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Abstract

This paper investigates to which extent dollar real exchange rate movements affect the relationship between oil prices and oil currencies. Estimating a panel cointegrating model between the real exchange rate and its drivers for a sample of 11 OPEC countries and 8 major oil-exporting economies over the 1980-2013 period, we find evidence to support the existence of oil currencies. To analyze how dollar movements may affect the oil price – oil currency nexus, we then estimate a panel smooth transition regression model. Results show that beyond a certain threshold for the dollar depreciation, the sign of the relationship between oil prices and oil countries' exchange rate switches from positive to negative. In fact, when the dollar depreciation is higher than 2.45%, an increase in oil price has a negative impact on oil exporters' exchange rate. We also re-explore the causality between the USD real exchange rate and the oil price, showing that the causality between the two variables has changed over the period under study. Finally, we investigate how the Fed monetary policy may impact the oil currency – oil price relationship, and find evidence to support that the US policy rate is a key to understand oil currencies movements.

Key words: Oil price; Oil currencies; Non-linearities

JEL classification: C33, F31, Q43

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1 Introduction

Since the early 2000s oil price has been showing an upwards trend, even considering its 2008-2009 main cliff caused by the financial crisis. Indeed, from 2003 to 2013 oil price has increased around 149% in real terms.[1] Part of this price boost is explained by both supply and demand sides. War in Middle East or political instability in Venezuela created market insecurity concerning oil supply, while the rapidly economic growth experienced in BRICS economies augmented considerably oil consumption. Yet, as it is a main energy resource for industrial production, fluctuations in oil prices can affect, to various degrees, most sectors of the economy (Baffes, 2007). Oil prices also seem to have a positive impact on the current account from oil economies (Allegret et al., 2014). In fact, oil-exporting countries have known an increase of their current account surplus in the last years which can be explained by a raise in oil price. Conversely, for developed economies that often import huge amounts of oil, a permanent price shock leads to sticky current account deficits.

Nevertheless, since oil-exporting countries by definition depend on oil exports, a permanent price increase of oil may not be positive for their economies. Other sources of energy may reduce oil monopoly in industrial production. Another issue for oil economies is that of deindustrialization. An increase in revenues from oil exports appreciates the domestic currency compared to that of its trade partners, which leads other exports to become more expensive and imports cheaper, making the manufacturing sector less competitive. There is a dual effect of oil price fluctuations on oil economies. In this paper, we aim to analyze how oil price movements affect oil economies' overall performance.

In this context, the real exchange rate offers information about a country's competitiveness, hence being an important macroeconomic indicator for evaluating exporting economies' performance. The real appreciation of a currency is often interpreted as a loss in competitiveness for the economy. Nevertheless, the relationship between changes in the competitive position of a country and movements in its real exchange rate is not as straightforward as one could assume. It is shown that economies with above average real exchange rates can excel in export performance (Iversen and Soskia, 2010). A country's production efficiency may or may not be compromised by a real exchange rate appreciation. As a matter of fact, an appreciation may reflect either a loss of competitiveness - when it is due to a disequilibrium between the real exchange rate and its fundamentals; or an improvement in competitiveness - productivity gains, for instance, have a positive impact on the real exchange rate of a country and increase its production efficiency. Thus, it is the underlying source of real exchange rate movements, which determines whether competitiveness is hurt by, or is itself the cause of the movements.

There is a broad literature devoted to the dynamics of the real effective exchange rate (**reer**). The main works related to the subject find that financial variables such as a country's net foreign asset position or its current account, as well as macroeconomic indicators of productivity are major determinants of **reer** movements (Clark and MacDonald, 1998; Lane and Milesi-Ferretti, 2002, 2007). Additionally, recent studies have found solid evidence to support that oil price is a key determinant of oil economies'

[1] Nominal series deflated by the US CPI (2005 = 100) retrieved from IFS database

reer, showing that both variables have a long-term positive relationship (Habib and Kalamova, 2007; Korhonen and Juurikala, 2007; Dauvin, 2013). Currencies with a **reer** that co-moves with oil price are also called ‘oil currencies’.

Furthermore, oil-exporting countries tend to anchor their currencies to the dollar for different reasons such as: the currency structure of their foreign debt is in dollar or/and network externalities that push countries to peg their currencies to a same dominant one (Coudert et al., 2012). However, pegging to the USD implies a straightforward link between the country’s real effective exchange rate and the dollar.

Yet, a long-term relationship between the dollar and the oil price has been studied in many papers (Armano and van Norden, 1995; Coudert et al., 2008). Such relationship suggests that even float economies with oil currencies, should have their exchange rate in some extent affected by dollar movements. Thus, there may be an inherent connection between oil price, oil currencies and the dollar. This paper aims to assess this connection by studying how dollar movements affect the relationship between oil price and oil currencies.

To this end, we begin by estimating a panel cointegration model between the real effective exchange rate and its fundamentals for a sample of 11 OPEC countries and 8 major oil-exporting economies over the period 1980 - 2013. Our results confirm and support previous studies on the existence of oil currencies, measuring that the **reer** of oil-exporting countries should appreciate by roughly 1.5% after a 10% increase in the oil price. To account for the impact of the dollar **reer** on the oil price - oil currency nexus and investigate whether this effect varies according to the amplitude of the dollar fluctuations, we estimate a Panel Smooth Transition Regression (PSTR) model. We find evidence that beyond a certain threshold for the dollar depreciation, the sign of the relationship between oil price and oil countries’ exchange rate switches from positive to negative. In fact, when the dollar depreciation is lower than 2.45%, an increase in oil price has a negative impact on oil exporters’ exchange rate.

Finally, in order to better understand the interaction between the dollar and the oil price we revisit the causality direction between the two variables. We find that the causality direction changes after September 2001. Indeed, before the end of 2001 our results are supported by the previous literature (Armano and van Norden, 1995; Coudert et al., 2008) finding a causality that runs from oil price to the dollar exchange rate. Nevertheless, after 2001, dollar exchange rate movements seem to rather cause oil price fluctuations. We highlight that a possible explanation for such changing in the causality direction relies on the Fed monetary policy.

This paper is structured as follows. Section 2 reviews the existing literature, and presents the theoretical framework used in this analysis. Section 3 describes the econometric framework and describes the data. Section 4 estimates a panel cointegration relationship between the **reer** and its fundamentals. Section 5 introduces the PSTR model, its estimation and discusses the dollar – oil price relationship. Section 6 concludes.

2 Assessing the oil price - oil currency relationship

2.1 Overview

The connection between oil price and the real exchange rate (**rer**) has been presented in different ways. The first studies focus on the links between the US dollar and the oil price (Krugman, 1980; Golub, 1983; Armano and van Norden, 1995). Further literature has also identified the terms of trade - defined as the ratio of the price of a country's exports to the price of its imports - as one of the potential determinants of the real exchange rate movements of a country. The influence of the terms of trade on the real exchange rate has been theoretically assessed by many authors (Neary, 1988; De Gregorio and Wolf, 1994; Chen and Rogoff, 2003; Cashin et al, 2004) using a quasi-similar framework. They consider an economy composed of two different sectors: one producing an exporTable good, and the other producing a non-traded good. In this type of model better terms-of-trade lead to an appreciation of the real exchange rate.

By definition, in oil-exporting countries, oil exports account for a large share of the total exports, thus representing a main component of their terms-of-trade movements. Baxter and Kouparitas (2000) studied the sources of fluctuations in the terms of trade identifying two components: "a good price effect" reflecting 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 key role of the price of the petroleum-good in these countries' relative export prices. In oil-exporting countries, the oil price is hence a reasonable proxy of the terms of trade. Furthermore, as it has been pointed by Backus and Crucini (2000) even in major industrialized countries, which are net importers of oil, the relation between terms of trade and oil prices and quantities seems to hold.

Habib and Kalanova (2007) study the relation between oil price and three main oil producers' currencies: the Russian rouble, the Norwegian krone and the Saudi Arabian riyal; using quarterly data from 1980 to 2006 for Norway and Saudi Arabia and from 1995 to 2006 for Russia. They find that the oil price and the Russian rouble follow a common stochastic trend, while none evidence for a long-term relationship between the riyal, the krone and the price of oil. Korhonen and Juurikala (2007) estimate the rer in a panel of nine OPEC countries over 1975-2005 and three CIS over 1993-2005 and find statistically significant effect of the price of oil on exchange rates. Dauvin (2013) analyzes two sets of countries: a group of 10 energy-exporting countries and a group of 23 commodity-exporting economies; from 1980 to 2011. She finds that a 10% increase in the terms-of-trade of the energy-exporting group would appreciate their exchange rate by roughly 2.8%. These studies find a causality that runs from energy prices to real exchange rates.

Some other works considered the relationship between other commodities and the real exchange rates of their exporters. Chen and Rogoff (2003) for instance observe a strong connection between the price of non-energy commodities exported by New Zealand and Australia and their respective **rer**. Cashin et al. (2004) extend this investigation to a set of 58 commodity-exporting developing countries over the period 1980-2002. They find evidence of a long-run relationship between the real exchange rate and real commodity prices in around one third of the countries. Both studies analyze the causality direction between the two variables, finding that commodity prices are weakly exogenous.

More recently, Clements and Fry (2008) build a theoretical model to explain the existence of causality running from real exchange rates to commodity prices and empirically investigate it for commodity exporting countries. Their approach requires a long period floating exchange rate regime which is hardly the case for energy exporters.[2] As it will be discussed further, oil economies often choose to anchor their currencies to the dollar.

