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Real Equilibrium Exchange Rate in Colombia: Thousands of VEC Models Approach

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Abstract

Behavioral Equilibrium Exchange Rate (BEER) models suggest many variables as potential drivers of equilibrium real exchange rates (ERER). This gives rise to model uncertainty issues, as ERER depends and varies, often drastically, on a particular set of chosen variables. We address this issue by estimating thousands of Vector Error Correction (VEC) specifications for Colombian data between 2000Q1-2019Q4. According to an extensive literature review, we employ thirty-five proxies categorized among five fixed groups of economic fundamentals that underlie the ERER: Indebtedness, Fiscal sector, Productivity, Terms-of-Trade, and Interest Rate Differentials. Our approach derives an empirical distribution of ERER that allows us to state with greater certainty, among hundreds of plausible economic specifications, whether the real exchange rate is either misaligned or in equilibrium.

JEL *codes*: F31, F32, F41, C32
Keywords: Real Exchange Rate, Misalignment, VEC

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Tasa de cambio real de equilibrio en Colombia: un enfoque de miles de modelos VEC

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Abstract

La metodología *Behavioral Equilibrium Exchange Rate* (BEER) sugiere muchas variables como fundamentales de la tasa de cambio real de equilibrio (TCRE). Esto genera incertidumbre en la especificación de los modelos debido a que la TCRE depende y varía, a menudo de manera drástica, del conjunto particular de variables elegidas. Abordamos este problema estimando miles de especificaciones de vectores de corrección de errores (VEC) para datos colombianos entre 2000Q1-2019Q4. De acuerdo con una extensa revisión de la literatura, empleamos treinta y cinco proxies clasificadas entre cinco grupos fijos de fundamentales económicos que subyacen la TCRE: endeudamiento, sector fiscal, productividad, términos de intercambio y diferenciales de tasas de interés. Nuestro enfoque deriva una distribución empírica de la TCRE que nos permite afirmar con mayor certeza, entre cientos de especificaciones económicas plausibles, si el tipo de cambio real está desalineado o en equilibrio.

Clasificación JEL: F31, F32, F41, C32
Palabras clave: Tasa de cambio real, desalineamiento, VEC

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1 Introduction

The real exchange rate (RER) and the misalignment from its long-term equilibrium are key inputs for assessing a country's macroeconomic imbalance. The equilibrium real exchange rate (ERER) helps policymakers to determine whether nominal exchange rate movements obey to temporary shocks that are likely to dissipate in the short term or are determined by more permanent changes in fundamental macroeconomic variables (Clark and MacDonald, 1998). In this sense, economic theory has approached the estimation of an RER long-term (or equilibrium) path through multiple methodologies. Given the multiple notions of equilibrium, a problem that thus arises is that the ERER estimates span over too many mixed results. Additionally, the results will still depend on several modeling assumptions even considering only a particular methodology (Adler and Grisse, 2017).

The literature (Edwards (1989); Isard (2007); Obstfeld and Rogoff (1996); Clark and MacDonald (1998); Sarno and Taylor (2003); De Grauwe and Mongelli (2005), among many others), has developed different methodologies to define and approach the ERER notion. The first, and one of the most commonly used, is the purchasing power parity (PPP), which is a generalization of the law of one price. A second one is the Fundamental Equilibrium Exchange Rate (FEER), which refers to the concept of medium-term equilibrium (Rubaszek and Rawdanowicz, 2009; Roudet et al., 2007) and, according to Fidora et al. (2021), is obtained from the required adjustment of the exchange rate to equalize the medium-term sustainable value of the current account and its cyclically adjusted value. Stein (1990) proposed a third methodology named the natural real exchange rate (NATREX) approach, which defines the "natural" RER as "*the RER that ensures the equilibrium of the balance of payments in the absence of cyclical factors, speculative capital movements and changes in international reserves*". The NATREX ensures internal and external equilibriums in the long run, specifically, when GDP converges to its potential level (or zero output gap), and the country's current account attains a sustainable level. The fourth methodology is called Behavioral Equilibrium Exchange Rate (BEER), which through cointegrated econometric methods, estimates a ERER determined by the long-term dynamics of the RER and its fundamentals.

In this paper, we focus on the BEER approach, as it is a methodology that uses economic fundamentals to explain the underlying structural movements of the ERER and derives a real exchange rate gap (or misalignment). This methodology is also an IMF's tool for exchange rate assessments.[1] According to Adler and Grisse (2017), BEER models have one fundamental weakness: in general, several variables can be used as explanatory variables of real exchange rates in structural macroeconomic models. Due to data limitations, it is often impossible (or impractical) to include all of these variables in the regression. As equilibrium rates and estimated coefficients depend directly on the specific model that the researcher is estimating, the issue of model uncertainty arises. To address this, we establish five groups of multiple fundamentals that, according to the literature, are the ones best explaining ERER movements: Indebtedness, Fiscal aggregates, Productivity, Terms-of-Trade (TOT) and Interest Rate Differentials. For each of the groups, we use several proxies.[2] We estimated real exchange rate vector error correction (VEC) models[3] for all possible combinations of the fundamental variables across groups (always keeping one variable for each group of fundamentals). Thus, iterating over the different variable specifications among each group leads to 18,144 models (for more details, see Section 4). Importantly, we are addressing only one specific and narrow type of model uncertainty: combinations of contemporaneous variables of each type. From these models, we filter out those that meet the expected sign and significance of their coefficients and those in which the residuals satisfied the non-autocorrelation, homoscedasticity, normality, and stationarity assumptions. We construct an empirical distribution for the RER equilibrium and its misalignment from the selected models.

[1] See Phillips et al. (2013) for a description of the methodology used in the IMF's external balance assessments.

[2] Our entire dataset consists of 35 variables. More detailed information about the dataset can be found on Section 3.

[3] We used the specification for the real exchange rate given by the multilateral RER index weighted by total non-traditional goods trade, deflated by the consumer price index.

It is important to note that since the ERER of alternative specifications differs, sometimes considerably, the results obtained can vary at some points in time. Adding to the fact that the long-term level of the RER (equilibrium) is an unobserved variable, makes it challenging to select the most appropriate model since no reference allows evaluating the magnitude of the estimate's error. Therefore, this document explores the robustness of Colombia's equilibrium real exchange rate by the BEER approach.

The document is organized as follows. This introduction is the first section. In the following section, we present the related literature and our contributions. The third section describes the data used and explains all the proxies used as fundamentals. In the fourth section, we present and derive the empirical strategy. In the fifth section, we present and analyze the results, and in the final section, we conclude and discuss the main findings.

2 Literature Review

This section presents a literature review on papers that are closely related to this document since they show estimates of ERER with a cointegration approach. The approach carried out in this document is framed within what Clark and MacDonald (1998) called the BEER. Under this methodology, the ERER is constructed based on reduced-form models and time series estimates that seek to capture how different variables determine the dynamics of the RER. In this sense, these models not only seek to understand the exchange rate in the medium and long term but also to explain its short-term dynamics. According to this notion of equilibrium, the ERER varies over time and is specified as a function of its fundamentals, determined by macroeconomic theory. Using a VEC model they differentiate between permanent (the terms of trade, relative prices on nontraded to traded goods, the stock of net foreign assets, and a proxy for the risk premium) and transitory (interest rate differential) components of RER fundamentals for the G-3 currencies. They found that BEER model was consistent with the theory as it explained actual movements of the real effective exchange rate.

