

## On the Impact of Dollar Movements on Oil Currencies

Gabriel Gomes

### Highlights

- We find evidence to support the existence of oil currencies on the long term.
- We show that dollar movements have a nonlinear impact on the relationship between the real price of oil and the real exchange rate of oil exporting economies.
- In the short term, oil currencies exist only if the dollar appreciation is lower than 2.6%.



## Abstract

This paper investigates to which extent dollar real exchange rate fluctuations explain the unexpected divergent movement between the real exchange rate of oil exporting countries and the price of oil in certain periods. Estimating a panel cointegrating model for 11 OPEC and 5 major oil exporting countries over the 1980-2014 period, we find evidence to support they have oil currencies in the long term. In fact, a 10% increase in the price of oil leads to a 2.1% appreciation of their real exchange rate. To analyse how swings on the dollar exchange rate affect the co-movement between the two variables in the short run, we rely on a non-linear approach and estimate a panel smooth transition regression model. Results show that, in the short term, oil currencies move in concert with the price of oil only if the dollar appreciation is lower than 2.6%. After the dollar appreciates beyond this threshold, the real exchange rate of oil exporting economies is rather negatively affected by the price of oil.

## Keywords

Oil Price, Oil Currencies, Non-linearities.

## JEL

C33, F31, Q43.

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RESEARCH AND EXPERTISE  
ON THE WORLD ECONOMY



# On the impact of dollar movements on oil currencies

Gabriel Gomes<sup>\*</sup>

## 1 Introduction

In oil exporting countries, the evolution of the price of oil is one, if not the most, important factor to be considered in economic policy decisions. These economies, whose GDP and exports are dominated by petroleum, may face costly and persistent macroeconomic instability when they fail to find optimal responses to oil price shocks. The comprehension of how their economies are affected by oil fluctuations is therefore essential for the effectiveness of policy actions. In this context, the real exchange rate has been a macroeconomic indicator of particular interest among scholars and policymakers because it measures the competitiveness of a country and offers a fair perception about its economic weight relative to the rest of the world. The economic literature has identified a co-movement between the price of oil and the real exchange rate of oil dependent economies which have 'oil currencies'.<sup>1</sup>

Empirical studies overall covering the 1975-2007 period find evidence to support that OPEC and other oil exporting countries have oil currencies in the long term (Korhonen and Juurikala, 2007; Coudert et al., 2008). Nevertheless, the expected co-movement between the two variables does not seem to be continuous over time. As a matter of fact, in some periods both series evolve in opposite directions. For example, during the 1980-1985 period the price of oil has fallen around 46% in real terms and the real exchange rate of OPEC members has appreciated by 48%. The same phenomenon can be seen during some years of the 1990's and the 2000's. More precisely, after the financial crisis the oil price has showed an upwards trend that does not seem to be accompanied by a real exchange rate appreciation in the corresponding exporting countries. West Texas Intermediate (WTI), for instance, has decreased around 15% in real terms from 2011 to 2014, while

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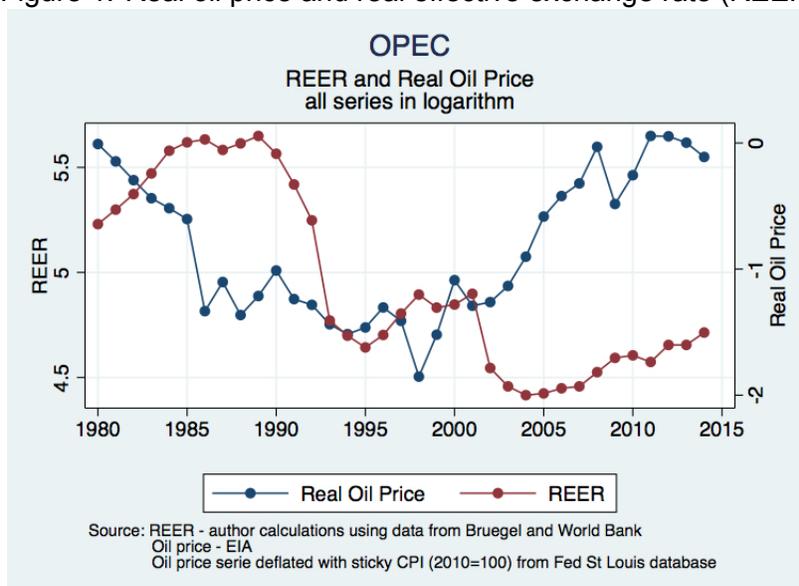
I would like to thank Valérie Mignon, Natacha Valla, Sébastien Jean, and the participants of the CEPPI internal seminar for their relevant comments and suggestions that helped me improve this paper.

<sup>1</sup>Chen and Rogoff (2003) introduce the term 'commodity currency' in the literature referring to the co-movement between the price of the commodity exported by a country and its real exchange rate. Following this terminology, oil dependent economies should have 'oil currencies'.

over the same period the real exchange rate of OPEC members has appreciated by 15%.<sup>2</sup>

For policymakers this may be a problem. In fact, the widely spread rule of thumb for oil exporting economies entails that oil price fluctuations spill over their exchange rate, which tend to appreciate after an oil price increase and to depreciate after a price decrease. Hence, following this guideline they should implement policies to appreciate their currencies after a negative shock in the price of oil (i.e. to sell their foreign reserves) in the interest of stabilizing their exchange rate. However, if the pressure of a negative oil shock goes rather on the opposite direction - appreciating the domestic currency - such measures would only exacerbate the instability of their exchange rate.

Figure 1: Real oil price and real effective exchange rate (REER)



Two different fields of the literature lead our economic intuition towards the dollar real exchange rate as a possible element to explain the divergent behavior of oil currencies in some periods. The first field concerns applied works that have identified long and short-term relationships between the dollar and the oil price (Armano and van Norden, 1998b; Coudert et al., 2008, Lizardo and Mollick, 2010, Reboredo et al., 2014). The second strand of literature studies the choice of the exchange arrangement in emerging countries (Husain et al., 2005; von Hagen and Zhou, 2007; Coudert et al., 2013). In fact, due to network externalities or to optimize transaction costs, oil exporting economies tend to manage their nominal exchange rates often pegging to some extent their currencies against the dollar. Therefore, since the dollar affects both the real exchange rate of

<sup>2</sup>Nominal WTI price deflated by the US sticky CPI (2010 = 100) retrieved from St. Louis Fed database. Real exchange rate series extracted from Bruegel's database. What we call the OPEC real exchange rate is a GDP weighted average of all OPEC countries real exchange rates excluding Iraq.

oil exporting economies and the price of oil, it is plausible to believe that its movements can modify the link between these two variables.