2.2 Theoretical model for the real exchange rate determinaton

Alberola, Cervero, Lopez and Ubide (1999) present a consistent methodology for the calculation of bilateral equilibrium exchange rates for a panel of currencies. In this model, there are two small open countries in the world, each producing two goods: one tradable and one non-tradable. In this context, they define the equilibrium real exchange rate as the real exchange rate that leads simultaneously to internal and external balances.

Internal balance is reached when the domestic goods' market is cleared, while external balance assumes current account stability, which implies that, in the long run, the current account is balanced and net foreign assets are stationary. In sum, the model supposes that on the long-term the real exchange rate is driven by three fundamentals: the level of net foreign assets, a measure of relative sector productivity and exogenous demand factors.

Cashin, Céspedes and Sahay (2004) develop a theoretical framework for commodity dependent countries (energy and non-energy commodity) that describes the mechanisms connecting the real exchange rate and the terms-of-trade in these economies.[3]

Cashin et al. (2004) consider a small open domestic economy with two sectors that produce, respectively, a tradable, X (i.e. a commodity); and a non-tradable, N, goods. It also assumes a foreign economy (indicated with a *) that besides the two sectors also produces intermediate, I, goods. The model expresses the real exchange rate as a function of a country's inter sector differentials of productivity (η) and its terms-of-trade - defined as the ratio of the prices (**P**) of a country's exports to the prices of its imports - as it follows.

$$RER = \left[\frac{\eta_X \eta_N^*}{\eta_N \eta_I^*}\right]^\alpha \left[\frac{P_X^*}{P_I^*}\right]^\alpha \tag{1}$$

With α the share of the consumed goods in the consumer's basket.

[2]Only floating currencies' exchange rate can be considered as an asset which price is determined by the market and the related economy fundamentals.

[3]The model construction is fully explained in Appendix 1

The first term represents the Balassa-Samuelson (**bs**) effect, and the second term represents the terms-of-trade (**ToT**) measured in foreign prices.

According to the model, an increase in the productivity of the tradable sector will push wages up, which in turn will lead to higher non-traded goods prices, thus having a positive effect on the real exchange rate. The same applies to the terms-of-trade. As the price of the tradable goods is exogenously determined, the final effect of a positive price shock will be an appreciation of the **rer**.

As aforementioned, oil exports account for a large share of the total exports in oil-exporting countries, thus representing a main component of their terms-of-trade movements. In this paper, all the countries analyzed are major oil exporters and therefore their terms-of-trade can be proxied by the oil price in real terms.

3 Empirical model

3.1 Econometric framework

We draw an empirical model that incorporates both Cashin et al. (2004) and Alberola et al. (1999, 2002) specifications. Therefore, the econometric framework assumes that the real effective exchange rate (**reer**) of a country in the long-term is driven by a group of variables such as its terms-of-trade, its relative sector productivity, its net foreign asset position and its current account.

The long-term specification is therefore:

$$log(reer_{it}) = \mu_i + \beta^{'} X + \varepsilon_{it} \tag{2}$$

Where **reer** is the real effective exchange rate of country i on year t, μ_i accounts for individual effects, X is a control matrix including the following variables: the oil price (**poil**) and the Balassa-Samuelson effect (**bs**) both in logarithm terms, the net foreign asset position (**nfa**) and the current account (**ca**) both expressed in percentage points of the GDP. To avoid colinearity issues as **nfa** and **ca** series are highly correlated we do not include them simultaneously in any of the specifications.

3.2 Sample

We consider yearly data from 1980 to 2013 for a set of 19 countries including 11 OPEC members and 8 major oil-exporting countries. The OPEC members are: Algeria, Angola, Ecuador, Iran, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela.[4]The oil exporters are: Bahrain, Canada, Indonesia, Mexico, Norway, Oman, Russia and Syria.

[4]Iraq was not included due to data availability issues.

3.3 Data[5]

The real effective exchange rate (**reer**) series are extracted from Bruegel's dataset.[6] The **reer** for a given country is calculated as a weighted average between its nominal bilateral exchange rate and that from its trading partners, adjusted to the studied country price movements relative to its trading partners.[7] An increase in the **reer** means an appreciation of it.

The Balassa-Samuelson effect (**bs**) is proxied by the PPP GDP of the studied country relative to its trading partners. We construct the weights for each trading partner following the Bruegel's dataset on reer to avoid consistency problems. PPP GDP data is extracted from World Bank database. Previous studies on developing economies found a positive impact of productivity increases on the real exchange rate which is supported by the theoretical model presented in Equation (1).[8]

The net foreign asset position (**nfa**) is extracted from the updated and extended version of Lane and Milesi-Ferretti's (2007) dataset that covers data spanning from 1980 to 2007. Net foreign assets are the sum of foreign assets held by monetary authorities and deposit money banks, less their foreign liabilities. Here they are expressed in percentage points of the GDP. We completed the 2008-2013 data using the trend from the nfa calculated by the World Bank.[9] The impact of the **nfa** on the exchange rate depends on the share of foreign assets that compose the portfolio of the home country agents. If domestic agents tend to hold domestic assets, a better **nfa** would have a positive impact on the **reer** as the domestic currency would be more requested. Conversely, if domestic agents are more prone to hold foreign assets, gains on the asset position could have a negative effect on the **reer**, as they would result from a higher demand of the foreign currency.

The current account (**ca**) data is provided by the International Monetary Fund's World Economic Outlook database. The impact of the **ca** on the **reer** depends on the direction of the causality between those two variables. A depreciation of the **reer** should have a positive impact on the **ca** through the exports channel. Conversely, current account surpluses tend to appreciate the **reer** which would penalize exports and leading to current account deficits if imports increase with a stronger domestic currency.

The oil price (**poil**) is retrieved from the IMF International Financial Statistics (IFS) database. It is a simple average of the three major oil markets (Brent, Dubai and West Texas Intermediate) expressed in US dollar. All three series are highly correlated and the choice of a single oil price series does not affect the robustness of the results.[10]

Nevertheless, as it has been pointed by Peterson and Tomek (2000) the choice of deflator of commodity prices can change their time-series properties. In fact, some vastly used deflators such as general price indexes may create spurious cycles that did not exist in the original data. In this paper, three different

[5] All of the following series - reer, poil, cpi, muv and hcpi - have the same base year (2005=100).

[6] Available at: http://www.bruegel.org/fileadmin/bruegel_files/Datasets/REER_database_ver4Apr2014.xls

[7] The explicit formula for each one of the variables can be found in Appendix 2.

[8] See Choudhri et al. (2004).

[9] The choice of expanding Lane and Milesi-Ferretti's work with such methodology rather than just filling the missing data with that from World Bank allowed keeping consistency in the added values.

[10] Complete results are available upon request to the author.

real oil price series are built, in order to insure the robustness of the results. Two of the series use common deflator such as the US consumer price index (**cpi**) and the Manufactured Unit Value (**muv**) both provided by the IMF's IFS database. For terminology simplicity here they are named, respectively, **poil/cpi** and **poil/muv**. The third deflator (**hcpi**) is calculated as the sum of the countries that import oil harmonized by their share on the total exports of the home country on a yearly basis for each of the countries in the studied sample:

$$hcpi_{it} = \sum_{p=1}^{P} \omega_{pt} cpi_{pt} \tag{3}$$

Where (ω) is the share of country p in the total oil exports of country i in year t. Data used for ω is provided by the Centre d'Etudes Prospectives et d'Informations Internationale's International Trade Database at the Product-Level (BACI).[11] The third real oil price series is named **poil/hcpi**.

The impact of the oil price on the **reer** of oil economies is expected to be positive. As described by the theoretical model, a positive shock to the oil price leads to an increase in wages in the exporting sector of these economies. Under the assumption of wage equalization across the two sectors, this leads to an increase in wages and prices in the non-traded goods sector appreciating the real exchange rate.

4 Estimating the intensity of the oil price - reer nexus

4.1 Preliminary analysis

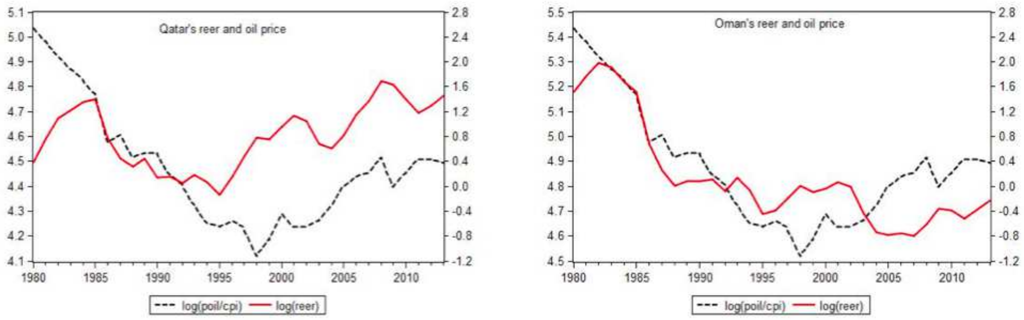
Figure 1 gives a first insight about the connection between the **reer** and the **poil/cpi** for Qatar and Oman, both series being taken in logarithms.[12] As shown, both series have similar evolutions whether there is an upward or a downward trend, and the same conclusion holds for most of the countries considered in our sample.[13]

[11] The missing data on ω for the periods 1980-1986 and 2007-2013 was calculated applying the US CPI trend to the hcpi calculated values. These added points were compared with those provided by the MIT Observatory for Economic Complexity website for the period 2007-2013. The values were reasonably close validating the methodology used.

[12] Similar graphs for all the countries concerned in this paper can be found in the Appendix 3 Figure 4.

[13] See Appendix 3 Figure 4.

