Sovereign Risk and the Real Exchange Rate: A Non-Linear Approach

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Sovereign Risk and the Real Exchange Rate: A Non-Linear Approach[♦]

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Abstract

We estimate a model of real exchange rate determination which is based on interest rate, term structure and purchasing power parities. This model takes into account sovereign risk as a key determinant with possibly non-linear effects. Estimations are performed for five Latin-American economies: Brazil, Chile, Colombia, Mexico and Peru. The results show that the model has good fit for all countries and the expected sign holds for most estimated coefficients. In particular, it is found that sovereign risk has a significant positive relation with the real exchange rate. There is evidence of the non-linearity of this relation for all countries except Mexico. This non-linearity implies coefficients that change with smooth transition as a function of international volatility indicators. In addition, we perform misalignment analyses and show that real exchange rates became over-depreciated during the initial development of the great financial crisis. Then, between 2011 and 2013, they went through a few periods of over-appreciation as international monetary and fiscal policies became expansive and international capital flows were bound to emerging economies searching for higher yields. Finally, the strong reduction of commodity prices led to a new over-depreciation episode during the second half of 2015.

Keywords: Real exchange rate, Misalignment, Sovereign Risk, International parities, Latin America, smooth transition regression.

JEL classifications: C32, F31, E43

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1. Introduction

Monetary policy authorities need a comprehensive analysis of the evolution of both real and nominal exchange rates in order to make better assessments of their external sector imbalances. In particular, central banks are interested on detecting possible real exchange rate (RER) misalignments, and have developed a set of techniques[1]. Financial crises in emerging economies have taught us that RER and sovereign risk indicators have an important degree of correlation. As sovereign risk indicators worsen during a crisis in an emerging economy, a depreciation of its RER is a natural response to the increased market risk within a flexible exchange rate regime (Della Corte et al, 2015). The tipping point for policymakers is whether or not the observed depreciation turns out to be excessive given current fundamentals including key risk indicators. Therefore, we need to understand better the relationship between RERs and sovereign risk (see Coudert and Mignon, 2013).

Addressing this concern, this paper estimates a RER determination model which incorporates the effects of sovereign risk movements through an augmented Uncovered Interest Rate Parity condition (UIP). The model also takes into account gradual adjustments to Purchasing Power Parity (PPP) and the effects of both short and long-term interest rates, similar to the capital enhanced equilibrium exchange rate approach (CHEER). In addition, as a contribution to the literature, we incorporate a non-linear effect of sovereign risk on the RER. The approach presented in this paper is especially suited for analyzing RER misalignments on a monthly basis since its fundamentals are financial variables which are readily available and easier to forecast than determinants in other type of models.

The model is estimated for five Latin-American economies: Brazil, Chile, Colombia, Mexico and Peru. We capture the non-linearity of sovereign risk through a smooth-transition cointegrated regression, which implies a time-varying effect of that variable on the RER as a function of international volatility measures. Following Coudert and Mignon (2013), we test the VIX indicator as one possible transition variable in this non-linear relation. We also make estimations using the volatility of each country's terms of trade as the transition variable. This volatility captures sudden swings in terms of trade that can have a significant impact on the stability of the national income and fiscal revenues.

Then, RER misalignments are computed for each country's bilateral rate vis-à-vis the US using monthly data. The estimation leads to consistent and well behaved econometric results and with evidence of a non-linear transmission of sovereign risk on the RER for all countries, except Mexico. In the non-linear estimation, we also find that as the volatility indicator increases, (the VIX in the cases of Brazil and Colombia and the volatility of the terms of trade, in the cases of Brazil, Chile and Peru), sovereign risk has a lower effect on the RER in Brazil, Colombia and Chile. That is, the effect of sovereign risk on the RER is greater when such increase is related to domestic, as opposed to international economic news.

[1] See for example, Lee et al (2008) and Bussiere et al (2010) for a discussion of alternative approaches.

Our results on RER assessment show an over-depreciation period right after the global financial crisis. Then, between 2011 and 2013, all five RERs went through some periods of over-appreciation as monetary policies became expansive in the US and the Euro zone and international capital flows were bound to emerging economies searching for higher yields. Finally, an over-depreciation episode is detected during the second half of 2015 which can be related to the significant downward movements in commodity prices.

This paper is organized as follows. Section 2 briefly reviews the empirical literature on risk indicators and RER misalignment. Section 3 describes the economic model of the RER. Section 4 describes the data and reports the econometric methodology. Section 5 shows the empirical results from linear and non-linear cointegration regressions. Section 6, discusses the implications of these results for RER misalignment. Finally, Section 7 makes some concluding statements.

2. Literature review

Trying to assess whether changes in the real exchange rate (RER) are driven by their fundamentals is crucial for policymakers at central banks and related institutions. For example, the International Monetary Fund (IMF) and The European Central Bank (ECB) have developed alternative methodologies to detect RER misalignments, see among others, Lee et al (2008) and Bussiere et al (2010).

Despite its importance, only a few papers have analyzed the effect of sovereign risk on RER determination. MacDonald and Dias (2007) study this issue by measuring the econometric effect of interest rate differentials, augmented with sovereign risk indicators, on the RER. However the corresponding estimated coefficient in the panel cointegration equation is found to be non-significant.

Keblowski and Welfe (2012), following the capital enhanced equilibrium exchange rate approach (CHEER), incorporate a measure of sovereign risk within a framework containing both UIP and the PPP conditions. They consider a Vector Error-Correction (VEC) model with data for Poland and use the Credit Default Swap (CDS) indicator as measure of risk. They find evidence of four cointegration vectors, one of which corresponds to the equilibrium RER. An increase in the Polish CDS is found to have a significant positive effect on the RER.

Coudert and Mignon (2013) study the relationship between carry trade gains and sovereign risk in 18 emerging economies. They find that the elasticity of exchange rates to default risk movements (measured by the CDS) is a non-linear function of the risk appetite (measured by the VIX). Smooth Transition Regression (STR) allows them to model this non-linear reaction on the vicinity of a threshold volatility level.

Della Corte et al (2015), considering a set of 20 countries (including emerging and developed countries), investigate the relationship between the sovereign risk (as measured by the CDS) and several key indicators of the foreign exchange market: spot exchange rates, currency excess returns, exchange rate volatility, skewness and kurtosis measures. They find that an increase of 50 basis points in the CDS spread is associated with a contemporaneous currency depreciation of 3.7%. They also find that shocks in global risk (instead of shocks in local sovereign risk) also play a major role in the estimation.

Coudert et al (2015) use data for 68 commodity exporters between 1980 and 2012 and non-linear econometric methods to study the relation between real exchange rates and terms of trade. They find that terms of trade volatility is the key transition variable to understand that relationship since high volatility periods are associated to increased uncertainty in commodity markets. Their empirical evidence shows that increased volatility exacerbates the transmission of terms of trade movements into the real exchange rate.

In this paper, we follow the CHEER approach, similarly to Keblowski and Welfe (2012), but incorporating the potential non-linear effects of sovereign risk, as in the specification of Coudert and Mignon (2013). In addition, we consider an alternative international volatility indicator as the transition variable. This estimation also allows us computing RER misalignments and analyzing them within the economic developments. As far as we know, this is the first paper explicitly incorporating sovereign risk within a non-linear econometric estimation in a RER determination model.

3. A Simple Model of Exchange Rate Parities and Adjustment

We follow the CHEER approach described by Keblowski and Welfe (2012) among others. This approach incorporates not only the UIP and purchasing power parity (PPP) conditions, but also long-term interest rates, inflation rates and sovereign risk.

The first component of the model is an equation relating exchange rate variations, interest rates and sovereign risk indicators. Thus, the UIP condition is a special case of the following equation:

$$E_t \Delta e_{t+1} = \alpha_0 + \alpha_1 i_t + \alpha_2 i_t^{US} + \alpha_{3,t} s_t \quad (1)$$

In this equation, $E_t \Delta e_{t+1}$ is the expected variation of the nominal exchange rate with respect to the US dollar. The exchange rate level, e_t tells the number of units of domestic currency per unit of US dollars as determined in domestic currency markets. Economic agents have rational expectations and therefore they are able to make unbiased predictions of future asset prices. The nominal short-run interest rates for the domestic country and for the US are i_t and i_t^{US}, respectively. The sovereign risk index is denoted as s_t.