Swings in the dollar real exchange rate have different effects on oil exporting and importing countries. A weak dollar increases the purchasing power in oil importing economies (except the USA), while having an opposite effect in oil exporting countries. Conversely, a strong dollar may adversely affect oil importing countries leading to a demand shock in the long term that ultimately affects oil exporting countries (Kilian, 2009; Reboredo, 2012). This paper aims to measure beyond which appreciation rate the dollar can be considered strong enough to change the relationship between oil currencies and the price of oil.

To achieve our goal we proceed in two steps. First, considering a sample of 16 oil exporting countries over the 1980-2014 period, we estimate the cointegrating relationship between their real exchange rate and the price of oil thus measuring the oil currency - oil price nexus. Then, we estimate a panel smooth transition regression (PSTR) model to assess how dollar swings affect the short-run dynamics of their real exchange rates. The PSTR is a nonlinear specification that groups the observations in different regimes according to the value of a chosen (transition) variable, in our case, the dollar real exchange rate variations. The PSTR estimation shows that the short term dynamics of oil exporting countries' real exchange rate is affected by dollar fluctuations. In fact, we find that shocks in the price of oil have a positive significant impact on oil economies' real exchange rate only if the dollar real exchange rate appreciation is lower than 2.6%. After the dollar appreciation exceeds this threshold value, we find an inverse relationship between the two variables.

Our contribution to the existing literature is twofold. First, it updates previous work on oil currency and confirms their existence on the long term. Second, it offers a deeper understanding of oil currencies that can be valuable for economic policy decisions.

This paper is structured as follows. Section 2 reviews the existing literature on oil currencies. Section 3 describes the data and offers some graphical insights. Section 4 performs all the compulsory econometric tests, estimates the cointegrating relationship and the error-correction model. Section 5 introduces and estimates the PSTR model. Section 6 concludes.

## **2 Oil currencies**

### **2.1 Theoretical overview**

Theoretically, the connection between the price of oil and the real exchange rate has been explored in different frameworks. We can identify a first set of studies developed by Krugman (1983) and Golub (1983) that focus on the links between the US dollar and oil price from a somewhat wealth transfer perspective.

Krugman (1983) considers the world is divided in three areas: the United States, Germany and OPEC. The first two sell goods and services to each other while OPEC only sells oil at a price

that is assumed exogenously fixed in dollars. There are only two assets in this model: dollars and marks; OPEC allocates their wealth between the two. The author uses a dynamic partial equilibrium model that allows distinguishing short and long run impacts, and thus between financial and real approaches, respectively. In the short run, the effect of an oil price increase depends on the US share in the global oil imports compared to the percentage of dollar assets held by OPEC. If American oil imports have a higher share than the dollar assets in OPEC's portfolio, then an increase in the price of oil will depreciate the dollar exchange rate. In the long run, the impact is determined by the weight of oil in the US total imports with regards to the share of OPEC total imports from the US. If US trade balance with OPEC is positive, then an oil price increase would benefit OPEC imports from the US, which would depreciate the dollar exchange rate in the long term.

Golub (1983) also assumes that the world is divided in three areas: OPEC, the US and the European Union. The model considers the US dollar and the Deutsch mark as the only two financial assets and studies the effects of oil price shocks on wealth transfer and consequently on portfolio equilibrium. The impact oil price movements have on exchange rates depends on the way wealth reallocation increases or decreases the overall demand for dollars. If OPEC has a preference for holding dollars, an oil price increase is followed by a dollar appreciation as the extra revenues would be allocated in dollar assets.

In this paper, we rely on another set of models that leans on a terms of trade perspective to connect the real exchange rate of an oil exporting economy with the price of oil.<sup>3</sup> More precisely, we consider the theoretical framework developed by Cashin et al. (2004).<sup>4</sup> This model finds its inspiration in the works of Neary (1988), De Gregorio and Wolf (1994) and Obstfeld and Rogoff (1996), among others, that use quasi-similar frameworks where the economy is composed of two sectors: one producing a tradable good, and the other producing non-tradable good. Labor is supposed to move freely and nominal wages are the same across sectors. In this context, better terms of trade leads to an increase in wages in the tradable goods sector, which translates in higher non-traded goods price, thus appreciating the domestic currency in real terms.

Baxter and Kouparitsas (2000) explore the sources of terms of trade volatility considering two main components: a 'goods-price effect' and a 'country-price effect'. The former refers to a country that exports one basket of goods, imports a different basket and has its terms of trade fluctuations driven by international changes in the price of the goods it exports. The 'country-price effect' concerns fluctuations of a country's terms of trade that arise from different selling prices of a same good in different countries. They find that for fuel products exporters most of the terms of trade variation come from goods-price effects. Based on this evidence, in this paper we proxy the terms of trade of oil exporting countries by the real price of crude oil.<sup>5</sup>

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<sup>3</sup>Terms of trade are defined as the price of a country's exports relative to the price of its imports.

<sup>4</sup>The model is fully presented in Appendix A.1.

<sup>5</sup>They consider 16 fuel exporters: Algeria, Congo, Ecuador, Egypt, Gabon, Indonesia, Kuwait, Mexico, Nigeria, Norway, Saudi Arabia, Syria, Trinidad and Tobago, Tunisia, United Arab Emirates and Venezuela; in a total of 100 countries.

## 2.2 Empirical overview

Empirically, the relationship between terms of trade and the real exchange rate has been tested and proved for many energy and non-energy commodity exporting countries. Here, we will focus on the literature related to oil exporters. Overall, empirical studies on the dynamics of the real exchange rate explained by the price of oil can be classified in two categories: 1) studies relying on time-series data offering a country-by-country analysis; 2) studies using panel data features allowing to deal with limited sample sizes.

### 2.2.1 The country-by-country approach

A country-by-country analysis enables to estimate the real exchange rate for each country separately, hence considering the specificities of each individual economy.

In this context, Spatafora and Stavrev (2003) use quarterly data to model the dynamics of the Russian ruble real exchange rate over 1995-2002. Aside with the nominal price of oil they also include productivity differentials and a post 1998 crisis dummy as explanatory variables, finding a positive long run elasticity for the oil price of around 0.31. Koranchelian (2005) and Zalduendo (2006) estimate the oil currency – real oil price nexus in, respectively, Algeria over 1970-2003, and Venezuela over 1950-2004. The long run elasticity of the real oil price on the Algerian dinar is equal to 0.20, while for the Venezuelan bolívar it varies according to the real exchange rate used: 1.04 under official rates and 0.44 under parallel market rates. Habib and Kalamova (2007) explore the connections between the price of oil and the dynamics of three oil exporting countries' currencies: the Russian ruble, the Norwegian krone and the Saudi Arabian riyal. They use quarterly data from 1980 to 2006 for Norway and Saudi Arabia; and from 1995 to 2006 for Russia. They find that only the ruble and the real price of oil follow a common stochastic trend which coefficient is equal to 0.29 in the short run.