Figure 1: **reer** (left axis) and oil price CPI deflated (right axis) in logarithm for Qatar (left graph) and Oman (right graph)



4.2 Unit root and cointegration tests

We first investigate the order of integration of our series by using different unit root tests. We start by checking the existence of a cross-section common unit root applying the Levin-Lin-Chu (2002, LLC) and Hadri (2000) tests to all series. We then consider two other tests: the Im-Pesaran-Shin (1997, 2003, IPS) and the Maddala and Wu (1999, MW) tests that take into account heterogeneity across individuals. For the series **poil/cpi** and **poil/muv** we perform regular time-series unit root and stationary tests such as ADF, PP and KPSS, as by construction these series do not have any cross-sectional dimension. Results are shown in the Appendix 3 Table 5 and suggest that all series are integrated of order 1.

The next step is to test if the series are cointegrated which allows us to determine the adequacy of specifying the long-run value of the real exchange rate as a function of the oil price and the other control variables as stated by equation (2). We apply two tests both based on the null hypothesis of no cointegration: the seven tests provided by Pedroni (1999, 2004) and the one proposed by Kao (1999). Pedroni's seven tests are composed on four within-residual and three between-dimension based tests, while Kao's test consists on a residual-based test for the null of no cointegration in panels. Results are reported in Appendix 3 Table 6 and show that the **reer** and its assumed drivers are cointegrated.

4.3 Estimation results

We then estimate Equation (2) for 6 different specifications. For each one of the price's series we estimate the cointegrating relationship including the **nfa** or the **ca** among the explaining variables. We also estimate the model for different panels of countries, considering four subgroups: OPEC, Others, Peg regime and Float regime; which allows us to gauge the importance that the quantity of oil exported and the exchange rate regime have on the oil currency - oil price nexus.[14]

All specifications are estimated with the Panel Dynamic Ordinary Least Squares (DOLS) procedure proposed by Kao and Chiang (2000) and Mark and Sul (2003). This procedure augments the regression

[14] All countries' group list is presented in the Appendix 3 Table 7.

parameters adding leads and lags values of differenced variables to reduce the possibility of endogenous feedback effect.

Table 1: Cointegrating estimation results

Real effective exchange rate and real oil price								
Dependent variable: log(reer)								
Independent variables:	log(poil/cpi)	log(poil/muv)	log(poil/hcpi)	log(bs)	nfa	ca	Observations	R^2
All COUNTRIES	**0.155*** **			-0.005	-0.033		565	0.71
	0.157* **			-0.009		-0.001	580	0.7
		0.055		-0.011	-0.038		569	0.65
		0.082		-0.019		0.001	577	0.63
			0.168* **	-0.011	-0.038		564	0.65
			0.175* **	-0.014		-0.002	581	0.7
OPEC	**0.172*** **			-0.012	-0.034		333	0.69
	0.182* **			-0.009		-0.001	346	0.67
		0.088		-0.019	-0.038		336	0.64
		0.126		-0.028		0,000	345	0.6
			0.197* **	-0.026	-0.035		332	0.73
			0.215* **	-0.017		-0.002	346	0.66
OTHERS	**0.133*** **			0.05	-0.173*		232	0.79
	0.121* **			-0.039		-0.006	234	0.84
		0.062		0.076*	-0.253**		233	0.67
		0.043		0.089**		-0.003	232	0.73
			0.137* **	0.072**	-0.164*		232	0.77
			0.081 **	0.216*		-0.005	235	0.82
PEG	**0.166*** **			0.018	-0.002		364	0.63
	0.173* **			0.007		-0.001	376	0.61
		0.084		0.019	0.012		367	0.59
		0.109		-0.001		0,000	372	0.55
			0.186* **	0.018	0.019		362	0.7
			0.185* **	0.008		-0.002	374	0.62
FLOAT	**0.147*** **			-0.063*	-0.247**		201	0.85
	0.130* **			-0.091***		-0.018***	204	0.9
		0.148*		-0.056	-0.412***		202	0.8
		0.155***		-0.065***		-0.034***	205	0.86
			0.215* **	-0.068**	-0.408***		202	0.85
			0.197* **	-0.086***		-0.028***	207	0.89

*, ** and *** represent statistically significance at the, respectively, 10%, 5% and 1% significance level

Some remarks have to be made about the results from the estimated cointegrating relationships that are displayed on the Table 1. Supporting previous studies on oil currencies, we find that the oil price has a positive effect on the real exchange rate of its exporters.[15] Additionally, both **poil/cpi** and **poil/hcpi** series have close coefficients in all estimations and are statistically significant. Oil price changes have a greater impact on the OPEC countries. In fact, the real exchange rate in OPEC countries should

[15]See references in Section 2.

increase by on average 1.92% following a 10% increase in real oil price, the impact on other countries from the sample for the same price increase would be of 1.18% on average.[16] These values are somewhat lower than those from previous studies on oil currencies, this could be explained by different elements such as: a different data span, a different set of countries and/or the fact the period covered in this work comprehends the financial crisis.

Results show that OPEC countries **reer** are more affected by oil price fluctuations compared to other oil exporters. Most part of OPEC countries are pegged to the dollar, which force their currencies to co-move with it. As it has been already discussed here, dollar movements and oil prices present a long-term relationship. Thus, dollar movements may amplify the impact of oil price fluctuations on OPEC economies' **reer**. This can be confirmed when the results from peg and float groups are compared. Indeed, peg economies **reer** are more sensitive than float ones to oil price movements.

Furthermore, variables from the control matrix do not seem to play a determinant role on the **reer**. In almost all specifications the **bs** is negative and/or close to zero. These values are not surprising, since the countries analyzed are not in the middle of an economic catch-up process. Concerning the **nfa** and the **ca** in almost all specifications they are negative – the **ca** being close to zero. This supports the assumption that agents from oil-exporting countries tend to hold assets in foreign currency, and therefore, a better **nfa** depreciates the domestic exchange rate.

The theoretical model used in this paper supposed that oil prices were exogenous to the real exchange rate. In fact, this has been confirmed by few empirical studies related the subject. Amano and van Norden (1995) find a causality that runs from oil price to the dollar real exchange rate. On a more precise set of works applied to oil currencies, Habib and Kalanova (2007) show that oil price was weakly exogenous to the rouble real exchange rate, while Coudert et al. (2011) find a bi-direction causality between the two variables. As a matter of fact, the reverse causality between oil price and its exporters' **reer** does not lack theoretical foundations. Clements and Fry (2007) developed a framework allowing the **reer** from large exporters of a commodity to influence the price of the commodity they export. This could be the case here. A positive shock on oil price would appreciate oil exporters' exchange rate, which - on the long run - would squeeze total oil exports. Nevertheless, only OPEC countries account for more than 40% of the world's total crude oil production over the period 2003 – 2012. A lower volume of total oil exports would be similar to a world decrease in oil supply, hence pushing oil prices up even more.

In order to determine the direction of causality, it is necessary to check which variables are weakly exogenous. The latter can be done by applying a panel non-causality Granger test on a linear vector autoregressive model. The test proposed by Dumitrescu and Hurlin (2011) is based on the null hypothesis of non-causality and defines four kinds of causal relationships: homogenous non-causality, homogenous causality, heterogenous causality, heterogenous non-causality. Here we consider the test under the null hypothesis of non-homogenously causality, which seems the more adapted to group considerations. Results (Table 8 in Appendix 3) suggest that for the whole sample (and the different groups) the causality

[16] Those average values are calculated using all prices' statistically significant coefficients for each of the groups.

runs from oil prices to **reer**. Peg economies' exchange rates are forced to mimic their anchor currency movements. An increase in oil price would push the **reer** of those countries to appreciate. Consequently, these countries' monetary authorities would interfere in the foreign exchange market in order to stabilize their exchange rate. This would prevent their **reer** to *de facto* appreciate and therefore to increase oil prices even more. The same explanation can be applied to OPEC countries' group. Actually, only two countries from OPEC group have a 'float alike' exchange rate regime. With regards to both float and others groups the direction of the causality is not surprising. Those countries' share on the world's total oil production is not big enough to place them as price makers. Thus, their exchange rate movements do not affect the oil price.

5 Investigating non-linearities in the oil currency – oil price nexus

Early studies on the connections between oil prices and exchange rates found that the dollar and oil price were linked. Coudert et al. (2005) find that the two variables are cointegrated at the 10% level for the period 1980M01-2004M11, and estimate that, *ceteris paribus*, a 10% increase in the real oil price leads to a 4.2% dollar appreciation. Amano and van Norden (1996) study the relationship between the two variables for the period 1972M02-1985M12 and estimate that a 10% increase in the real oil price would lead to a 5.13% dollar appreciation.

Oil exporters are more prone than other commodities' exporters to anchor their currencies against the dollar. Indeed, 12 of the 19 countries studied in this paper present (or have presented) a peg exchange rate regime over the covered period. There are multiple rationales for choosing a peg regime in those countries. First, the currency structure of the foreign debt plays a role. Countries as oil exporters are incited to peg to the currency in which they are indebted, in order to stabilize their debt burden. Second, network externalities create an incentive for all countries to peg to the same dominant currency. As a matter of fact, by pegging to the same dominant currency, countries in the same area may attempt to stabilize their exchange rates relative to their trade partners. These two reasons may explain why oil exporters choose the dollar as anchor currency. Nevertheless, pegging to the dollar implies that the country's effective exchange rate is forced to move in sympathy with the dollar. In this context, Coudert et al. (2012) show that currencies linked to the dollar are more likely to loosen their pegs when the dollar is appreciating. As aforementioned, most of the oil-exporting countries peg their currencies to the dollar. When the US dollar appreciates they may loosen their pegs to maintain competitiveness, which could affect the way their currencies are tied to oil price movements.

