranges from around twenty percent of GDP in Russia, to around one quarter in Norway and more than forty percent of GDP in Saudi Arabia. Following the surge in world oil prices since 2000, Norway, Russia and Saudi Arabia have become also major actors in the global constellation of external imbalances. In 2006, these three countries recorded a combined current account surplus of around USD 250 billion, which is around a half of the total current account surplus of oil exporting countries, as classified by the IMF, and almost one third of the current account deficit in the United States.

The three countries in our sample adopted different exchange rate arrangements throughout the period under examination. In Norway, the exchange rate was subject to limited flexibility, at least until the second half of the 1990s, and gained more flexibility only over the past few years. Formally, the regime switched from a moving band around the German mark until mid-1982, to a loose peg to a basket of currencies until mid-1987 - which was punctuated by a sharp depreciation in May 1986 - again to a moving band around the mark until 1990 and to a peg to the ECU between 1990 and 1992. In 1992, Norway adopted a managed floating regime which was kept until 2001, when the authorities introduced the inflation targeting regime, which implies the independent floating of the krone. In Russia, the flexibility of the exchange rate has been also somewhat limited. Between 1995 and 1998, the *de jure* exchange rate arrangement of the rouble was a floating exchange rate with rule-based intervention, according to the IMF, although Reinhart and Rogoff (2002) refer to a pre-announced crawling band around the US dollar. After the currency and financial crisis in the summer of 1998, the IMF *de jure* classified Russia as a floating exchange rate regime. However, since 1999, the Russian authorities *de facto* have been targeting the real exchange rate - with a basket of currencies mainly composed by the US dollar and the euro – stabilising the nominal effective exchange rate and leaning against real appreciation. Finally, in Saudi Arabia, the exchange rate regime is a rigid conventional peg throughout the period under examination. The riyal has been *de facto* pegged to the US dollar since 1981 –

before it was pegged to the IMF SDR – and subject to only a small devaluation in June 1986[3].

2.2. Data description and discussion

The aim of this paper is to test a relationship between the real effective exchange rate, the real oil price and the productivity differential in three oil exporting countries. For this purpose, we use the model developed by Cashin et al. (2004) for commodity dependent countries (see Appendix A for a description of the theoretical framework). The data sample ranges from 1980Q1 to 2006Q2, for Norway and Saudi Arabia for a total of 106 observations. Due to lack of reliable data, the sample for Russia starts only in 1995 and ranges from 1995Q1 to 2006Q2 period, for a total of 46 observations. Following the IMF methodology, we create our own measure of the real effective exchange rate (REER), calculating a trade-weighted geometric average of bilateral exchange rates vis-à-vis trading partners' currencies multiplied by the differential between the domestic consumer price index and the trade weighted foreign consumer price index[4]. Differently from the IMF, the weights are based on the total trade against the main 15 OECD trading partners and averaged over non-overlapping five-year windows during the period 1980 – 2005[5]. The set of trading partners is smaller than in the IMF case but our index better captures changes in the direction of trade, owing to more frequent changes in the weights, and, moreover, includes oil exports[6]. Crucially, by calculating our own weights, we may apply the same weights to calculate both the real effective exchange rate and the productivity differential variable, allowing for a better comparison of these two variables. Data of consumer price indices and bilateral exchange rates are from the International

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[3] Even in this rather straightforward case, the *de jure* classification does not coincide with the *de facto* one. According to the IMF, the riyal was *de jure* pegged to a "basket" of currencies until 2002.

[4] Formally, $REER_i = \prod_{j \neq i} \left[{CPI_i E_i} \big/ {CPI_j E_j} \right]^{W_{ij}}$.

CPI_i and CPI_j denote the consumer price indices of the home country and the trading partner, correspondingly, and E_i and E_j stand for the bilateral exchange rates with respect to the US dollar (measured as units of US dollar for a unit of domestic currency) for the home and foreign country, respectively. W_{ij} indicates the relative weight of the bilateral trade between the home country, *i*, and the foreign country, *j*, on the total trade of the home country. The index *j* runs from 1 to 15, as we consider only the 15 main OECD trading partners of Norway, Saudi Arabia, and Russia. An increase in the real effective exchange rate indicates real appreciation. See Zanello and Desruelle (1997) for more details on the construction of real effective exchange rates.

[5] See Table "Trade eights" in Appendix C. The list of trading partners includes Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, Korea (South), the Netherlands, Spain, Sweden, Switzerland, United Kingdom, and United States of America. We consider only these 15 countries as i) they constitute more than 80%, around 50% and more than 60% of the trade between Norway, Russia, Saudi Arabia and the world, correspondingly; ii) all of them are developed countries for which we may obtain reliable data. In order to combine the series based on different trade weights we use the chain rule $Z_t = X_{t-1} Y_t / Y_{t-1}$, where *t* denotes time period, *X* is the series comprising the last five years, *Y* is the series using the trade weights of the following five years, and *Z* is the combined series.

[6] Zanello and Desruelle (1997) and recently Bayoumi et al. (2005) from the IMF consider only trade in manufactures, non-oil primary commodities and tourism services. In addition weights are changed only every ten years.

Financial Statistics (IFS) of the IMF and trade weights are calculated from the Direction of Trade Statistics (DOTS) of IMF.

The trade-weighted relative productivity differential variable (PROD) is constructed using the same methodology and trade weights as in the real effective exchange rate index. For Norway and Russia, and the OECD trading partners productivity is defined as the seasonally adjusted real gross domestic product (GDP) relative to the number of people employed. GDP and employment are provided by the OECD Economic Outlook Database for most of the considered countries. For Russia we use data from Global Insight/World Market Monitor. Unfortunately, in the case of Saudi Arabia it is not possible to create a well behaved variable for the productivity differential due to lack of consistent data on employment and quarterly GDP. For this reason, the productivity differential does not enter into the regression for the real exchange rate of Saudi Arabia. In a similar fashion, we constructed an additional control variable, real interest rate differentials between Norway – the only country where short and long term interest rates were available across the whole sample – and the main OECD trading partners in order to control for the impact of deviations from the real uncovered interest parity[7].

The real price of oil (ROP) is calculated as the US dollar price of crude oil deflated by the IMF index of the unit value of world manufactured exports[8] which is often used in the literature as a proxy of the import prices of commodity exporters (see for instance Deaton and Miller 1996 and Cashin et al. 2004). As a nominal oil price we use the price of the *UK Brent* barrel for Norway, the *Urals* for Russia, and the *Dubai* for Saudi Arabia[9]. All variables are transformed in logarithms.

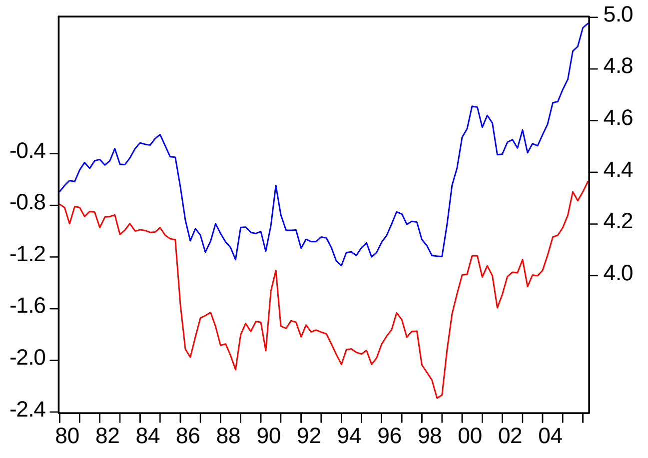

Figure 1. The relationship between the terms of trade of Norway and the real price of UK Brent

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[7] For Russia and Saudi Arabia, only money market rates were available for a large part of the sample, but not long term rates. We constructed real interest rate differentials also for these short-term rates and tested for their relevance in explaining real exchange rates over the period for which data were available. However, we did not find any significant relationship. Results are available upon request.

[8] The variable is a unit value index of exports from 20 industrial countries calculated in US dollar terms.

[9] In any case, these three oil prices are very similar with a correlation coefficient of 0.99.