Maeso-Fernández et al. (2002) show an empirical analysis of the medium-term determinants of the euro exchange rate. The empirical analysis derives a BEER and a Permanent Equilibrium Exchange Rate (PEER).[4] Both models were rather similar, being the PEERs smoother than the BEERs. The results of this paper show that the variables that have a significant influence on the euro effective exchange rate are: productivity, differentials in real interest rates, relative fiscal stance, and the real oil price. Ricci and MacDonald (2003) estimate a VEC model to find the ERER in South Africa using quarterly data for the period 1970Q1 to 2002Q1. The determinants of the real exchange rate that these authors consider are the real interest rate differential, relative GDP per capita, real commodity prices, an openness indicator, the fiscal balance, and the net foreign assets (NFA). Clark and MacDonald (2004) extend the BEER approach using real interest rate differential, net foreign assets, and the relative price of nontraded/traded goods as economic fundamentals. Using Johansen cointegration methods, the fundamentals are decomposed into transitory and permanent components. The permanent component was used to estimate the PEER for the pound sterling and U.S. and Canadian dollars. They found for the U.S. and Canadian dollars that the BEER and the PEER are very similar and generally follow the observed exchange rate.

Paiva (2006) estimates the BEER model for Brazil through a VEC specification for the period of 1970 to 2004. The author considers the relative price of non-tradable to tradable, the terms of trade, real interest rate differentials, net foreign assets position, and the relative stock of public domestic debt as the fundamentals related to the real exchange rate. After estimating the unit root test, he finds that the real interest rate differential is stationary but

[4] This methodology seeks to decompose the estimated BEER into transitory and permanent components, making the PEERs smoother than the BEERs.

because of the changing economic structure and macroeconomic instability observed in Brazil during the sample period he estimates different models. One in which this variable is included in the long-run determinants and the other in which it is included as an exogenous variable (incorporating it into the short-term coefficients). Results show that the absolute value of the interest rate differential coefficient in the cointegrating equation is relatively small, hence reflecting an almost negligible contribution. The author decomposes the equilibrium in its components and concludes that the strong real appreciation from 2003-2005 was a response to improved economic fundamentals.

Lee et al. (2008) describe all the methods used by the International Monetary Fund to evaluate the misalignment of the exchange rate in member countries. The use of cointegration methods between the RER and its fundamentals is classified by these authors within the Equilibrium Real Exchange Rate methodology and they describe an estimate of a panel VEC for 48 countries with annual data for the period 1980-2004. The following are the fundamentals considered by these authors: NFA, productivity differentials, Terms-of-Trade (ToT) commodities, government consumption, trade restrictions index, and an indicator of price controls. Caputo and Núñez (2008) estimate an equation for Chile's RER based on its fundamental determinants for the period 1977-2007 with quarterly data. The fundamentals used by these authors are the ratio between tradable and non-tradable productivity, Government spending, ToT, NFA, and the level of tariffs. The estimation of the VEC is carried out using minimum dynamic squares.

Bénassy-Quéré et al. (2009a) study the robustness of the equilibrium exchange rate estimations from BEER methods. They investigate industrial and emerging countries' potential fundamentals that include net foreign asset position, relative productivity, interest-rate differential, and terms of trade. From this analysis, they conclude that the interest-rate differential is integrated of order 0, while the other series can be considered as I(1). For this reason, they estimate two models, one in which they do not include the interest rate differential in the long-term relationships and the other in which they include this variable as it might be important. As the two strategies were very similar, they conclude that the results were consistent with literature that suggests that real exchange rate movements are unrelated to real interest rate differentials in the long run. Also, because of uncertainty associated with how to measure the relative productivity of the tradable and non-tradable sectors, they investigate the impact of using alternative proxies for this fundamental. After this, they investigate how the choice of the numeraire on the derivation of bilateral equilibrium rates could affect estimations. Finally, they test the robustness of the different BEER models. The main conclusion is that BEER estimations are robust to several tests and the choice of the productivity proxy tends to be the more sensible.

Bussiére et al. (2010) carry out an analysis of the main methodologies for estimating the RER equilibrium, focusing on describing the most recent methodological advances that allow an improvement in the estimation. These authors recommend, in the case of estimating a reduced form of the RER and its determinants, to consider fundamentals related to trade restrictions, productivity, government consumption, capital formation, NFA, and commodity prices. The authors carry out an estimate with a balanced panel of 44 countries in the period 1980-2007 using a methodology that considers the presence of heterogeneous countries and the dependence of the cross-section of the data. For each combination of fundamentals, they select only the models that pass the test for the existence of a long-run relationship, then those that have significant level elasticities, and finally those in which their coefficient meets the expected sign in line with the theoretical restrictions.

In the same line as our work, Adler and Grisse (2017) explore the robustness of BEER models addressing the issue of model uncertainty. Using price-level data of several countries, they explore the robustness of including country fixed effects and evaluate how sensitive the estimated coefficients are to different combinations of economic fundamentals behind the RER. In their estimation, the authors consider several variables such as trade balance, terms of trade, real interest rate, productivity, private credit, population growth, output gap, trade openness, old age dependency rate, net foreign assets, government consumption, GDP per capita, fiscal balance, fertility rate, and central bank reserves. They estimate thousands of RER regressions over all possible combinations of the aforementioned fundamentals, ranging from models with one or two variables to the inclusion of all variables. To statistically weight these models in an optimal way, they use Bayesian model averaging and filter out those models that meet the expected sign in at least 95% of specifications. Finally, they construct the distribution of the misalignment across all the cointegrating models to identify the median of the estimation and the widest bands over 95% of the distribution. Their main finding is that the estimated coefficients and, consequently, the implied equilibrium exchange rates, are sensitive to several modeling assumptions. Therefore, it is important to interpret the point estimates of equilibrium exchange rates with care and explore how the effects of specific variables depend on the model specification. The reasons addressed by Adler and Grisse (2017) were the main motivation for the methodological approach of our work.

In Colombia, several papers have attempted to estimate ERER and RER misalignments. Oliveros and Huertas-Campos (2003) were one of the first to perform a VEC estimation to find the equilibrium RER with annual data during the period 1958-2001. The determinants used were NFA, interest rate differential and the relationship between tradable and non-tradable prices as a proxy for the Balassa-Samuelson effect. Echavarría et al. (2005) estimated a VEC with annual data for the period 1962-2004 and considered the following long-term determinants (fundamentals) of the RER: NFA, GDP growth differential between Colombia and the US, ToT, Government consumption, US RER and the nominal COP/USD exchange rate of Colombia.