Mehara and Oskoui (2007) rely on a SVAR approach to study the sources of macroeconomic fluctuations over 1970-2002 in four oil exporting countries: Iran, Indonesia, Kuwait and Saudi Arabia.<sup>6</sup> Their results show that in Indonesia and Saudi Arabia an oil price boom leads to an appreciation of the real exchange rate in the long run, whereas in Iran and Kuwait the real exchange rate tends to depreciate. Authors suggest this unexpected effect may be associated with the Kuwait's structural reforms and 'oil revenue fund', while in Iran this might be due to exchange restrictions and import controls.

Nevertheless, the aforementioned literature and results should be interpreted carefully. As a matter of fact, the majority of these studies deal with short length series due to scarce data and political breaks (i.e. Russia). A time series approach may, therefore, offer distorted results on the magnitude of the link between the price of oil and the real exchange rate of oil exporting countries.

<sup>6</sup>For Kuwait and Saudi Arabia the covered periods are, respectively, 1972-2002 and 1971-2002.

### 2.2.2 The panel data approach

More recent and sophisticated studies have investigated the oil currency – oil price nexus from a panel data perspective in order to overcome the problem of short time series.

Korhonen and Juurikala (2007) estimate the real exchange rate dynamics in a panel of nine OPEC countries over 1975-2005 and three CIS countries over 1993-2005 and find statistically significant effect of the price of oil on their exchange rates (0.40 for OPEC and 0.50 for CIS). Coudert et al. (2008) consider 16 oil exporting countries over 1980-2007 and find an impact of around 0.22 of the real oil price on these countries' real effective exchange rate. Dauvin (2014) analyses a group of 10 energy exporting countries over 1980-2011, finding a 0.28 elasticity of the terms of trade on their real exchange rate.<sup>7</sup>

## 3 Data and stylized facts

This section introduces our empirical study by discussing about possible control variables that could be incorporated to our model, then it presents the econometric framework, the data used and the preliminary econometric analysis.

### 3.1 Exchange-rate determinants

Apart from terms of trade and productivity differentials, a wide range of variables has been used for explaining exchange rates.<sup>8</sup> Considering data availability, two control variables were added to our empirical analysis: government spending (*gov*) and the degree of economic openness (*open*).<sup>9</sup>

First, variables related to the fiscal stance and monetary policy considerations are often included as determinants of the real exchange rate, because they reflect the domestic economic environment. In this context, government spending relative to GDP is one variable typically included in such regressions. In the short to medium run, if the marginal propensity of the public sector to spend on non-traded good is higher than the one from the private sector, a positive impact of government spending on the real exchange rate is likely to occur. For oil exporting countries this seems plausible since in these countries government sector's spending on infrastructure, for instance, is mainly satisfied by domestic inputs. Therefore, a rise in government spending could positively affect the

<sup>7</sup>The 10 energy exporting economies are: Australia, Colombia, South Africa, Algeria, Iran, Nigeria, Saudi Arabia, Venezuela, Canada and Norway.

<sup>8</sup>See MacDonald (2000) for a detailed overview.

<sup>9</sup>On a macroeconomic balance perspective, the foreign indebtedness of a country is often assumed to be an important exchange rate fundamental (Alberola et al., 1999). This latter can be captured by a country's net foreign asset position, which is too incomplete for the oil exporting economies considered in this paper. For that reason, we decided not to include it in our model.

real exchange rate via higher demand for non-traded goods. In the long term, however, higher government spending, in particular if kept unbalanced, may lead to economic distortions undermining the market's confidence in the domestic currency thus having a negative impact on the exchange rate.

Second, some studies suggest that variations on the degree of a country's economic openness should influence its exchange rate dynamics.<sup>10</sup> There are, nevertheless, arguments in favor of both a positive and a negative impact of the economic openness on the real exchange rate of a country. On the one hand, the more open to trade a country is, the less it relies on protection and distortions to its external accounts: hence increasing the openness should enhance the country's economic performance and lead to an appreciation of the real exchange rate. On the other hand, greater openness to foreign trade may lead to a real depreciation if lower tariffs on imports or taxes on exports are applied (Edwards, 1994), which is more likely to be the case in oil exporting economies.

### 3.2 Sample

We consider yearly data from 1980 to 2014 for 16 countries among which 11 are OPEC members and 5 are major oil exporting countries. The OPEC members are: Algeria, Angola, Ecuador, Iran, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela. The other countries are: Bahrain, Congo, Gabon, Norway and Oman. Over 2000-2010 they were responsible for on average 60% of the world's total crude oil exports.<sup>11</sup>

In the countries included in our analysis, crude oil accounts for a large part of the total exports, and its rents represent an important share of the GDP. Additionally, their terms of trade ( $ToT$ ) and the real price of oil ( $roil$ ) they export are highly correlated. Table 1 illustrates the importance of oil exports to their economies.<sup>12</sup>

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<sup>10</sup>See Kim and Korhonen (2005), for instance.

<sup>11</sup>According to the EIA statistics.

<sup>12</sup>Five other countries fit our criteria: Iraq, Syria, Russia, Azerbaijan and Kazakhstan; but could not be included for the following reasons. Most of the variables used in our study did not exist for Iraq. Syria has been going through political instabilities since 2010. Russia, Azerbaijan and Kazakhstan have reliable data only after 1995, as most of the econometric features we use rely on lags and leads, thus depending on series with at least 30 years of observations, we prefer not to include them.

Table 1: Selected oil exporting countries

Average values between 2000 - 2010

	fuel exports (% total exports)	oil rents (% GDP)	correlation ( $\Delta l.roil$ ; $\Delta l.ToT$ )
Algeria	97.36	17.38	0.87
Angola*	94.15	55.24	0.77
Bahrain	66.91	17.63	0.92
Congo*	77.37	63.29	0.83
Ecuador*	51.73	18.14	0.83
Gabon*	76.92	45.22	0.81
Iran*	79.69	30.48	0.98
Kuwait	94.51	49.41	0.98
Libya*	97.24	49.97	0.97
Nigeria*	94.71	30.41	0.92
Norway	64.24	12.30	0.93
Oman	83.62	37.54	0.89
Qatar	85.89	23.91	0.93
Saudi Arabia	89.55	43.58	0.98
United Arab Emirates*	74.72	18.79	0.97
Venezuela*	87.94	27.84	0.97

\* countries with incomplete data.

For Angola fuel exports share was calculated over 1990-1991.

Source: World Bank - World Development Indicators and St Louis Fed

### 3.3 Data

The real effective exchange rate (*reer*) series are extracted from Bruegel's database.<sup>13</sup> The *reer* of a given country is calculated as a weighted average between its nominal bilateral exchange rate and that from its trading partners, adjusted to its price movements relative to that of its trading partners. An increase in the *reer* means an appreciation of it.