Now we describe a few important features of equation (1). First, following the empirical results about the UIP failure and the forward premium puzzle[2], we do not assume any specific values for α_1 or α_2. Second, we allow for $\alpha_0 \neq 0$ so that gradual exchange rate adjustments may occur[3]. Third, the effect of sovereign risk on exchange-rate variations ($\alpha_{3,t}$) can be time varying (Coudert and Mignon, 2013).

We use equations for the term structure of the interest rate in order to incorporate long-run rates into the model:

$$i_{l,t} = \beta_0 + \beta_1 i_t \tag{2}$$

$$i_{l,t}^{us} = \gamma_0 + \gamma_1 i_t^{us} \tag{3}$$

Equation (2) and (3) show the relation between long and short-run interest rates for the domestic country and the US, respectively. This is a linear stable relation in which changes to the short-run rate do not necessarily pass through completely to the long-run rates (β_1 or γ_1 can be different to 1).

Following Juselius and MacDonald (2003), the nominal exchange rate partially adjusts each period in order to correct deviations of the RER from its PPP level. This mechanism implies a reaction function of the nominal exchange rate to the domestic inflation, US inflation and to the distance between the observed RER and its PPP level:

$$\Delta e_{t+1} = \delta_0 + \delta_1 \pi_{t+1} + \delta_2 \pi_{t+1}^{us} + \delta_3 \left(q_{t+1} - q_{ppp}\right) + \varepsilon_{1,t+1} \tag{4}$$

Equation (4) assumes the existence of a constant PPP level of the RER which is also the mean-reversion level of this variable[4]. π_t and π_t^{us} represent domestic and US inflation, respectively. The natural logarithm of the observed RER is denoted by q_t. The error term ($\varepsilon_{1,t+1}$) is stationary and has a zero mean.

We can use equations (1) and (4), as well as rational expectations, in order to derive an expression for the observed RER as a function of its PPP level, short-term interest rates, inflations and sovereign risk[5]:

$$q_t = q_{ppp} + \left(\frac{\alpha_0 - \delta_0}{\delta_3}\right) + \frac{\alpha_1}{\delta_3} i_t + \frac{\alpha_2}{\delta_3} i_t^{us} + \frac{\alpha_{3,t}}{\delta_3} s_t - \frac{\delta_1}{\delta_3} \pi_t - \frac{\delta_2}{\delta_3} \pi_t^{us} \tag{5}$$

[2] According to the UIP condition, variations in e_t should depend directly on the interest rate differential between the US and domestic countries. That is, $\alpha_0 = 0$, $\alpha_1 = 1$ and $\alpha_2 = -1$. However, the empirical evidence has shown that this condition does not hold although interest rates are still key determinants of exchange rate movements. See for example, Verdelhan (2010).

[3] A well-known example is the Balassa-Samuelson effect (Obstfeld and Rogoff, 1996).

[4] Bahmani-Oskooee et al (2013) show empirical evidence of long-run PPP for 15 Latin-American currencies including those studied here. See also Sarno and Taylor (2002) for a summary of the PPP methodological debate.

[5] Rational expectations imply that $E_t \pi_{t+1} = \pi_t$ and $E_t q_{t+1} = q_t$, thus it is possible to derive Equation 5 including all variables contemporaneously.

In Equation (5), the observed RER is a linear function of unobserved parameters and observed determinants. Additionally, the parameter on the sovereign risk indicator is the only time varying parameter.

We can insert Equations (2) and (3) and write down Equation (5) in terms of long-term interest rates only.

$$q_t = q_{ppp} + \left(\frac{\alpha_0 - \delta_0}{\delta_3}\right) - \left(\frac{\alpha_1\beta_0}{\delta_3\beta_1} + \frac{\alpha_2\gamma_0}{\delta_3\gamma_1}\right) + \frac{\alpha_1}{\delta_3\beta_1} i_{l,t} + \frac{\alpha_2}{\delta_3\gamma_1} i_{l,t}^{us} + \frac{\alpha_{3,t}}{\delta_3} s_t - \frac{\delta_1}{\delta_3}\pi_t - \frac{\delta_2}{\delta_3}\pi_t^{us} \quad (6)$$

Furthermore, if we compute a weighted average of equations (5) and (6), it is possible to include both short and long-term interest rates in the same RER equation, in line with the CHEER approach.

$$q_t = \phi_0 + \phi_1 i_t + \phi_2 i_{l,t} + \phi_3 i_t^{us} + \phi_4 i_{l,t}^{us} + \phi_{5,t} s_t + \phi_6 \pi_t + \phi_7 \pi_t^{us} \quad (7)$$

Let ω be the exogenous weight of Equation (5) used for the computation of (7). Therefore, $0 \leq \omega \leq 1$ and $(1-\omega)$ is the corresponding weight of Equation (6). Thus the coefficients in Equation (7) can be written in terms of the parameters of equations (5) and (6) in the following way: $\phi_0 = q_{ppp} + \frac{\alpha_0 - \delta_0}{\delta_3} - \frac{(1-\omega)}{\delta_3}\left(\frac{\alpha_1\beta_0}{\beta_1} + \frac{\alpha_2\gamma_0}{\gamma_1}\right), \phi_1 = \omega\frac{\alpha_1}{\delta_3}$, $\phi_2 = (1-\omega)\frac{\alpha_1}{\delta_3\beta_1}$, $\phi_3 = \omega\frac{\alpha_2}{\delta_3}$, $\phi_4 = (1-\omega)\frac{\alpha_2}{\delta_3\gamma_1}$, $\phi_{5,t} = \frac{\alpha_{3,t}}{\delta_3}$, $\phi_6 = -\frac{\delta_1}{\delta_3}$ and $\phi_7 = -\frac{\delta_2}{\delta_3}$. Notice that the sign of each coefficient is driven by the value of the parameters of the model. In general, it is expected that the RER be a positive function of sovereign risk and US interest rates, and a negative function of domestic interest rates.

4. Econometric Methods and Data

4.1 Econometric Techniques

Equation (7) is estimated with cointegration methods and data for five Latin American economies. Notice that we allow the coefficient of sovereign risk ($\phi_{5,t}$) to be time varying as in Equation (1). Estimation is performed country by country, using data on RER, nominal interest rates, inflation and sovereign risk. Since most of these variables are I(1), we apply the Dynamic Ordinary Least Squares (DOLS) approach proposed by Stock and Watson (1993), in which lags and leads of the endogenous variables are added to the regression in order to correct for non-stationarity and endogeneity. It is worth pointing out that these estimation results are similar when alternative cointegrating regression techniques are applied, namely, Fully Modified OLS (Phillips and Hansen, 1992), and Canonical Cointegrating Regression (Park, 1992).

The DOLS regressions allow us to determine the number of leads and lags and to identify the significant coefficients within equation (7). Using these regressions, we can also give economic interpretations to the estimated coefficients, apply those coefficients to the observed levels of interest rates, inflations and risk indicators, and compute RER misalignments (see Section 6).

We study the possibly non-linear relationship between sovereign risk and RER by estimating a time-varying coefficient ($\phi_{5,t}$) in Equation (7), using smooth transition regressions within a cointegrating framework. This technique is based on Saikkonen and Choi (2004) and uses non-linear least squares in the first stage and a Gauss-Newton estimator in the second stage. We consider the following specification:

$$q_t = \phi_0 + \phi_1 i_t + \phi_2 i_{l,t} + \phi_3 i_t^{us} + \phi_4 i_{l,t}^{us} + \phi_5 s_t +$$

$$+\bar{\phi}_5 s_t g(\nu_t - \bar{\nu}; \xi) + \phi_6 \pi_t + \phi_7 \pi_t^{us} + \varepsilon_{2,t} \quad (8)$$

In Equation (8) the relation between the RER and sovereign risk is driven by two components. First, a standard linear component which is summarized by the coefficient ϕ_5. Second, a non-linear (time varying) effect that is represented by $\bar{\phi}_5 g(\nu_t - \bar{\nu};\ \xi)$ where $\bar{\phi}_5$ is a constant coefficient and $g(\nu_t - \bar{\nu};\ \xi)$ is the transition function which is defined by the following logistic function:

$$g(\nu_t - \bar{\nu};\ \xi) = \frac{1}{1+e^{-\xi(\nu_t - \bar{\nu})}},\ \ \xi > 0 \quad (9)$$

Equation (9) is a function of a market volatility index (ν_t) relative to a threshold value ($\bar{\nu}$) which is estimated within the same regression. The parameter ξ determines the smoothness of this transition function which makes the regression coefficient for s_t vary between ϕ_5 and ($\phi_5 + \bar{\phi}_5$). When ν_t is sufficiently below $\bar{\nu}$, the regression coefficient takes a value close to ϕ_5. As ν_t increases well above $\bar{\nu}$, the coefficient approaches ($\phi_5 + \bar{\phi}_5$).

