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On the impact of oil price volatility on the real exchange rate – terms of trade nexus: Revisiting commodity currencies

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Highlights

- We investigate the relationship between terms of trade and real exchange rates for a panel of 69 commodity-producing countries over the 1980-2012 period.

- We show that the terms of trade - real exchange rates nexus is nonlinear and depends on the volatility on the oil market.

- Exchange rates are mainly driven by fundamentals in the low-volatility regime, and are mostly sensitive to changes in terms of trade when oil price variations exceed a certain threshold.

RESEARCH AND EXPERTISE
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▐ Abstract

The aim of this paper is to study the relationship between terms of trade and real exchange rates of commodity-producing countries on both the short and the long run. We pay particular attention to the dominant role played by oil among commodities by investigating the potential non-linear effect exerted by the situation on the oil market on the real exchange rate - terms of trade nexus. To this end, we rely on the panel smooth transition regression methodology to estimate the adjustment process of the real effective exchange rate to its equilibrium value depending on the volatility on the oil market. Considering a panel of 52 commodity exporters and 17 oil exporters over the 1980-2012 period, our findings show that while exchange rates are mainly driven by fundamentals in the low-volatility regime, they are mostly sensitive to changes in terms of trade when oil price variations exceed a certain threshold. The commodity-currency property is thus at play in the short run only for important variations in the oil price.

▐ Keywords

Commodity currencies, Oil price, Non-linearity.

▐ JEL

C23 ; F31; Q43.

On the impact of oil price volatility on the real exchange rate – terms of trade nexus: Revisiting commodity currencies[♦]

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1.   Introduction

Commodity-producing countries are reliant on world commodity prices regarding their exports, income and inflation rates. Their currencies are also known to be affected by commodity prices, in such a way that they are dubbed "commodity currencies" on the forex market, a denomination that gathers together the Australian dollar, the New Zealand dollar, the Canadian dollar as well as a number of currencies issued by emerging commodity exporters. Indeed, their real exchange rates tend to respond to the commodity terms of trade, defined as the ratio of the country's commodity export price to the import price. Two types of theoretical effects are at stake depending on the horizon. First, in the long run, a rise (fall) in terms of trade brings about more (lower) income and wealth in the exporting countries, which causes the real exchange rate to appreciate (depreciate). This long-run effect has been extensively documented in the economic literature dealing with the influence of fundamentals on equilibrium real exchange rates (Edwards, 1994; Isard, 2007; Ricci et al., 2008). Second, even if the real effect is felt only in the long term, market participants anticipate this movement and bid up the currency, as soon as commodity prices begin to rise. Consequently, commodity currencies have been shown to closely follow the fluctuations of commodity prices (Chen and Rogoff, 2003; Clements and Fry, 2007).

In this paper, we aim at better capturing the relation between terms of trade and the real exchange rates of commodity-producing countries on both the short and the long run by paying particular attention to non-linearities. Indeed, the forex markets are subject to non-linear responses to fundamentals, as they are often disrupted in times of financial strains. In those periods, as risk aversion rises, long positions taken on risky currencies through carry trades are abruptly unwound, and exchange rates' movements are disrupted (Clarida et al.,

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2009). Consequently, it is very likely that the real exchanges rates of commodity producers also respond in a non-linear way to terms of trade, depending on risk aversion and uncertainty on the global economy. More precisely, we argue that commodity prices spill over into the forex markets to a larger extent in periods of uncertainty, i.e., when volatility is high.

We therefore state the hypothesis that the real exchange rates of commodity-producing countries are more tightly linked to their terms of trade in times of high volatility on commodity markets. In other words, we name "commodity-currency property" the tendency for a currency to co-move with commodity prices, and we check for this feature being exacerbated in periods of high volatility. If our hypothesis holds, the relationship between real exchange rates and commodity terms of trade should be reformulated to account for these non-linearities. We therefore test for this hypothesis in the framework of a non-linear model. In this sense, our study can be viewed as an extension of the literature on commodity currencies (see e.g., Cashin et al., 2004) which analyzes the link between exchanges rates and commodity prices without accounting for non-linearities caused by market volatility.

Commodity markets strongly interact with one another for a number of reasons; among them the exchange-traded funds buying futures on indexes of commodities contribute to enhance the co-movements. In this respect, the oil market has a key role by its dominating size and its preponderant weight in commodity indexes. We thus retain the oil price volatility as a gauge of strains on all commodity markets, and search for non-linearities in exchange rates' response to terms of trade depending on the volatility of oil price. Volatility spillovers from oil to commodity markets may have amplifying effects on the reaction of commodity currencies to prices, as crude oil price changes are transmitted to other commodity prices (Baffes, 2007). While research has been extensive on the interdependencies between oil and commodity markets, no study has been devoted to the link between real exchange rates and those interactions. This is however a key issue: if oil price volatility is transmitted to other commodity prices, it can also aggravate pressures on commodity currency markets. Thus, commodity currencies may turn more sensitive to commodity prices in times of high oil price volatility. To the best of our knowledge, our contribution is the first to tackle this issue and also to investigate the impact of commodity terms of trade on currencies within a non-linear framework.