Norway is the only country in our sample for which a measure of the terms of trade is available. This allows us to assess to what extent the terms of trade of an oil exporting country are dominated by changes in oil prices. In **Figure 1** we plot the terms of trade ratio for Norway - obtained from the Bank for International Settlement - against our measure of the real UK Brent oil price. The visual analysis confirms that the two series generally co-move across the whole sample and the real oil price is a very good proxy for the terms of trade of Norway. In particular, the degree of synchronisation of the two series is remarkably high since 1986[10]. For our purposes, the use of real oil prices instead of the terms of trade presents an additional advantage as it eliminates any potential problem of endogeneity in the relationship between the terms of trade and the real exchange rate, as long as the shocks to the real oil price are assumed to be exogenous[11].

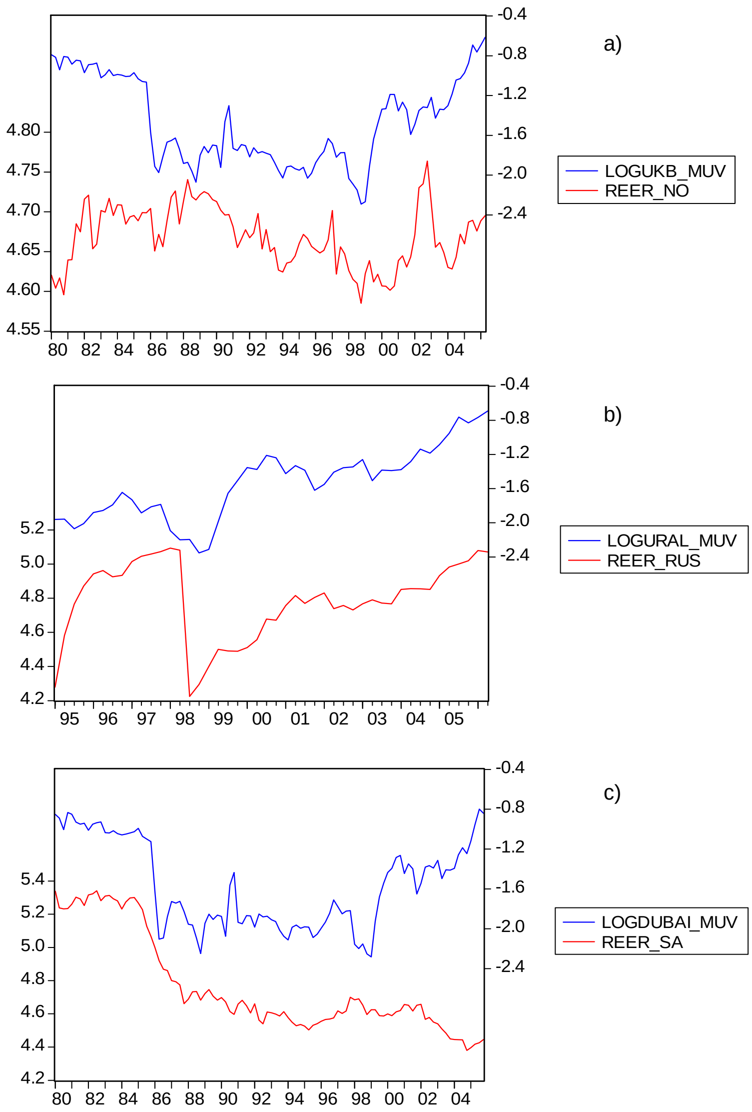

Figure 2 a) Norwegian real effective exchange rate and real UK Brent oil price; b) Russian real effective exchange rate and real Urals oil price; c) Saudi Arabian real effective exchange rate and real Dubai oil price.

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[10] The correlation coefficient is equal to 0.85 over the whole sample and increases to 0.95 after 1986.

[11] Granger causality tests confirm that the real oil price is exogenous to the real exchange rate.

In **Figure 2** we compare the real effective exchange rates of Norway, Russia and Saudi Arabia against the real UK Brent price, real Urals price and real Dubai oil price, correspondingly. Only in the case of Russia, a preliminary inspection shows evidence of co-movement between the real exchange rate and the real oil price, which is particularly tight after the 1998 currency crisis. In the case of Norway, it is possible to identify only a positive common trend in the real oil price and the exchange rate since 1999. In the case of Saudi Arabia, there is a downward trend in both the real exchange rate and the real oil price since 1986. This relationship, however, is rather loose and breaks down with the latest upswing in the oil price since 1999, which is not followed by an appreciation of the real exchange rate. Actually, since 2002, the riyal, which is pegged to the US dollar, depreciates in real terms whereas the oil price continues to increase, resulting in a negative relationship between the two variables.

2.3. Unit root analysis

Following the descriptive analysis of the data, in this subsection we discuss the statistical features of our time series. In particular, the identification of the order of integration of the real exchange rate is a delicate task, as exchange rates usually display near-unit root behaviour. In general, the hypothesis of stationarity of real exchange rates is accepted over very long samples and rejected in shorter samples over the post-Bretton Woods period (Taylor 2003). The behaviour of our series indeed shows that both stationary and non-stationary data-generating processes may characterise the real exchange rate. In Figure 2, the time path of the real exchange rate of Norway could imply the existence of an underlying stationary process, as the krone seems to fluctuate around a long term average, whereas the exchange rates of Russia and Saudi Arabia seem subject to long-lasting shocks.

In **Table 1** we present the results of the formal unit root analysis of our series, applying three different tests. As unit root tests have low power and may fail to distinguish between a unit root process and a near-unit root process, we compare the results of the standard Augmented Dickey-Fuller (ADF) test with the null of non-stationarity and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test with the null of stationarity. In addition, we run a third test allowing for structural breaks in the series following Lanne et al. (2002), since these breaks may modify the outcome of standard unit root tests[12].

Overall, the unit root analysis of the real exchange rates produces results which are generally in line with our preliminary inspection. The three different tests produce coherent results for the real exchange rate of Norway, which appears to be a stationary process. The stationarity of the Norwegian krone is a rather unusual result for a currency with exchange rate flexibility - although to a certain extent limited in a large part of the sample - in a post-Bretton Wood sample. However, this result is consistent with other recent studies such as Akram

[12] All unit root tests include a constant. We also tested for the presence of a deterministic time trend in our series, which however has been rejected at standard significance levels. Tests on the first differences of the variables are not shown, but they all reject the hypothesis of the presence of a unit root. We therefore conclude that there are no I(2) variables in our sample.

(2006)[13]. Unit root tests also produce consistent results for the real exchange rate of Saudi Arabia, which appears to have a unit root in our sample[14]. However, for the real exchange of Russia, the three tests lead to different conclusions about the data generating process. The KPSS cannot reject the null of *stationarity* for the Russian rouble. In contrast, the ADF test cannot reject the null of *non-stationarity*, indicating the presence of a unit root. The real exchange of Russia has certainly a structural break in 1998 and the test of Lanne et al. (2002), which accounts for this break, also cannot reject the null of *non-stationarity*. Therefore, we conclude that the real exchange rate of Russia has most likely a unit root. However, since the results for Russia are not unequivocal and we have to model data with near unit root behaviour, we follow Chen and Rogoff (2003) and consider also the possibility that the series for the rouble is stationary.

The results from unit root tests of the other variables, productivity differentials and real oil prices, are easier to interpret. The productivity differentials that we have created for Norway and Russia are clearly non-stationary and, therefore we need to use them in first differences when regressing stationary variables or use them in levels with other non-stationary variables. The same conclusion applies to the real oil prices.

Table 1. Unit root tests

		lag length	KPSS H_0: x ~ I(0)	ADF H_0: x ~ I(1)	Lanne et al. H_0: x ~ I(1)
Real exchange rate					
	Norway	0	0.42	3.46**	3.15**
	Russia	0	0.17	2.77	2.64
	Saudi Arabia	0	1.71**	1.58	1.09
Productivity differential					
	Norway	1	2.02**	0.49	0.35
	Russia	0	0.90**	0.50	0.66
Real oil price					
	UK Brent	3	0.52**	1.88	1.41
	URAL	5	0.82**	0.24	0.21
	Dubai	3	0.53**	1.80	1.23

Notes: The table reports the absolute value of the statistics for the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) test for the null of stationarity in the series; the Augmented Dickey Fuller (ADF) test for the null of non-stationarity, and the Lanne et al. test for the null of non-stationarity allowing for structural breaks. The lag length for the ADF and Lanne et al. tests was chosen according to the Schwartz criterion. For the KPSS test we calculate the number of lags according to the following formula for quarterly data: 4(T/100)^1/4. Asterisks ** denote rejection of the null hypothesis at 5 percent level.