Saikkonen and Choi (2004) show that both the first and second stage estimators are consistent. However, the Gauss-Newton estimation is found to be more efficient with long samples. In addition, this estimator eliminates most of the bias from the presence of I(1) determinants.

4.2 Description of the Data

We use monthly information for each country starting between 2003 and 2007 and updated to December 2015. The specific start date depends on each country's data availability which is described on the notes of Table 1.

We utilize the natural logarithm of the bilateral RER for each country vis-à-vis the United States. Those RERs are part of the information employed by Banco de la Republica in the computation of the multilateral RER index[6]. The short-term interest rate indicator for Colombia, Chile and Peru, is the 90-day deposit rate obtained from each country's central bank. For the US, Brazil and Mexico we use the three-month zero coupon treasury rate. The

[6] The sources for the required information on nominal exchange rates and consumer price indices are the World Markets Company PLC, central banks the IMF's databases.

long-term interest rate indicator is defined as the zero-coupon yield for 5-year sovereign bonds. The sovereign risk indicator corresponds to the 5-year CDS spread for sovereign debt. All these data are retrieved from Bloomberg. Inflation is defined as the annual variation of the consumer price index and is downloaded from the IMF's databases except for Colombia where this indicator is obtained from its National Bureau of Statistics (DANE).

We use two alternative indicators of market volatility. On the one hand, the VIX index which is based on US stocks market volatility is a measure of international risk aversion. On the other hand, the volatility of the terms of trade in each country allows capturing the incidence of international shocks on commodity exporting economies. The volatility is computed as the rolling standard deviation of the log terms of trade using 36-month windows. For Chile, since no monthly terms of trade series is available, we use the volatility of the real price of copper[7] instead (see figures A1 and A2 in the Appendix).

5. Estimation Results

In this section, first we describe the results of unit-root tests. Second, we present the DOLS estimates and their associated cointegration tests. Third, we show the linearity tests and the model selection. Finally, we explain the outputs from the smooth transition regressions for the selected models.

5.1 Unit-Root Tests

We apply unit-root tests to all macroeconomic variables included in the estimation. We perform the Augmented Dickey-Fuller (ADF) and the Ng-Perron tests[8]. Both tests are computed using appropriate estimators of the zero-frequency spectral density in order to take into account the long-run variance of these variables. The results show that most of the variables are I(1). Results are presented on Table A1 in the Appendix.

5.2 DOLS Regressions

DOLS estimations of Equation (7) are performed with data for the five Latin American economies already mentioned. We initially include all variables in the estimation, but only those with statistically significant coefficients (confidence degree of at least 90%) are considered in the final specification. These results are presented in Table 1, country by country. The notes of this table describe the sample as well as the number of leads and lags included in each country's regression, which are selected with the Bayesian information criterion. All estimations include corrections for heteroskedasticity and autocorrelation of the standard errors following Andrews (1991). The same information criterion is used for the lag selection in order to compute the long-run variance.

[7] Real copper price was retrieved from the Chilean central bank website.
[8] See Dickey and Fuller (1979) and Ng and Perron (2001).

Results in Table 1 show that an increase of sovereign risk has a positive effect on the the real exchange rate implying a real depreciation. The estimated coefficients show that a 100 basis-point increase in the CDS indicator leads to a depreciation that ranges from 2.8% in Peru to 16.5% in Brazil. The low response of the RER in Peru is perhaps due to the active role authorities have in the foreign exchange market and the high degree of dollarization.

Table 1: Results of DOLS Regressions

A. Brazil			
Variable	Coefficient	t-statistic	p-value
Constant	4.5758	77.9141	0.0000
Domestic long-term interest	-0.0102	-1.7187	0.0890
CDS	0.1648	10.7978	0.0000
US Short-term interest	0.0662	11.2179	0.0000
US Inflation	-0.0278	-4.3430	0.0000

Note: Sample is March 2007 to December 2015. The estimation includes 0 lags and 2 leads.

B. Chile			
Variable	Coefficient	t-statistic	p-value
Constant	4.7896	148.8935	0.0000
Domestic Long-term interest	-0.0689	-9.8586	0.0000
CDS	0.1037	7.6789	0.0000
US Long-term interest	0.0735	16.5030	0.0000
US Inflation	-0.0094	-2.2962	0.0236

Note: Sample is September 2005 to December 2015. The estimation includes 0 lags and 3 leads.

C. Colombia			
Variable	Coefficient	t-statistic	p-value
Constant	4.5559	103.2192	0.0000
Domestic Short-term interest	-0.0442	-3.1650	0.0019
Domestic Long-term interest	-0.0206	-2.1907	0.0301
Domestic Inflation	0.0557	3.9267	0.0001
CDS	0.1258	7.8372	0.0000
US Short-term interest	0.0289	2.2411	0.0266
US Long-term interest	0.0597	4.1391	0.0001
US Inflation	-0.0168	-1.9604	0.0519

Note: Sample is January 2003 to December 2015. The estimation includes 0 lag and 0 leads.

D. Mexico			
Variable	Coefficient	t-statistic	p-value
Constant	4.6782	150.6642	0.0000
Domestic Long-term interest	0.0074	1.6880	0.0936
Domestic Inflation	-0.0397	-4.4570	0.0000
CDS	0.0716	6.1724	0.0000
US Inflation	-0.0229	-4.5304	0.0000

Note: Sample is August 2003 to December 2015. The estimation includes 0 lags and 0 leads.

E. Peru			
Variable	Coefficient	t-statistic	p-value
Constant	4.4029	326.3313	0.0000
Domestic Long-term interest	0.0252	5.4337	0.0000
Domestic Inflation	-0.0065	-2.7951	0.0062
CDS	0.0280	4.2887	0.0000
US Short-term interest	0.0106	3.3400	0.0012
US Long-term interest	0.0387	7.8684	0.0000
US Inflation	-0.0117	-4.4740	0.0000

Note: Sample is April 2006 to December 2015. The estimation includes 0 lags and 0 leads.
Source: Authors' computations.

Since we are estimating a cointegration model, both directions of causality are potentially important for the relation between RERs and sovereign risk. In this sense, Table 1 shows that currency depreciations are consistent with higher sovereign risk levels. The most important transmission channel, according to Coudert and Mignon (2013), is the effect that the probability of a sovereign default has on investors performing carry-trade[9].

Higher US interest rate weakens RER. The reason, according to international parities, is that investors rebalance their investment portfolios in order to have a greater share of US securities. The estimated effect of a 100 basis-point increase in the US interest rate on the RER implies depreciations of 4.9% in Peru, 6.6% in Brazil, 7.4% in Chile and up to 8.9% in the case of Colombia[10]. In the case of Mexico, US interest rates are not significant RER determinants.

Table 1 also shows that the relation between domestic interest rates and the RER is negative in Brazil, Chile and Colombia. This negative relationship is related to the international-parity condition in which domestic increases of interest rates are attractive for investors who bring capital inflows. The estimated RER appreciation that follows a 100 basis-point increase in the domestic interest rates goes from 1.0% in Brazil up to 6.9% in Chile.

Consumer inflation is also included as a determinant of the RER in Equation 7. Its effect is significantly different from zero in Colombia, Mexico and Peru. In the first of these countries, the estimated relation is positive and the coefficient implies that a 100 basis-point increase in domestic annual inflation is associated to a real depreciation of around 5.6%. The transmission channel of this effect is probably related to the pass-through from exchange rates to domestic inflation. For the other two countries the relation is negative and implies an appreciation between 0.6% and 4.0%.