To this end, we consider a panel made of two groups of countries—17 oil exporters and 52 commodity exporters—over the 1980-2012 period. Our empirical approach involves two steps. First, we estimate a long-run, cointegrating relationship between the real effective exchange rate and economic fundamentals, including the commodity-terms of trade. This estimation amounts to finding an equilibrium value of the real effective exchange rate, in line with the behavioral equilibrium exchange rate (BEER) approach introduced by Clark and MacDonald (1998, 2000). Second, we estimate the short-run adjustment process to this equilibrium value through a panel smooth transition regression (PSTR) which is able to account for non-linearities. To provide a full analysis and deal with potential heterogeneity across the types of commodities, we also split the commodity producers by main exported

products: energy and metals, food, beverages and raw materials in order to compare the behavior of their exchange rates.

The rest of the paper is organized as follows. After a brief review of the related literature, Section 2 presents some stylized facts. Section 3 describes the methodology, and Section 4 deals with the construction of the dataset. Section 5 discusses the estimation results. Section 6 concludes.

2.   Main literature results and stylized facts

As we aim at analyzing the link between real exchange rates and commodity terms of trade, we give a first insight by looking at main literature results as well as pinpointing some stylized facts, evidencing the key role of oil among other commodity markets.

2.1.   Brief literature survey on real exchange rates, commodity and oil prices

The relationship between real exchange rates and commodity prices goes through the terms of trade, that are mainly driven by commodity prices in commodity-exporting countries. From a theoretical perspective, the influence of terms of trade on the real exchange rate was first investigated during the 1980s in the framework of two-sector models that analyzed the potential harmful impact of a natural resource sector boom on the economy, known as the "Dutch disease". The real exchange rate is defined either internally as the relative price between the two sectors, or externally by the relative price of the consumption basket between the home country and abroad. In both cases, it appreciates when the price of the non-tradable goods increases relatively to that of the tradables, due to the law of one price on tradables. In this framework, a rise in the exported commodity price triggers an appreciation of the real exchange rate through both substitution and income effects (Neary, 1988). Indeed it brings about a reduction in the supply of non-traded goods, through a substitution effect, increasing their price and therefore pushing up the real exchange rate. It raises as well the demand for those non-traded goods, through an income effect, contributing also to swelling their relative prices. These effects directly result from two key assumptions: (i) resources are drawn towards the commodity sector and (ii) non-traded goods are normal goods, whose demand increases with income. Consequently, the effects are attenuated by the release of these assumptions, especially if the commodity sector has production links with the rest of the economy, and thus encourages production of non-traded goods.

More recently, other studies have focused on the long-run relationship between the commodity price and the real exchange rate, going beyond demand-side considerations by extending the flexible-price Balassa–Samuelson model (Chen and Rogoff, 2003; Cashin et al., 2004). This long-run relationship only holds to a substitution effect under the assumption that wage movements diffuse across sectors. Indeed, an increase in the international commodity price is likely to set off wage hikes in the commodity sector; as wages equalize across sectors, pay rises push up the price of the non-traded goods and therefore also the

domestic consumption price relatively to the foreign one and the real exchange rate. As only the substitution effect is involved, the elasticity of the real exchange rate to the commodity price is smaller in these models than in the former ones derived from the Dutch disease effect (Tokarick, 2008). This elasticity is given by the share of non-tradable goods in the consumption basket (Cashin et al., 2004), and can be larger if the non-traded goods production is more labor intensive than the export goods sector (Chen and Rogoff, 2003).

The potential role of commodity prices in driving real exchange rate movements has also received much attention in the empirical literature. Cashin et al. (2004) find a significant long-run relationship between the real commodity price and the real exchange rates for one-third of 58 commodity-dependent countries, over the 1980–2002 period. Chen and Rogoff (2003) also evidence a cointegration relationship between these two variables for three OECD economies (Australia, Canada, and New Zealand) where primary commodities constitute a significant share of their exports. More recently, Bodart et al. (2012) conclude to a significant long-run impact of the price of a given commodity on the real exchange rate, if this commodity is predominant in the considered country's exports, its share being greater than 20 percent. Other empirical studies focus on oil currencies and find that a positive oil price shock is likely to generate an appreciation over the long run. Koranchelian (2005) and Zalduendo (2006) show that oil prices play a significant role in determining the equilibrium real effective exchange rate of Algeria and Venezuela. Similarly, estimating equilibrium real exchange rates over a panel of nine OPEC countries, Korhonen and Juurikkala (2007) confirm the statistically significant effect of the real price of oil on exchange rates.