Later on, Echavarría et al. (2007) estimated a common trend approach associated with a Structural VEC model to obtain an ERER for Colombia. In this case, they used annual data for the period 1962-2005 and the following fundamentals for the RER: NFA, ToT, and an openness indicator. The exercise indicated that the RER has been overvalued mainly between 1962 and 1974, in 1983-1985 and from 1995 to 1997. The results suggested that the RER was not far from its long-term equilibrium from 1999 to 2005.

Alonso et al. (2008) proposed easy-to-follow alternative measures to periodically assess the evolution of the RER. A preliminary analysis was made on how misaligned its different methodologies were with respect to their long-term level. Up to that moment, available information suggested that Colombian industry increased its productivity, in particular when compared to the United States and that the level of the RER was close to what was consistent with the degree of development of the economy. Puyana-Martínez (2010) estimated the relationship of relative tradable versus non-tradable productivities with information from the Colombian manufacturing sector. This variable was then compared with a similar one for the United States to construct an indicator of the Balassa-Samuelson effect for Colombia with annual data for the period 1987-2004. The author finds that this indicator is highly correlated with the RER for the period 1992-2004. Arteaga et al. (2013) studied the behavior of the RER using a cointegration model between 1994 and 2012. Their results highlight the importance of national terms of trade and the Balassa-Samuelson effect in explaining the real appreciation observed since the end of 2003. Our work adds to this strand of literature by studying the dynamics of the real exchange rate in Colombia in a more recent period (2000-2019) and its robustness when changing variables specifications.

3 Data

We use quarterly data between 2000Q1 and 2019Q4. The selection of the period is constrained by the availability of information and the fact that Colombia has adopted a flexible exchange rate within the frame of an inflation-targeting regime. The variables in the dataset were seasonally adjusted using the Census X-13 method (if seasonality is present). All variables that were not percentages were introduced in their logarithmic transformation to have comparable magnitudes.

As mentioned before, we group all our variable specifications in five different groups (Table 1) and proceed with estimating the VEC models, iterating on the variables within each group. Each group represents a theoretically intuitive and relevant channel in the literature (Annex A). Given that each type corresponds to one of the channels relevant in the RER literature, we consider appropriate to include one variable of each group in our candidate specifications. The variable in the first group is the logarithm of the real exchange rate index (RERI) that uses total weights[5] and the CPI as the deflator for all countries (details on its construction can be found in Annex C), which is assumed to be the most endogenous, as these variables respond to all the fundamentals. All the variables used, their detailed description and source can be found in Annex E.

3.1 Fundamental determinants of ERER

Economic theory and economic literature suggest several fundamental macroeconomic variables that determine fluctuations in the RER. The *Balassa-Samuelson* (productivity) effect constitutes the main factor of the relative supply of non-traded versus traded goods. In this way, the supply of non-traded goods is constrained; from the point of view of a small open economy, like Colombia, traded goods are supplied elastically at exogenous world market prices. Therefore, an increase in the demand for traded goods is related to an increase in non-traded goods prices relative to traded goods, and thus with an appreciated RER. Other factors that alter the relative demand among tradable and non-tradable goods that affect their relative price, and the RER are also considered. This section will describe in detail the set of groups of fundamental drivers, along with the variables that compose them. In Annex A, we present the classification of the five fundamental variables that, according to most of the literature, constitute the main drivers of the RER.

The literature (i.e. Adler and Grisse, 2017; Phillips et al., 2013) has identified that the estimation of the ERER using the BEER methodology tends to be very sensitive to the specification of the model and the set of fundamentals used. To address this uncertainty, this document is inspired by the work carried out by Adler and Grisse (2017), which estimates “Thousands of BEERS.” In particular, they estimate all possible combinations of long-term drivers (fundamentals) within a panel of countries. This allows them to have a varying number of explanatory variables, but with the issue of having omitted variables in many of the models, especially in the ones with few variables. Our empirical strategy takes Adler and Grisse (2017) methodology as a reference. However, it differs because we fix the number of fundamentals (variables in the cointegrating vector) and iterate over the different variable specifications within the groups defined in Table 1. This has the advantage of having a fixed number of explanatory variables (fundamentals) and ensures that at least one specification (variable) represents each channel while discarding an omitted variable bias. Thus, our approach allows us to generate an empirical distribution function for the ERER from the multiple results derived from the cointegration vectors associated with all VEC models.

[5]The non-traditional weights correspond to the 12th moving average of the share in total trade of the 22 main trading partners for Colombia (imports and exports excluding coffee, oil, coal, ferronickel, emeralds and gold).

In the following items, we will describe in detail the channels in which each of the variables belonging to each group of fundamentals affects the RER:

- **Fiscal**

The relationship between the real exchange rate and fiscal policy has had multiple views in the literature. In the first place, Keynesian theories framed in the Mundell–Fleming model imply that a positive fiscal shock increases domestic demand. This, along with sticky wages and prices, induces a real appreciation (Mundell, 1963; Fleming, 1962; Badia and Segura-Ubiergo, 2014). In the case of real business cycle models, government spending shocks crowd out domestic private consumption, increasing labor supply and appreciating the real exchange rate (Backus et al., 1995). However, other papers, such as Ravn et al. (2007) and Kollmann (2010), find opposite results. Maeso-Fernández et al. (2006) and Badia and Segura-Ubiergo (2014) also highlight the role of the composition of government spending. In particular, the latter authors mention that "*increases in government spending—whether tax or debt-financed—will result in a real appreciation if skewed toward nontradable goods. The effect of public investment, on the other hand, is ambiguous. An increase in public investment may lead to a real appreciation if it raises productivity in the tradable sector through the Balassa-Samuelson mechanism (Balassa, 1964; Samuelson, 1964). But the opposite effect may result if public investment disproportionately increases productivity in the non-tradables sector. Moreover, if productivity increases symmetrically in both sectors, there will be no impact on the real exchange rate (Galstyan and Lane, 2009)*".

In this work, we follow the New-Keynesian approach in which an increase in public spending generates an appreciation of the real exchange rate (negative sign), as it is channeled more often towards non-tradable goods and services (De Gregorio and Wolf, 1994; De Gregorio et al., 1994; Froot and Rogoff, 1995). The channel would be as follows: GDP and aggregate demand increase, increasing the demand for labor and capital, increasing wages and marginal costs and therefore inflation, which implies an increase in the policy rate, capital inflows, and an appreciation of the exchange rate.

- **Productivity**

The inclusion of a productivity variable is commonly motivated by the Balassa– Samuelson theory, according to which "*the greater are productivity differentials in the production of traded goods between two countries, the larger will be the differences in wages and in the prices of services and, correspondingly, the greater will be the gap between purchasing-power parity and the equilibrium exchange rate.*" (Balassa, 1964). Because total factor productivity is difficult to measure, De Broeck and Slok (2006) and Fischer (2004) employ labor productivity measures in different sectors and find evidence that a rise in productivity implies a real appreciation of the respective currency. As most of our variables are defined as ratios with Colombia in the denominator, the expected sign for the coefficients in this set of variables is positive.