3. Empirical analysis

Following the literature on time series analysis, after having checked for the order of integration, we estimate three different models based on the different results

[13] Akram (2006) explores in a vector error correction model the convergence to purchasing power parity of the real effective exchange rate of Norway between 1970 and 2003 by disentangling it into its three components: the nominal exchange rate, domestic consumer price index and the weighted foreign consumer price index. He notes that deviations are primarily eliminated by adjustments in the nominal exchange rate within 1.5 years.

[14] The results for Saudi Arabia are in line with Dibooglu and Aleisa (2004).

concerning the underlying data-generating process. First, under the assumption of stationarity of the real exchange rate of Norway - and also Russia - we test whether the *change* in real oil prices and productivity differentials may help to explain the *level* of the real exchange rate. Second, under the assumption of non-stationarity of the real exchange rate of Russia and Saudi Arabia, we search for a long-run relationship with the real oil prices and the productivity differential, testing for cointegration and estimating a vector error correction model if we find evidence of a common stochastic trend. Finally, if we do not find evidence of cointegration among non-stationary series, we consider the possibility of an ordinary linear relationship between the first differences of the (non-stationary) variables[15].

3.1. REER as a stationary process

The first step of the empirical analysis is to test for a simple linear relationship between the level of the real effective exchange rate and the first differences of the real oil price. We are therefore testing whether the real exchange rate reacts to changes in oil price *inflation*. We also included the relative productivity differential as an explanatory variable (in first differences), but we do not report results of these estimations as the coefficients were always statistically insignificant. Similarly, we controlled for the impact of real interest rate differentials vis-à-vis OECD trading partners on the exchange rate of Norway. Also this control variable does not appear to be significant across the whole sample, but only over a sub-sample starting in the first half of the 1990s when Norway adopted a floating exchange rate regime (see Appendix B)[16]. Therefore, the equation that has been estimated and for which we report the results is the following:

$$REER_t = const. + \rho REER_{t-1} + \sum_j \gamma_j \Delta ROP_{t-j} + \varepsilon_t$$

where $REER_t$ is the log of the real effective exchange rate at time t, and ΔROP_t is the first difference of the log of the real oil prices at time t. We test for both the contemporaneous and lagged impact of the change in real oil prices on the exchange rate. **Table 2** reports the results of these simple OLS regressions for Norway and Russia, the two countries where we concluded – or could not exclude – that the real effective exchange rate is stationary. Results in **Table 2** are

[15] See also Hamilton (1994), p. 561-562, for a discussion on the cures for spurious regressions.

[16] In particular, we find that the lagged coefficient for the real (long-term) interest rate differential is positive, very small and statistically significant since 1993Q1, but not in the preceding period. These results for Norway are broadly in line with Akram (2003), who estimates various models for the exchange rate of the krone between 1972 and 2001. He confirms that the purchasing power parity model holds well for the krone over the long-run and that deviations from equilibrium are mainly corrected through changes in the nominal exchange rate. Indeed, he finds that both real oil prices and real interest rate differentials have low explanatory power for the real exchange rate. Therefore, he uses "nominal" interest rate differentials in order to gauge short-term movements in the "nominal" exchange rate. Indeed, other studies, such as Kloster at al. (2003) and Naug (2003) provide evidence that positive nominal interest rate differentials in Norway contributed to the nominal appreciation of the krone between mid-2000 and the beginning of 2003. Overall, in the case of Norway, interest rate differentials seem to be a significant potential explanatory variable only for short or medium term movements in the nominal exchange rate.

generally robust to the usual misspecification tests[17]. Only in the case of Russia are the residuals not normally distributed, even after the inclusion of a dummy variable accounting for the Russian crisis in 1998, but this depends on some volatility of the real exchange rate at the beginning of the sample and does not affect our results[18].

Table 2. Norway and Russia. Real effective exchange rates and real oil prices. Ordinary least squares

	Norway		Russia	
REER (-1)	0.807***	0.788***	0.874***	0.866***
	[0.061]	[0.059]	[0.054]	[0.056]
D(Real oil price)	**0.024**	**0.013**	**-0.068**	**-0.025**
	[0.017]	[0.016]	[0.054]	[0.063]
(-1)		**0.023**		**-0.159****
		[0.018]		[0.069]
(-2)		**-0.029***		**0.069**
		[0.016]		[0.068]
(-3)		**0.015**		**-0.043**
		[0.017]		[0.049]
(-4)		**-0.043*****		**0.120****
		[0.015]		[0.053]
const.	0.900***	0.992***	0.641**	0.678**
	[0.284]	[0.275]	[0.265]	[0.274]
Dummies			1998q3	
Adj. R-sq	0.64	0.64	0.93	0.94
No. obs.	106		46	
Sample period	1980q1-2006q2		1995q1-2006q2	

Notes: All variables are in logs. The dependent variable is the real effective exchange rates of Norway and Russia. White heteroskedasticity consistent standard errors are reported in square brackets. Regressions for Russia include spike dummies at 1998q3. Asterisks ***, **, and * denote significance at 1, 5, and 10 percentage levels.

In Norway, the results show that there is no contemporaneous impact of the change in real oil prices on the real exchange rate. The coefficient is indeed positive, but very small and not significantly different from zero. Moreover, looking at the lagged impact of changes in oil prices, we find that (i) some of the lags of the change in real oil prices are significant and enter with the negative signs and (ii) negative and positive signs alternate, with a greater impact of negative effects. Results for Russia are partially similar. As in the case of Norway, the contemporaneous effect of the change in real oil prices is not significantly

[17] The presence of serial correlation is rejected by Lijung-Box Q-statistics up to 20 lags. We account for some minor heteroskedasticity in the residuals reporting White robust standard errors. Chow, CUSUM and CUSUM-squared tests exclude structural breaks, apart from a break in 1998Q3 in Russia due to the currency crisis. The possibility of an incorrect functional form is tested and rejected by the standard RESET test. The normality of standardized residuals is tested through the usual Jarque-Bera test.

[18] Eliminating the first four quarters of data in the case of Russia, we obtain normal residuals and eliminate residual heteroskedasticity, however the main results do not change. For consistency reasons, we prefer to show the results with the complete sample.

different from zero, however, this time it enters with the negative sign. Again, we find an alternation in the sign of the coefficients for the lagged impact. The real exchange rate tends to depreciate over the very short run, as the coefficient for the first lag of the change in the real oil price is negative and significantly different from zero, but then appreciates after one year, as the coefficient for the fourth lag is of similar magnitude, positive and significantly different from zero.

A tentative interpretation of these results is the following. When real oil price inflation accelerates, this is interpreted as good news for an oil exporting country and may have a positive immediate impact on the nominal exchange rate, if this is flexible. However, the increase in oil prices fuels domestic inflation in the main trading partners of oil exporters, which are net oil importers. As a result, the price of the basket of consumer goods in the main trading partners relative to the oil exporting country tends to increase and the CPI-based real exchange rate of the oil exporting country tends to depreciate. Depending on the relative strength of changes in the nominal exchange rate and changes in the relative price levels, over the short run, the change in real oil prices may have either a negative or positive impact on the real exchange rate of oil exporters[19].

In particular, in the case of Russia, on the basis of the visual analysis in section 2, we could have expected a closer positive relationship between the two variables. Taking into account that there is evidence that the real exchange rate of Russia is an I(1) process, we therefore conclude that the change in the real oil price does not help to explain the level of the real exchange rate of the rouble and, in this case, it is necessary to proceed with the analysis of a potential cointegrating relationship between the level of the two variables. This is indeed the purpose of the next section.

3.2. REER as a non-stationary process

The second step of the analysis is to search for a potential cointegrating relationship between exchange rates and oil prices when the real exchange rate is indeed non-stationary as in the case of Saudi Arabia and, most likely, Russia. Evidence of cointegration would imply that the real oil price can adequately capture all the permanent innovations in the real effective exchange rate. For Russia, we also consider the role of the productivity differential in the adjustment of the real effective exchange rate to its equilibrium level, which may be particularly important for a transition country that has been subject to supply shocks. We first determine the number of cointegrating relations for Russia and Saudi Arabia. If we find evidence of cointegration, we then estimate a vector error correction model (VECM) and, in addition, we run some tests for weak exogeneity in order to control for the causal link running from oil prices to the exchange rate. In case of no cointegration, we estimate the model in first differences.