Evidence from the literature also highlights the role played by exchange-rate regimes in the face of terms-of-trade shocks. Coudert et al. (2011) find that the real exchange rates of pegged commodity currencies depend on the behavior of their anchor. In particular, USD-pegged currencies had a tendency to depreciate with the dollar in the late 2000s, while those pegged to the euro had been pushed upwards. Aizenman et al. (2012) emphasize the role played by international reserves and managed exchange-rate flexibility in buffering and stabilizing the real exchange rate in the presence of large commodity terms of trade. By testing this hypothesis empirically for a set of Latin American countries, they find evidence that those economies actively countered appreciation pressures due to commodity terms of trade shocks in the 1970–2007 period, by accumulating forex reserves. Buetzer et al. (2012) confirm and extend these results to oil-exporting countries. Moreover, those authors show that the potential role of oil price changes in driving real exchange rates depends on the nature of the oil shock. Following the decomposition of oil shocks developed by Kilian (2009), they find that oil demand shocks are more prone to exert significant appreciation pressures in oil-exporting economies than oil supply and global demand shocks.

In addition to the influence of the commodity prices on real exchange rates, Clements and Fry (2007) explore the two-way spillovers between the two variables. They suggest that the world commodity prices may also respond to exchange rate movements in commodity currencies. This may happen if a country has a dominant position on the market of a given commodity in such a way that its market power puts it in a position of a price-maker. In this

case, all its economic fundamentals, including its exchange rate, may influence the market price. Although this dominant position is rather unusual for a single country, the same kind of results holds if several countries are in a dominant position on one commodity market, while their currencies head for the same direction. Then the appreciation (depreciation) of their real exchange rates is liable to increase (decrease) the world price of this commodity.

Finally, as oil prices have been found to be a major source of real disturbances (Zhou, 1995), a number of articles have paid close attention to the relationship between real oil prices and real exchange rates (see, for example, Chen and Chen, 2007). While emphasizing the particular role played by oil, the existing literature in this area mainly focuses on industrialized countries. Commodity exporters have then received little attention. However, oil price fluctuations can be a key factor to consider in explaining the behavior of their real exchange rates, given the linkages between oil and commodity markets.

2.2. The special case of oil

The dominant role of oil among commodity markets stems from its price impacting numerous sectors of an economy1 and also other commodity prices as well (Holtham, 1988; Gilbert, 1989; Borensztein and Reinhart, 1994; Baffes, 2007). As recalled by Baffes (2007) among others, the pass-through of oil price variations to commodity prices can be understood from both demand and supply sides. Considering the demand side, three main factors are at play. First, an oil price increase generates a rise in the disposable income of oil exporters, leading to a surge in the demand for other commodities, obviously especially those that are characterized by a high demand and high income elasticity. Second, given their potential substitutability property, a rise in the oil price affects the price of other energy commodities, such as coal, gas and electricity. Third, due to inflationary pressures associated with an oil price increase, the demand for precious metals may rise thanks to their safe-haven role, hence leading to an increase in their price. Turning to the supply side, oil is used as an input for the production of many other commodities, as well as for transportation. Thus, an augmentation in its price obviously leads to an increase in the production cost, impacting the price of those other commodities. For all those reasons, oil price variations may impact prices of other commodities and thus play a key role in the relationship between real exchange rates and commodity terms of trade.

As a simple illustration, consider the New Zealand dollar, which is usually viewed as a case-in-point for commodity currency (Chen and Rogoff, 2003; Cashin et al., 2004; Makin, 2013). Figure 1 reports the evolution of the real effective exchange rate and commodity terms of trade of New Zealand over the 1980-2012 period, while Figure 2 displays the oil price volatility over the same period. As those figures clearly show, movements in the terms of trade have closely followed changes in the real effective exchange rate, especially during episodes of high volatility on the oil market. This overall pattern is corroborated by calculating

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[1] See e.g., Jones and Leiby (1996), Brown and Yücel (2002), Jones et al. (2004) and Hamilton (2005).

the correlations between changes in the real exchange rate and terms of trade. Indeed, the average correlation is as high as 81.56% during periods of high volatility on the oil market, whereas it turns negative, falling to -32.09% in phases of low oil price volatility.[2] These stylized facts seem to support our hypothesis that the link between the real exchange rate and terms of trade depends on the situation on the oil market.

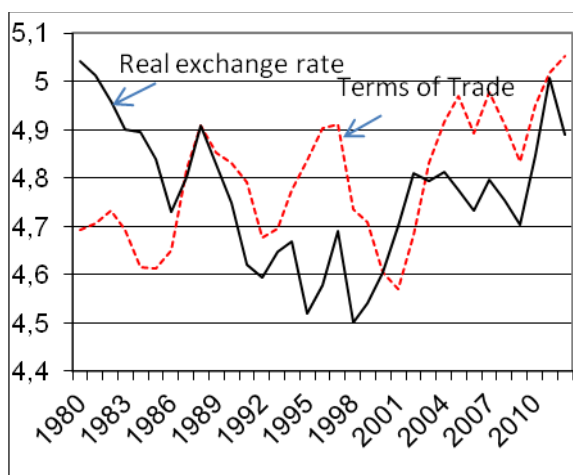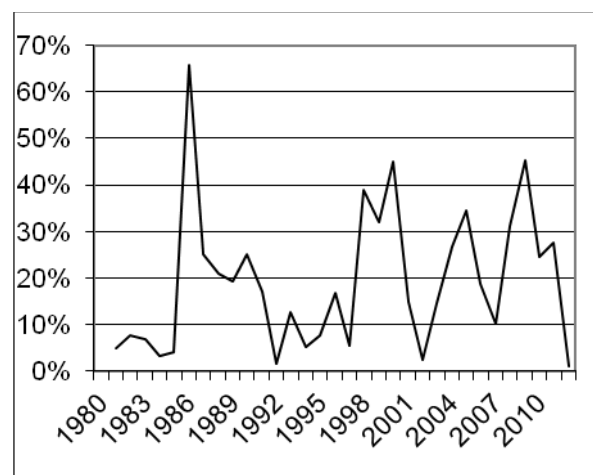**Figure 1. Real effective exchange rate and terms of trade for New Zealand**