- **Indebtedness**

In this group, we include nine variables that offer different measures of indebtedness of the Colombian economy. This includes outstanding debt variables and Net Foreign Assets (NFA). In the case of the debt variables, the expected sign would be positive, as a more indebted country is perceived as riskier (Cosset and Roy, 1991) and, as Ajevskis et al. (2014) clearly states: *"If a country is in a debtor's position, net interest payments weigh on the current account balances. The latter requires strengthening the international price competitiveness and a more depreciated real exchange rate."* In the same way, as Phillips et al. (2013) and Mano (2019) point out, NFA are expected to have a negative coefficient as a country with higher foreign borrowing (worse NFA position) requires a more depreciated RER to improve the trade balance deficit.

- **Terms of Trade**

Terms of trade proxy indicators should have negative signs. Neary (1988) indicates that more favorable terms of trade are associated with higher wealth and, thus, more appreciated RER. According to Ajevskis et al. (2014), higher commodity terms of trade should lead to real exchange rate appreciation via real income effect. Deepening into this idea, Calderón (2004) states that terms of trade improvements would increase tradable goods' consumption and generate positive wealth effects that would reduce the supply of labor in the non-tradable sector. This leads to a relative non-tradable goods price increase and thus, appreciating the RER.

- **Interest Rate Differentials**

According to Adler and Grisse (2017) and Paiva (2006), real interest rate differentials should have a negative sign, indicating that an increase in the differential will cause an appreciation of the RER. This is because a higher domestic interest rate relative to foreign interest rates offers investors higher returns in the country, attracting foreign capital and, thus, an appreciated RER.

Table 1: Fundamental Group Variables

RERI	**Fiscal**	**Productivity**
RERI CPI NT	Public consumption	Relative Labour Productivity USA/COL
	Public comsumption % Total Consumption	Relative labour productivity USA/COL (moving average four quarters)
	CNG Spending	T/NT relative GDP US/COL
	NFPS Spending	T/NT relative GDP US/COL (moving average four quarters)
	Public consumption % GDP	Trade partners/COL index ratio
	NFPS Spending % GDP	Per capita trade partners/COL index ratio
		Per capita relative index USA/COL
		GDP PPP Per capita ratio USA/COL

Indebtedness	**Terms of Trade**	**Int. Rate Diff**
Public external debt outstanding	Terms of Trade CE	Dif Assets-Prime
Total external debt	Terms of Trade PPI	Diff FTD 90 days
NFA prime REAL GDP	Mining Terms of Trade	Diff FTD360-Prime
NFA GDP	Implicit Real Oil Price	Diff FTD-Prime
Real NFA	Real Brent price	Diff FTD-3mlibor
NFA prime GDP	National accounts Terms of Trade	
Private external debt		
NFA prime real		
CNG Outstanding Debt		

4 Empirical Strategy

We estimate thousands of Vector Error Correction (VEC) specifications for 2000Q1-2019Q4. Each model corresponds to a realization of all possible contemporaneous combinations of the fundamental variables across the groups described in Section 3.1 (fixing one variable for each group of fundamentals) for the RER specification. The latter is built as the multilateral RER index weighted by total non-traditional goods trade, deflated by the consumer price index (for more details, see Annex C). The estimated VEC corresponds to DRIFT models according to the usual notation (Arteaga et al., 2013; Johansen, 1992; Maeso-Fernández et al., 2006) with one lag and one cointegration relationship.[6]

For this work, a maximum of lags $p = 2$ was established in the VAR ($p = 1$ in the VEC) to avoid losing so many degrees of freedom given the limitations of data. Also, we conduct unit root tests on all variables, and, as it is

[6] The main reason for this is computational since having more than one cointegration relationship is required to estimate more than one equilibrium for the same model (one for each cointegration relationship). The second reason is that forcing to estimate a single cointegration vector when the test suggests more than one may be wrong. If it is being suggested that there is more than one, there may be different signs and significance levels.

shown in Annex B, all endogenous variables are non-stationary with integration order 1 ($I(1)$). Following Paiva (2006) and Arteaga et al. (2013), interest rate differentials variables are treated as exogenous as they are stationary ($I(0)$), and they are excluded from the cointegration vector. See Annex B for the entire Unit Root Tests of all the variables in our VEC models.

4.1 Cointegration Tests

Once the VEC lags are defined, the cointegration test is applied using the trace test and the maximum eigenvalue test (eigen test) of Johansen (1992) for each resulting combination between one variable of each leading group, one variable for the exogenous Interest Rate Differentials group, and one constant. If at least one of the two tests concludes there is one cointegration relationship, the model is selected.

Once the number of cointegration relationships for each combination of variables is established, we estimate all the VEC models with one cointegration relationship.

4.2 Model and Cointegration Vector Estimation

For the estimation of a VEC model the following specification was used:

$$\begin{aligned}\Delta X_{it} &= \alpha[\beta' : \mu'] \begin{bmatrix} X_{i,t-1} \\ 1 \end{bmatrix} + \Gamma_1 \Delta X_{i,t-1} + \ldots + \Gamma_{p-1}\Delta X_{i,t-(p-1)} + \Phi Z_t + \epsilon_t \\ &= \alpha \beta^{+'} X^{+}_{i,t-1} + \Gamma_1 \Delta X_{i,t-1} + \ldots + \Gamma_{p-1}\Delta X_{i,t-(p-1)} + \Phi Z_t + \epsilon_t \end{aligned} \tag{1}$$

where

$$X_{it} = \begin{bmatrix} RERI_{it} & FISCAL_{it} & PRODUCTIVITY_{it} & INDEBTEDNESS_{it} & TOT_{it} \end{bmatrix},$$

$$X^{+}_{it} = \begin{bmatrix} X_{it} & 1 \end{bmatrix}$$

$$\beta^{+} = \begin{bmatrix} \beta \\ \hline \mu \end{bmatrix} = \begin{pmatrix} 1 & \beta_{12} & \ldots & \beta_{1r} \\ \beta_{21} & 1 & \ldots & \beta_{2r} \\ \vdots & \vdots & \ddots & \vdots \\ \beta_{k1} & \beta_{k2} & \ldots & \beta_{kr} \\ \hline \mu_1 & \mu_2 & \ldots & \mu_r \end{pmatrix} = \begin{pmatrix} \beta^{+}_1 & \beta^{+}_2 & \ldots & \beta^{+}_r \end{pmatrix}$$

i is the subscript of the model, p is the order in which the variables are lagged in the VAR representation, α is a matrix of dimension $K \times r$ containing the convergence speeds to equilibrium, and $[\beta : \mu]$ is the matrix of dimension $(K+1) \times r$ which represents the concatenation between the matrix $\beta_{(\text{K x r})}$, which contains the long-term relationships and the array $\mu_{(\text{1 x r})}$ which contains the constant term. $\Gamma_l (l = 1, \ldots, p-1)$ are matrices $K \times K$ containing the short-term fit coefficients, Z is the vector of exogenous variables that, in this case, are associated with the group of rate differentials, and ϵ is the $K \times 1$ vector of errors.[7]

[7] As our aim is not to make forecasts and/or impulse-response analysis, the order in which the variables enter the cointegration equation does not matter.