The real price of oil (*roil*) is the annual average of the spot oil price in dollars used as benchmark by an exporting country deflated by the sticky American CPI from St. Louis Fed database, which excludes energy and food prices in its calculation.<sup>14</sup> For Bahrain and Oman, we use the price of

<sup>13</sup> Available at: <http://www.bruegel.org/datasets/>; we use the *reer* calculations based on 67 trading partners.

<sup>14</sup> Available at: <http://research.stlouisfed.org/fred2/series/CPILFESL#>

Dubai retrieved from the IFS database.<sup>15</sup> For Norway, Congo and Gabon the oil price is the one from Brent, which is provided by the EIA.<sup>16</sup> Finally, for OPEC countries the oil price used is the one from the OPEC basket and comes from OPEC database.<sup>17</sup>

The productivity differential or Balassa-Samuelson effect ( $bs$ ) is proxied by the PPP GDP of the concerned country relative to its trading partners. We construct the weights for each trading partner following the same countries used in Bruegel's *reer* calculations, allowing for a consistent measure of our variable. PPP GDP and GDP data are extracted from IFS database.

The control variables -  $gov$ ,  $open$  - were extracted from World Bank World Development Indicators and updated for 2014 using IMF FM report.<sup>18</sup> General government expenditure,  $gov$ , includes all government current expenditures for purchases of goods and services (including compensation of employees). It also includes most expenditures on national defense and security, but excludes government military expenditures that are part of government capital formation. The degree of economic openness,  $open$ , is proxied by the sum of exports and imports of goods and services measured as a share of gross domestic product.

## 4 Estimating the impact of the real price of oil on the real exchange rate

### 4.1 Panel unit root and cointegration tests

#### 4.1.1 Cross-sectional dependence in oil exporting economies

As a first step, we must determine if our variables are correlated across countries in order to choose the appropriate set of panel unit root tests to be performed in the next subsection. In our case, this test is meaningful since OPEC, which composes half of our panel, is believed to influence the oil market at a world level.

In this context, we perform the error cross-sectional dependence test (CD) proposed by Pesaran (2004). This test is based on an average of pairwise correlation coefficients of OLS residuals from individual regressions and is robust to single and multiple structural breaks in the slope coefficients and the error variances of individual regressions. Results are displayed in Appendix A.2 and indicate that the null hypothesis of cross-section independence is strongly rejected for all time series. Moreover, the correlation coefficients are rather high.

<sup>15</sup> Available at: <http://www.opendataforafrica.org/IMFPCP2014Jan>

<sup>16</sup> Available at: [http://www.eia.gov/dnav/pet/pet\\_pri\\_spt\\_s1\\_d.htm](http://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.htm)

<sup>17</sup> Available at: <http://www.opec.org/library/Annual%20Statistical%20Bulletin/> Prior to 1983 we use the price of Brent as benchmark. From 1993 to 2007 we use the WTI as Ecuador's oil price because during this period the country was not an OPEC member. For Gabon from 1980 to 1994 we use the same benchmark price as OPEC, since the country was also a member of the organization.

<sup>18</sup> For the United Arab Emirates (1980-1998), Qatar (1985-1989) and Libya (1985-1989) we completed missing points in  $gov$  and  $open$  series using, respectively, investment data's trend and autoregressive models.

### 4.1.2 Panel unit root tests

In the presence of cross-section dependence, the so-called first generation panel unit root tests – that rely on the cross-section independence assumption – tend to reject the null hypothesis of unit root excessively.<sup>19</sup> Therefore we perform two second generation unit root tests: Choi (2002) and Pesaran (2007). The former test relies on an error-component panel model and eliminates the cross-section dependence by removing both individual and time trend effects. The second test is based on the mean of individual ADF t-statistics, eliminating the cross-section dependence by a single factor model that augments the ADF regression with the lagged cross-sectional mean and its first difference of the individual series (CADS statistics).<sup>20</sup> Results are summarized in Appendix A.3 and lead us to conclude that all series are I(1).

### 4.1.3 Panel cointegration tests

As a third step, we apply panel cointegration tests that reveal whether there is a linear combination of our series with time invariant properties, meaning they follow a common stochastic process. We perform Westerlund (2007) panel cointegration test, which has the null hypothesis of no cointegration, to all the other variables that are I(1). The test offers two main advantages: 1) it allows for a large degree of heterogeneity, both in the long run relationship and in the short run dynamics of the error correction model; 2) it is designed to handle cross-sectional dependent data through bootstrapping of the test statistics. Results are shown in Appendix A.4 and confirm that all series are cointegrated.<sup>21</sup>

## 4.2 The cointegrating relationship

We draw an empirical model based on Cashin et al. (2004) and on the literature on exchange rate determinants. Thus, our econometric framework assumes that, in the long term, the real effective exchange rate (*reer*) of an oil exporting country is driven by: the real price of oil (*roil*) it exports, its tradable sector relative productivity (*bs*), its government spending (*gov*) and its economy degree of openness (*open*), the last two variables being expressed in terms of GDP percentage.

The long-term specification is therefore:

$$l.reer_{it} = \mu_i + \gamma_1 l.roil_{it} + \gamma_2 l.bs_{it} + \alpha_1 gov_{it} + \alpha_2 open_{it} + \varepsilon_{it} \quad (4.1)$$

<sup>19</sup>See Hurlin and Mignon (2006) and Hurlin (2010) for a detailed review of panel unit root tests.

<sup>20</sup>The lag length considerably influences the test results. We determine the optimal number of lags by two approaches: AIC criterion and Newey and West's (1994) plug-in procedure.

<sup>21</sup>We select the optimal number of leads and lags in order to minimize the Akaike's Information Criterion. We run the tests with constant and trend, no constant or trend, and with constant but no trend. We also consider the robust p-values obtained after bootstrapping using 250 replicates in order to avoid misleading inference in case of cross-member correlation.

where  $x_{it}$  is a variable for country  $i$  on year  $t$  with  $l.x_{it} = \ln(x_{it})$ ;  $\mu_i$  accounts for individual effects and  $\varepsilon_{it}$  is the error term.

Our series being I(1) and cointegrated, we begin by estimating Equation (4.1). To this end, we rely on the Panel Dynamic OLS (DOLS) procedure proposed by Kao and Chiang (2000) and Mark and Sul (2003). This procedure involves a parametric adjustment to the errors of the static regression, which is achieved by assuming that there is a relationship between the residuals from the static regression and first differences of leads, lags and contemporaneous values of the explanatory variables in first differences.<sup>22</sup>

The estimated cointegrating relationship with the estimators p-values in parentheses is given by:

$$l.re\hat{e}r_{i,t} = \hat{\mu}_i + \underset{(0.00)}{0.21} l.roil_{i,t} + \underset{(0.03)}{0.14} l.bs_{i,t} + \underset{(0.07)}{0.33} gov_{i,t} - \underset{(0.00)}{0.74} open_{i,t} \quad (4.2)$$

As expected, the real price of oil is significant at the 1% level, supposing that the real exchange rate should appreciate by roughly 2.1% after a 10% increase in the price of oil. This estimated coefficient is very close to the one calculated by Coudert et al. (2008) equal to 0.22. The productivity differential variable is significant at the 5% level and has a positive impact on the real exchange rate. The real exchange rate is also influenced by the government spending and the economic openness. The coefficient of the first variable is significant at the 10% level and has a positive impact on the real exchange rate. The last variable is significant at the 1% level and has a negative sign. As we discussed in subsection 3.1, this negative elasticity is coherent with oil exporting economies because they usually import most of the goods consumed domestically. Furthermore, our model explains 79% of the variations in the real exchange rate.