Finally, the US inflation is a significant determinant in all five countries and its relation with the RER is negative. Therefore, a 100 basis-point increase of US inflation is related to a RER appreciation ranging from 0.9% (Chile) to 2.8% (Mexico).

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[9] Historically, financial crises have occurred after or during sovereign default episodes, (Reinhart and Rogoff, 2009).

[10] We add up the effects of both short and long term US interest rates.

Cointegration tests were applied to the five DOLS regressions in Table 1. These tests show strong evidence of stationary residuals which validates the existence of cointegration. See Table A2 in the Appendix.

5.3 Linearity Tests and Model Selection

We perform a linearity test based on Choi and Saikkonen (2004), which is especially devised to assess the statistical significance of the non-linear component of the cointegrated smooth transition regression described in Equations (8) and (9). The standard significance test on the non-linear coefficient is not useful in this case, since it inherits distortions from nuisance parameters[11]. The proposed linearity test is constructed with Taylor approximations to the transition function and allows deriving test statistics with well-defined asymptotic distributions.

We apply the test to each country for both transition variables and in addition, use these results for model selection. If the null hypothesis of linearity is confirmed in both cases, the selected model is the linear one (Table 1). If the null hypothesis is rejected for both transition variables, either specification is valid and can be useful for policy makers, but we prefer the model in which the test has the lowest p-value[12]. In spite of our selection we show the results using both transition variables for each country in Tables A3 and A4 in the Appendix.

Table 2 presents the results of the linearity test. They imply that the non-linear model with terms of trade (ToT) volatility as transition variable is selected for Brazil, Chile and Peru. The model using VIX as transition variable is selected for Colombia. Finally, the linear model (DOLS) is the one selected for Mexico since the null hypothesis was not rejected at the usual confidence degrees.

Table 2: Linearity Tests for Both Transition Variables

A. Brazil		
Transition Variable	t-statistic	p-value
VIX	-3.3795	0.0011
ToT volatility	-4.8332	0.0000
B. Chile		
Transition Variable	t-statistic	p-value
VIX	-0.6345	0.5271
ToT volatility	-2.5463	0.0123
C. Colombia		
Transition Variable	t-statistic	p-value
VIX	-2.9860	0.0033
ToT volatility	-0.0461	0.9633

[11] They are associated to the presence of estimation errors on the derivatives of the non-linear transition function (Equation 9).

[12] We made this decision since we needed one model for the misalignment analysis.

D. Mexico		
Transition Variable	t-statistic	p-value
VIX	-1.0118	0.3134
ToT volatility	0.3803	0.7043
E. Peru		
Transition Variable	t-statistic	p-value
VIX	-0.3490	0.7278
ToT volatility	2.6441	0.0095

Source: Authors' calculations based on Choi and Saikkonen (2004).

5.4 Cointegrating Smooth Transition Regressions

According to the results in section 5.3, we estimate Equation (8) in which a non-linear relationship between RER and sovereign risk is included using the selected transition variable. In particular, we add a smooth transition component to the basic specification described in Table 1 for each country. This non-linear effect allows the sovereign risk coefficient to be time varying as a function of indicators of market volatility.

There are three new coefficients related to the non-linear component (see Equations (8) and (9)). First, $\bar{\phi}_5$ measures the non-linear effect of sovereign risk on the RER. Second, the threshold of the market volatility index ($\bar{v}$) is a critical value for the smooth transition function. Third, ξ measures the smoothness of the logistic transition function.

Table 3 shows the results of the non-linear cointegration regressions. The three coefficients corresponding to the non-linear component are reported on the last lines of each panel. The remaining coefficients are described in the same order as those in Table 1, thus they can be easily compared. For Brazil we present the estimation when the volatility of ToT is the transition variable as well as the one using the VIX, so we can contrast the two options for this country and the estimated coefficients for Colombia.

Table 3: Results of Smooth Transition Cointegration

i) Transition variable: VIX

A. Brazil			
Variable	Coefficient	t-statistic	p-value
Constant	4.5009	53.4129	0.0000
Domestic long-term interest	-0.0032	-0.3934	0.6950
CDS	0.1790	7.2368	0.0000
US Short-term interest	0.0693	5.8454	0.0000
US Inflation	-0.0286	-3.0156	0.0033
Non- Linear CDS	-0.03193	-2.0788	0.0405
Threshold VIX	16.344	13.7751	0.0000
Smoothness	3.3267	0.5732	0.5679

B. Colombia			
Variable	Coefficient	t-statistic	p-value
Constant	4.5699	137.7980	0.0000
Domestic Short-term interest	-0.0364	-3.8067	0.0000
Domestic Long-term interest	-0.0366	-3.7668	0.0000
Domestic Inflation	0.0575	5.5713	0.0000
CDS	0.1567	11.2898	0.0000
US Short-term interest	0.0238	1.6753	0.0960
US Long-term interest	0.0690	3.2494	0.0014
US Inflation	-0.0143	-2.0669	0.0405
Non- Linear CDS	-0.0358	-4.5985	0.0000
Threshold VIX	26.1672	19.4175	0.0000
Smoothness	3.7690	0.1461	0.8840

Note: Sample is January 2003 to December 2015. The estimation includes 0 lag and 0 leads.
Source: Author's computations.

ii) Transition variable: Terms of Trade Volatility (VToT)

A. Brazil			
Variable	Coefficient	t-statistic	p-value
Constant	4.6278	56.822	0.0000
Domestic long-term interest	-0.01359	-1.6314	0.1063
CDS	0.1496	4.6084	0.0000
US Short-term interest	0.0585	4.6625	0.0000
US Inflation	-0.0170	-1.5487	0.1250
Non- Linear CDS	-0.0129	-0.1555	0.8768
Threshold VToT	6.1982	2.1366	0.0354
Smoothness	2.7277	1.7650	0.0810

Note: Sample is March 2007 to December 2015. The estimation includes 0 lags and 2 leads.

B. Chile			
Variable	Coefficient	t-statistic	p-value
Constant	4.7490	73.0466	0.0000
Domestic Long-term interest	-0.0624	-4.5860	0.0000
CDS	0.1197	3.6629	0.0004
US Long-term interest	0.0761	9.6368	0.0000
US Inflation	-0.0110	-1.2784	0.2040
Non- Linear CDS	-0.0288	-1.4465	0.1511
Threshold VToT	24.979	10.5053	0.0000
Smoothness	4.8487	0.0808	0.9358

Note: Sample is September 2005 to December 2015. The estimation includes 0 lags and 3 leads.

C. Peru			
Variable	Coefficient	t-statistic	p-value
Constant	4.4023	205.361	0.0000
Domestic Long-term interest	0.0297	3.5639	0.0005
Domestic Inflation	-0.0039	-0.8436	0.4008
CDS	0.0157	1.0353	0.3029
US Short-term interest	0.0147	2.3183	0.0223
US Long-term interest	0.0301	2.6675	0.0088
US Inflation	-0.0165	-4.3645	0.0000
Non- Linear CDS	0.0113	1.4640	0.1461
Threshold VToT	9.888	12.8153	0.0000
Smoothness	12.258	0.4196	0.6756

Note: Sample is April 2006 to December 2015. The estimation includes 0 lags and 0 leads.
Source: Authors' computations.

Table 3 shows that the non-linear CDS coefficient is negative in Brazil (in both estimations), Colombia and Mexico. This sign implies that the total effect of sovereign risk shrinks when it is associated to an increase in the market volatility indicator (either the VIX or the ToT volatility). Therefore, RER is more sensitive to sovereign risk shocks when they are not driven by international volatility episodes but by domestic events instead. In the case of Peru, the coefficient for the non-linear effect is positive. Hence a sovereign risk increase leads to an extra depreciation of 1.1% on the RER if it coincides with a surge of the ToT volatility.

Notice that, including the non-linear component, a 100 basis-point increase on sovereign risk has the following total depreciation effect on the RER (assuming that the transition indicator is on its threshold[13]): 14.3% in Brazil[14], 10.5% in Chile, 13.9% for Colombia, 7.2% for Mexico[15] and 2.1% in Peru. Those values are similar to the ones reported in the DOLS regressions (Table 1).