4.3 Real Equilibrium Exchange Rate and its Misalignment

The predicted value from the VEC model regression is interpreted as the ERER in the BEER literature. The ERER associated with each model is obtained from the models estimated in the previous section. The total equilibria are equivalent to the total number of possible models estimated. For its calculation, the linear combination in equation (2) between the vector (β_1^+) and the observed data of each variable that compose it (X_{it}^+) is made. This estimate is done for each model i for each t.

$$X_{it}^+\beta_1^+ = \begin{bmatrix} RERI_t & FISCAL_{it} & PRODUCTIVITY_{it} & INDEBTEDNESS_{it} & TOT_{it} & 1 \end{bmatrix} \begin{bmatrix} 1 \\ \beta_{21} \\ \beta_{31} \\ \beta_{41} \\ \beta_{51} \\ \mu_1 \end{bmatrix} = 0$$
$$RERI_t^* + \beta_{21}FISCAL_{it} + \beta_{31}PRODUCTIVITY_{it} + \beta_{41}INDEBTEDNESS_{it} + \beta_{51}TOT_{it} + \underbrace{\mu_1}_{Constant} = 0 \tag{2}$$

where $\beta_{k,1}$ together with μ_1 are the coefficients of the first cointegration vector: β_1^+ associated with the model i. The equilibrium is noted by $RERI^*$ to avoid confusion with the observed RERI.

Considering that RERI has been transformed into logarithms and that the cointegration vector is normalized, the equilibrium of the i-th model is obtained in each t:

$$RERI_{it}^* = exp[-(\beta_{21}FISCAL_{it} + \beta_{31}PRODUCTIVITY_{it} + \beta_{41}INDEBTEDNESS_{it} + \beta_{51}TOT_{it} + \mu_1)] \tag{3}$$

Once the equilibrium has been calculated, the misalignment of model i is calculated for each time t. The misalignment is calculated as the percentage change between the observed exchange rate and the equilibrium rate.
Following the literature (Clark and MacDonald, 1998), a smoothed equilibrium measure is calculated. We use equation (3) but replace the smoothed versions of the right-hand side variables using the Hodrick and Prescott filter, denoted as $\hat{x_{it}}$. The aforementioned procedure is made to obtain the equilibrium that does not incorporate short-term movements of its fundamentals.

$$\widehat{RERI}_{it}^* = exp[-(\beta_{21}\widehat{FISCAL}_{it} + \beta_{31}\widehat{PRODUCTIVITY}_{it} + \beta_{41}\widehat{INDEBTEDNESS}_{it} + \beta_{51}\widehat{TOT}_{it} + \mu_1)] \tag{4}$$

Then the smoothed misalignment is calculated as the percentage deviation between the observed exchange rate and the smoothed equilibrium rate.

4.4 Model Selection

Once we have all the misalignments, we filter out those models where β_1^+ together with the exogenous component Φ, do not meet the expected signs (as explained in Section 3.1). The significance of the coefficients of the remaining models is evaluated, and the cases where at least 4 out of 6 were significant (at 10% level) are selected.

In addition to the sign and significance filter, all models that do not meet the criteria of non-auto-correlation, homoscedasticity, normality, and stationarity in the residuals are excluded.

4.5 Equilibrium and Misalignment Distribution

To obtain a central path of equilibrium and misalignment in each period of time, we group the selected models, and for each t, their median is calculated. This process is done for both smoothed and unsmoothed estimates. We obtain the equilibria calculated for each time t, $(t = 1, \ldots, T)$ and each model i, $(i = 1, \ldots, N)$. The 20th and 80th percentiles are obtained in the same way and will represent the intervals around our central path (median). A matrix representation of this process is presented in Tables 2 and 3:

Table 2: Equilibrium Models

Model 1	Model 2	$\cdots$	Model N
$exp\left(RERI^*_{11}\right)$	$exp\left(RERI^*_{21}\right)$	$\cdots$	$exp\left(RERI^*_{N1}\right)$
$exp\left(RERI^*_{12}\right)$	$exp\left(RERI^*_{22}\right)$	$\cdots$	$exp\left(RERI^*_{N2}\right)$
$exp\left(RERI^*_{13}\right)$	$exp\left(RERI^*_{23}\right)$	$\cdots$	$exp\left(RERI^*_{N3}\right)$
$\vdots$	$\vdots$	$\ddots$	$\vdots$
$exp\left(RERI^*_{1T}\right)$	$exp\left(RERI^*_{2T}\right)$	$\cdots$	$exp\left(RERI^*_{NT}\right)$

Table 3: Distribution for each t

$median(exp\left(RERI^*_{11}\right), exp\left(RERI^*_{21}\right), \ldots, exp\left(RERI^*_{N1}\right))$
$median(exp\left(RERI^*_{12}\right), exp\left(RERI^*_{22}\right), \ldots, exp\left(RERI^*_{N2}\right))$
$median(exp\left(RERI^*_{13}\right), exp\left(RERI^*_{23}\right), \ldots, exp\left(RERI^*_{N3}\right))$
$\vdots$
$median(exp\left(RERI^*_{1T}\right), exp\left(RERI^*_{2T}\right), \ldots, exp\left(RERI^*_{NT}\right))$

5 Results

This section begins by showing the distribution of coefficients across all models[8] that test how robust the sign and the magnitude of the estimated coefficients are to alternative model specifications. We empirically address the different hypotheses on the signs of the coefficients associated with variables discussed in Section 3.1. Following this, from the selection of models that meet the criteria on sign, significance and residual assumptions (as discussed in Section 4), we show the empirical distribution of equilibria and misalignments across all range of models. It is important to note that we are addressing only one specific and narrow type of model uncertainty: combinations of contemporaneous variables of each type.

5.1 Distribution of Coefficients

In Annex D (Figures AD.1 through AD.4), we report the distribution of the estimated coefficients associated with variables inside the cointegration vector and across models. The proportion of red to white shows the share of estimations in which the coefficients are statistically significant at the 10% level. These distributions illustrate how robust the sign and the magnitude of the estimated coefficients are to alternative model specifications. A negative (positive) coefficient implies that increases in the corresponding variable are associated with a real effective appreciation (depreciation) of the RER.

Our results suggest that the terms of trade group variables are robustly linked with real exchange rates in the sense that their coefficients are, on average among all six variables, significant in 79% of all possible models and in approximately 76% of the total models they have the theoretically predicted sign (Figure AD.1). The latter strongly supports the theory in the sense that higher commodity terms of trade should lead to real exchange rate appreciation via real income effect (Neary, 1988; Ajevskis et al., 2014).

[8] Previous to eliminating those with a different expected sign, not significant, nor those of models whose residuals do not meet the desired assumptions.

In the productivity group (Figure AD.2), variables with the highest percentage of significant coefficients across all possible combinations of models (and with the expected sign) are the ones relating productivity measures between Colombia and its main trading partners. Indeed, among the two variables measuring relative productivity of Colombia and its main trading partners, 98% and 95% of the models were significant and met the expected sign, respectively. In this group, the worst performer productivity proxy is the per-capita relative index between the US and Colombia, in which 45.8% is significant and, among those, 53.5% have the expected positive sign. It is worth noting here that as our variables are defined as ratios with Colombia in the denominator, the expected sign for the coefficients in this set of variables is positive. As mentioned in Section 3.1, the inclusion of a productivity variable is commonly motivated by the Balassa– Samuelson theory. Our results mostly support both the theoretical and empirical evidence that a rise in productivity implies a real appreciation of the local currency.