### 4.3 Estimation of the error-correction model

The existence of a cointegrating relationship between our variables allows us to estimate an error-correction model (ECM). To this end, we calculate the error-correction term as the difference between the observed real effective exchange rate and its equilibrium value given by the cointegrating relationship, lagged from one period:  $z_{i,t-1} = l.reer_{i,t-1} - l.re\hat{e}r_{i,t-1}$ . Results are the following with the estimators p-values in parentheses:

$$\Delta l.re\hat{e}r_{i,t} = \underset{(0.00)}{-0.16} z_{i,t-1} + \underset{(0.20)}{0.04} \Delta l.roil_{i,t} + \underset{(0.26)}{0.15} \Delta l.bs_{i,t} - \underset{(0.56)}{0.69} \Delta gov_{i,t} - \underset{(0.00)}{0.71} \Delta open_{i,t} \quad (4.3)$$

<sup>22</sup>OLS estimates of Equation (4.1) have biased distributions that depend on the nuisance parameter corresponding to the serial correlation properties of the data. We also estimate Equation (4.1) using the Fully-Modified OLS (FMOLS) procedure proposed by Phillips and Hansen (1990). Results are very similar, even though, this last may suffer from higher size distortion when compared to the DOLS method.

As expected, we find a negative and significant coefficient for the error-correction term, implying a mean reverting process. More precisely, if the estimated real exchange rate in the previous period is lower (higher) than its observed value, then the real exchange rate will decrease (increase) in the current period, adjusting 16% of its misalignment every year. Except for the economic openness, the other variables do not have a significant impact on the real exchange rate short run dynamics. As our theoretical model establishes, the real price of oil and the productivity differential have an impact over the real exchange rate through the wage channel. Based on this, a fair assumption to explain our results is that wages do not accommodate changes in the price of oil or productivity differentials in the short run. The same applies to a rise in government spending, which translates into higher demand for non traded goods, thus impacting the real exchange rate rather in the long run. Finally, the degree of economic openness, as discussed in subsection 3.1, is expected to affect the real exchange rate through the imports channel, which is likely to be variant in the short run.

## 5 Investigating non-linearities in the short term dynamics

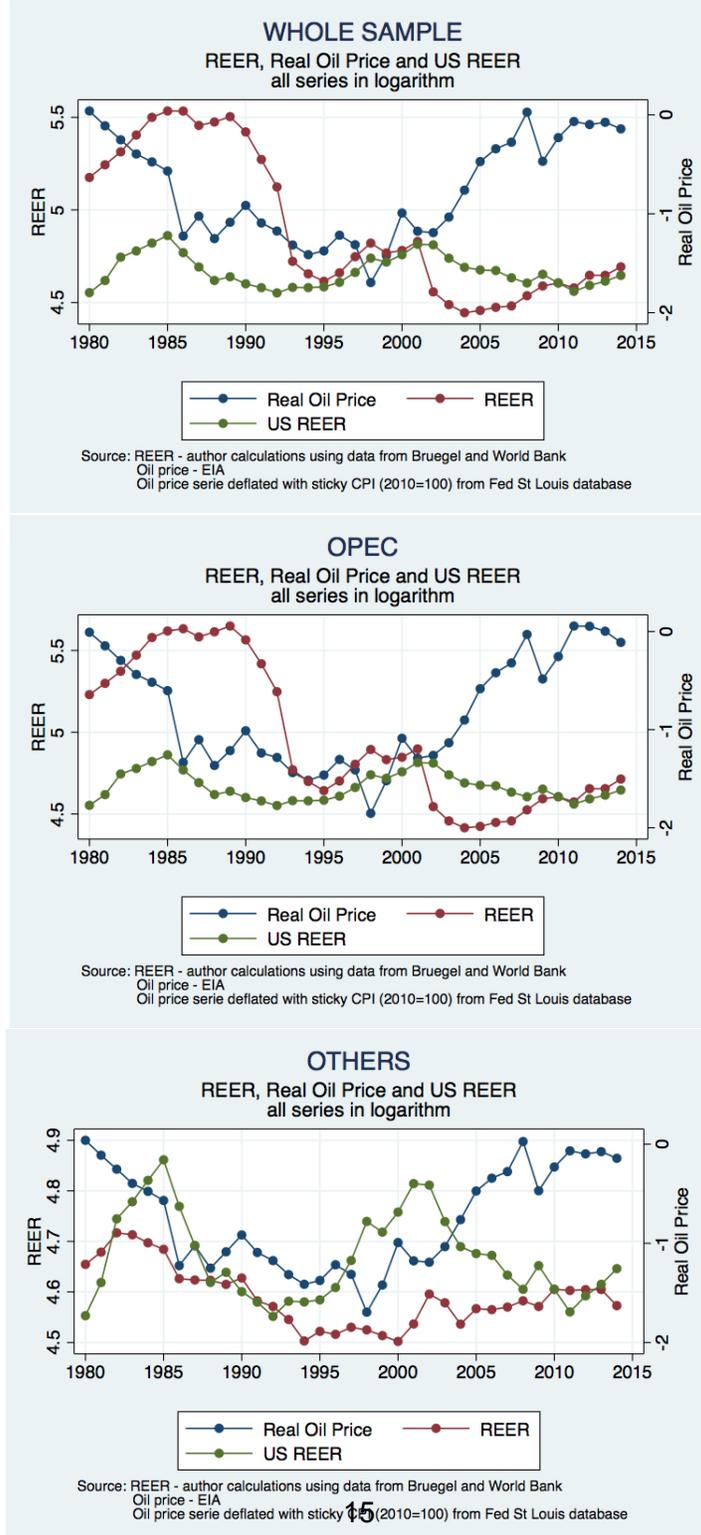
### 5.1 Graphical evidence

Figure 2 gives a first insight of the impact of dollar movements on the relationship between oil prices and the exchange rate of oil exporting economies.<sup>23</sup> To obtain a group level representation of the real exchange rate evolution, we calculate a GDP weighted average of it. The first graph includes the real exchange rate of all 16 countries, the second only considers OPEC members and the third illustrates the other 5 major oil exporters.<sup>24</sup> Overall, the real effective exchange rate tends to co-move with the real price of oil. It is easier to suggest that both series share a common trend before 2000. After that, the connection between the two variables becomes less explicit on the graphs. Nevertheless, the two series tend to evolve in opposite directions when the dollar exchange rate shows a somewhat steep upwards trend, suggesting that the later may exert a non-linear impact on the two variables.