For Brazil and Colombia, countries for which the VIX can be used as the transition variable, the non-linear effect is similar[16], but the threshold is significantly higher for the latter. For Brazil, Chile and Peru, for which ToT volatility is the transition variable, the threshold is slightly above the mean of the variable. In the case of Brazil the coefficients have the same sign when either the VIX or the ToT volatility is used as transition variable.

[13] Notice from equations 8 and 9, that if $\nu_t = \bar{\nu}$, the total effect is $\phi_{5,t} + \bar{\phi}_{5,t}/2$.

[14] For Brazil, calculations are based on the ToT volatility model. If the estimation using the VIX as the transition variable is considered, the total effect is 16.3%.

[15] For Mexico, calculations are based on the linear model.

[16] As can be seen in the Appendix, in the estimations using the VIX a lower effect for Mexico and Peru is suggested.

6. Real Exchange Rate Misalignment

An important goal of this paper is using the selected model to evaluate real exchange rate (RER) misalignments in each country. Following the literature, we define misalignments as significant deviations (at least one standard deviation) of the observed RER from what its economic fundamentals in Equation (7) predict.

It is possible to identify some stylized facts across countries from the misalignment analysis in Figure 1. First, in all countries except Mexico, there is an over-depreciation period within the first months after the Lehman Brothers bankruptcy (September 2008). This period is characterized by high levels of international volatility in financial markets, which are associated to important increases of sovereign risk and currency depreciation in most emerging economies.

The second finding is the over-appreciation observed once the US authorities (as well as those in the Eurozone and other developed countries) implemented expansive monetary and fiscal policies as the response to the global financial crisis. The ensuing presence of low interest rates and broad liquidity increased capital flows to Latin-American and other emerging economies. These capital inflows coincided with increasing commodity prices, especially, those associated to major export products in Latin-American economies. Thus the specific over-appreciation periods do not coincide across countries because they are also determined by their own external sector developments (see Table 4).

Finally, the third stylized fact in Figure 1 is the RER over-depreciation observed during the second half of 2015 in all five countries. This result is very likely related to the significant drop in oil and other important commodity prices. In addition, the announcements about monetary policy normalization in the US were especially strong during that period. Both developments (commodities and US monetary policy) increased uncertainty about the future explaining the rapid RER depreciation in Latin American economies.

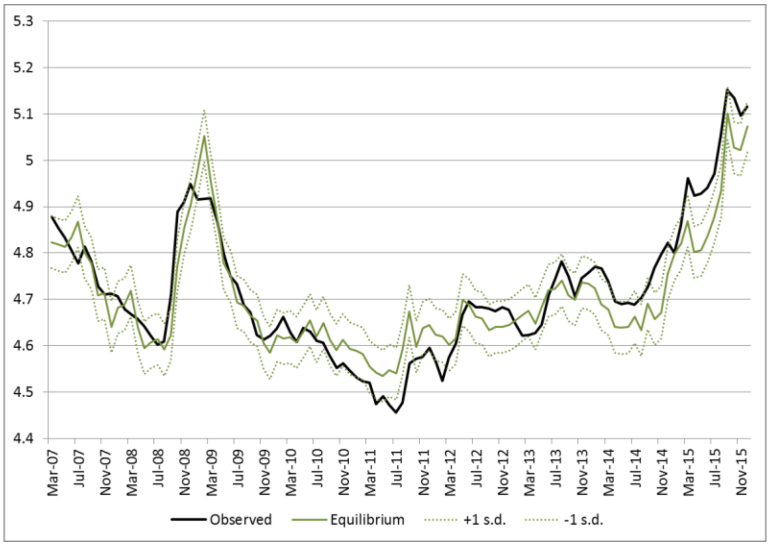
Table 4: Over-appreciation periods after September 2008

Country	Periods
Brazil	Apr 2011 to Oct 2011; Jan 2012 to Mar 2012.
Chile	Jan 2011; Sept 2013 to Nov 2013.
Colombia	Sep 2009 to Nov 2009; Dic 2010 to Feb 2011; May 2012.
Mexico	Dic 2010 to Jul 2011; Dic 2012; Jul 2013 to Dic 2013.
Peru	Aug 2013 to May 2014

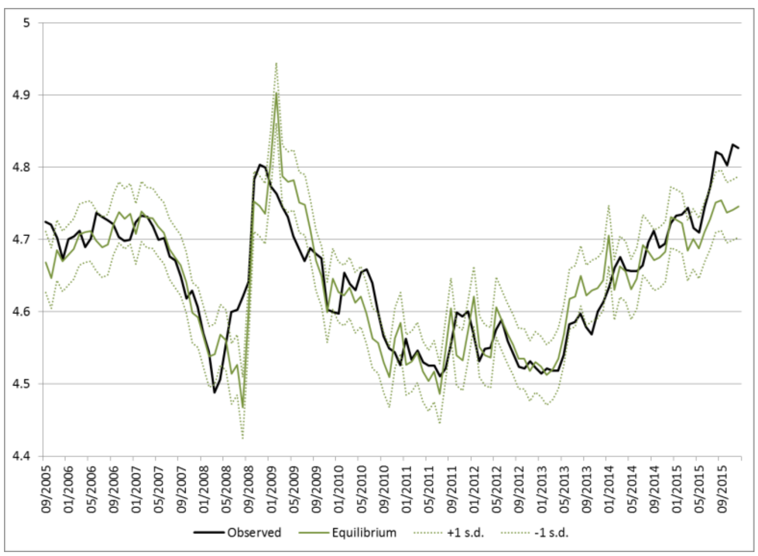
Source: Authors' calculations

Figure 1: Analyzing RER Misalignment Country by Country

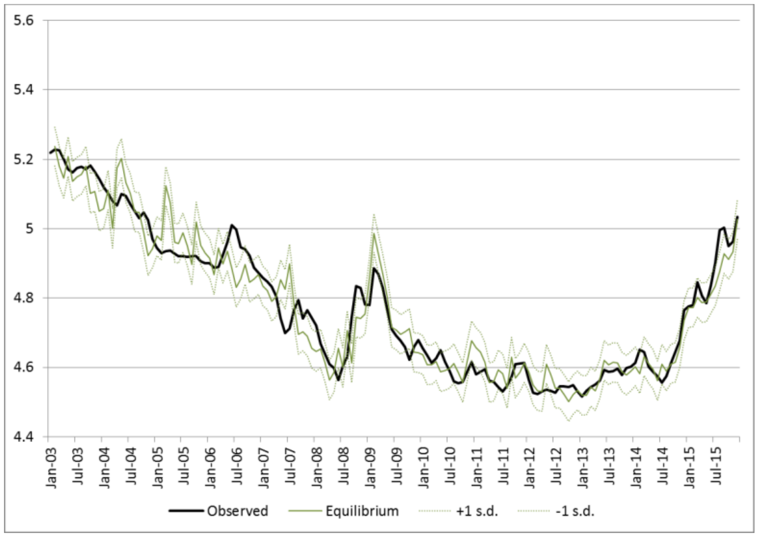
A. Brazil



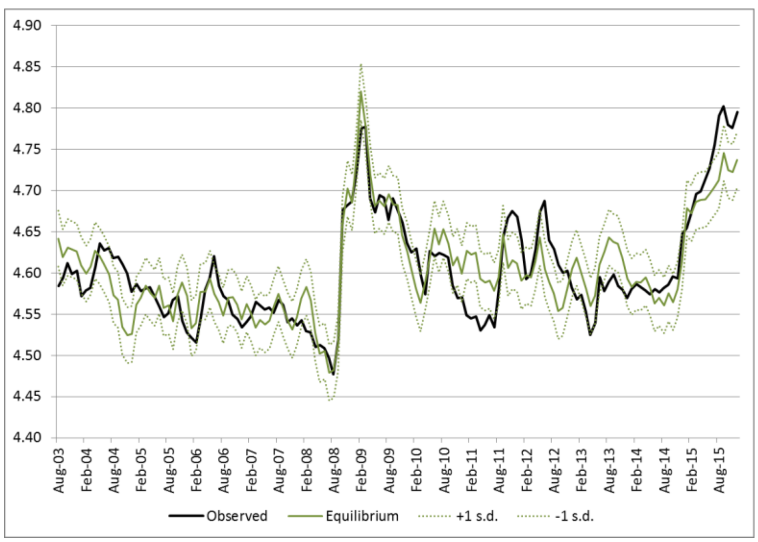
B. Chile



C. Colombia



D. Mexico



E. Peru

Source: Authors' calculations

7. Conclusions

In this paper we estimate a RER determination model based on interest rate and purchasing power parities. The explicit incorporation of the effects of sovereign risk in models of RER determination is helpful for policy-makers to better understand the movements of domestic currency markets. These types of models allow identifying when strong exchange-rate movements should be regarded as misalignments. In this work, we use a new framework by taking into account sovereign risk, inflation and interest rates, and considering possible non-linear effects of sovereign risk on RER. The approach presented in this paper is especially suited for analyzing RER misalignments on a monthly basis since its fundamentals correspond to financial variables which are readily available and easy to forecast.