With respect to the Indebtedness group of variables, they overwhelmingly exhibit the expected sign in most variables, specifically in the ones including outstanding debt (Figure AD.3). Public external debt outstanding as percentage of the moving sum four quarters of nominal GDP in USD, and NFA as percentage of nominal GDP, show a percentage of significance on more than 95% of the regressions and, approximately, 92% exhibit the expected sign (positive for the public debt outstanding and negative for the NFA/GDP). Total external debt is another outperformer, having 77% of the coefficients significant with 75% the expected positive sign from the total estimated models. It is worth noting that NFA times the prime interest rate divided by the sum of four quarters of the GDP (NFA prime GDP), NFA times the prime real interest rate deflated by US CPI (NFA prime real) and NFA times the prime interest rate as percentage of real GDP (NFA prime REAL GDP) exhibit a distribution with 54%, 47% and 38% of the models, respectively, having the expected sign.

Lastly, in the fiscal group, all variables considered are significant in more than 52% of the cases (Figure AD.4). In particular, the three variables relative to Public Consumption (Public Consumption, Public Consumption as a percentage of GDP, and Public Consumption as a share of Total Consumption) have a clear majority in the expected negative sign. These results support Maeso-Fernández et al. (2006) and Badia and Segura-Ubiergo (2014), which highlight the role of the composition of government spending as "*increases in government spending—whether tax or debt-financed—will result in a real appreciation if skewed toward non-tradable goods*." Our results also seem to support the New-Keynesian approach in which an increase in public spending generates an appreciation of the real exchange rate (negative sign), as it is channeled more often towards non-tradable goods and services (De Gregorio and Wolf, 1994; De Gregorio et al., 1994; Froot and Rogoff, 1995). In the long term, high government/public sector spending, mainly if it is financed by debt, may widen the interest rate differential between the economy and the rest of the world as it increases the country's risk premium (Bouakez and Eyquem, 2015; Kollmann, 2002; Schmitt-Grohé and Uribe, 2003; Senhadji, 2003). This may lead to distortions in the economy and undermine the market's confidence in a currency. As Colombia has had a persistent fiscal deficit, this could explain the positive coefficients on CNG Spending, NFPS Spending, and NFPS Spending as a percentage of GDP.

5.2 Distribution of ERER and Misalignment

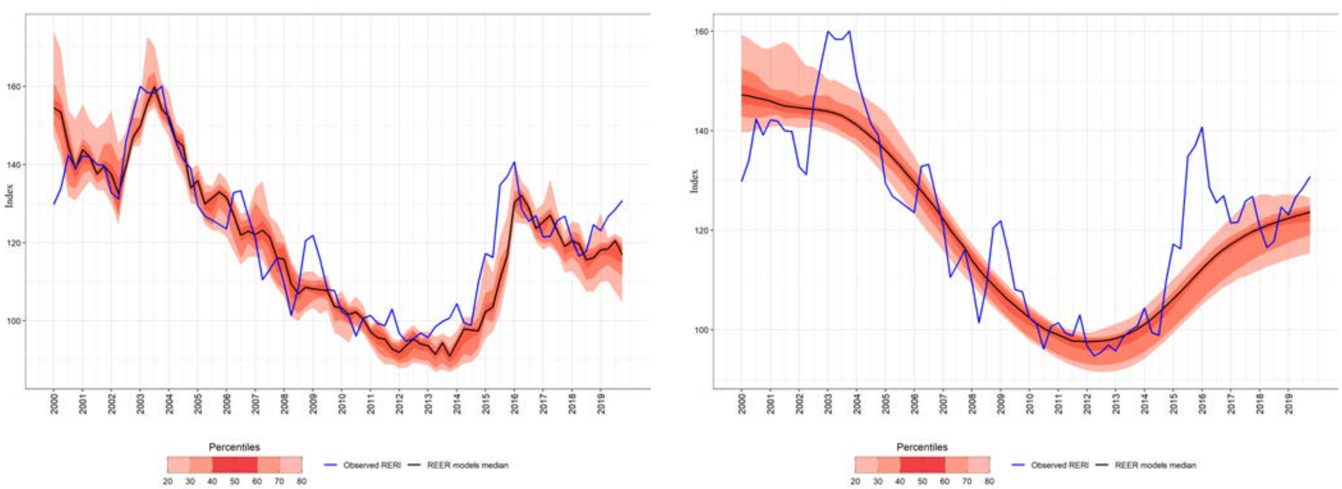
As documented in Section 5.1, both magnitude and sign of the estimated coefficients are sensitive to the combinations of variables that are in a particular regression. Thus, the model implied that the ERER will also depend on the chosen specification and each model would imply a different path for the equilibrium exchange rate. For that reason, we present the empirical distributions of ERER and smoothed ERER (Ricci and MacDonald, 2003). In a VEC model, the equilibrium relationship results from multiplying the cointegration vector found by the values of the variables at each moment of time. In the smoothed ERER, we use the cointegration vector of the VEC and multiply it by the smoothed variables[9] to omit transient movements in them that should not lead to changes in the ERER.

Figure 1 shows the empirical distribution of ERER (Panel A) and the empirical distribution of smoothed ERER (Panel B). From 2004 to 2013, the median of these empirical distributions shows that the country experienced a reduction in ERER. In addition, the complete distribution also exhibits a trend towards appreciation of the ERER in these years. This result is associated with higher terms of trade,[10] some improvement of relative productivity, an increase of government spending[11] and a reduction of external indebtedness as a percentage of GDP.[12] Arteaga et al. (2013) found a similar trend for ERER by estimating a VEC model for Colombia between 1994Q2 and 2012. Our estimation also reveals that from 2014 to 2019, ERER increased in the middle of a negative shock to the terms of trade, higher external debt and a worsening of net foreign assets.[13]

In addition, Figure 2 presents the corresponding misalignment of RER. According to both methodologies, during the global financial crisis (2008-2009) and the oil price shock (2014-2015), there was a significant deviation of the RER from the equilibrium in the sample period. Additionally, taking into account the flexible exchange rate regime adopted in Colombia since 2000, the RER oscillated around the equilibrium over our sample period.

Figure 1: Distribution of ERER and smoothed ERER

Panel A: ERER and RERI Panel B: Smoothed ERER and RERI



Note: Figures in both Panel A and Panel B cover the period 2000Q1 - 2019Q4. Panel B reports the ERER distribution that results from replacing the fundamentals by its long-term equilibriums (Hodrick–Prescott trend component). The widest bands correspond to the area between percentiles 20 and 80 of the distribution.

[9] Resulting of substituting the fundamentals by its Hodrick–Prescott trend component to obtain the equilibrium.