Therefore, if oil price movements affect dollar movements and if the price of oil and dollar movements impact oil currencies, the relationship between oil price and oil currencies should be affected by dollar swings.

At some extent, other variables that were considered in this paper as long-term drivers of the **reer** of oil exporters may also be affected by dollar fluctuations. Oil exporters' net foreign asset is directly related to the dollar exchange rate. In fact, domestic agents from these countries tend to hold assets in dollar, and therefore their **nfa** improves when the dollar appreciates. The same applies for their current account. Since they export oil, which price is expressed in dollar, upward dollar movements may negatively affect their current account as it may harm exports on the long run. Finally, dollar fluctuations may affect productivity costs in oil exporters. Oil extraction machinery needs to be constantly replaced. Therefore, an upward trend on dollar exchange rate could have a negative impact on the Balassa-Samuelson effect as it would increase total production costs.

Graphical analysis supports the assumptions concerning the impact of dollar movements on the relationship between the **reer** and its main drivers. As a matter of fact, higher dollar fluctuations either break the variables' co-movement or amplify a previous break. To assess in which extent dollar swings affect the oil price – **reer** nexus considering the **reer** long-term dynamics, we rely on a PSTR error correction model (PSTRECM).[17]

5.1 Linearity tests and PSTR framework

Panel Smooth Transition models (PSTR) developed by González et al. (2005) are a generalization of the panel threshold regression (PTR) model proposed by Hansen (1999). In PTR models observations are grouped in different regimes (usually 2) following the value of one (transition) variable, the shift from one regime to another occurs instantly. The main feature of PSTR models is that the transition from one regime to another can occur smoothly. To this end, they rely on a logistic transition function that is bounded by zero and one.

In our case, the PSTR specification can be written as follows:

$$\Delta log(reer_{it}) = \alpha_{it} + \beta^{'}_{1,x}K + \beta^{'}_{2,x}KG(.) + \varepsilon_{it} \tag{4}$$

Where:

$$\begin{aligned}
\beta^{'}_{1,x} &= [\beta_{1,1} \quad \beta_{1,2} \quad \beta_{1,3} \quad \beta_{1,4}] \\
\beta^{'}_{2,x} &= [\beta_{2,1} \quad \beta_{2,2} \quad \beta_{2,3} \quad \beta_{2,4}] \\
K^{'} &= [\Delta log(poil/def) \quad \Delta log(bs_{it}) \quad \Delta(nfa)\, or\, \Delta(ca) \quad z_{i,t-1}]\,; \quad def = \{cpi;\ muv;\ hcpi\} \\
G(s_t, \gamma, c) &= [1 + \exp(-\gamma(s_t - c))]^{-1}
\end{aligned}$$

for i = *1,..., N* countries over t = *1,..., T* years.

In this nonlinear Error Correction Model (ECM) specification, the lagged residuals ($z_{i,t-1}$) from the cointegrating Estimation (2) were included to account for the long-term dynamics of the **reer**. As

[17] For space issues, graphs are available upon request to the author.

usual, α_{it} and ε_{it} represent an unobservable time-invariant regressor (fixed effects) and an error term, respectively. G(.) is the transition function that depends on three parameters: the speed of adjustment or the transition's smoothness (γ); the threshold or the point on which the shift occurs (c) and the variable that triggers the regime shift (s_t). Here, we use the variation of the dollar real exchange rate in logarithm, $\Delta log(reer\_us_t)$, as the transition variable.

We follow the three steps strategy proposed by González et al. (2005). In the first step, which concerns the specification of the model, we test for the null hypothesis of linearity of the model using the LM-test statistic provided by González et al. (2005) along with two other tests statistics: Fisher and LRT. The results are reported in Table 9 in Appendix 4. For the whole sample, all specifications strongly reject the null hypothesis of linearity. With regards to the groups, tests suggest no evidence of dollar movements affecting floating economies or non-OPEC countries in the sample, which is not surprising. From an exchange regime point of view, there is no reason for floating economies to be strongly affected by dollar fluctuations since their exchange rates are fully determined by market equilibrium and their own fundamentals. In the second step, which concerns the estimation of the model, we use nonlinear least squares to obtain the parameters estimates. Finally, in the third step, we apply misspecification tests in order to check the validity of the estimated PSTRECM model. Results are fully displayed in Table 10 in Appendix 4.

5.2 PSTR results

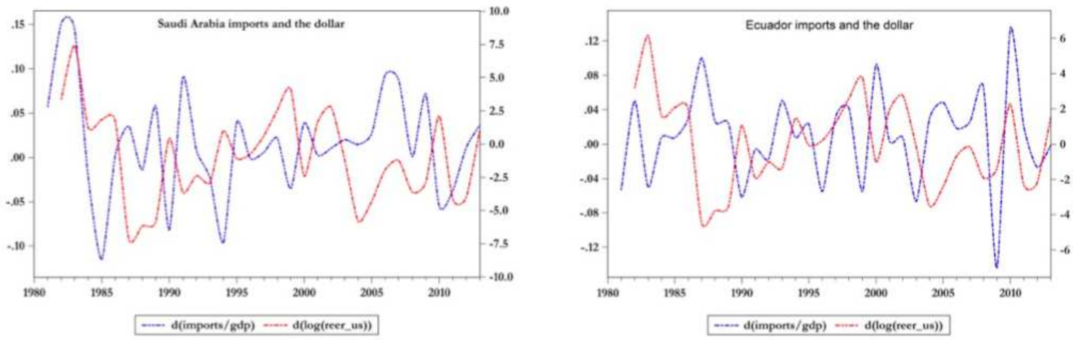
Table 2 below presents the estimation results for the whole sample using **poil/hcpi** as the real oil price in two different specifications: with **nfa** and **ca**. The coefficients of the estimated parameters have close values in both specifications. Results show that the short-term impact of oil price on the **reer** becomes negative whenever the dollar reaches a 2.45% devaluation threshold. All other variables seem to be affected as well, but the corresponding coefficients are not significant. The analysis of the results will be focused on offering an explanation for the oil price coefficient in the two regimes.

Table 2: PSTR results

Whole sample	Regime 1	Regime 2	Regime 1	Regime 2
$\Delta log(poil/hcpi)$	0.1336***	-0.2171***	0.1320***	-0.2069***
$\Delta log(bs)$	-0.0026	0.0063	-0.004	0.0053
$\Delta(nfa)$	0.0482**	-0.0064		
$\Delta(ca)$			-0.0383	-0.0192
$z_{i,t-1}$	-0.088	-0.1981	-0.0678	-0.2478
c	-0.0245		-0.0256	
gamma	1.3047e+04		1.3265e+04	
SSR	27.104		26.183	

The oil price and the **reer** tend to evolve in the same direction when the dollar depreciates (up until a threshold of 2.45%). Nevertheless, this relationship reverses when the dollar tends to appreciate. In this case, a 10% increase in the oil price leads to a depreciation of the exchange rate of 1.58%. There are few potential explanations for these results. Firstly, countries tend to stick to their anchors whenever it is not appreciating (Coudert et al., 2012). In other words, when the dollar is weak the impact of oil movements on the exchange rate remains positive, as expected. Conversely, when the dollar appreciates countries loosen their pegs leading their currencies to depreciate. In such case, an oil price increase has a negative impact on the exchange rate of oil exporters. A second potential explanation to this phenomenon relies on oil economies' imports. When the dollar appreciates, oil economies tend to increase their imports, leading to a depreciation of their **reer** in the short-term.[18] Such evolution can be illustrated by Figure 2 below, which shows the Saudi Arabian and the Ecuadorian both goods and services imports as a share of the GDP and the dollar real exchange rate.

Figure 2: Imports (right axis in first difference and percentage points) and the dollar (left axis in first difference logarithm)



Finally, results could be related to monetary authorities' behavior after a dollar appreciation. Anticipating a fall on exports that would follow a permanent dollar appreciation, monetary authorities operate in the foreign exchange market in order to prevent any shock on the exchange rate resulting from the oil price increase, which leads to a negative impact of the oil price on the **reer** on the short run.

5.3 Re-testing the causality direction between the USD reer and the oil price

Empirical studies on the links between the dollar and the oil price (Amano and van Norden, 1995; Coudert et al., 2008) find that the two variables co-move and that oil prices are weakly exogenous to the dollar exchange rate. The causality direction between these two variables is of great concern for this paper. Indeed, if oil prices affect the dollar **reer** this implies that the PSTR model estimated in

[18] All PSTR estimation results are displayed in Table 11 in Appendix 4.

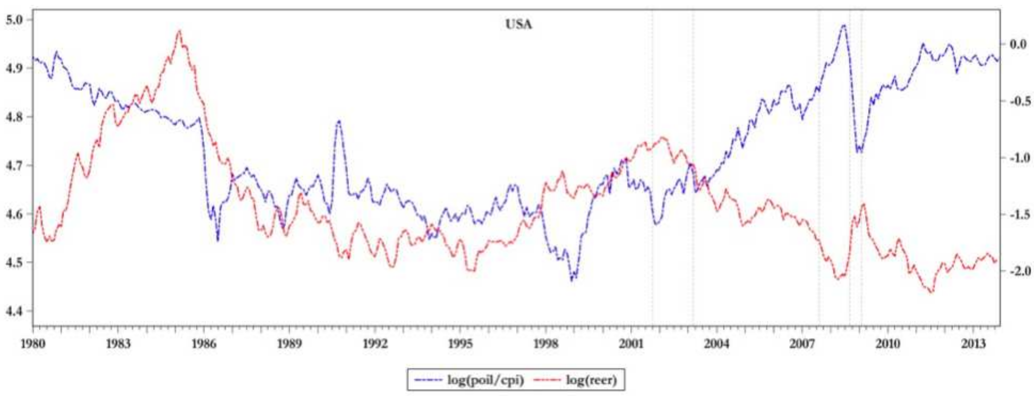
section 5.1 may not fully capture the impact of the dollar swings on the oil currency – oil price nexus. The threshold values may be misleading, as they are not exogenous to oil price movements. Short-term changes in oil price may be directly related to dollar fluctuations and therefore the dollar would not be a relevant transition variable from an economic point of view.