The first goal of this estimation is computing the effect of sovereign risk on the RER. We use monthly data until December 2015 for five Latin-American economies. The start dates (between 2003 and 2007) depend on data availability for each country.

The results for this exercise show that sovereign risk movements have significant effects on the RER of all five economies. Specifically, a 100-basis point increase of the CDS indicator leads to a real depreciation of between 2.8% (Peru) and 16.5% (Brazil) in the linear model. However, we find significant evidence of non-linear cointegration for all countries, except Mexico, when we allow the effect of sovereign risk to be time-varying as a function of the VIX or the volatility of terms of trade. In the non-linear case, as the volatility indicator increases, sovereign risk movements have a lower effect on the RER in Brazil, Colombia and Chile. This result implies that the incidence of this variable on the RER is weaker when it is explained by international market volatility. In Peru, on the contrary, the effect is stronger when market volatility increases.

The second goal of this paper is performing a RER misalignment analysis to each currency using the estimated regressions. We identify three stylized facts. First, there was an over–depreciation episode in 2008-2009 due to the high international volatility caused by the Lehman Brothers bankruptcy and the initial developments of the great financial crisis. Second, several over-appreciation episodes are detected during the period of massive capital inflows to Latin America (2010-2013). Finally, an over-depreciation episode is observed in all five countries during the second half of 2015. This episode is very likely related to the reaction of currency markets to the significant drop of commodity prices, high international financial volatility and the uncertainty about US monetary policy.

References

Andrews, D. (1991). "Heteroskedasticity and Autocorrelation Consistent Covariance Matrix Estimation," *Econometrica*, 59(3): 817-858.

Bahmani-Oskooee, M., T. Chang, and K. Hung, (2013). "Revisiting Purchasing Power Parity in Latin America: Sequential Panel Selection Method," *Applied Economics*, 45 (32), pp. 4584-4590.

Bussière, M; Ca' Zorzi, M; Chudík, A & Dieppe, A. (2010). "Methodological advances in the assessment of equilibrium exchange rates". European Central Bank Working Paper Series 1151.

Choi, I., and P. Saikkonen, (2004). "Testing Linearity in Cointegrating Smooth Transition Regresssions," *Econometrics Journal*, 7, pp. 341-365.

Coudert, V. and V. Mignon. (2013). "The Forward Premium Puzzle and the Sovereign Default Risk". *Journal of International Money and Finance*, 32: 491–511.

Coudert, V., C. Couharde, and V. Mignon, (2015). "On the Impact of Volatility on the Real Exchange Rate – Terms of Trade Nexus: Revisiting Commodity Currencies," *Journal of International Money and Finance*, 58: 110–127.

Della Corte, P., L. Sarno, M. Schmeling, and C. Wagner, (2015). "Exchange Rates and Sovereign Risk," Available at SSRN: http://ssrn.com/abstract=2354935

Dickey, D. and W. Fuller. (1979). "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association*, 74: 427-431.

Juselius, K. (2004). "Inflation, Money Growth, and I(2) Analysis," Discussion Papers 04-31, University of Copenhagen. Department of Economics.

Juselius, K., and R. MacDonald. (2003). "International Parity Relationships between Germany and the United States: A Joint Modelling Approach," FRU Working Papers 2004/08, University of Copenhagen. Department of Economics. Finance Research Unit.

Keblowski, P. and A. Welfe. (2012). "A Risk-Driven Approach to Exchange Rate Modeling". *Economic Modelling*, 29: 1473-1482.

Lee, J., G.M. Milesi-Ferretti, J. Ostry, A. Prati, & L.A. Ricci, (2008). "Exchange Rate Assessments: CGER Methodologies", IMF Occasional Paper No. 261, (Washington DC: International Monetary Fund).

MacDonald, R. and P. Dias. (2007). "Behavioural Equilibrium Exchange Rate Estimates and Implied Exchange Rate Adjustments for Ten Countries," Workshop on Global Imbalances, Peterson Institute of International Economics, Washington DC.

Ng, S. and Perron, P. (2001). "Lag Length Selection and the Construction of Unit Root Tests with Good Size and Power." *Econometrica* 69, 1519-1554.

Obstfeld, M., and K. Rogoff. (1996). "Foundations of International Macroeconomics," The MIT Press, Cambridge, Massachusetts, 804 p.

Park, J. (1992). "Canonical Cointegrating Regressions," *Econometrica,* 60: 119-143.

Phillips, P. and B. Hansen (1990). "Statistical Inference in Instrumental Variables Regression with I(1) Processes," *Review of Economics Studies*, 57, 99-125.

Reinhart, C. M., and K. S. Rogoff, (2009). "This Time is Different: Eight Centuries of Financial Folly," Princeton University Press, Princeton, NJ.

Saikkonen, P., and I. Choi. (2004). "Cointegration Smooth Transition Regressions," *Econometric Theory*, 20: 301-340.

Sarno, L. and M. Taylor (2002). "The Economics of Exchange Rates," Cambridge University Press, Cambridge, UK.

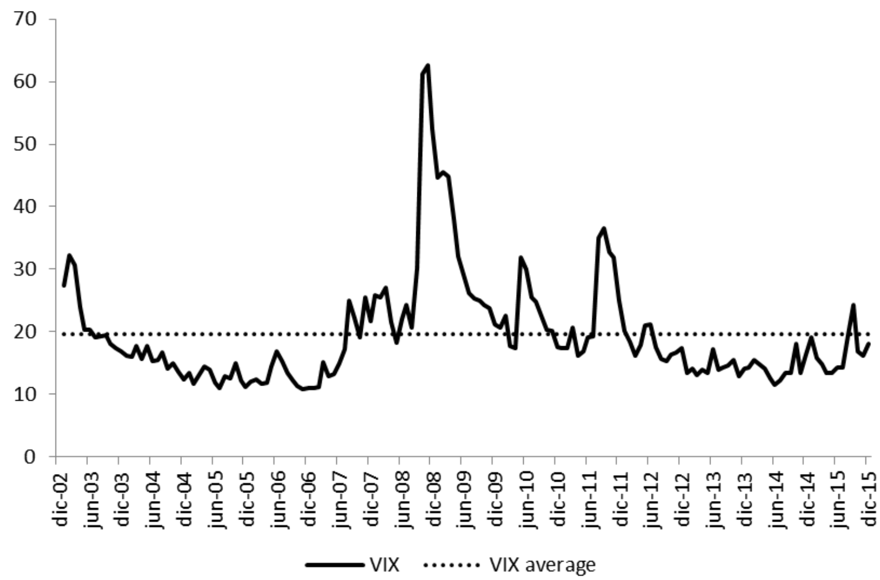
Stock, J. and M. Watson (1993). "A Simple Estimator Of Cointegrating Vectors In Higher Order Integrated Systems," *Econometrica*, 61: 783-820.

Verdelhan, A. (2010). "A Habit-based Explanation of the Exchange Rate Risk Premium," *Journal of Finance*, 65(1), pp. 123-145.