[10] Between 2004 and 2013 terms of trade increased by 45% due to the price commodity boom, including higher oil prices, which have had a significant share in Colombian exports. There was a transitory decline in terms of trade explained by the oil prices reduction in the first years after the beginning of the global financial crisis (2008).

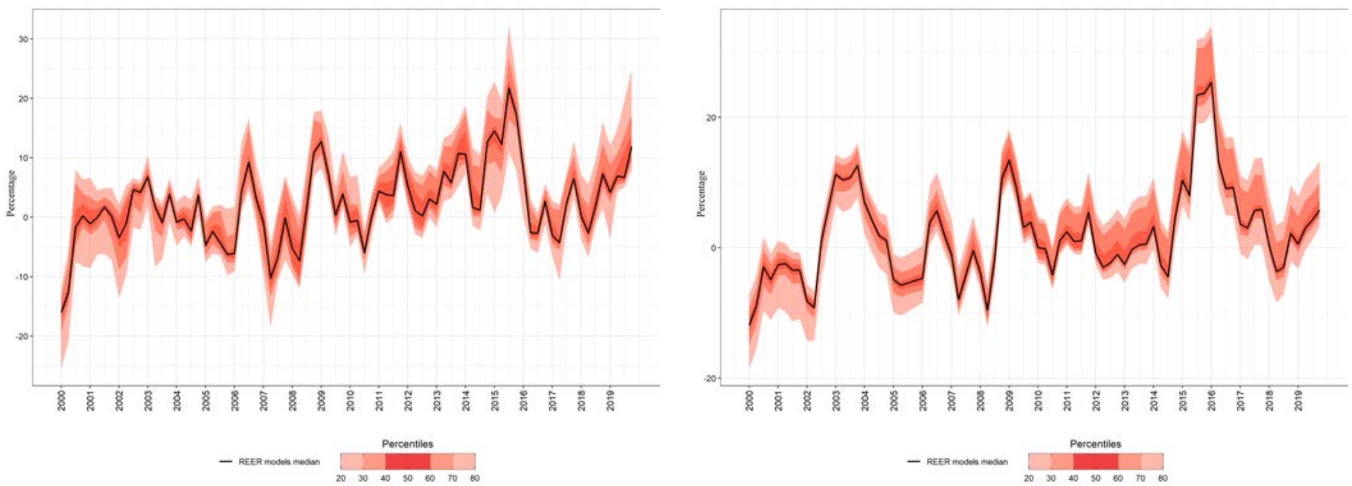
[11] According to the Fiscal Monitor of the International Monetary Fund, total government expenditure expanded from 26.6% of GDP in 2004 to 30% of GDP in 2013.

[12] Total external debt dropped from 40.6% of GDP in 2003 to 24.1% of GDP in 2013.

[13] During this period, Colombia raised its external debt as a share of GDP (from a 24% in 2013 to 43% in 2019), which in turn greatly deteriorated the net foreign position as a share of GDP (from -25.3% in 2013 to -48.9% in 2019).

Figure 2: RER and smoothed RER misalignments

Panel A: RERI misalignment from ERER Panel B: RERI misalignment from smoothed ERER



Note: Figures in both Panel A and Panel B cover the period 2000Q1 - 2019Q4. Panel A report the distribution of RER Misalignment corresponding to the percentage difference between observed RER and the effective ERER from Figure 1, Panel A. Panel B reports the distribution of RER Misalignment corresponding to the percentage difference between observed RER and the ERER from Panel A. The widest bands correspond to the area between percentiles 20 and 80 of the distribution.

6 Conclusions

The equilibrium in the real exchange rate is not a unique concept, and it depends on the horizon of analysis and the assumptions made. Like any other relative price, the real exchange rate is determined by a series of economic variables and random shocks.

The approach carried out in this document is framed within what Clark and MacDonald (1998) called the Behavioral Equilibrium Exchange Rate (BEER). Under this methodology, the equilibrium real exchange rate (ERER) is constructed based on reduced-form models and time series estimates that seek to capture how different variables determine the dynamics of the RER. According to this notion of equilibrium, the ERER varies over time and is specified as a function of its fundamentals, determined by macroeconomic theory. The literature (i.e., Adler and Grisse, 2017; Phillips et al., 2013) has identified that the estimation of the ERER through the BEER methodology tends to be very sensitive to the specification of the model and the set of fundamentals used. In general, BEER models suggest several variables as potential drivers of real exchange rates. However, with a limited dataset, it is often not practicable nor optimal to include all of these variables (some of which may have little explanatory power on real exchange rates) in the regression. This gives rise to the issue of model uncertainty, as coefficients and equilibrium rates depend on the particular specification that the researcher is estimating. To address this issue, we establish five groups of multiple fundamentals that, according to the literature, best explain ERER movements: Indebtedness, Fiscal aggregates, Productivity, Terms-of-Trade, and Interest Rate Differentials. We use several proxies for each group and estimate real exchange rate VEC models for all possible combinations of the fundamental variables across groups (fixing one variable for each group of fundamentals). Thus, iterating over the different variable specifications among each group leads to 18,144 possible models. We filter out those that meet the expected sign and significance of their coefficients and those in which the residuals satisfied the non-auto-correlation, homoscedasticity, normality, and stationarity assumptions. From the selected models, we derive an empirical distribution of ERER that allows us to state with greater certainty, among hundreds of plausible economic specifications, whether the real exchange rate is either in equilibrium or misaligned. It is important to note that we address only one specific and narrow type of model uncertainty: combinations of contemporaneous variables of each type. To address other uncertainty sources, future works should also contemplate robustness among different methodological specifications, such as Autoregressive Distributed Lag Model (ARDL), Fully-Modified OLS (FMOLS), or Dynamic OLS (DOLS), among others.

In Colombia, from 2004 to 2013, the median of the empirical distributions shows that the country experienced a reduction in ERER and a trend towards its appreciation in these years. This result is associated with higher terms of trade, slight improvement of relative productivity, increase of government spending and reduction of external indebtedness as a share of GDP. Our estimations also reveal that between 2014 and 2019, ERER depreciated as a consequence of a negative terms-of-trade shock, higher external debt and worsening of net foreign assets.