In order to determine the exact number of long-run relationships among the variables, it is first necessary to specify a vector autoregression (VAR) model.

[19] This is not in conflict with the theory, which assumes a positive impact of the real oil price on the real exchange rate. The positive impact should, presumably, emerge over the medium to long-run, once in particular domestic prices are allowed to adjust in the oil exporting country.

The lag order of the VAR model for each country has been chosen according to the Akaike or the Schwartz information criteria, after having checked for the absence of residual serial autocorrelation[20]. In the case of Russia, we account for the financial and currency crisis in August 1998 by including a break dummy. We specify the models for the two countries with a constant term in the cointegrating relation only, thus, not allowing for a linear trend[21]. After having specified the VAR model, we run two different tests in order to determine the cointegration rank of our systems of equations, which corresponds to the number of independent long-run stable relationships. The first test – the small sample corrected Johansen trace* test (Johansen 2000, 2002) – is a likelihood ratio test, which computes the Bartlett correction factor thus giving a better approximation of the finite sample distribution of the statistic. As a robustness check, we run another test, the Zt* test of Gregory and Hansen (1996), which extends the standard Philipps-Oularis (1990) Zt test for cointegration by allowing for structural shift of unknown timing in the cointegrating relationship.

Table 3. Russia and Saudi Arabia. Cointegration tests for real exchange rates and real oil prices.

		Trace* test			Zt* test
		(1)	(2)	(3)	(4)
		r=0	r≤1	r≤2	r=0
Russia	*without PROD*	44.52**	11.07		-5.62**
	including PROD	64.65**	31.95**	11.85	-5.94**
Saudi Arabia		7.69	3.23		-4.46

Notes: Columns (1), (2) and (3) provide the results for the small sample corrected Johansen trace test and (4) reports the Gregory and Hansen Zt* test. The critical values at 5% level for the Gregory and Hansen Z*t test are -4.61 and -4.92 for models with one and two regressors, respectively. Asterisks ** denote significance at 5% level.

Table 3 presents the results of the two cointegration tests for the real effective exchange rate, the real oil price and, in the case of Russia, the productivity differential[22]. The table reports the test statistics and their statistical significance at the usual 5 percent level, under different null hypotheses about the cointegrating rank *r*. In columns (1) and (4), we test the null of no cointegration (*r=0*) against the hypothesis of at least one cointegrating relation for the two Russian specifications and the model for Saudi Arabia. Columns (2) and (3) show

[20] The Schwartz information criterion has been preferred as it is more parsimonious in the lag structure. However, the increase in efficiency of this criterion comes at the cost of a higher probability of serial correlation in the residuals. We opted for the Akaike criteria and a richer lag structure when it was necessary to eliminate residual serial correlation. We always obtained well-behaved residuals, except for Russia in the specification including the relative productivity differential, where the hypothesis of normality has been rejected. The VAR including the real oil price and real effective exchange rate in Saudi Arabia was specified with four lags. For Russia, an asymmetric structure of up to four lags has been chosen for the three endogenous variables – real effective exchange rate, relative productivity, and real oil price – excluding the insignificant lags.

[21] As discussed in the section concerning the unit root analysis, there is no evidence of deterministic trends in our series.

[22] As noted in section 2.1, there are no available data to measure productivity in Saudi Arabia.

the trace* test results for the hypotheses of $r \leq 1$ against $r \geq 2$ and $r \leq 2$ against *r>2*, correspondingly. Only for Russia can we find at least one cointegrating relation in both specifications, since the null of no cointegration is always rejected at the 5 percent significance level[23]. However, according to the tests, in Saudi Arabia the real exchange rate does not seem to be cointegrated with the real oil price[24].

Indication of cointegration is a prerequisite for estimating the model in an error correction form. This procedure allows us to distinguish between stationarity created by linear combinations of the I(1) variables and stationarity created by differencing. Only in the case of Russia did we find evidence of cointegration, thus only for this country we continued specifying and estimating a vector error correction model in the following form:

$$\Delta y_t = \Pi y_{t-1} + \Phi D_t + \sum_{j=1}^{3} \Gamma_j \Delta y_{t-j} + \varepsilon_t ,$$

where $y_t = \left| REER_t, PROD_t, ROP_t \right|^T$ is a three or two-dimensional column vector of endogenous variables, depending on whether we included or excluded the productivity variable. D_t is a vector of deterministic exogenous variables (e.g. constant terms, intervention dummies), ε_t is the error term, and Δ is the difference operator. Γ_j is a matrix of the short-run dynamics, for which we consider up to three lags in differences; $\Phi = \alpha\gamma'$ consists of the coefficients for the deterministic terms. The number of cointegrating relationships corresponds to the rank of the matrix Π, the latter taking the form $\Pi = \alpha\beta'$. $\alpha = \left| \alpha_{REER}, \alpha_{PROD}, \alpha_{ROP} \right|^T$ describes an adjustment matrix, which shows the speed at which each endogenous variable reverts to its equilibrium level, and β is the matrix of cointegrating vectors, implying that some linear combination of the vector series $\beta_i' y_t$ is stationary for some non-zero vector β_i.

In **Table 4**, we report the long-run parameters of the estimated system given by the matrix Π after normalizing by the coefficient of the real effective exchange rate:

$$\tilde{\alpha}_{REER} \left(REER_{t-1} + \tilde{\beta}_2 PROD_{t-1} + \tilde{\beta}_3 ROP_{t-1} + \tilde{\gamma} const \right),$$

---

[23] The trace* test indicates two cointegrating relations for Russia in the augmented model including real oil price and relative productivity differential. However, one should take this result with caution as some of the standard residual assumptions have not been satisfied in this specification. Furthermore, trace tests tend to reject the null hypothesis of no cointegration in small samples. Johansen (2002) shows that as long as the number of parameters per observation, *kn/T* (with *k* equal to the number of VAR lags, *n* to the number of endogenous variables and *T* to the length of the sample), is less than 0.20, the test will give robust results. However, when using three variables, we obtain the value of 0.26 for the *kn/T* ratio, which is above the threshold for reliable estimates and may indicate the presence of small-sample bias. Thus, it seems preferable to use only one cointegrating vector, as the result is more robust.

[24] It is worth noting that if we cut the sample in 2001 at the onset of the latest oil price upswing which preceded the start of the US dollar depreciation, the results for Saudi Arabia change and we are then able to detect the presence of cointegration between the real exchange rate of the riyal and the real oil price.

where $\widetilde{\alpha}_{REER} = \alpha_{REER}\beta_{REER}^{-1}$, $\widetilde{\beta}_i = \beta_i\beta_{REER}^{-1}$, and $\widetilde{\gamma} = \gamma\beta_{REER}^{-1}$. The results clearly show that the Russian rouble could indeed be classified as an "oil currency", since the elasticity of the real exchange rate to the oil price over the long-run is, as expected, positive, relatively large and highly significant[25]. Whenever international oil prices double in value, the real exchange rate appreciates by 30 to 55 percent. The coefficient for productivity differential is also positive and significant. If the relative productivity differential doubles the real exchange rate is expected to almost double as well. Thus, in Russia, the Balassa-Samuelson effect seems to play an important role in driving the real effective exchange rate along with the real oil price, with the coefficient of the latter remaining positive and significant also in the second augmented specification. This is not surprising as Russia is a transition economy on its way to catch up with its developed trading partners. Therefore, one should expect the productivity growth in Russian tradable sector to be higher compared to foreign countries, thus increasing the domestic relative price of non-tradables and leading to an appreciation of the real exchange rate.

Table 4. Russia. Vector error correction model of the real exchange rate

Real oil price	**0.55*** **	**0.29*** **
	[0.041]	[0.051]
Producitivity differential		**0.82*** **
		[0.192]
Constant	6.08***	5.63***
	[0.083]	[0.087]
Error correction (alpha)	**-0.375*** **	**-0.528*** **
	[0.050]	[0.070]
Half-life of deviations	**1.5Qs**	**1Q**
No. obs.	46	46
Sample period	95Q1- 06Q2	95Q1 - 06Q2

Notes: Asterisks *** denote significance at 1% level. Standard errors are given in square brackets. The half-life of deviations is calculated by the following formula: ln (0.5) / ln (1- |alpha|).