Appendix

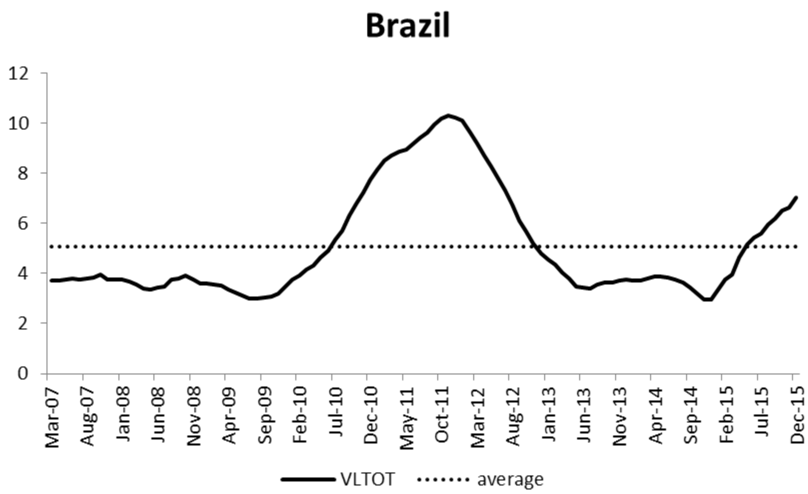
Figures of Transition variables

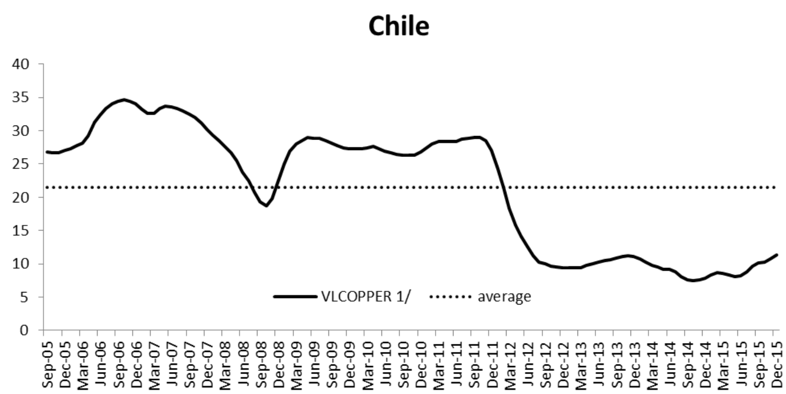
Figure A1 - Evolution of VIX Indicator (basis points)



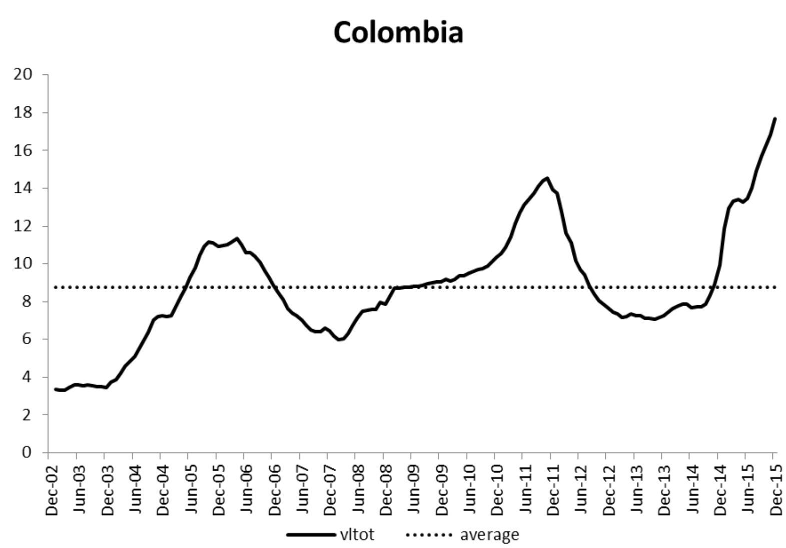
Source: Bloomberg – Chicago Board Options Exchange

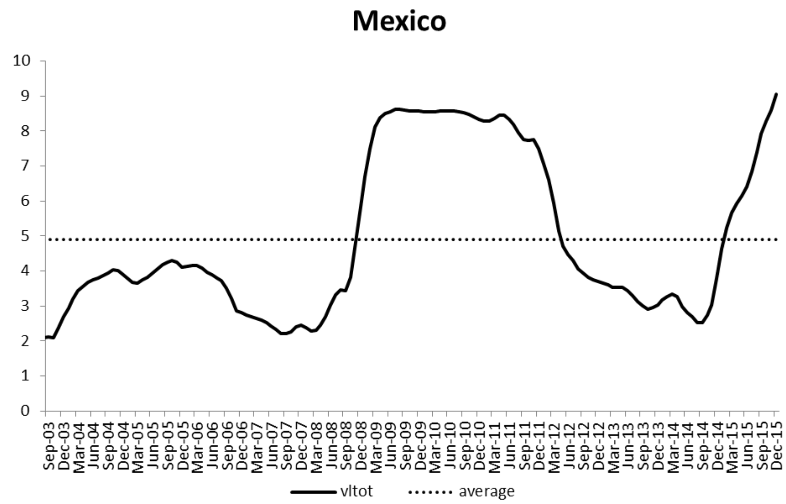
Figure A2 - volatility of terms of trade

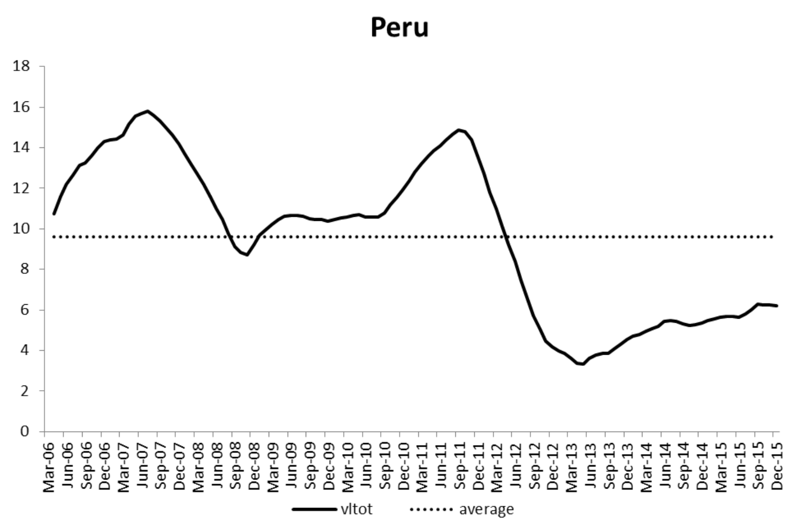




1/ Since monthly terms of trade are not available for Chile, we use the real price of copper (source : Banco Central de Chile).







Source: Author's calculations with information retrieved from central banks.

Table A1 - Unit root tests

A. Brazil			
Variable	ADF	Ng-Perron	Decision
Domestic Short-term interest	-2.0793	-1.5538	I(1)
Domestic Long-term interest	-1.9643	-1.8382*	I(1)
Domestic Inflation	-0.5835	-1.1232	I(1)
CDS	-0.3646	0.0654	I(1)
Real Exchange Rate	-1.1531	-1.0264	I(1)
B. Chile			
Variable	ADF	Ng-Perron	Decision
Domestic Short-term interest	-2.2156	-2.1840**	I(0)
Domestic Long-term interest	-2.3469	-2.0450**	I(0)
Domestic Inflation	-4.0844***	-2.3408**	I(0)
CDS	-2.2388	-1.5450	I(1)
Real Exchange Rate	-1.7832	-1.4371	I(1)
C. Colombia			
Variable	ADF	Ng-Perron	Decision
Domestic Short-term interest	-1.5230	-0.6425	I(1)
Domestic Long-term interest	-2.5423	-0.2226	I(1)
Domestic Inflation	-1.9215	-1.0887	I(1)
CDS	-4.3122***	-0.0976	I(1)
Real Exchange Rate	-1.8558	-0.6275	I(1)
D. Mexico			
Variable	ADF	Ng-Perron	Decision
Domestic Short-term interest	-0.7728	-0.5910	I(1)
Domestic Long-term interest	-1.0699	-1.0057	I(1)
Domestic Inflation	-2.2056	-1.7633*	I(0)
CDS	-2.6101*	-2.3396**	I(0)
Real Exchange Rate	-2.2599	-1.9017*	I(1)
E. Peru			
Variable	ADF	Ng-Perron	Decision
Domestic Short-term interest	-2.2873	-1.4866	I(1)
Domestic Long-term interest	-2.3319	-1.2701	I(1)
Domestic Inflation	-2.9137**	-2.0784**	I(0)
CDS	-3.2689**	-2.6531***	I(0)
Real Exchange Rate	-1.9186	-0.4649	I(1)
F. USA			
Variable	ADF	Ng-Perron	Decision
Domestic Short-term interest	-1.3612	-1.4303	I(1)
Domestic Long-term interest	-1.2280	-1.1242	I(1)
Domestic Inflation	-1.1969	-2.6043***	I(0)
VIX	-3.7574***	-2.5143**	I(0)

Note: For the USA, the sample is January 2003 to December 2015. For the remaining countries, the sample corresponds to Table 1. *, **, *** stand for rejection of the null hypothesis with a degree of confidence of 90%, 95% and 99%, respectively. NG-Perron corresponds to the MZt test with intercept and using HAC corrected variance as described in Ng and Perron (2001). ADF test corresponds to the Augmented Dickey and Fuller (1979) test with intercept and using the Schwartz criterion for lag selection. Source: Author's computations.