<sup>23</sup>Graphs for individual countries can be provided upon request to the author.

<sup>24</sup>Due to the fact that more than 2/3 of our countries are OPEC members, the first and the second graphs are very similar.

Figure 2: Oil economies' real exchange rate, the real price of oil and the US real exchange rate



## 5.2 The PSTR framework

The Panel Smooth Transition Regression (PSTR) model, presented by González, Teräsvirta and van Dijk (2005), is a fixed effects model with exogenous regressors, which is useful for describing heterogenous panels with time-varying coefficients across individuals. It consists in grouping the observations in different regimes (usually 2) according to the value of a transition variable. The framework is a generalization of the threshold panel model developed by Hansen (1999), and its main feature is that the transition from one regime to another may occur smoothly.

The basic PSTR model with two extreme regimes can be written as follows:

$$y_{i,t} = \mu_i + \beta_1' x_{i,t} + \beta_2' x_{i,t} g(s_{i,t}; \gamma, c) + u_{i,t} \quad (5.1)$$

where the transition function,  $g(s_{i,t}; \gamma, c)$  is a continuous function that is normalized to be bounded between 0 and 1;  $s_{i,t}$  is the transition variable that triggers the shift from one regime to another when it reaches a certain threshold value,  $c$ ; the speed of adjustment from one regime to another is determined by  $\gamma$ .

The transition function for a two regimes PSTR model is:

$$g(s_{i,t}; \gamma, c) = [1 + \exp(-\gamma(s_{i,t} - c))]^{-1} \quad (5.2)$$

with  $\gamma > 0$ . The described model implies that the two regimes are associated with low and high values values of  $s_{i,t}$ .

Furthermore, González et al. (2005) propose a three-steps strategy for estimating PSTR models. In the first step, which concerns the specification of the model, we test for the null hypothesis of linearity using the LM-test statistic provided by the authors along with Fisher and LRT statistics. This step is also important for selecting the most relevant transition variable and the number of regimes.<sup>25</sup> The second step estimates the model with nonlinear least squares (NLS), after individual effects  $\mu_i$  are eliminated by removing individual-specific means. Finally, in the third step, we evaluate the validity of the model by applying misspecification tests.

We start by specifying our error-correction model in a non-linear form as follows:

$$\Delta l.reer_{it} = \mu_i + (\theta_1 z_{i,t-1} + \beta_1' X_{i,t}) + (\theta_2 z_{i,t-1} + \beta_2' X_{i,t}) g(q_{i,t}; \gamma, c) + \varepsilon_{i,t} \quad (5.3)$$

Where  $X_{i,t}$  represents the vector of real exchange rate determinants in first difference, namely,  $\Delta l.roil_{i,t}$ ,  $\Delta l.bs_{i,t}$ ,  $\Delta gov_{i,t}$ ,  $\Delta open_{i,t}$ , and  $\beta$  is a vector of coefficients associated to each one of the variables according to the regime, which is indexed, respectively, by 1 or 2. Depending on the value of the transition variable, the link between  $\Delta l.reer_{i,t}$  and its drivers switches from  $\theta_1$  and  $\beta_1$  in Regime 1 to  $\theta_2$  and  $\beta_2$  in Regime 2; with  $\theta_1 + \theta_2$  and  $\beta_1 + \beta_2$  the total coefficients value after the threshold value is exceeded.

<sup>25</sup>From an empirical perspective, it is sufficient to capture the presence of non-linearities to first consider the existence of a maximum of 3 regimes and then test for the existence of 2 regimes.

### 5.3 PSTR estimation results

We apply linearity tests considering two transition variables: the real effective exchange rate of the dollar retrieved from the same database as our countries' and the dollar index, which measures the value of the U.S. dollar relative to its most significant trading partners.<sup>26</sup> For both variables test results strongly reject the null hypothesis of linearity.<sup>27</sup>

Table 2 shows the PSTR estimation results. Regardless of the transition variable chosen, we observe that the transition occurs slowly, the estimated coefficients and the threshold have close values. Regime 1 coincides with a depreciating or slightly appreciating dollar, whereas Regime 2 corresponds to an appreciating dollar. First, let us analyze the estimated coefficients in Regime 1. Opposite from Equation (4.3), except for  $b_s$ , their coefficients are statistically significant, whereas, their signs are in line with our cointegrating relationship from Equation (4.2). The explanation for this is rather intuitive, considering a weak dollar. A rise in the price of oil is unlikely to affect the demand of crude oil because importers have greater purchasing power. Consequently, an increase in the real price of oil is followed by an appreciation of the real exchange rate of oil exporters. Economic agents tend to have higher expectations about future crude oil exports and hence government spending tends to have a positive impact on the real exchange rate. Finally, imports are likely to increase in oil exporting countries with floating currencies and therefore positive variations in their economic openness depreciate their real exchange rate.

When we consider the coefficients after the variation of the dollar real effective exchange rate is greater than its threshold value of 2.6%, many interesting facts emerge. Adding Regime 1 and Regime 2 values our results considerably change. More precisely, the impact of the real oil price variations over the real exchange rate changes becomes negative supposing that the real exchange rate should depreciate after a oil price increase.<sup>28</sup> A possible explanation for our results follows. With a strong dollar, variations in the price of oil are likely to increase the chances of a demand shock in the long term, as oil importers lose purchasing power, which has a negative impact on the real exchange rate of oil exporters. Overall, this seems to over compensate the appreciating pressure that follows a positive shock in oil prices and as a result the net impact of the real price of oil on the real exchange rate becomes negative.<sup>29</sup>

During the studied period, roughly 63% of the observations belong to Regime 1, meaning that in the short run the real exchange rate of our 16 oil exporting countries is not often positively affected

<sup>26</sup>Currently, this index is calculated by factoring in the exchange rates of six major world currencies: the euro, Japanese yen, Canadian dollar, British pound, Swedish krona and Swiss franc. Data was retrieved from St Louis Fed database and we set 2010 = 100.

<sup>27</sup>The p-value associated to LM, Fischer and LRT statistics is equal to 0.00 for both transition variables.

<sup>28</sup>The matching between values above the threshold and the explaining variables we described also fits the dollar index variations. As a matter of fact, around 92% of the observations for the fluctuations of real exchange rate of the dollar that are higher than 0.026 are also higher than 0.031.