Besides identifying the cointegrating vector, it is important to control for the causal relationship between the variables. If a variable is weakly exogenous when estimating the elements of the cointegrating vector, then the corresponding element of α (the speed of adjustment of this variable to the long-run equilibrium level) will be zero. Therefore weak exogeneity of the real exchange rate (the real oil price or the relative productivity differential) can be tested by testing the null of $\alpha_{REER} = 0$ ($\alpha_{ROP} = 0$ or $\alpha_{PROD} = 0$). The test statistic asymptotically distributes as a χ^2. The rejection of the null of weak exogeneity for one particular variable

[25] In order to check whether our model is well specified we test whether the assumptions of parameter constancy are holding in both models. Therefore, we estimate the models recursively, as suggested by Dennis et al. (2005), and perform two main tests, fluctuation test of the eigenvalues of the cointegrated vectors and recursively calculated trace test statistic. Both tests perform remarkably well, thus accepting the null hypothesis of parameter stability.

implies that this variable adjusts in response to deviations from the long-run equilibrium. In our case, one would expect the real effective exchange rate to be endogenous, and the real oil price and the productivity differential to be weakly exogenous to the system. This hypothesis is indeed supported by the empirical evidence, since the null of weak exogeneity is strongly rejected by the test only for the real exchange rate and, instead, is not rejected for the real oil price and the productivity differential (see **Table 5**).

Table 5. Russia. Test of weak exogeneity

Null hypothesis:		Including productivity
α (REER) = 0	26.09**	10.95**
α (ROP) = 0	1.72	0.00
α (PROD) = 0		0.23

Notes: The table shows the test statistic for the null of weak exogeneity against the alternative of endogeneity. Asterisks ** denote rejection of the null at the 5% significance level.

The coefficient α_{REER}, negative and highly significant, represents the error-correction term in the system. From its value – 0.375 in the model without productivity and 0.528 in the model with productivity – it is possible to derive the half-life of deviations from the equilibrium following exogenous shocks to the real exchange rate. In this case, the Russian rouble needs only between one and one and half quarters to dissipate half of the shock, depending on whether the model includes or excludes productivity differentials, respectively[26]. This is a remarkably rapid adjustment when compared to standard PPP models estimating half-life of shocks to the real exchange rate of more than three years in industrial countries. We are going to discuss the implications of this result in greater details in the next section.

Finally, it is necessary to complete the analysis of the real exchange rate in Saudi Arabia. In this case, the cointegration tests in Table 3 did not indicate any long-run stationary relationship between the real exchange rate of the riyal and oil prices. However, this does not exclude the possibility of a relationship between the two variables. However, since the variables are integrated of order one, it is necessary to use their first differences in order to avoid spurious regressions. **Table 6** reports the results of the regression:

$$\Delta REER_t = const. + \sum_j \gamma_j \Delta ROP_{t-j} + \varepsilon_t$$

The equation has been estimated through ordinary least squares, accounting for all usual misspecification tests. There is some evidence of a positive impact of the change in real oil prices on the change in the real exchange rate after two quarters. However, the magnitude of this impact is very small (0.06) and the change in oil prices explains only a tiny part of variation in the real

[26] It is possible to compute the half-life of deviations of the real exchange rate as a response to exogenous shocks of shocks according to the following formula: $\ln(0.5)/\ln(1-|\alpha_{REER}|)$.

exchange rate, with an adjusted R-squared equal to 0.03 (see second column in Table 6).

Table 6. Saudi Arabia. Real exchange rate and real oil price in first differences. Ordinary least squares

D(Real oil price)	**-0.002**	**0.010**
	[0.026]	[0.026]
(-1)		**0.010**
		[0.026]
(-2)		**0.06****
		[0.026]
Constant	-0.009**	-0.008**
	[0.004]	[0.004]
Adj. R-sq	0.00	0.03
No. obs.	106	106
Sample period	1980Q1 - 2006Q2	1980Q1 - 2006Q2

Notes. The dependent variable is the real effective exchange rate of Saudi Arabia in first differences. Standard errors are reported in square brackets. Asterisks ** denote significance at 5% level.

4. Accounting for the findings

The empirical investigation of the relationship between oil prices and the exchange rate produced mixed results. In this section, we attempt to summarise these results, elaborate their implications in terms of the Purchasing Power Parity (PPP) theory and account for the institutional features that may help to explain different results across our three countries.

First, it is evident that there is not a *"one size fits all"* model for the real exchange rate for our three countries and that only in Russia is it possible to identify a robust long-run relationship between the exchange rate and oil prices. In Russia, there is strong evidence of non-stationarity of the real exchange rate once one accounts for the structural break in the series in 1998. The cointegration analysis finds evidence of a long-run relationship between the real exchange rate and real oil prices, which is robust to the inclusion of productivity differentials as an additional explanatory variable. The productivity differential relative to the main OECD trading partners plays a significant role in the determination of the rouble real effective exchange rate, thus, accounting for the Balassa-Samulson effect, a common feature of exchange rates in transition economies. In the case of Norway, the real exchange rate is stationary and changes in the real oil price have only a very marginal impact after a few lags. The interpretation of the significant negative sign of some of the lags is not straightforward, therefore raising doubts about the robustness of this relationship. Finally, in Saudi Arabia, the real exchange rate is not stationary, but does not share any common stochastic trend with the real oil price. A model in first differences, estimated through ordinary least squares, detects a very small positive impact of the change in the real oil price on the change in the real exchange rate. Considering the small value of this parameter, the economic implications of this result do not seem particularly meaningful.

Second, the PPP puzzle – i.e. the high degree of persistence of shocks to the real exchange rate – is absent in two out of our three countries: Norway and Russia[27]. If we estimate a standard autoregressive model of order one, AR(1), of the real exchange rate, we may calculate the so called *half-life* of deviations from PPP measuring how many periods the real exchange rate would need to absorb half of an exogenous shock, according to the formula: $\ln(0.5)/\ln \rho$, where *rho* is the AR(1) parameter. This coefficient is rather low in the case of Norway, around 0.80, slightly higher in the case of Russia once the 1998 crisis is accounted for, 0.88, and finally approaching the unit root in the case of Saudi Arabia, 0.98. Correspondingly, the speed of reversion of the real exchange rate to its long-run mean, as measured by the *half-life* of deviations, is relatively fast in the case of Norway, only three quarters, slower in Russia, around one and a half year, and very slow in Saudi Arabia, more than six years. It is worth noting that the *half-life* in Norway and Russia is much smaller than the consensus estimates of three to five years for the real exchange rates of industrial countries (see Taylor, 2003). In addition, in the case of Russia, we have been able to specify a well-behaved vector error correction model and compute a speed of adjustment of only three to five months, when including oil prices and productivity differentials. In other terms, by controlling for the influence of real oil prices and productivity on the real exchange rate, the persistence of real exchange rate shocks in Russia decreases from 18 to less than five months.

Third, we wonder whether the exchange rate regime may help us explain the different results of the empirical analysis. We already noted that the three countries adopted diverse exchange rate arrangements, with Norway and Russia granting some more flexibility compared with Saudi Arabia, which has anchored the riyal to the US dollar since the 1980s (see section 2.1). However, the implications of these regimes for the actual behaviour and volatility of the nominal *effective* exchange rate are rather surprising. **Figure 3** shows the (log) nominal effective exchange rate of the three countries. Contrary to what one would have expected, the Norwegian krone is more stable than the Saudi riyal[28]. Indeed, for most of the 1980s and 1990s, Norway targeted the German mark and then the ECU, therefore stabilising the nominal exchange rate against its main trading partners. The relative stability of the *nominal* effective exchange rate translates into a relative stability of the *real* effective exchange rate around a long-run mean, thus, generating the stationarity of the latter, as oil price shocks do not seem to matter. On the contrary, the peg of the Saudi riyal to the US dollar does not reflect the direction of trade of Saudi Arabia. The United States is indeed an important trading partner of Saudi Arabia, but accounts for only 14 to 17 percent of Saudi Arabia's total trade (see table in Appendix C). As a result, the nominal

[27] Rogoff (1996) provides a succinct and effective description of the PPP puzzle: "How can one reconcile the enormous short-term volatility of real exchange rates with the extremely slow rate at which shocks appear to damp out?".