Table A2 – Cointegration Tests on DOLS Regressions

Country	Engle-Granger	Phillips-Ouliaris	Cointegration?
Brazil	-3.7898*	-3.8095*	Yes
Chile	-4.3587**	-4.4951***	Yes
Colombia	-5.6090***	-5.6274***	Yes
Mexico	-4.0288*	-3.8884*	Yes
Peru	-4.4428**	-4.4570**	Yes

Note: *, **, *** stand for rejection of the null hypothesis (no-cointegration) with a degree of confidence of 90%, 95% and 99%, respectively. Engle-Granger: We report the Tau Statistic with Bayesian information criterion for lag selection. Phillips-Ouliaris: We report the Tau statistic with pre-whitening, and using quadratic spectral kernel and Andrews bandwith for long-run variance computation.

Table A3 - Results of Smooth Transition Cointegration- All Countries

Transition variable: VIX

A. Brazil			
Variable	Coefficient	t-statistic	p-value
Constant	4.5009	53.4129	0.0000
Domestic long-term interest	-0.0032	-0.3934	0.6950
CDS	0.1790	7.2368	0.0000
US Short-term interest	0.0693	5.8454	0.0000
US Inflation	-0.0286	-3.0156	0.0033
Non- Linear CDS	-0.03193	-2.0788	0.0405
Threshold VIX	16.344	13.7751	0.0000
Smoothness	3.3267	0.5732	0.5679

Note: Sample is March 2007 to December 2015. The estimation includes 0 lags and 2 leads.

B. Chile
Non-linear estimation does not converge

Note: Sample is September 2005 to December 2015. Source: Author's computations.

C. Colombia			
Variable	Coefficient	t-statistic	p-value
Constant	4.5699	137.7980	0.0000
Domestic Short-term interest	-0.0364	-3.8067	0.0000
Domestic Long-term interest	-0.0366	-3.7668	0.0000
Domestic Inflation	0.0575	5.5713	0.0000
CDS	0.1567	11.2898	0.0000
US Short-term interest	0.0238	1.6753	0.0960
US Long-term interest	0.0690	3.2494	0.0014
US Inflation	-0.0143	-2.0669	0.0405
Non- Linear CDS	-0.0358	-4.5985	0.0000
Threshold VIX	26.1672	19.4175	0.0000
Smoothness	3.7690	0.1461	0.8840

Note: Sample is January 2003 to December 2015. The estimation includes 0 lag and 0 leads.

D. Mexico			
Variable	Coefficient	t-statistic	p-value
Constant	4.6762	136.341	0.0000
Domestic Long-term interest	0.0069	1.5543	0.1223
Domestic Inflation	-0.0383	-4.2266	0.0000
CDS	0.0739	3.8795	0.0002
US Inflation	-0.0228	-4.3491	0.0000
Non- Linear CDS	-0.0022	-0.1805	0.8570
Threshold VIX	22.9512	4.3447	0.0000
Smoothness	5.2846	0.0019	0.9985

Note: Sample is August 2003 to December 2015. The estimation includes 0 lags and 0 leads.

E. Peru			
Variable	Coefficient	t-statistic	p-value
Constant	4.414	198.449	0.0000
Domestic Long-term interest	0.0276	3.5575	0.0006
Domestic Inflation	-0.0061	-1.3311	0.1859
CDS	0.0146	0.9044	0.3678
US Short-term interest	0.0164	2.5455	0.0123
US Long-term interest	0.0307	2.7826	0.0064
US Inflation	-0.0149	-4.4047	0.0000
Non- Linear CDS	0.0120	1.2856	0.2013
Threshold VIX	16.9321	6.0726	0.0000
Smoothness	2.1824	0.3629	0.7174

Note: Sample is April 2006 to December 2015. The estimation includes 0 lags and 0 leads.

Source: Authors' computations.

Table A4 - Results of Smooth Transition Cointegration- All Countries

Transition variable: Terms of Trade Volatility (VToT)

A. Brazil			
Variable	Coefficient	t-statistic	p-value
Constant	4.6278	56.822	0.0000
Domestic long-term interest	-0.01359	-1.6314	0.1063
CDS	0.1496	4.6084	0.0000
US Short-term interest	0.0585	4.6625	0.0000
US Inflation	-0.0170	-1.5487	0.1250
Non- Linear CDS	-0.0129	-0.1555	0.8768
Threshold VToT	6.1982	2.1366	0.0354
Smoothness	2.7277	1.7650	0.0810

Note: Sample is March 2007 to December 2015. The estimation includes 0 lags and 2 leads.

B. Chile			
Variable	Coefficient	t-statistic	p-value
Constant	4.7490	73.0466	0.0000
Domestic Long-term interest	-0.0624	-4.5860	0.0000
CDS	0.1197	3.6629	0.0004
US Long-term interest	0.0761	9.6368	0.0000
US Inflation	-0.0110	-1.2784	0.2040
Non- Linear CDS	-0.0288	-1.4465	0.1511
Threshold VToT	24.979	10.5053	0.0000
Smoothness	4.8487	0.0808	0.9358

Note: Sample is September 2005 to December 2015. The estimation includes 0 lags and 3 leads.

C. Colombia			
Variable	Coefficient	t-statistic	p-value
Constant	4.5023	139.274	0.0000
Domestic Short-term interest	-0.0276	-3.1891	0.0017
Domestic Long-term interest	-0.0160	-2.1473	0.0334
Domestic Inflation	0.0287	2.5307	0.0124
CDS	0.1273	13.9989	0.0000
US Short-term interest	0.0250	2.4208	0.0167
US Long-term interest	0.0696	4.4257	0.0000
US Inflation	-0.0176	-3.4222	0.0008
Non- Linear CDS	0.0726	2.9373	0.0038
Threshold VToT	13.7239	16.4625	0.0000
Smoothness	0.1449	0.0869	0.9930

Note: Sample is January 2003 to December 2015. The estimation includes 0 lag and 0 leads.

D. Mexico			
Variable	Coefficient	t-statistic	p-value
Constant	4.6889	136.616	0.0000
Domestic Long-term interest	0.0046	0.9199	0.3592
Domestic Inflation	-0.0338	-3.3483	0.0010
CDS	0.0370	1.7470	0.0828
US Inflation	-0.0217	-3.8633	0.0002
Non- Linear CDS	0.0284	2.0267	0.0446
Threshold VToT	3.6646	68.5057	0.0000
Smoothness	137.303	0.5385	0.5911

Note: Sample is August 2003 to December 2015. The estimation includes 0 lags and 0 leads. Source: Author's computations.

E. Peru			
Variable	Coefficient	t-statistic	p-value
Constant	4.4023	205.361	0.0000
Domestic Long-term interest	0.0297	3.5639	0.0005
Domestic Inflation	-0.0039	-0.8436	0.4008
CDS	0.0157	1.0353	0.3029
US Short-term interest	0.0147	2.3183	0.0223
US Long-term interest	0.0301	2.6675	0.0088
US Inflation	-0.0165	-4.3645	0.0000
Non- Linear CDS	0.0113	1.4640	0.1461
Threshold VToT	9.888	12.8153	0.0000
Smoothness	12.258	0.4196	0.6756

Note: Sample is April 2006 to December 2015. The estimation includes 0 lags and 0 leads.
Source: Authors' computations.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