Figure 2. Oil price volatility

Note: Annual data over the 1980-2012 period. Real effective exchange rate and terms of trade series are expressed in logarithms. Oil price volatility is proxied by the absolute value of oil price in first logarithmic differences. See Section 4 for data sources.

3.   Methodology

3.1.   The PSTR specification

To investigate this potential non-linear effect exerted by the situation on the oil market on the real exchange rate-terms of trade relationship, we rely on the PSTR methodology proposed by González et al. (2005). According to this specification, the observations are divided in—say—two regimes, with estimated coefficients that vary depending on the considered regime. The change in the estimated value of coefficients is smooth and gradual, since PSTR models are regime-switching processes in which the transition from one state to the other is smooth rather than discrete.

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[2] See below for the definition of low- and high-volatility regimes.

Let $\left\{ y_{i,t}, s_{i,t}, x_{i,t}; t = 1,...,T; i = 1,...,N \right\}$ be a balanced panel with t denoting time and i the individual (i.e., the country), $y_{i,t}$ being the dependent variable, $s_{i,t}$ the transition variable, and $x_{i,t}$ a vector of k exogenous variables. The PSTR model with two regimes is given by:

$$y_{i,t} = \alpha_i + \beta_0^{'} x_{i,t} + \beta_1^{'} x_{i,t} \times F\left(s_{i,t}; \gamma, c \right) + \varepsilon_{i,t} \tag{1}$$

where α_i denotes the country-fixed effects and $\varepsilon_{i,t}$ is an independent and identically distributed (i.i.d.) error term. The transition function F is normalized and bounded between 0 and 1, and is given by (González et al., 2005):

$$F\left(s_{i,t}; \gamma, c \right) = \left[1 + \exp\left(-\gamma \prod_{j=1}^{m}\left(s_{i,t} - c_j \right) \right) \right]^{-1} \tag{2}$$

γ $\left(\gamma > 0 \right)$ stands for the slope parameter, and c_j, $j = 1, ..., m$, are the threshold parameters satisfying $c_1 \leq c_2 \leq ... \leq c_m$. The two most common cases in practice correspond to $m = 1$ (logistic) and $m = 2$ (logistic quadratic). In the case of a logistic function, the dynamics is asymmetric and the two regimes are associated with small and large values of the transition variable relative to the threshold. In the case of a logistic quadratic function, the dynamics is symmetric across the two regimes, but the intermediate regime follows a different pattern compared to that in the extremes.

We follow the three-step methodology proposed by González et al. (2005) to apply PSTR models.[3] The aim of the first, identification step is twofold: (1) testing for homogeneity against the PSTR alternative; and (2) selecting (i) between the logistic and logistic quadratic specification for the transition function, and (ii) the transition variable. In the second, estimation step, non-linear least squares are used to obtain the parameter estimates, once the data have been demeaned (Hansen, 1999; González et al., 2005). In the third, evaluation step, various misspecification tests are applied to check the validity of the estimated PSTR model and determine the number of regimes.

3.2. The exchange-rate model

We thus use a PSTR model to study whether the real exchange rate – terms of trade relationship differs depending on oil price volatility. To this end, we account for both the long-term and short-term dynamics by considering the following PSTR specification:

$$\Delta LREER_{i,t} = \alpha_i + \theta_0 z_{i,t-1} + \beta_0^{'} \Delta x_{i,t} + \left(\theta_1 z_{i,t-1} + \beta_1^{'} \Delta x_{i,t} \right) \times F\left(\left| \Delta LOIL_t \right|; \gamma, c \right) + \varepsilon_{i,t} \tag{3}$$

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[3] For details regarding the methodology, the reader is referred to the original contributions by Hansen (1999) and González et al. (2005).

with:

$$z_{i,t} = LREER_{i,t} - \left(\hat{a}_i + \hat{b}' x_{i,t} \right)$$

(4)

$LREER_{i,t}$ is the logarithm of the real effective exchange rate of country i at time t, $|\Delta LOIL_t|$ is the absolute value of the oil price variation—i.e., a proxy of the oil price volatility—that acts as the transition variable, and $x_{i,t}$ is a vector of fundamentals which are expected to influence the long-run real effective exchange rate. Among these fundamentals, we consider those which have long been evidenced in the literature: the Balassa-Samuelson effect (Balassa, 1964), the country's net foreign asset position (Gagnon, 1996) and its terms of trade (De Gregorio and Wolf, 1994) (see Section 4). $\hat{a}_i$ and $\hat{b}'$ respectively denote the estimated long-run fixed effects and fundamentals' coefficients from the cointegrating relationship between the real effective exchange rate and its determinants; $z_{i,t}$ standing for the misalignments, i.e., the difference between the observed real effective exchange rate and its estimated long-run value.