[28] The coefficient of variation – the ratio of the standard deviation to the mean – of the Saudi riyal, 2.9%, is twice as large as that of the Norwegian krone, 1.4%.

effective exchange rate of the Saudi riyal reflects the fluctuation of the US dollar - to which it is pegged - against the currencies of the other main trading partners. In Saudi Arabia, the real effective exchange rate follows the non-stationary path of the US dollar real rate and is not influenced by the oil price.

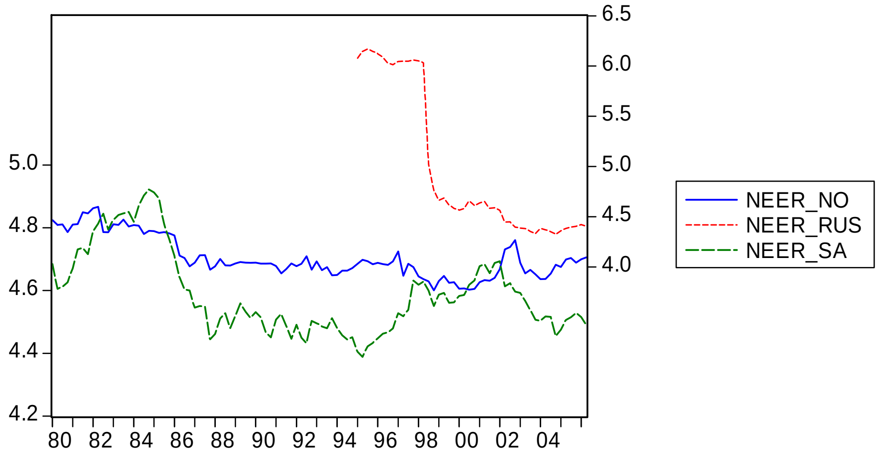

Figure 3. Nominal effective exchange rates in Norway, Russia and Saudi Arabia

Finally, **Figure 3** shows that the *nominal* effective exchange rate of Russia did not appreciate after the 1998 crisis and did not react to the upswing in the oil price from the trough in 1999. The relative nominal flexibility of the rouble does not contribute to the absorption of the positive oil shock by the real exchange rate, which instead takes place through changes in relative prices. Indeed, inflation in Russia has been much higher than in its main trading partner and the *real* exchange rate has been increasing in line with the real oil price (see figure 2 in section 2.1).

Why has the real exchange rate of Norway been insulated by oil price shocks? Why are consumer prices not increasing in Saudi Arabia in spite of a depreciating nominal effective exchange rate since 2002 and a booming economy driven by the rise in oil prices? Why, instead, in Russia, has the real exchange rate been appreciating in line with rising oil prices? The exchange rate regime alone cannot help to answer these questions without considering the monetary policy reaction to oil shocks and the role of the public sector in "sterilising" the impact of rising oil prices on the domestic economy, in particular, through the accumulation of oil revenues in sovereign wealth funds and foreign assets. Other country-specific institutional features may also matter.

Differently from the oil shocks of the 1970s, in the last decade oil producing countries raised domestic public saving and increased the pace of accumulation of net foreign assets, setting up in many cases separate sovereign wealth funds to manage these foreign assets[29]. In this way, the authorities aimed at spreading the benefits of volatile oil revenues through time and different

[29] An analysis of the different macroeconomic responses of these economies to the oil shocks of the 1970s and the most recent one goes beyond the scope of this paper. For more details see for instance IMF (2006).

generations. To the extent that oil revenues are invested abroad, that they are not converted in domestic currency and do not reflect a readily available increase in the wealth of the current generations, the impact of higher oil prices on the domestic economy and on the real exchange rate may remain muted[30]. A closer look at the behaviour of the net foreign assets of the monetary authorities and their impact on monetary growth in our three countries shows that the "sterilisation" of oil revenues may indeed represent a potential explanation of the lack of reaction in the real exchange rate of Norway and Saudi Arabia to the recent upsurge in oil prices.

Net foreign assets and base money in Norway, Russia, and Saudi Arabia are reported in **Table 7**. The net foreign assets of the Norges Bank are consolidated with the assets of the Global Pension Fund – former Global Petroleum Fund - which was set up at the beginning of the 1990s and started to accumulate the proceeds of oil revenues since 1996. The balance sheet of the Central Bank of Russia also included – at least until 2006 – the foreign assets of the Oil Stabilisation Fund, which started in 2004. In Saudi Arabia, there is no separate wealth fund and the proceeds of higher oil revenues show up among the assets of the Saudi Arabian Monetary Agency. In the balance sheets of the various monetary authorities, these foreign assets are wholly or partly matched by domestic currency liabilities to the government, or governments' agencies, and in this way "sterilised"[31].

Focussing in particular on the developments since the mid-1990s, which encompass the largest oil price shock in our sample, **Table 7** reveals that "high-powered" monetary growth in Norway has not been affected by higher oil prices, whereas the net foreign assets of Norwegian monetary authorities surged to almost 100 percent of GDP in 2006 – most of it accounted by the assets of the Global Pension Fund – almost 26 times larger than base money. It is therefore no surprise that higher oil prices in Norway do not have an impact on domestic prices and the Norges Banks has been able to achieve its inflation target. As the nominal exchange rate does not seem to have incorporated expectations of further appreciation, the real exchange rate does not co-move with the real oil price[32].

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[30] In the literature, net foreign assets are included among the potential determinants of real exchange rates (see for instance Lane and Milesi-Ferretti, 2004). There are however two sets of problems with the inclusion of this variable in our investigation: an empirical and a theoretical one. First, the inclusion of net foreign assets as an explanatory variable in time-series models of the real exchange rate is often not very robust, since the former variable moves slowly and is less volatile than real exchange rates. In technical terms, net foreign assets are often I(2) variables, which should be regressed with I(0) or I(1) variables. In addition, we could not get a complete dataset of quarterly data for this variable. Second, in the case of oil exporting countries, where those net foreign assets are managed and largely sterilised by the public sector, the wealth effect that should lead to an increase in the real exchange rate is weak or absent, unless one would assume perfect Ricardian behaviour of private agents.

[31] Usually, the term "sterilisation" refers to open market operations in domestic bonds or the issuance of central bank bills to mop up the excess liquidity in the markets resulting from the increase in foreign exchange reserves. However, in our three countries, this is not the case and larger net foreign assets are mainly "sterilised" by increasing government deposits at the central bank.

[32] As noted in section 3.1, differential in real interest rates vis-à-vis Norway's main trading partners seem to matter in the short run during the flexible exchange rate period, in particular explaining the temporary nominal appreciation of the krone since 2000.

Table 7. Net foreign assets of the monetary authorities (NFA) and base money

	1980	1990	1995	2000	2006	1980-89	1990-99	2000-06
	% of GDP (unless otherwise indicated)					*Average annual % growth rate*		
Norway [1]								
NFA (incl. GPF)	9.2	11.5	14.1	37.4	94.4	12.6	17.8	24.2
Base money	7.3	4.6	4.9	4.7	3.7	4.6	10.5	1.9
NFA to money (ratio)	*(1.3)*	*(2.5)*	*(2.9)*	*(7.9)*	*(25.8)*	-	-	-
Russia [2]								
NFA	-	-	3.5	7.1	29.9	-	na[3]	57.8
Base money	-	-	9.0	10.0	15.4	-	35.6[4]	33.5
NFA to money (ratio)	-	-	*(0.4)*	*(0.7)*	*(1.9)*	-	-	-
Saudi Arabia [5]								
FA	52.8	48.5	32.6	26.0	64.5	-2.6	-4.0	28.9
Base money	6.3	12.0	10.3	9.7	8.5	2.2	3.4	8.4
FA to money (ratio)	*(8.4)*	*(4.0)*	*(3.2)*	*(2.7)*	*(7.6)*	-	-	-

Sources: IMF, International Financial Statistics and Norges Bank. Notes. [1] Net foreign assets of the monetary authorities including the Global Pension Fund (GPF) - former Global Petroleum Fund - which is managed by the Norges Bank and included as a separate item in the Bank's balance sheet. As of 2006, the foreign assets of the GPF amounted to USD 285 billion or 79 percent of GDP and were matched by krone deposits at the Norges Bank. [2] The net foreign assets of the Central Bank of Russia include the assets of the Oil Stabilisation Fund which has been created in 2004. Until 2006 the rouble denominated counterpart of the foreign assets of the Fund were deposited by the Ministry of Finance in an unremunerated account at the Central Bank of Russia. [3] In both 1998 and 1999, the Central Bank of Russia recorded negative net foreign assets as a consequence of the financial crisis. This prevents the calculation of a meaningful growth rate up to 1999. [4] Starting from 1995. [5] Foreign assets of the Saudi Arabian Monetary Agency.