Furthermore, the causality direction or the sign of the relationship between oil price and the dollar has not been recently studied. A first look on both variables (Figure 3) suggests that the relationship between them may have changed. The dollar has been depreciating since mid-2001, while oil price has been increasing since the same period. As a matter of fact, since the early 2000s, some historical facts could be related to a change in the way both variables are connected.

In 2001, after the 11/9 attacks the US Congress authorized the use of military weapons against terrorism and the US declared war against Afghanistan. This raised instability in the world's oil supply, since main global oil producers belong to the Middle East, which could explain why crude oil prices increased from the end of 2001 until the middle of 2002.[19] In March 2003, the US invaded Iraq searching for massive destruction weapons only leaving the country at the end of 2011. At the same period crude oil price increased at an extremely fast pace while the dollar exchange rate depreciated. On the demand side, the economic prosperity of BRICS economies increased oil consumption, what contributed even more to push oil price up.

Figure 3 below illustrates these events representing the evolution of both variables. It is possible to notice that the only cliff on oil price series corresponds to the financial crisis. Nevertheless, since the Fed has started its quantitative easing monetary policy in late November 2008 both series seem to steadily co-move in opposite directions: the oil price following an up- while the dollar a down-ward trend.

Figure 3: real oil price and dollar reer



All these exogenous facts could have changed the relationship between the dollar exchange rate and oil prices. In order to verify in which extent they explain a possible change in the connection of both

[19] For a more detailed analysis see the American Congress Report from September 2002.

series, we estimate the cointegrating relationship and perform a Granger-causality test between the two variables relying on an error correction model. To this end, we use monthly data from 1980M1 to 2013M12 provided by the IMF IFS and analyze all different sub-periods aforementioned: which are listed in Table 3.

During all different periods both series are non stationary and cointegrated. Results from the Granger-causality test applied to the error correction model framework as well as the sign of the cointegrating relationship are summarized in Table 3:[20]

Table 3: Relationship sign and Granger-causality test results

Sub-period	Relationship	Granger-causality
1980M01-2001M10	positive	OIL → REER (LT)**
2001M11-2013M12	negative	REER → OIL (ST)**
1980M01-2003M03	positive	OIL → REER (LT)**
2003M04-2013M12	negative	REER → OIL (ST)**
2003M03-2011M12	negative	REER → OIL (ST)***
1980M01-2009M02	positive	REER → OIL (ST)***
2009M02-2013M12	negative	REER ↔ OIL (ST)**
1980M01-2013M12	negative	REER → OIL (ST)***

x → y means x Granger-causes y

First, until Iraq war our results support previous studies (Armano and van Norden, 1995; Coudert et al., 2008) suggesting that oil price fluctuations have an impact on the dollar exchange rate, and the long-term (LT) relationship between the two variables is positive. Nevertheless, the connection between the two variables seems to be affected by all different events aforementioned. During the sub-periods from the beginning of Afghanistan war or the beginning of Iraq war until the end of 2013 the sign of the relationship becomes negative on the short-term (ST) and the causality direction goes from the dollar exchange rate to the oil price. Results also suggest that after the ARRA in 2009M02 the two series present a bi-directional causality on the short run. Yet, both causality directions can be explained.

5.3.1 A negative causality that runs from the dollar to the oil price

In order to understand how the causality goes from the dollar to the oil price in a negative relationship, it is important to analyze how the dollar affects the oil demand and supply both on the short and on the long run. On the demand side, oil purchases are paid in dollar. Nevertheless, consumer countries care about its price in their domestic currency. On the supply side, oil companies use local currencies of producer countries to pay their employees, taxes and other costs (Coudert et al., 2005).

On the short run, due to production constraints and a lack of low cost substitutes, oil supply and demand are both inelastic to the price (Carnot and Hagege, 2004). On the long run, oil supply and demand become flexible and can adjust to price fluctuations. In this context, a dollar appreciation increases oil price in floating economics, which reduces its global demand leading to a negative impact on its price.

[20]Some of the periods are not long enough to offer conclusive results.

Conversely, in oil countries that are pegged to the dollar, a depreciation of the anchor currency generates inflation as prices from importing products relatively increase, decreasing the purchasing power. The real disposable income in these countries falls, which *ceteris paribus* reduces the revenue available for drilling. Consequently, there is a shortage in oil supply, which increases oil price.

China's huge demand for oil could be another fact behind a negative causality that runs from the dollar do the oil price. Since the end of 2005 the Chinese renminbi has been moving towards a fully float currency.[21] Therefore, when the dollar depreciates, it favors China's crude oil imports increasing global demand. Consequently, oil price increases in the short run to reach market equilibrium.

5.3.2 A positive causality that runs from the oil price to the dollar

Courdert et al. (2005) explain that a positive shock on oil price can appreciate the US dollar, if the United States imports less oil relatively to its European partners. Another explanation the authors present is the following: if the US demand for oil is very elastic in the long run, an oil price increase generates an improvement of the trade balance that is compensated by an appreciation of the dollar exchange rate in order to restore the external balance.

These explanations sound appealing even though contradictory. A missing point on the mechanism they describe is the way oil price movements spill on inflation. Oil is an important component of consumer price index. In the past, positive oil price shocks would provoke inflationary pressure. To tackle inflation, monetary authorities would increase interest rates. Since the mid-90s inflation has been stable. Hence, oil price movements are not fully transferred to inflation, and therefore do not lead to monetary policy responses. This change in the way oil movements affect inflation is a key point because otherwise an oil price increase would appreciate the exchange rate through the monetary policy channel.

Fed fund rates started decreasing in 2001. Since 2008M12 interest rates remain constantly low (0.25%). In this context, the mechanism described in 5.3.1 seems to be consistent with a stable low rate Fed monetary policy. In such situation, investors benefit from a cheaper dollar and expand investment drilling. Nevertheless, they anticipate a further increase in interest rates setting current oil price higher – assuring overall investment profit. Higher oil price does not impact demand as long as the dollar remains weak (which on average is the case since 2001).

Low US interest rates may explain that oil prices steadily increase since the mid-2001; as well as the change in the relationship between the dollar and the oil price. Both factors could be at the center of the oil currencies - oil price nexus.

5.4 What is the Fed's monetary policy impact on oil economies' reer?

In order to assess how the US monetary policy affects the relationship between oil currencies and oil price, we use the same PSTRECM framework and strategy from section 5.1 considering the transition

[21] China has become the largest net crude oil consumer in 2014 according to the Energy Information Administration (EIA)

variable as the annual standard deviation of the Fed monthly policy rate. All tests results are reported in Tables 11 and 12 in Appendix 4. They confirm the presence of a non linear effect of the Fed monetary policy volatility for the whole sample, and for both the OPEC and PEG groups.

Table 4 below reports the estimation results for the whole sample, which are similar across groups regardless the price set used.

Table 4: PSTR results

Whole sample	Regime 1	Regime 2	Regime 1	Regime 2
Δ*log(poil/ hcpi)*	-0.1477***	0.2614	-0.1048**	0.2112***
Δ*log(bs)*	-0.0021	0.0026	-0.0005	-0.0034
Δ*(nfa)*	-0.0073	0.0749		
Δ*(ca)*			-0.228	0.1951
$z_{i,t-1}$	-0.4357**	0.3821*	-0.4370**	0.3779*
c	0.3041		0.3039	
gamma	4.1740e+03		5.0937e+03	
SSR	260.582		251.987	

According to our results, an oil price increase has a negative impact on oil exporters' exchange rate if the standard deviation of the Fed policy rate is lower than approximately 0.30. In fact, a 10% increase on oil price leads the real exchange rate to depreciate of 1.26% on average. This is hardly what happens. In fact, on the covered period only 12 observations are below the threshold of 0.30, in which 7 appear after 2001. This validates the hypothesis that the Fed monetary policy is behind the causality direction between the dollar exchange rate and oil prices.

Conversely, if the Fed starts to interfere in the interbank market - whenever the standard deviation of the policy rate for a given year is higher than 0.30 – the impact of the oil price on the real exchange rate is positive (0.11). The coefficient value of the oil price is close but lower than the one calculated for the cointegrating relationship meaning a higher elasticity of the exchange rate to the oil price on the long run. This supposes that previous results that state a positive relationship between oil currencies and oil price could be indirectly related to US monetary policy.

6 Conclusion

This paper investigated if the connection between oil currencies and the oil price is affected by dollar movements. Our findings support the existence of oil currencies estimating that, in the long-term, a 10% increase in the oil price leads to roughly 1.55% appreciation of the exchange rate of the considered oil-exporting countries. Our study also validates the hypothesis that dollar movements affect the relationship between oil currencies and oil price. When the dollar is appreciating, oil price fluctuations have a negative impact on oil-exporting economies' exchange rates. Multiple reasons may explain this phenomenon. Firstly, positive shocks on the dollar exchange rate increase overall imports in oil-exporting economies, which results in a depreciation of their currency. Secondly, oil-exporting countries that are pegged to the dollar tend to loosen their pegs when the anchor currency appreciates (Coudert et al., 2011), changing the way oil price affects their currencies. Finally, monetary authorities from oil-exporting economies anticipate a fall in exports that would follow a permanent dollar appreciation, and operate in the foreign exchange market in order to prevent any shock on the exchange rate resulting from the oil price increase, which leads to a negative impact of the oil price on the real effective exchange rate on the short run.