In this model, the link between the real effective exchange rate and its determinants varies according to the value taken by the transition function. Indeed, let us define the sum of coefficients as $\phi_l = \delta_{0l} + \delta_{1l} \times F\left(|\Delta LOIL_t|; \gamma, c \right)$, with $\delta_{0l} = \theta_0, \beta_{01}, ..., \beta_{0k}$ and $\delta_{1l} = \theta_1, \beta_{11}, ..., \beta_{1k}$, k being the number of explanatory variables in the $x_{i,t}$ vector. Then, when $F(.) = 0$—i.e., in the first regime—the estimated coefficients are given by $\phi_l = \delta_{0l}$, and when $F(.) = 1$—i.e., in the second regime—they are equal to $\phi_l = \delta_{0l} + \delta_{1l}$. Between those two extremes, ϕ_l takes a continuum of values depending on the realization of the transition variable.

4.   Data

4.1.   Sample of countries

We consider yearly data from 1980 to 2012 for a panel of 69 commodity-exporting countries. The list of countries is given in the Appendix, together with the main type of commodities exported by each one. Among this panel, 17 are oil-exporting countries, 12 belonging to OPEC (Algeria, Angola, Ecuador[4], Indonesia, Iran, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia Republic, United Arab Emirates, Venezuela), 2 being other Gulf countries (Bahrain and Oman), and 3 other leading oil exporters, namely Mexico, Norway and the Syrian Arab Republic. The 52 other commodity-exporting countries are the same as in Cashin et al. (2004) except five countries that mainly export oil and have been included in the panel of oil

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[4] To be precise, note that Ecuador joined OPEC in 1973, suspended its membership in 1992 and resumed it in 2007.

exporters (Ecuador, Indonesia, Mexico, Norway and Syrian Arab Republic). Nicaragua and Zimbabwe have also been discarded because of lack of available data.

4.2. The real effective exchange rates

As bilateral trade data are not available for all the considered countries, we cannot define genuine real effective exchange rates (REER). To circumvent this issue, we construct a proxy of the REERs, as an exchange rate against a world basket of currencies.

More specifically, we start from the usual formula for a REER:

$$LREER_{it} = \sum_{j=1, j\neq i}^{M} w_{ij}\left(s_{jt}^{\$} - p_{jt}\right) - \left(s_{it}^{\$} - p_{it}\right)$$

(5)

where w_{ij} denote the weights put on currency j for calculating country i's REER, $s_{jt}^{\$}$ (resp. $s_{it}^{\$}$) is currency j (resp. i)'s bilateral exchange rate against USD (number of units of national currency per USD), and p_j (resp. p_i) is country j (resp. i)'s consumer price index (CPI). All these variables are set to 100 in a basis year and taken in logarithms. M is the number of partner countries that should include the largest sample of countries, be them advanced or emerging. Note that an increase in the REER indicates a real appreciation of the currency.

Here, instead of defining the weights w_{ij} according to country i's trade partners as in the usual formula (5), we define them as country j's share in the world gross domestic product (GDP) in USD. Therefore, these weights are the same for all countries i:

$$w_{ij} = w_j = GDP_j \Big/ \sum_{k=1}^{M} GDP_k$$

(6)

This amounts to defining an exchange rate against a world basket of currencies. This REER stands for the value of currencies relatively to a world sample of countries, whether they are trade partners or not.

The shares in the world GDP are calculated on average over the 1980-2012 period, using the GDP in USD, from IMF's WEO database. The sample of countries includes all economies whose GDP exceeds 0.05% of the world GDP on average on the period. Central and Eastern Europe countries as well as those belonging to the Commonwealth of independent states are excluded, because either they did not exist at the beginning of the period, or their price and exchange rates were not relevant. Overall, we retain 69 countries in the weighting scheme, standing for more than 90% of the world GDP. Bilateral exchange rates and price series are extracted from IMF's WEO database.

4.3. 4.3. The long-run explanatory variables

To account for the long-run relationship between the real exchange rate and its determinants, we follow the behavioural equilibrium exchange rate (BEER) approach introduced by MacDonald (1997, 2000), Clark and MacDonald (1998) and adopted by the IMF (Isard, 2007). In this framework, the real effective exchange rate is expressed as a function of three fundamental variables standing for the Balassa-Samuelson effect, the country's net foreign asset position and its terms of trade. Hence, the long-run relationship is given by:

$$LREER_{i,t} = a_i + b_1 LBS_{i,t} + b_2 NFA_{i,t} + b_3 LTOT_{i,t} + u_{i,t} \tag{7}$$

where $LBS_{i,t}$ is the Balassa-Samuelson effect (expressed in logarithms), $NFA_{i,t}$ denotes the net foreign asset position (in percentage of GDP), $LTOT_{i,t}$ stands for terms of trade (in logarithms), and $u_{i,t}$ is an i.i.d. error term. Let us now specify those three explanatory variables.