<sup>29</sup>We note, by grid searching, that over the study period the dollar real exchange rate variations are above the estimated threshold value 13 times, of which around 92% of points match with a decrease in the real price of oil, 85% correspond to a negative variation of productivity variable, 77% coincide with a positive variation in the government spending, whereas no matching can be made with the economic openness variable.

by fluctuations in the real price of oil.

Table 2: PSTR results

	$\Delta l.reer\_us_{i,t}$		$\Delta l.index\_us_{i,t}$	
	Regime 1	Regime 2	Regime 1	Regime 2
$\Delta l.roil_{i,t}$	0.11**	-0.13*	0.10*	-0.18***
$\Delta l.bs_{i,t}$	0.06	-0.04	0.04	0.03
$\Delta gov_{i,t}$	1.09***	-2.21***	1.08***	-1.99**
$\Delta open_{i,t}$	-0.48***	0.01	-0.48***	-0.09
$z_{i,t-1}$	-0.14**	0.02***	-0.14**	0.02***
$\gamma$	95.68		101.05	
$c$	0.026		0.031	
SSR	16.61		16.69	

\*, \*\* and \*\*\* stand for a p-value lower than 10%, 5% and 1% respectively.

#### 5.4 Does the exchange rate arrangement matter?

It is important to notice that half of our countries have (or have had) been pegged to the USD. By definition, in countries pegged to the dollar, their real exchange rate is likely to co-move with the dollar itself rather than with other macroeconomic variables. If this is the case here, our previous results capture the monetary authorities response to an appreciation of the anchor currency rather than the impact of our drivers on the real exchange rate, which explains why all coefficients are negative in Regime 2.<sup>30</sup>

In order to determine the accuracy of our analysis in subsection 5.2, we estimate a PSTR model similar to the one described above including only countries that have not been de facto pegged to the dollar in the last 20 years.<sup>31</sup> We apply all the previous econometric steps described in section 4, but for the sake of space, we present only the PSTR estimation results (Table 3).<sup>32</sup>

<sup>30</sup>If monetary authorities anticipate an appreciation of the pegged currency, they are likely to operate in the foreign exchange market in order to depreciate their currency.

<sup>31</sup>The not USD pegged counties are: Angola, Congo, Gabon, Kuwait, Nigeria, Norway, Libya.

<sup>32</sup>Results can be provided upon request to the author.

Table 3: PSTR results not USD pegged

	$\Delta l.reer_{us}_{i,t}$		$\Delta l.index_{us}_{i,t}$	
	Regime 1	Regime 2	Regime 1	Regime 2
$\Delta l.roil_{i,t}$	0.12*	-0.18*	0.11	-0.14
$\Delta l.bs_{i,t}$	0.14	-0.38*	0.12	-0.32
$\Delta gov_{i,t}$	1.52***	-2.27***	1.30***	-1.83***
$\Delta open_{i,t}$	-0.55***	0.31	-0.51***	0.14
$z_{i,t-1}$	-0.16***	0.02***	-0.16***	0.02***
$\gamma$	1.40e+04		4.27e+03	
$c$	0.0015		-0.0007	
SSR	5.48		5.76	

\*, \*\* and \*\*\* stand for a p-value lower than 10%, 5% and 1% respectively.

We can observe that the transition occurs roughly, which is not surprising since we purged the exchange rate movement inertia implied by the dollar peg. As in our first PSTR estimation, the estimated coefficients and the threshold have close values regardless of the transition variable chosen. Overall, the estimated coefficients have similar signs and close intensity to that of the first PSTR.

These similar results in both PSTR estimations show that our first estimation does not suffer from the specification problem discussed above, meaning that dollar movements interact with oil economies' real exchange rate whether they are USD pegged or not. Nevertheless, it is important to notice that the threshold values are lower and close to zero in this second estimation. This supposes that the transition occurs whenever the dollar appreciates, which seems normal for not USD pegged countries. In fact, their economies adjust through the nominal exchange rate which is more volatile than the real exchange rate, thus implying a lower threshold. Furthermore, we observe that around 52% of the observations belong to Regime 1, meaning that in countries that are not pegged to the US dollar the co-movement between their real exchange rate and the real price of oil does not represent a rule.

## 6 Conclusion

This paper investigated to which extent dollar real exchange rate fluctuations explain the unexpected divergent movement between the real exchange rate of oil exporting countries and the price of oil in certain periods. To this end, we considered a sample of 16 oil exporting countries from 1980 to 2014. We began our analysis by estimating a long term cointegrating relationship between the real exchange rate of these countries and the real price of oil. Our results supported the existence of oil currencies in the long run, showing that that a 10% increase in the price of oil

leads these countries' real exchange rate to appreciate by roughly 2.1%, which is in line with the existing literature.

To explore how swings in the dollar exchange rate affect the co-movement between the two variables in the short run, we relied on a non-linear approach and estimated a panel smooth transition regression model. For the whole sample, our results showed that oil currencies move in concert with the price of oil only if the dollar does not appreciate more than 2.6% in real terms. Beyond this threshold value, the real exchange rate of oil exporting economies is rather negatively affected by the price of oil. For countries that are not pegged to the US currency, the co-movement between oil currencies and the price of oil is more sensitive to dollar fluctuations. As a matter of fact, results showed the existence of a negative relationship between the two variables whenever the dollar appreciates.

Finally, we conclude that in the short term the oil currency - oil price co-movement is a misleading rule of thumb for oil exporting economies. As our results have shown, in countries with a peg exchange rate arrangement not more than 63% of the observations fit the expected co-movement between the two variables, while this frequency falls to only 52% in countries not pegged to the dollar.

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## A Appendix

### A.1 Cashin, Céspedes and Sahay (2004) theoretical model

The theoretical model developed by Cashin, Céspedes and Sahay (2004) determines the real exchange rate of a commodity exporting country to be a function of its terms of trade and the productivity differential between its non-traded sector and traded sectors of its trading partners. The model considers a small open economy composed of two different sectors: the one associated with the production of a primary commodity is the tradable good sector, and the other producing a non-exporting good is the non-traded sector. In our case, the tradable good is crude oil, which is traded with the rest of the world against manufactured goods. Firms in both sectors are supposed to benefit from constant returns to scale technology in a perfect competition structure. Labor is the only input factor for producing traded and non-traded goods and can move freely across sectors. Finally, households supply labor inelastically and increase their utility by consuming the domestic - non-traded - good and the - imported - foreign good.