Similar to the case of Norway, in Saudi Arabia the net foreign assets of the monetary authorities surged from 26 percent of GDP in 2000 to 65 percent of GDP in 2006 and from three times the size of base money to almost eight times over the same period. Reserve money does not seem to have been fully "insulated" as monetary growth accelerated from an average annual rate of 4 percent in the 1990s to around 8 percent since 2000, without having any major impact on domestic inflation so far. The explanation of these subdued inflationary pressures rests on the peculiar institutional features of the Saudi economy, which is characterised by a very flexible labour market, a very elastic labour supply curve, owing to the inflow of migrant workers, and by regulated and subsidised prices preventing the consume price index from increasing.

Finally, as already noted, since 1999 the real exchange rate appreciation of the Russian rouble took place mainly through an increase in domestic prices and not through nominal appreciation. This was mainly due to the interventions of the Russian monetary authorities in the foreign exchange market, which led to a surge in net foreign assets from 7 percent of GDP in 2000 to 30 percent of GDP in 2006. These interventions have been only partially sterilised, leading to a strong expansion of domestic money supply, which increased at an average annual rate of more than 30 percent, in turn contributing to persistent inflationary pressures[33].

[33] After the financial crisis, in Russia, inflation declined from more than 20 percent in 2000 to around 10 percent in 2006, remaining above the level of its main trading partner. It should be

Summing up, different exchange rate regimes may not help in explaining whether or not the relationship between the real oil price and the real exchange rate holds in practice. Irrespective of the exchange rate regimes, other factors may interfere and neutralise the transmission of shocks to the real exchange rate. These include specific policy responses to volatile oil revenues, monetary policy interventions which modify the specific combination of changes in relative prices and the nominal exchange rate which are necessary to restore the equilibrium and other institutional features. In the case of Norway, the exchange rate regime underwent a number of modifications, with full exchange rate flexibility being introduced only over the last few years, thus complicating any possible interpretation of the impact of these regimes over the long-run. At the same time, over the past decade, Norway "sterilised" the impact of higher oil revenues on the domestic economy and the real exchange rate through the massive accumulation of net foreign assets. In Russia, instead, the oil shock has been transmitted to the real exchange rate through a partial sterilisation of oil revenues and an adjustment in price levels. In Saudi Arabia, the "sterilisation" of oil revenues, as well as the presence of flexible labour markets and price subsidies, may have played an important role in breaking the relationship between oil price and the real exchange rate.

5. Conclusion

In this paper we studied the real effective exchange rates of three oil exporting countries: Norway, Russia and Saudi Arabia. In particular, we investigated whether the real exchange rate reacts to movements in the real price of oil. In addition, we controlled for the possible role of productivity differentials against 15 OECD trading partners in explaining exchange rate fluctuations. We find that the Russian rouble can be defined as an "oil currency", since the real effective exchange rate seems to share a common stochastic trend with the real oil price. This relationship is robust to the inclusion of the productivity differential as an explanatory variable, which appears to be an important determinant of the real exchange rate in Russia, a transition economy. Due to the relatively short sample for Russia, it is necessary to take this conclusion with some caution and possibly test it again over a longer time-span in the future. On the contrary, we find no – or at best a very marginal – impact of the real oil price on the real exchange rates of Norway and Saudi Arabia. In general, there is not sufficient evidence to maintain that the diverse exchange rate regimes of these countries may account for the different empirical results on the impact of oil prices. However, different policy responses to volatile oil revenues – such as the accumulation of net foreign assets and their sterilisation – and specific institutional characteristics may account for the different behaviour of the real exchange rate and interactions of changes in relative prices and nominal exchange rates in these countries.

noted that part of the monetary growth accommodated the rising demand for roubles as the Russian economy went through a process of de-dollarisation.

Appendix A. Theoretical Framework

In this appendix we sketch the theoretical framework underlying our empirical investigation. The model determines the real exchange rate to be a function of terms of trade and relative productivity between the non-traded and traded sectors of trading partners. The model is a standard small open economy adopted from Cashin et al. (2004).

We consider a small open economy, *O*, which is composed of two different sectors: the one associated with the production of a primary commodity as an export tradable good, and the other producing a non-traded good. This country trades the domestic commodity production with the rest of the world against imports of final manufactured goods. Since crude oil is the primary commodity of interest in this work, we keep to the wording "oil", "crude oil" and "petroleum", henceforth. Firms in both sectors work in a perfect competitive environment and have access to constant returns to scale technology. Labour is fully mobile and the only input factor for both traded and non-traded goods. As a result, wages are equalized across sectors. Households supply labour inelastically and derive utility from the consumption of the non-traded good produced at home and the imported good. Consequently, we describe algebraically the oil exporter's economy and the rest of the world so that, eventually, we can define the real exchange rate of the oil producing country. To focus on the long-run factors behind real exchange rate movements, a simple static framework is adopted.

A.1. The oil producing country

In this subsection we describe the supply and demand sides of the economy of the oil exporter.

A.1.1. Firms

As mentioned above, the economy consists of two sectors: the one producing crude oil and the other which consists of a continuum of firms producing a non-traded good. Since the representative firm in both sectors employs similar technology, profit maximisation problems are identical:

$$\max_{L_i^O} \Pi_i = P_i^O Y_i^O - w^O L_i^O ,$$

$$\text{s.t.} \quad Y_i^O = \alpha_i^O L_i^O ,$$

where index *i* can take the notation of either *N* (non-tradable sector) or *X* (export tradable sector), L_X^O is the amount of labour demanded in the petroleum sector, and L_N^O – in the non-traded one. Firms in sector $i = N, X$ maximize revenues $P_i^O Y_i^O$, where Y_i^O stands for output, net of labour costs $w^O L_i^O$ by using technology $\alpha_i^O L_i^O$; α_i^O captures the labour productivity in the production of good *i*. Crucially, due to free labour movement, wages (w^O) are equalized across sectors. Profit optimization in the non-tradable and tradable sectors yields the following conditions: $P_N^O = w^O / \alpha_N^O$ and $P_X^O = w^O / \alpha_X^O$, respectively, where P_N^O is the price of the non-tradable good and P_X^O the nominal price of crude oil.

Since in equilibrium the marginal productivity of labour must equal the real wage in each sector, and under the assumption of exogeneity of the nominal oil price, we can rewrite the price of the non-traded good as follows:

$$P_N^O = \frac{\alpha_X^O}{\alpha_N^O} P_X^O . \tag{1}$$

Thus, productivity differential between the export and non-traded sector of the economy is the only determinant of the relative price of non-tradables in terms of oil (P_N^O / P_X^O). Hence, an increase in the price of oil will raise the wage in that sector leading to a rise in the wage and price level of the non-traded sector.

A.1.2. Households

A continuum of identical households maximise their utility over the consumption of the non-traded good produced domestically and the *imported* tradable good. The petroleum good is consumed exclusively abroad. Furthermore, households supply labour inelastically ($L^O = L_X^O + L_N^O$). Thus, the representative household is characterised by Cobb-Douglas preferences and solves the following utility problem under the wealth constraint:

$$\max_{C_N^O, C_T^O} U^O = \left(C_N^O\right)^{\gamma} \left(C_T^O\right)^{1-\gamma}$$

$$\text{s.t. } P_N^O C_N^O + P_T^O C_T^O = W ,$$

where C_N^O is consumption in country *O* of domestic non-tradables, $\left(C_T^O\right)$ – of traded goods imported from abroad. Composite consumption $C^O = \kappa \left(C_N^O\right)^{\gamma} \left(C_T^O\right)^{1-\gamma}$ is an aggregate of C_N^O and $\left(C_T^O\right)$ with $\kappa = \dfrac{1}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}}$ being a constant. The household is assumed to cover its expenses by utilising its total wealth *W*. The consumer price index of the oil producing country, which is obtained by solving the optimization problem above, is a geometric average, with weights γ and $1-\gamma$, of the prices of tradables and non-tradables:

$$P^O = \left(P_N^O\right)^{\gamma} \left(P_T^O\right)^{1-\gamma} , \tag{2}$$

where $\left(P_T^O\right)$ is the price in local currency of one unit of the tradable good imported from a foreign region *D*, which will be discussed in the next subsection. Under the assumption that the law of one price holds for tradables and, hence, for the imported good, then $P_T^O = P_T^D / E$. Here, we define E to be the nominal exchange rate expressing country *D*'s currency for one unit of country *O*'s currency; $\left(P_T^D\right)$ is the price of tradable goods in region *D*.