To better understand the interactions between the dollar and the oil price we re-visit the causality direction between the two variables finding that it has changed direction over the recent years: after 2001, dollar movements negatively affect oil price and not the inverse. This could be in part explained by China's crude oil enormous demand and its currency that since the end of 2005 has been loosing its peg to the dollar. When the dollar depreciates it increases Chinese demand for oil, which - due to its quantity – has an impact on the global demand. As a consequence, oil price increases.

Finally, we investigate if the US monetary policy is related (if not at the center) to the oil currency – oil price nexus. Estimating a panel smooth transition regression model, we find evidence to support that oil currencies' connection with oil price is affected by the Fed's interest rate. As a matter of fact, oil price has a negative impact on oil exporters' real effective if the US monetary policy has a low volatility, which from a historical perspective rarely occurs but has been the case since 2008M12. This could be the reason why oil price has been increasing in the last years without any counter impact on oil-exporting countries' performance. Oil price constant increases no longer seem to have a positive impact on their **reer**. Albeit this paper offers some insights on how the US monetary policy may influence the relationship between oil price and oil currencies, more research has to be done, in order to fully comprehend these mechanisms.

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A Appendix

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

Cashin et al. (2004) consider a small open domestic economy where two goods are produced: a tradable, X (i.e. a commodity); and a non-tradable, N, good. Labor can move freely across the economy in such a way that nominal wages (w) are the same across sectors. At the equilibrium, the marginal productivity (η) must equal the real wage (w/P) in each sector i:

$$\eta_i = w/P_i \tag{1}$$

Furthermore, tradable goods are only consumed abroad while non-tradable goods are only consumed in the domestic country. Hence, the price of tradable goods (P_X) is determined 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:

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

Domestic agents consume an imported good (T) which price is defined by the law of one price as follows:

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

The nominal exchange rate (E) is defined as the amount of foreign currency per unit of local currency. Hence, when the local currency appreciates $\boldsymbol{E}$ value increases.

The foreign economy is composed of three sectors: non-tradable good (N^*), an intermediate good (I^*) and a final good (T^*). The final good requires an intermediate input (I) and the tradable good (X). Labor also moves freely across sectors, which implies:

$$P_N^* = \frac{\eta_I^*}{\eta_N^*} P_I^* \tag{4}$$

The real exchange rate is defined as the ratio between the foreign price of the domestic consumption basket (EP) and the foreign price of a foreign consumption basket (P^*) as follows:

$$RER = \frac{EP}{P^*} \tag{5}$$

The consumer price index (CPI) is defined as the weighted average of the goods price, where the share of the consumed goods in the consumer's basket accounts for the weights (α):

$$P = (P_N)^{\alpha}(P_T)^{1-\alpha} \tag{6}$$

Plugging Equation (6) in Equation (5):

$$RER = \frac{E(P_N)^{\alpha}(P_T)^{1-\alpha}}{(P_N^*)^{\alpha}(P_T^*)^{\alpha}} \tag{7}$$

Plugging Equations (2), (3) and (4) in Equation (7):

$$RER = \left(\frac{\eta_X \eta_N^*}{\eta_X \eta_I^*}\right)^{\alpha} \left(\frac{P_X^*}{P_I^*}\right)^{\alpha} \tag{8}$$

Where the first term represents the Balassa-Samuelson effect (**bs**) and the second term represents the terms of trade (**ToT**) measured in foreign prices.

A.2 Formulas

The **real effective exchange rate** (Darvas, 2012) is calculated as:

$$REER_t = \frac{NEER_t CPI_t}{CPI_t^{(foreign)}}$$

Where $REER_t$ is the real effective exchange rate of the country under study against a basket of currencies of trading partners, CPI_t is the consumer price index of the country under study, $NEER_t = \prod_{i=1}^{N} S(i)_t^{w(i)}$ is the nominal effective exchange rate of the considered country, which is in turn the geometrically weighted average of $S(i)_t$, the nominal bilateral exchange rate between the country under study and its trading partner i (measured as the foreign currency price of one unit of domestic currency), $CPI^{foreign} = \prod_{i=1}^{N} CPI(i)_t^{w(i)}$ is the geometrically weighted average of CPI indices of trading partners,

$CPI(i)_t$ is the consumer price index of trading partner i, $w^{(i)}$ is the weight of trading partner i, and N is the number of trading partners considered. The weights sum to one, $\sum_{i=1}^{N} w^{(i)} = 1$

The Balassa-Samuelson effect

$$
\begin{aligned}
BS_{i,t} &= \frac{PPP\,GDP\,cap_{i,t}}{\prod_{j=1,j\neq i}^{78} PPP\,GDP\,cap_{j,t}^{(w_j)}} \\
w_j &= \frac{GDP_j}{\sum_{k=1}^{78} GDP_k} \\
\sum_{j=1}^{78} w_j &= 1
\end{aligned}
$$

A.3 The oil price - oil currency nexus

Figure 4: Graphs reer x oil price

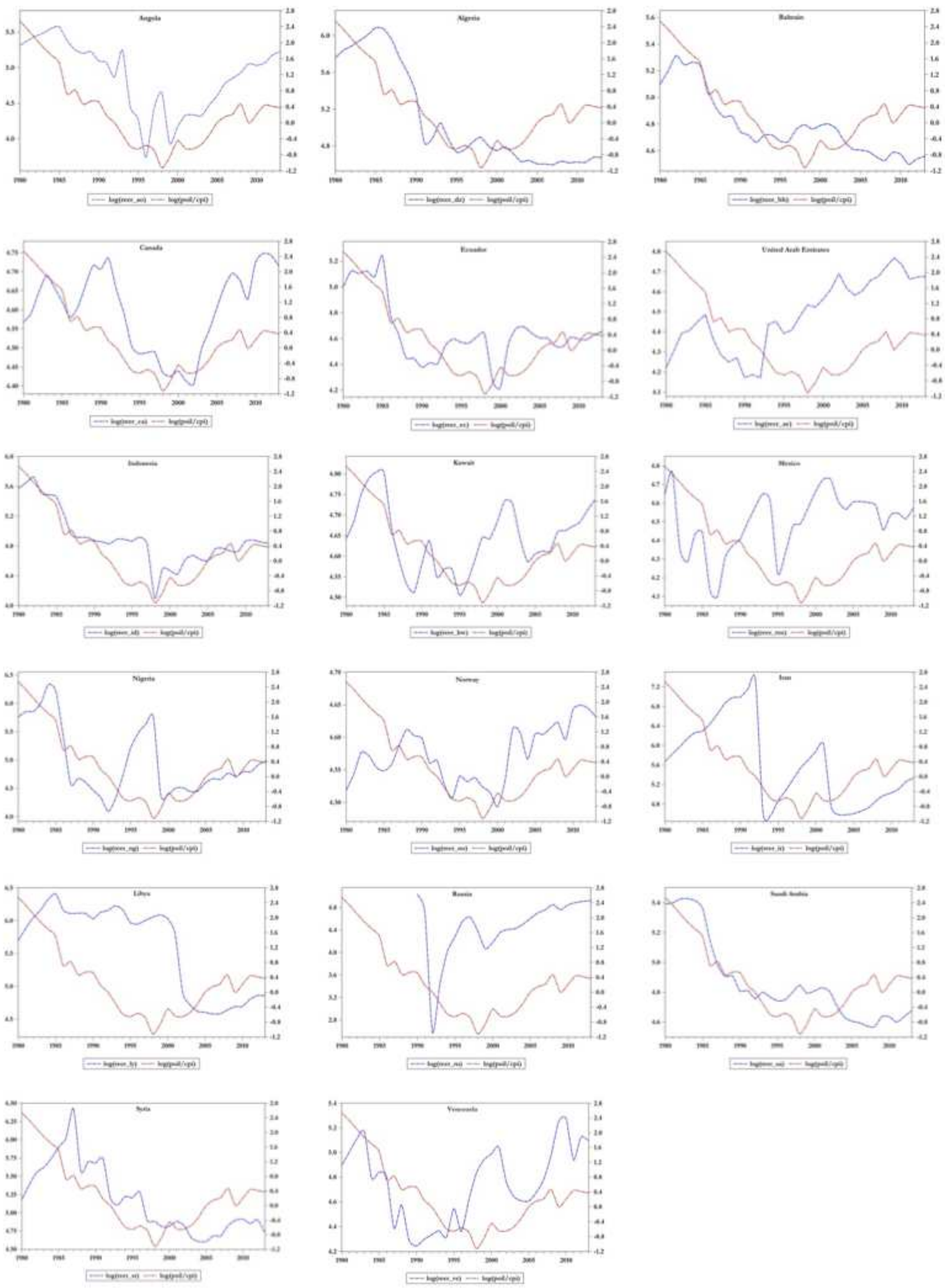

Table 5: Unit root tests results

Series	LLC	Hadri	I-P-S	MW
log(reer)	**1.02 (0.85)**	**6.27 (0.00)**	**-1.03 (0.15)**	50.26 (0.09)
log(poil/cpi)	-5.01 (0.00)	**13.68 (0.00)**	**0.43 (0.66)**	**24.57 (0.95)**
log(bs)	**0.54 (0.71)**	**5.79 (0.00)**	**2.60 (1)**	**21.30 (0.99)**
nfa	-2.14 (0.02)	**8.94 (0.00)**	**0.02 (0.51)**	**37.17 (0.51)**
ca	-8.13 (0.00)	**9.24 (0.00)**	-5.99 (0.00)	103.84 (0.00)