#### Domestic firms

As aforementioned, the domestic economy has two sectors: one producing a tradable,  $X$ , good such as crude oil; and another that makes a non-tradable,  $N$ , good. Firms have similar technology and thus identical profit maximization problems:

$$\begin{aligned} \max_{L_i} \Pi_i &= P_i Y_i - w L_i \\ \text{s.t. } Y_i &= \eta_i L_i \end{aligned}$$

where  $i$  can take the notation of either the non-tradable sector,  $N$ , or the tradable sector,  $X$ ;  $L_X$  ( $L_N$ ) is the labor demanded in the oil (non-traded) sector. Firms in both sectors maximize their revenues,  $P_i Y_i$ , discounting labor costs,  $w L_i$ , subject to a technology constraint,  $\eta_i L_i$ , where  $P_i$  stands for the price of the good,  $Y_i$  the quantity produced,  $w$  are nominal wages which are equalized across sectors due to free labor movement and  $\eta_i$  the labor marginal productivity that varies across sectors. At the equilibrium, the marginal productivity must equal the real wage in each sector  $i$ :

$$\eta_i = \frac{w}{P_i} \tag{A.1}$$

Crude oil is only consumed abroad while non-tradable goods are only consumed in the domestic country. Hence, the price of oil ( $P_X$ ) is determined exogenously by the world's demand and supply, whereas non-tradable goods' price ( $P_N$ ) is determined by domestic's demand and supply. Nominal wages are the same across sectors, this implies:

$$\begin{aligned}
 P_N \eta_N &= P_X \eta_X = w \\
 P_N &= \frac{\eta_X}{\eta_N} P_X
 \end{aligned}
 \tag{A.2}$$

Equation (A.2) gives us a first insight about how oil prices affect domestic prices. The only determinant of the relative price of non-traded goods in terms of oil ( $P_N/P_X$ ) is the productivity differential between the tradable and non-tradable sectors ( $\eta_N/\eta_X$ ). Hence, a positive shock in the price of oil - and consequent increase in the wage of the exportable sector - translates into a rise in the wage and price of the non-tradable sector.

### Domestic households

Domestic households consume the domestic produced non-traded good ( $N$ ) along with an imported good ( $T$ ) that has its price in domestic currency determined by the nominal exchange rate ( $E$ ) assuming the law of one price as follows:

$$P_T = \frac{P_T^*}{E} \tag{A.3}$$

where  $P_T^*$  is the price of the imported good in the foreign country's currency,  $E$  is expressed as the number of foreign currency units per domestic currency unit.

Households are assumed to be identical and maximize their utility over the consumption ( $C$ ) of the non-traded domestic good and the imported traded good ( $T$ ), subject to the expenditure of their total wealth ( $w$ ). Households supply labor inelastically ( $L = L_N + L_X$ ). The maximization program of a representative household is characterized by a Cobb-Douglas function as follows:

$$\begin{aligned}
 \max_{C_N, C_T} U &= (C_N)^\alpha (C_T)^{1-\alpha} \\
 s.t. \quad w &= P_N C_N + P_T C_T
 \end{aligned}$$

where  $\alpha \in ]0; 1[$ .

Solving the maximization problem above we find the consumer price index (CPI) of the oil exporting country, which is a weighted average of the consumed goods price:

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

### Foreign firms

The foreign economy is composed of three sectors: non-traded ( $N^*$ ) and traded ( $T^*$ ) sectors, and a third producing an intermediate good ( $I^*$ ). The only input for producing the non-traded and the intermediate good is labor, and the sectors productivity are respectively,  $\eta_N^*$  and  $\eta_I^*$ . As for the domestic economy, the non-traded good is only consumed in the foreign country, and nominal wages are equal across sectors which leads to:

$$P_N^* = \frac{\eta_I^*}{\eta_N^*} P_I^* \quad (\text{A.5})$$

The firms producing the final good need two inputs in the manufacturing process. The first is crude oil ( $Y_X^*$ ) imported from several countries among which figures our domestic economy. The second is the intermediate good ( $Y_I^*$ ). The profit maximization problem of a representative firm is hence:

$$\begin{aligned} \max_{Y_X^*, Y_I^*} \Pi_T &= P_T^* Y_T^* - (P_X^* Y_X^* + P_I^* Y_I^*) \\ \text{s.t. } Y_T^* &= \lambda (Y_I^*)^\beta (Y_X^*)^{1-\beta} \end{aligned}$$

where  $\lambda$  is a constant. The solution to the maximization 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 oil good prices:

$$P_T^* = (P_I^*)^\beta (P_X^*)^{1-\beta} \quad (\text{A.6})$$

### Foreign households

Foreign households consume their non-traded good ( $N^*$ ) along with the final good produced in the foreign country ( $T^*$ ), considering a same labor market structure as in the domestic economy, consumer price index in the foreign economy can be written as:

$$P^* = (P_N^*)^\gamma (P_T^*)^{1-\gamma} \quad (\text{A.7})$$

### Real exchange rate determination

We define the real exchange rate ( $RER$ ) of the oil exporting economy as the ratio between the foreign price of the domestic consumption basket ( $EP$ ) and the foreign price of the foreign consumption basket ( $P^*$ ) as follows:

$$RER = \frac{EP}{P^*} \quad (\text{A.8})$$

where an increase in  $E$  means that the domestic currency appreciates.

Plugging Equations (A.4) and (A.7) in Equation (A.8) and then using Equations (A.2), (A.3) and (A.5) we can determine the real exchange rate of the domestic country as a function of the productivity differential and the terms of trade:

$$RER = \left[ \left( \frac{\eta_X \eta_N^*}{\eta_I^* \eta_N} \right) \left( \frac{P_X^*}{P_I^*} \right) \right]^\gamma \quad (\text{A.9})$$

The two productivity differentials can be interpreted as the Balassa-Samuelson effect, thus implying that the domestic currency appreciates in real terms if domestic productivity in the tradable sector exceeds productivity in non-tradable sector relatively to the trading partners. The last ratio - the relative price of crude oil exports in terms of imports expressed in the foreign country currency - denotes the terms of trade of the oil exporting country.

## A.2 Pesaran (2004) CD test results

Ho: series are cross-section independent

	p-value	correlation	correlation
$\ln \text{reer}_{i,t}$	0.00	0.24	0.48
$\ln \text{roil}_{i,t}$	0.00	0.99	0.99
$\ln \text{bs}_{i,t}$	0.00	0.22	0.47
$\text{gov}_{i,t}$	0.00	0.23	0.40
$\text{open}_{i,t}$	0.00	0.17	0.35

## A.3 Panel unit root test results

	<u>Pesaran</u>		<u>Choi</u>	
	Ho: $x \sim I(1)$		Ho: $x \sim I(1)$	
	p-values	Pm	Z	L*
$\ln \text{reer}_{i,t}$	0.11	0.17	0.29	0.18
$\ln \text{roil}_{i,t}$	0.93	0.99	0.99	0.99
$\ln \text{bs}_{i,t}$	0.85	0.39	0.65	0.60
$\text{gov}_{i,t}$	0.32	0.13	0.05	0.06
$\text{open}_{i,t}$	0.75	0.10	0.11	0.17

#### A.4 Westerlund (2007) cointegration test results

robust p-value			
Group		Panel	
$G_T$	$G_A$	$P_T$	$P_A$
0.08	0.14	0.07	0.05