A.2. Foreign region

In the last subsection we showed that households in the oil producing country consume beside the domestic non-traded good a traded good imported from abroad. At the same time, total production of crude oil is exported and utilized exclusively abroad. Here, we will present the foreign region.

A.2.1. Foreign firms

The economy of the foreign region *D* consists of three sectors: non-traded (*N*) and traded sectors (*T*), and a third one (*I*) producing an intermediate good. Labour is the only input in the production of the intermediate and non-traded goods; the technology for their production is given by $Y_I^D = \alpha_I^D L_I^D$ and $Y_N^D = \alpha_N^D L_N^D$, respectively. Moreover, the non-traded good is consumed only in the foreign region. Thus, the profit maximization problems of the firms in the non-traded and intermediate good sectors are identical with the optimization problems of the firms in the oil producing country. The first order conditions yield for the price of non-tradables and for the price of intermediate goods in the foreign region the following: $P_N^D = \frac{w^D}{\alpha_N^D}$ and $P_I^D = \frac{w^D}{\alpha_I^D}$. Similarly, as in the oil exporting country, due to wage equalisation across sectors, we can express the price of non-tradables in terms of the price of intermediate goods:

$$P_N^D = \frac{\alpha_I^D}{\alpha_N^D} P_I^D . \tag{3}$$

The firms producing the final traded good involve two production factors in the manufacturing process. The first is crude oil imported from several oil producing countries, including country *O*. The second is an intermediate good. The foreign firms produce the final traded good $\left(Y_T^D\right)$ by assembling the foreign intermediate input $\left(Y_I^D\right)$ and the petroleum good $\left(Y_X^D\right)$. Eventually, their profit maximization problem looks slightly more complicated:

$$\max_{Y_X^D, Y_I^D} \Pi_T = P_T^D Y_T^D - \left(P_X^D Y_X^D + P_I^D Y_I^D\right),$$

$$\text{s.t.} \quad Y_T^D = \nu \left(Y_I^D\right)^{\beta} \left(Y_X^D\right)^{1-\beta},$$

where $\nu = \frac{1}{\beta^{\beta}(1-\beta)^{1-\beta}}$ is a constant. The solution to the problem yields the cost of a unit of the tradable good, expressed in terms of the foreign currency, as a geometric average of the intermediate good and petroleum good prices: $P_T^D = \left(P_I^D\right)^{\beta} \left(P_X^D\right)^{1-\beta}$.

A.2.2. Foreign households

Consumers in the foreign country are assumed to consume their nontraded good and this final good in the same fashion as consumers in the oil exporting country. Labour market arrangements are the same and, therefore, the consumer price index of country *D* can be represented by:

$$P^D = \left(P_N^D\right)^{\gamma} \left(P_T^D\right)^{1-\gamma} . \tag{4}$$

A.3. Real exchange rate determination

The discussion of the domestic economy (i.e. of the oil producing country) and the foreign region was necessary so that we can show now how the real exchange rate is determined for the oil exporter. We define the real exchange rate of the oil producing economy as the foreign price of the oil exporting country's basket of consumption (EP^O) relative to the foreign region's price of the consumption basket of the latter (P^D): EP^O/P^D. E denotes the nominal exchange rate of country O expressed as the number of foreign currency units per domestic currency unit. Thus, an increase in E means that the domestic currency appreciates, since one should pay a larger number of foreign currency units to get just one domestic currency unit. Using equations (1) to (4) we can determine the real price of country O as a function of terms of trade and productivity differentials:

$$\frac{EP^O}{P^D} = \left(\frac{\alpha_X^O}{\alpha_I^D} \frac{\alpha_N^D}{\alpha_N^O} \frac{P_X^D}{P_I^D} \right)^{\gamma}, \tag{5}$$

where the last term (P_X^D / P_I^D) – the relative price of crude oil exports in terms of imports expressed in the foreign country currency – denotes terms of trade of the oil exporting country O. Algebraically, an increase in terms of trade will lead to real currency appreciation. The two productivity differentials, i.e. the first two ratios, can account for the Balassa-Samuelson effect, which implies that the domestic currency will experience real appreciation if its productivity-growth advantage in tradables exceeds its productivity growth advantage in non-tradables against its trading partners.

Appendix B.

Real effective exchange rate in Norway. Ordinary least squares

	Full sample	Fixed rate	Floating rate
REER (-1)	0.815***	0.762**	0.731***
	[0.060]	[0.097]	[0.086]
D(Real oil price)	**0.024**	**0.014**	**0.038**
	[0.016]	[0.020]	[0.025]
D(Productivity)	**-0.242**	**-0.295**	**0.019**
	[0.016]	[0.255]	[0.258]
Real int. rate differential (-1)	**-0.0000**	**-0.002**	**0.009*** **
	[0.001]	[0.001]	[0.003]
const.	0.867***	1.117**	1.249***
	[0.279]	[0.455]	[0.398]
Adj. R-sq	0.64	0.54	0.64
No. obs.	106	52	54
Sample period	1980q1-2006q2	1980q1-1992q4	1993q1-2006q2

Notes: All variables are in logs except for the real interest rate differential. The dependent variable is the real effective exchange rate of Norway. Explanatory variables include the real oil price (in first differences) the productivity differential vis-à-vis the main 15 OECD trading partners (in first differences) and the first lag of the real interest rate differential (in level) vis-à-vis the same OECD trading partners. Interest rates are long term government bond yields from IMF IFS (line 61) deflated by CPI inflation. Asterisks ***, **, and * denote significance at 1, 5, and 10 percentage levels. All results are robust to the usual misspecification tests for serial correlation, heteroskedasticity and normality of residuals, functional form and stability.

Appendix C. Data

Trade Weights

	Norway		Russia		Saudi Arabia	
	(1)	(2)	(3)	(4)	(5)	(6)
	1980-1984	2001-2005	1995-1999	2001-2005	1980-1984	2001-2005
Australia	0.40	0.19	0.11	0.09	1.38	1.57
Canada	1.21	3.58	0.31	0.26	0.84	0.73
Denmark	4.91	5.13	0.59	0.56	0.27	0.20
Finland	2.81	2.47	3.32	3.25	0.39	0.22
France	3.09	8.22	2.33	2.80	7.23	3.59
Germany	16.41	12.34	9.76	10.12	5.42	3.36
Italy	1.98	2.95	4.35	6.15	6.13	3.05
Japan	2.96	2.19	2.84	2.47	21.57	13.48
Korea	0.65	0.86	1.10	1.36	2.45	7.88
Netherlands	4.67	8.06	3.96	5.08	3.82	2.82
Spain	0.58	1.85	0.68	1.08	2.39	1.71
Sweden	12.93	10.58	1.23	1.47	1.14	0.69
Switzerland	1.09	0.67	3.42	3.05	0.81	0.76
United Kingdom	26.22	15.94	3.38	3.46	3.91	3.11
USA	6.22	7.48	7.49	6.29	13.91	16.90
% of total trade	86.12	82.52	44.85	47.51	71.67	60.07

Notes: Columns (1) and (2) report trade volumes between Norway and each of its 15 OECD trading partners as a ratio of Norwegian overall trade with the world. Columns (3) and (4) and columns (5) and (6) do the same for Russia and Saudi Arabia, correspondingly. All values are created as arithmetic averages of five consequent years. The last line in the table summarizes the ratio of trade with the 15 OECD partners to total trade of Norway, Russia and Saudi Arabia for each of the periods considered.

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