Series	ADF	PP	KPSS
log(poil/cpi)	-3.2 (0.00)	**-1.21 (0.89)**	**0.20****
log(poil/muv)	**-1.95 (0.60)**	**-1.82 (0.67)**	**0.20****

p-values in parentheses, **bold** means non-stationary process

Table 6: Cointegration tests results

Pedroni (log(reer) ; log(poil/cpi) ; log(bs) ; nfa)							Kao
whithin-dimension				*between-dimension*			
v-stat	*rho-stat*	*PP-stat*	*ADF-stat*	*p-stat*	*PP-stat*	*ADF-stat*	*ADF*
0.70 (0.24)	0.97 (0.83)	**-1.73** (0.04)**	**-2.81*** (0.00)**	2.42 (0.99)	-1.19 (0.11)	**-2.95*** (0.00)**	**-3.55*** (0.00)**

Pedroni (log(reer) ; log(poil/cpi) ; log(bs) ; ca)							Kao
whithin-dimension				*between-dimension*			
v-stat	*rho-stat*	*PP-stat*	*ADF-stat*	*p-stat*	*PP-stat*	*ADF-stat*	*ADF*
-0.31 (0.62)	1.50 (0.93)	-0.98 (0.16)	**-2.81*** (0.00)**	2.87 (0.99)	-0.59 (0.27)	**-2,74*** (0.00)**	**-2,15** (0.02)**

Pedroni (log(reer) ; log(poil/muv) ; log(bs) ; nfa)							Kao
whithin-dimension				*between-dimension*			
v-stat	*rho-stat*	*PP-stat*	*ADF-stat*	*p-stat*	*PP-stat*	*ADF-stat*	*ADF*
0.49 (0.31)	0.40 (0.65)	**-2.42*** (0.01)**	**-2.68*** (0,00)**	1.77 (0.96)	**-1.89 (0.03)**	**-2.18*** (0.01)**	**-2,27** (0.01)**

Pedroni (log(reer) ; log(poil/muv) ; log(bs) ; ca)							Kao
whithin-dimension				*between-dimension*			
v-stat	*rho-stat*	*PP-stat*	*ADF-stat*	*p-stat*	*PP-stat*	*ADF-stat*	*ADF*
-0.27 (0.61)	1.09 (0.86)	**-1.51* (0.07)**	**-2.98*** (0.00)**	2.54 (0.99)	-1.22 (0.11)	**-2.88*** (0.00)**	-1.12 (0.13)

Pedroni (log(reer) ; log(poil/hcpi) ; log(bs) ; nfa)							Kao
whithin-dimension				*between-dimension*			
v-stat	*rho-stat*	*PP-stat*	*ADF-stat*	*p-stat*	*PP-stat*	*ADF-stat*	*ADF*
0.82 (0.21)	0.80 (0.79)	**-2.06** (0.02)**	**-3.54*** (0,00)**	1.93 (0.97)	**-1.85** (0.03)**	**-3.87*** (0.00)**	**-2.22** (0.01)**

Pedroni (log(reer) ; log(poil/hcpi) ; log(bs) ; ca)							Kao
whithin-dimension				*between-dimension*			
v-stat	*rho-stat*	*PP-stat*	*ADF-stat*	*p-stat*	*PP-stat*	*ADF-stat*	*ADF*
-0.36 (0.64)	0.94 (0.83)	**-1.51* (0.07)**	**-3.18*** (0.00)**	2.45 (0.99)	-1.25 (0.11)	**-3.23*** (0.00)**	**-1.28* (0.09)**

p-values in parentheses, **bold** means acceptance of the null of cointegration

Table 7: Country groups

OPEC	Others	Peg regime	Float regime
Angola	Bahrain	Angola	Algeria
Algeria	Canada	Ecuador	Libya
Ecuador	Indonesia	Iran	Canada
Iran	Mexico	Kuwait	Indonesia
Kuwait	Norway	Nigeria	Mexico
Libya	Oman	Qatar	Norway
Nigeria	Russia	Saudi Arabia	Russia
Qatar	Syria	United Arab Emirates	
Saudi Arabia		Venezuela	
United Arab Emirates		Bahrain	
Venezuela		Oman	
		Syria	

Table 8: Granger-causality test results (p-values)

Whole sample

X/Y	Δlog(reer)	Δlog(poil/cpi)	Δlog(poil/muv)	Δlog(poil/hcpi)	Δlog(bs)	Δ(nfa)	Δ(ca)
Δlog(reer)	-	0.34	0.45	0.82	**0.02**	0.12	0.00
Δlog(poil/cpi)	**0.03**	-	-	-	**0.04**	**0.00**	0.81
Δlog(poil/muv)	**0.02**	-	-	-	0.11	**0.03**	**0.06**
Δlog(poil/hcpi)	**0.01**	-	-	-	**0.07**	**0.02**	0.58
Δlog(bs)	**0.01**	0.69	0.64	0.63	-	0.19	**0.00**
Δ(nfa)	**0.08**	0.15	0.68	**0.09**	0.51	-	-
Δ(ca)	**0.09**	0.58	0.06	0.72	0.63	-	-

OPEC

X/Y	Δlog(reer)	Δlog(poil/cpi)	Δlog(poil/muv)	Δlog(poil/hcpi)	Δlog(bs)	Δ(nfa)	Δ(ca)
Δlog(reer)	-	0.10	0.84	0.16	**0.08**	0.82	0.43
Δlog(poil/cpi)	**0.01**	-	-	-	**0.00**	**0.00**	**0.22**
Δlog(poil/muv)	**0.00**	-	-	-	**0.00**	**0.00**	0.58
Δlog(poil/hcpi)	**0.00**	-	-	-	**0.00**	**0.00**	0.28
Δlog(bs)	**0.03**	0.86	0.68	0.73	-	**0.05**	**0.00**
Δ(nfa)	**0.01**	**0.03**	0.88	**0.01**	0.26	-	-
Δ(ca)	**0.07**	0.86	0.11	0.82	0.20	-	-

Others

X/Y	Δlog(reer)	Δlog(poil/cpi)	Δlog(poil/muv)	Δlog(poil/hcpi)	Δlog(bs)	Δ(nfa)	Δ(ca)
Δlog(reer)	-	0.66	0.37	0.20	0.13	**0.03**	**0.00**
Δlog(poil/cpi)	0.05	-	-	-	0.29	0.82	**0.08**
Δlog(poil/muv)	0.07	-	-	-	0.25	0.99	**0.00**
Δlog(poil/hcpi)	0.08	-	-	-	0.40	0.58	0.70
Δlog(bs)	**0.09**	0.69	0.81	0.74	-	0.78	0.02
Δ(nfa)	0.58	0.75	0.43	0.68	0.78	-	-
Δ(ca)	0.62	0.52	0.30	0.78	0.47	-	-

Peg

X/Y	Δlog(reer)	Δlog(poil/cpi)	Δlog(poil/muv)	Δlog(poil/hcpi)	Δlog(bs)	Δ(nfa)	Δ(ca)
Δlog(reer)	-	0.11	0.79	0.28	**0.09**	**0.06**	0.42
Δlog(poil/cpi)	**0.00**	-	-	-	**0.00**	**0.03**	0.63
Δlog(poil/muv)	**0.00**	-	-	-	**0.01**	**0.06**	0.42
Δlog(poil/hcpi)	**0.00**	-	-	-	**0.01**	**0.05**	0.22
Δlog(bs)	0.95	0.89	0.95	0.91	-	0.17	**0.00**
Δ(nfa)	**0.00**	**0.96**	0.42	0.49	**0.52**	-	-
Δ(ca)	**0.07**	0.40	**0.11**	0.88	**0.33**	-	-

Float

X/Y	Δlog(reer)	Δlog(poil/cpi)	Δlog(poil/muv)	Δlog(poil/hcpi)	Δlog(bs)	Δ(nfa)	Δ(ca)
Δlog(reer)	-	0.62	0.38	0.32	0.12	0.88	**0.00**
Δlog(poil/cpi)	0.04	-	-	-	0.63	**0.05**	0.32
Δlog(poil/muv)	0.06	-	-	-	0.50	0.26	**0.05**
Δlog(poil/hcpi)	0.07	-	-	-	0.81	0.18	0.51
Δlog(bs)	**0.00**	0.40	0.39	0.35	-	0.72	**0.00**
Δ(nfa)	0.12	**0.02**	0.72	**0.06**	0.81	-	-
Δ(ca)	0.67	0.86	0.31	0.70	0.65	-	-

H_0: X does not granger cause Y; H_1: X does granger cause Y
X: vertical column; Y: horizontal range