The Balassa-Samuelon effect is proxied by the country's GDP per capita measured in purchasing power parity (PPP) that is extracted from the WEO database and taken relatively to the partners; the weights applied to calculate the relative PPP GDP per capita are the same w_{ij} as for the real effective exchange rates. Net foreign assets are taken from the database constructed by Lane and Milesi-Ferretti (2007) that is available on the internet. They are divided by GDP in USD, extracted from IMF's WEO. We have updated the data after 2007 by cumulating the current accounts in USD to the previous NFA position. We have also done this for the few missing data in the sample (for example for Suriname).

To better capture the exogenous component of terms of trade shocks and avoid potential endogeneity problem, commodity terms of trade are calculated in the same way as in Cashin et al. (2004). For the 52 commodity-producing countries, terms of trade are a weighted average price of the three main commodities exported by the country deflated by the unit value of industrial countries' manufactured exports; they are therefore expressed as:

$$TOT_{i,t} = \frac{\sum_{h=1}^{3} share_i^h \, p_t^h}{pex_{IND_t}^{MANUF}} \tag{8}$$

where $share_i^h$ denotes the share of commodity h among the three main commodity exports of country i, p_t^h is the price of commodity h in the world market, $pex_{IND_t}^{MANUF}$ is the unit value of manufactured exports of industrialised countries, extracted from the WEO. The weights of each commodity in the countries' exports are taken from Cashin et al. (2004), and commodity prices are extracted from IFS database.

For the 17 oil-exporting countries, terms of trade are set equal to the crude oil price divided by the same deflator $pex_{IND_t}^{MANUF}$, namely:

$$TOT_{i,t}^{Oil} = \frac{p_t^{Oil}}{pex_{IND_t}^{MANUF}} \qquad (9)$$

5.   Estimation results

5.1.   5.1. Estimating the long-run relationship

As a preliminary step, we estimate the cointegrating relationship (7)[5] on our panel data. Ordinary least squares (OLS) estimates being biased and dependent on nuisance parameters, we rely on the Dynamic OLS (DOLS) method introduced by Kao and Chiang (2000) and Mark and Sul (2003) in the context of panel cointegration.[6] Roughly speaking, the DOLS procedure consists in augmenting the cointegrating relationship with lead and lagged differences of the regressors to control for the endogenous feedback effect. Using this procedure, we get the following results for the estimation of the cointegrating relationship:[7]

$$LREER_{i,t}^{est} = \hat{a}_i + \underset{(2.92)}{0.2085}\, LBS_{i,t} + \underset{(2.88)}{0.0637}\, NFA_{i,t} + \underset{(6.17)}{0.2027}\, LTOT_{i,t} \qquad (10)$$

where $LREER_{i,t}^{est}$ stands for the value of LREER given by the estimation of Equation (7).

The estimated coefficients on three fundamental variables are significant at conventional levels and have the expected sign. A rise in the relative productivity, the NFA position as well as in the terms of trade leads to an exchange-rate appreciation. Terms of trade appear to be an important determinant of the real exchange rate, consistent with Cashin et al. (2004) findings. Other things being equal, a 10% increase in terms of trade leads to a real exchange-rate appreciation of around 2%.

We then calculate the currency misalignments as the gap between the observed real exchange rate and the estimated one, as stated in Equation (4):

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[5] Various panel unit root and cointegration tests have been applied, showing that our fourth series (*LREER*, *LBS*, *NFA*, *TOT*) can be considered as unit root processes and are cointegrated. Complete results are available upon request to the authors.

[6] Other procedures exist, such as the Fully-Modified OLS (FM-OLS) method proposed by Phillips and Hansen (1990). Compared to the FM-OLS estimator, the DOLS one has the same asymptotic distribution, but presents smaller size distortions (see the simulations made by Kao and Chiang, 2000).

[7] t-statistics associated with the estimated coefficients are given between parentheses.

$$z_{i,t} = LREER_{i,t} - LREER_{i,t}^{est} \tag{11}$$

5.2. 5.2. Linearity tests

The next step is to test for the null hypothesis of linearity in Equation (3) using the González et al. (2005) test. The transition variable is oil price volatility that we calculate as the absolute values of oil price variation (in logarithm). In other words, we test if the exchange-rate response to the explanatory variables is different whether facing low or high price volatility on the oil market.

The results of the Lagrange multiplier and Fisher-type tests are displayed in Column (1) of Table 1 for our whole sample. The null hypothesis is that of linearity, it is tested against the alternative of a PSTR specification with two regimes. As expected, the null of linearity is rejected in favour of the PSTR alternative, and the significance level is far beyond the usual 5%. This result supports our hypothesis that the explanatory variables impact the exchange-rate dynamics differently, depending on the situation—in terms of oil price variation—on the oil market.

Table 1. Results of linearity tests.

	Whole (1)	Energy and metals (2)	Food (3)	Beverages (4)	Raw materials (5)
LM	64.939 (0)	22.126 (0.005)	14.706 (0)	73.059 (0)	34.566 (0)
F	16.034 (0)	2.722 (0.006)	3.643 (0)	20.947 (0)	8.903 (0)

Note: LM and F are the Lagrange multiplier and F tests for linearity. P-values are given in parentheses.

5.3. Short-run estimations

We now proceed to the estimation of our non-linear PSTR specification. Results are reported in Table 2 for the whole sample of countries. The value of the threshold parameter *c* is estimated at 0.1860. This defines two regimes: a regime in which oil price variations (in absolute value) are lower than 18.6% (low-volatility regime) and a regime characterized by

important volatility on the oil market, with oil price variations higher than 18.6% (in absolute value). As expected, results show that the impact of the explanatory variables differs according to the situation on the oil market, confirming the conclusions of the linearity tests.

Table 2. Estimation of the PSTR model, whole sample.

		Regime 1	Regime 2
		Low oil price volatility	High oil price volatility
Misalignment	$z_{i,t-1}$	-0.1265***	0.0264
Balassa effect	$\Delta LBS_{i,t}$	0.0578	0.1203
Net foreign assets	$\Delta NFA_{i,t}$	-0.0074	0.1445***
Terms of trade	$\Delta LTOT_{i,t}$	-0.0269	0.0724*
$\hat{\gamma}$		3666	
$\hat{c}$		0.1860	

Note: * (resp. **, ***): significant at the 10% (resp. 5%, 1%) level.

Some key findings can be highlighted from the estimated coefficients presented in Table 2. First, concerning the response of the REER to the misalignments, the exchange rates behave quite differently under the two regimes: when oil price volatility is low, the exchange rate tends to return to its fundamental value (given by the cointegrating relationship) as only the misalignment variable is significant with the expected negative sign. On the other hand, in the high-volatility regime, the real effective exchange rate does not exhibit mean reversion, the misalignment series being no longer significant. Second, the Balassa-Samuelson effect is not a determinant of the exchange rate in the short run, as its coefficient is significant in neither regimes; it is only a long-term effect, attested in the cointegrating relationship. Third, the net foreign position influences the exchange-rate changes in the high-volatility regime; as expected, its impact has the same positive sign as in the long-run relation, an improvement in the foreign position resulting in an exchange-rate appreciation.

Fourth, the variations in the terms of trade also become a significant driver of exchange-rate variations (at the 10% significance level) only in the high-volatility regime. This is a very interesting finding supporting our hypothesis that the commodity-currency link is at play in the short run only when oil price volatility is high. On the whole, results in Table 2 are in line with our hypothesis of different behaviour of commodity currencies according to market volatility. More precisely, they show that the exchange rate is essentially driven by fundamentals in the

low-volatility regime, whereas it turns mainly sensitive to variations in terms of trade once oil price volatility exceeds a given threshold.

5.4. Estimations by types of commodities

We now aim at checking if this overall finding may mask some heterogeneity across countries according to the types of commodities they export. To investigate this issue, we subdivide our panel in four groups depending on the nature of the main commodity exported by each country: energy and metals, food, beverages, and raw materials.

We first perform the estimation of the long-term relationship for those subgroups of countries and present the estimated cointegration coefficients in Table 3. The findings confirm that terms of trade are a significant determinant of the real exchange rate for all groups of commodities. On the other hand, the results of both the other variables are mixed, being significant or not depending on the considered panel.

Table 3. Estimation of the cointegrating relationship, subgroups of countries according to the main exported commodity.

	Balassa-Samuelson effect	Net asset position	Terms of trade
	$LBS_{i,t}$	$NFA_{i,t}$	$LTOT_{i,t}$
Energy and metals	0.3804*** (2.92)	0.0205 (0.62)	0.1223*** (2.90)
Food	-0.2940** (-2.29)	0.0051 (0.08)	0.1794** (2.30)
Beverages	-0.1745 (-1.05)	0.0263 (0.64)	0.6507*** (6.73)
Raw materials	0.1077 (0.89)	0.3212*** (5.56)	0.3226*** (3.05)
Whole panel	0.2085*** (2.92)	0.0637*** (2.88)	0.2027*** (6.17)

Note: t-statistics are given in parentheses. ** (resp. ***): significant at the 5% (resp. 1%) level.

We then turn to the PSTR estimation, and display the results for our four subgroups of countries in Table 4. Regarding first the value of $\hat{c}$, while the estimated threshold values are quite similar for "beverages" and "raw materials" groups, they strongly differ across "energy and metals" and "food" panels. Food producers are much more likely to tip over into high-volatility regime, as their estimated threshold $\hat{c}$ is much smaller (0.0887) than the energy and metals producers (0.4516). This makes them more vulnerable to oil price volatility.

Table 4. Estimation of the PSTR model, subgroups of countries according to the main exported commodity.