A.4 PSTR steps

Table 9: Linearity tests results (p-values) -$\Delta log(reer\_us)$

Ho: linearity	Δlog(reer_us)/PSTRECM - Whole Sample					
p-values displayed	cpi/nfa	cpi/ca	muv/nfa	muv/ca	hcpi/nfa	hcpi/ca
LM-stat	**0.003**	**0.005**	0.564	0.289	**0.01**	**0.008**
Fischer-stat	**0.004**	**0.006**	0.58	0.305	**0.011**	**0.009**
LRT-stat	**0.000**	**0.000**	**0.019**	**0.001**	**0.000**	**0.000**
Ho: linearity	Δlog(reer_us)/PSTRECM - OPEC					
p-values displayed	cpi/nfa	cpi/ca	muv/nfa	muv/ca	hcpi/nfa	hcpi/ca
LM-stat	**0.001**	**0.003**	0.377	0.228	**0.006**	**0.004**
Fischer-stat	**0.001**	**0.004**	0.394	0.242	**0.007**	**0.004**
LRT-stat	**0.000**	**0.000**	**0.002**	**0.000**	**0.000**	**0.000**
Ho: linearity	Δlog(reer_us)/PSTRECM - Others					
p-values displayed	cpi/nfa	cpi/ca	muv/nfa	muv/ca	hcpi/nfa	hcpi/ca
LM-stat	0.602	0.422	0.958	0.336	0.756	0.404
Fischer-stat	0.619	0.441	0.961	0.353	0.769	0.422
LRT-stat	**0.028**	**0.004**	0.628	**0.001**	0.111	**0.003**
Ho: linearity	Δlog(reer_us)/PSTRECM - Peg					
p-values displayed	cpi/nfa	cpi/ca	muv/nfa	muv/ca	hcpi/nfa	hcpi/ca
LM-stat	**0.000**	**0.003**	0.259	0.135	**0.001**	**0.002**
Fischer-stat	**0.000**	**0.003**	0.274	0.145	**0.001**	**0.003**
LRT-stat	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Ho: linearity	Δlog(reer_us)/PSTRECM - Float					
p-values displayed	cpi/nfa	cpi/ca	muv/nfa	muv/ca	hcpi/nfa	hcpi/ca
LM-stat	0.258	0.913	0.335	0.203	0.255	0.909
Fischer-stat	0.274	0.919	0.353	0.234	0.270	0.915
LRT-stat	**0.000**	0.420	**0.001**	0.203	**0.000**	0.403

H_0: linearity; H_1: non-linearity
p-values in **bold** represent presence of non-linearity

Table 10: PSTR estimation results - $\Delta log(reer\_us)$

	ALL COUNTRIES/PSTRECM							
	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
Δlog(poil/cpi)	0.1214***	-0.2369***	0.1462***	-0.1989***				
Δlog(poil/muv)								
Δlog(poil/hcpi)					0.1336***	-0.2171***	0.1320***	-0.2069***
Δlog(bs)	-0.0008	0.0031	-0.0038	0.0074	-0.0026	0.0063	-0.0040	0.0053
Δ(nfa)	0.0701**	-0.0871*			0.0482**	-0.0064		
Δ(ca)			-0.0307	-0.0848			-0.0383	-0.0192
z_{t-1}	-0.1430*	-0.2400	-0.0774	-0.2606	-0.0880	-0.1981	-0.0678	-0.2478
c	0.0056		-0.0212		-0.0245		-0.0256	
gamma	138.8355		541.4698		1.3047e+04		1.3265e+04	
RSS	25.592		26.184		27.104		26.183	
	OPEC COUNTRIES/PSTRECM							
	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
Δlog(poil/cpi)	0.0991*	-0.3113***	0.1325**	-0.2416**				
Δlog(poil/muv)								
Δlog(poil/hcpi)					0.1405**	-0.3835***	0.1141**	-0.2819***
Δlog(bs)	-0.0002	0.0024	-0.0019	0.0068	-0.0011	0.004	-0.0017	0.0042
Δ(nfa)	0.0486	-0.1197**			0.071**	-0.1132*		
Δ(ca)			-0.0347	-0.0255			-0.0374	0.01
z_{t-1}	-0.1261	-0.4027	-0.0407	-0.3161	-0.0838	-0.2418	-0.0443	-0.2938
c	0.0246		-0.0219		-0.0049		-0.0245	
gamma	7.0764e+03		582.4303		4.63E+01		1.1563e+04	
RSS	15.6498		16.7963		17.935		16.651	
	PEG COUNTRIES/PSTRECM							
	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
Δlog(poil/cpi)	0.1015*	-0.2974***	0.1162**	-0.2211**				
Δlog(poil/muv)								
Δlog(poil/hcpi)					0.1275**	-0.3803***	0.0742	-0.1972**
Δlog(bs)	-0.0034	0.006	-0.0118	0.0216	-0.0041	0.0111	-0.0114	0.0181
Δ(nfa)	0.0680**	-0.1301***			0.0813	-0.1335		
Δ(ca)			-0.0193	-0.1622			-0.0201	-0.0855
z_{t-1}	-0.119	-0.5152*	-0.0871	-0.3095	-0.1148	-0.3265	-0.0792	-0.3372
c	0.0246		-0.0098		0.0113		-0.0103	
gamma	8.4283e+03		133.8284		4.68E+01			
RSS	15.3202		17.114		17.934		16.861	

Table 11: Linearity tests results (p-values) - $\sigma(policy\_rate)$

Ho: linearity	**σ(policy_rate)/PSTRECM - Whole Sample**					
p-values displayed	cpi/nfa	cpi/ca	muv/nfa	muv/ca	hcpi/nfa	hcpi/ca
LM-stat	**0.000**	**0.000**	**0.005**	**0.000**	**0.000**	**0.000**
Fischer-stat	**0.000**	**0.000**	**0.006**	**0.000**	**0.000**	**0.001**
LRT-stat	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Ho: linearity	**σ(policy_rate)/PSTRECM - OPEC**					
p-values displayed	cpi/nfa	cpi/ca	muv/nfa	muv/ca	hcpi/nfa	hcpi/ca
LM-stat	**0.000**	**0.000**	**0.002**	**0.000**	**0.000**	**0.000**
Fischer-stat	**0.000**	**0.000**	**0.002**	**0.000**	**0.000**	**0.000**
LRT-stat	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Ho: linearity	**σ(policy_rate)/PSTRECM - Others**					
p-values displayed	cpi/nfa	cpi/ca	muv/nfa	muv/ca	hcpi/nfa	hcpi/ca
LM-stat	0.847	0.923	0.867	0.975	0.843	0.501
Fischer-stat	0.856	0.928	0.875	0.977	0.852	0.519
LRT-stat	0.238	0.458	0.282	0.749	0.231	**0.010**

Ho: linearity	**σ(policy_rate)/PSTRECM - Peg**					
p-values displayed	cpi/nfa	cpi/ca	muv/nfa	muv/ca	hcpi/nfa	hcpi/ca
LM-stat	**0.000**	**0.000**	**0.001**	**0.000**	**0.000**	**0.000**
Fischer-stat	**0.000**	**0.000**	**0.001**	**0.000**	**0.000**	**0.000**
LRT-stat	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Ho: linearity	**σ(policy_rate)/PSTRECM - Float**					
p-values displayed	cpi/nfa	cpi/ca	muv/nfa	muv/ca	hcpi/nfa	hcpi/ca
LM-stat	0.691	0.945	0.845	0.954	0.825	0.987
Fischer-stat	0.707	0.949	0.855	0.957	0.835	0.988
LRT-stat	**0.064**	0.558	0.236	0.608	0.199	0.852

H_0: linearity; H_1: non-linearity
p-values in **bold** represent presence of non-linearity

Table 12: PSTR results - $\sigma(policy\_rate)$

	ALL COUNTRIES/PSTRECM							
	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
Δlog(poil/cpi)	-0.1291*	0.2223**	-0.0391	0.1546*				
Δlog(poil/muv)								
Δlog(poil/hcpi)					-0.1477***	0.2614	-0.1048**	0.2112***
Δlog(bs)	-0.0051	0.0073	0.0028	-0.0068	-0.0021	0.0026	-0.0005	-0.0034
Δ(nfa)	-0.0650	0.1496**			-0.0073	0.0749		
Δ(ca)			-0.3131*	0.2709			-0.2280	0.1951
z_{t-1}	-0.6065**	0.5575*	-0.4661**	0.4232	-0.4357**	0.3821*	-0.4370**	0.3779*
c	0.2363		0.3250		0.3041		0.3039	
gamma	14.3987		215.6913		3.0289e+03		5.0937e+03	
RSS	24.157		24.909		26.058		25.199	
	OPEC COUNTRIES/PSTRECM							
	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
Δlog(poil/cpi)	-0.2267**	0.3342***	-0.1433	0.2538*				
Δlog(poil/muv)								
Δlog(poil/hcpi)					-0.2603***	0.3643***	-0.2420***	0.3271***
Δlog(bs)	-0.0027	0.0077	0.0019	-0.0036	-0.0036	0.0087	-0.0017	-0.0002
Δ(nfa)	-0.0556	0.1116*			-0.0559	0.1130*		
Δ(ca)			-0.1561	0.1177			-0.0007	-0.0236
z_{t-1}	-0.5690**	0.5532**	-0.4999**	0.4807**	-0.5074**	0.4868**	-0.4938**	0.4674**
c	0.3041		0.3297		0.3044		0.3041	
gamma	4.4805e+03		255.3071		3.8664e+03		4.3038e+03	
RSS	14.353		15.371		16.259		15.359	
	PEG COUNTRIES/PSTRECM							
	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
Δlog(poil/cpi)	-0.2112***	0.3346***	-0.1352	0.2513**				
Δlog(poil/muv)								
Δlog(poil/hcpi)					-0.1938***	0.3135***	-0.1678**	0.2642***
Δlog(bs)	0.0015	-0.0029	0.0094	-0.0156	0.0035	-0.0043	0.0042	-0.0102
Δ(nfa)	-0.0266	0.0905			-0.0211	0.0858		
Δ(ca)			-0.1913	0.1555			-0.1763	0.1548
z_{t-1}	-0.6028**	0.5863**	-0.5320**	0.5014*	-0.5388**	0.5114*	-0.5260**	0.4856*
c	0.3263		0.3255		0.3047		0.3041	
gamma	167.9168		153.1229		3.5812e+03		4.1955e+03	
RSS	14.493		15.586		16.581		15.592	