	Energy and metals		Food		Beverages		Raw materials	
	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
$z_{i,t-1}$	-0.1237***	0.2109	-0.1241***	-0.0127	-0.2307***	0.4767	-0.0730*	-0.0891
$\Delta LBS_{i,t}$	0.2735***	-0.3393	0.7933**	-0.5207	-0.5793	0.4737	-0.3185***	-0.5132
$\Delta NFA_{i,t}$	0.0959***	0.0243	0.6512***	-0.5745**	-0.0089	0.1721***	0.3327***	0.2923***
$\Delta LTOT_{i,t}$	0.0185	0.2243***	-0.0666	0.1602*	-0.0724	0.0607	-0.0719	0.0804
$\hat{\gamma}$	5742		3354		7550		276.1	
$\hat{c}$	0.4516		0.0887		0.2464		0.2108	

* (resp. **, ***): significant at the 10% (resp. 5%, 1%) level; for the name of variables see Table 2.

A closer look at the estimated coefficients presented in Table 4 gives an insight into the response of the real exchange rates to the fundamental variables. First, as for the whole panel of countries, the misalignment variable is negatively significant only in the first regime. This confirms our previous result that the exchange rate tends to revert to its fundamental value only in times of low oil price volatility. Second, the Balassa-Samuelson effect appears significant in the low-volatility regime for energy, metals and food exporters, though it is still not significant in the short run for beverages exporters, and wrongly signed in the case of raw materials producers. Third, changes in the net foreign position exert a significant impact in both regimes, except for the "energy and metals" panel in the high-volatility state and for beverages' exporters in the low-volatility regime.

Fourth, turning to our main variable of interest, our results show that changes in terms of trade are significant in the high-volatility regime for the "energy and metals" group and, to a lesser extent, for the "food" exporters. This finding indicates that the commodity-currency property depends on the type of commodity considered and is especially strong for oil-exporting countries in case of important fluctuations on the oil market. These results are consistent with the conclusions obtained by Baffes (2007) mentioning the links between prices of various commodities. Indeed, this author shows that oil price changes are heavily passed-through to the prices of other commodities, such as precious metals, energy

products and, to a lesser extent, food products. Nevertheless, he does not evidence a clear effect for beverages and raw materials groups, a result that we retrieve here as terms of trade are not significant for these two panels of commodities in the above specification.

6.   Conclusion

This paper studies the link between terms of trade and real exchange rates of commodity-producing economies on both the short and the long run. We pay particular attention to the key role played by oil among commodity markets and investigate its potential non-linear effects on the terms of trade – real exchange rates nexus. More specifically, we consider the oil price volatility as a gauge of strains on commodity markets, and account for non-linearities of exchange rates' responses to terms of trade depending on the situation—calm of volatile—on the oil market.

Our findings show that the exchange rate tends to revert to its equilibrium value in the low-volatility regime, while such mean-reverting process is not observed in the case of important variations on the oil market. Specifically, in the high-volatility regime, changes in the terms of trade become a significant driver of exchange-rate variations. Splitting our countries by main exported commodities, we also find that the exchange rate reverts to its long-term level only when oil price variations do not exceed a certain threshold. Moreover, changes in terms of trade are significant to explain the dynamics of the real exchange rate in the high-volatility state, especially for the group of "energy and metals" as well as food exporters. On the whole, our results evidence that the commodity-currency property is at play in the short run only in periods of high oil price volatility, and depends on the type of commodity exported.

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Appendix: List of countries

Country	Commodity group	Country	Commodity group
Algeria*	Energy and metals	Mexico*	Energy and metals
Angola*	Energy and metals	Morocco	Raw materials
Argentina	Food	Mozambique	Raw materials
Australia	Energy and metals	Myanmar	Raw materials
Bahrein*	Energy and metals	New Zealand	Food
Bangladesh	Food	Nicaragua	Beverages
Bolivia	Energy and metals	Niger	Energy and metals
Brazil	Energy and metals	Nigeria*	Energy and metals
Burundi	Beverages	Norway*	Energy and metals
Cameroon	Beverages	Oman*	Energy and metals
Canada	Raw materials	Pakistan	Food
Central African Republic	Raw materials	Papua New Guinea	Metals
Chile	Energy and metals	Paraguay	Food
Colombia	Beverages	Peru	Metals
Costa Rica	Food	Philippines	Food
Côte d'Ivoire	Beverages	Qatar*	Energy and metals
Dominica	Food	Saudi Arabia*	Energy and metals
Ecuador*	Energy and metals	Senegal	Raw materials
Ethiopia	Beverages	South Africa	Metals
Ghana	Beverages	Sri Lanka	Beverages
		St. Vincent and Grenadines	Food
Guatemala	Beverages	Sudan	Raw materials
Honduras	Beverages	Suriname	Energy and metals
Iceland	Food	Syrian Arab Republic*	Energy and metals
India	Food	Tanzania	Beverages
Indonesia*	Energy and metals	Thailand	Food
Iran*	Energy and metals	Togo	Raw materials
Kenya	Beverages	Tunisia	Raw materials
Kuwait*	Energy and metals	Turkey	Raw materials
Lybia*	Energy and metals	Uganda	Beverages
Madagascar	Beverages	United Arab Emirates*	Energy and metals
Malawi	Raw materials	Uruguay	Food
Malaysia	Food	Venezuela*	Energy and metals
Mali	Raw materials	Zambia	Energy and metals
Mauritania	Metals		
Mauritius	Food		

*: oil-exporting country.