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Annex A: ERER Determinants According to Literature

	Productivity	Fiscal	Indebtedness	Terms of Trade	Int. Rate Differential
Clark and MacDonald (1998)	X	X	X	X	X
Chinn (2000)	X	X		X	
Zhang (2001)		X		X	
MacDonald (2002)	X		X	X	X
Akram et al. (2003)	X		X	X	X
Lane and Milesi-Ferretti (2004)	X		X	X	
Nilsson (2004)	X		X	X	X
Clark and MacDonald (2004)	X		X		X
Stephens et al. (2004)	X				X
Maeso-Fernández et al. (2006)	X	X			
MacDonald and Ricci (2007)	X		X		X
Wang et al. (2007)	X			X	
Meleckỳ and Komárek (2007)	X	X	X	X	X
Bénassy-Quéré et al. (2009a)	X		X	X	X
Galstyan and Lane (2009)	X	X			
Bénassy-Quéré et al. (2009b)	X		X	X	X
Bénassy-Quéré et al. (2010)	X		X	X	
Bussiére et al. (2010)	X	X	X	X	
Béreau et al. (2010)	X		X	X	X
Sallenave (2010)	X		X		
Alstad (2010)				X	X
Sax and Gubler (2011)	X	X	X	X	
Bénassy-Quéré et al. (2011)	X		X		
Baak (2012)	X		X	X	X
Berka and Devereux (2013)	X	X			
Phillips et al. (2013)		X	X	X	X
Couharde et al. (2013)	X	X	X	X	
Coudert et al. (2013)	X		X	X	X
Ricci et al. (2013)	X	X	X	X	
Zhang and Chen (2014)	X		X		
Caputo et al. (2014)	X	X	X	X	
Ajevskis et al. (2014)	X	X	X	X	
Chen and MacDonald (2015)	X	X		X	X
Comunale (2015)	X	X	X	X	
Griffoli et al. (2015)	X	X	X	X	
Coudert et al. (2015)	X		X	X	
Caputo et al. (2014)	X	X	X	X	
Grekou (2015)	X	X	X	X	
Baak (2017)	X		X	X	X
Martinsen (2017)				X	X
Adler and Grisse (2017)	X	X	X	X	X
Couharde et al. (2018)	X		X	X	
Latin American countries					
Gugliermino et al. (2003)	X	X		X	
Calderón (2004)	X		X		
Paiva (2006)	X	X	X	X	X
Ferreyra and Salas (2006)	X		X		
Echavarría et al. (2007)	X		X	X	
Bastourre et al. (2008)	X	X		X	
Orellana (2010)	X	X	X	X	
Colque (2012)	X	X	X	X	
Arteaga et al. (2013)	X	X	X	X	X

Meza Pérez et al. (2016)	*X*		*X*	*X*	*X*
Cruz (2018)	*X*	*X*	*X*	*X*	
Caputo (2018)	*X*	*X*	*X*	*X*	
González (2020)		*X*		*X*	*X*

Annex B: Unit-Root Tests

	adf orden	pp orden
PANEL A: Non-stationary variables		
RERI CPI NT	I(1)***	I(1)***
Public consumption	I(1)***	I(1)***
Public comsumption % Total Consumption	I(1)**	I(1)***
CNG Spending	I(1)***	I(1)***
CNG Outstanding Debt	I(1)***	I(1)**
NFPS Spending	I(1)***	I(1)***
Public consumption % GDP	I(1)***	I(1)***
NFPS Spending % GDP	I(1)*	I(1)^{***a}
Relative Labour Productivity USA/COL	I(1)***	I(1)***
T/NT relative GDP US/COL	I(1)***	I(1)***
Trade partners/COL index ratio	I(1)***	I(1)***
Per capita trade partners/COL index ratio	I(1)***	I(1)***
Per capita relative index USA/COL	I(1)***	I(1)***
GDP PPP Per capita ratio USA/COL	I(1)***	I(1)***
Relative labour productivity USA/COL	I(1)***	I(1)***
T/NT relative GDP US/COL	I(1)***	I(1)***
Public external debt outstanding	I(1)***	I(1)***
Total external debt	I(1)***	I(1)***
NFA prime REAL GDP	I(1)^{***a}	I(1)***
NFA GDP	I(1)***	I(1)***
Real NFA	I(1)***	I(1)***
NFA prime GDP	I(1)***	I(1)***
Private external debt	I(1)^{**a}	I(1)***
NFA prime real	I(1)^{**a}	I(1)***
Terms of Trade CE	I(1)***	I(1)***
Terms of Trade PPI	I(1)***	I(1)***
Mining Terms of Trade	I(1)***	I(1)***
Implicit Real Oil Price	I(1)***	I(1)***
Real Brent price	I(1)***	I(1)***
National accounts Terms of Trade	I(1)***	I(1)***
PANEL B: Non-stationary Variables		
Dif Assets-Prime	I(0)***	I(0)***
Diff FTD 90 days	I(0)***	I(0)***
Diff FTD360-Prime	I(0)***	I(0)***
Diff FTD-Prime	I(0)***	I(0)***
Diff FTD-3mlibor	I(0)***	I(0)***

Unit root tests were performed under a type of model with constant. **a**: Unit root test under a type of model without constant nor tendency. Significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Annex C: Non-Traditional Real Exchange Rate Index Deflated by CPI

The most common application of the RER is carried out with the consumer price index (CPI). This indicator aggregates both tradable and non-tradable goods and has several advantages since it is highly available in countries and frequency (Harberger, 2004). Its formula is defined as follows.

$$RERI_1 = \prod_i \left(\frac{CPI_i \cdot NERI_i}{CPI_{Col}} \right)^{w_i}$$

where $i = 1, ..., 22$ is the number of trading partners used. $NERI_i$ corresponds to the nominal exchange rate index for each trading partner (average 2010 = 100). The weights (w_i) for calculating the multilateral rate are given by total trade with each country (exports plus imports) so that the main trading partners are given greater importance. The formula that describes the weights is the following:

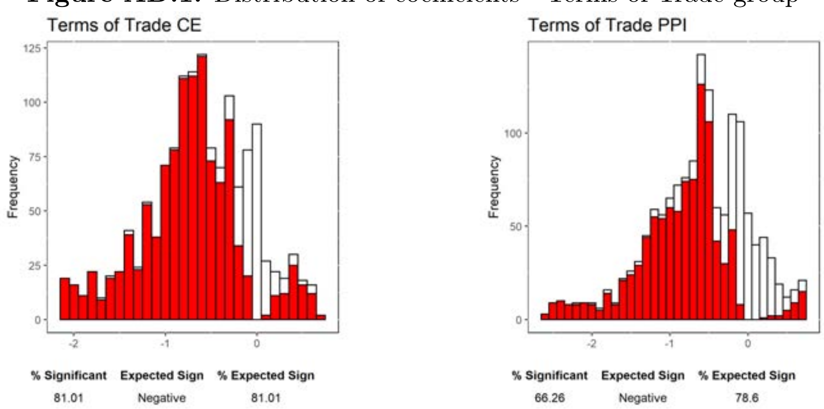
$$w_i = \frac{X^i_{Col} + M^i_{Col}}{\sum_i \left(X^i_{Col} + M^i_{Col} \right)}$$

where X^i_{Col} are Colombia's exports to country i and M^i_{Col} are Colombia's imports from country i. The dynamics of the $RERI_1$ indicator are interpreted as changes in the competitiveness of the country, so that if the $RERI_1$ appreciates, it is interpreted as a loss of competitiveness of Colombia against its competitors abroad.

Annex D: Distribution of Coefficients

Figures AD.1 through AD.4 plot the distribution of coefficients across all models where they appear. The proportion of red to white illustrates the share of estimations in which the coefficient is statistically significant at the 10% level ("% Significant"). "% Expected Sign" corresponds to the proportion of models that meet the expected sign over the total number of models. White bars correspond to non-significant coefficients and red bars to significant coefficients.

Figure AD.1: Distribution of coefficients - Terms-of-Trade group



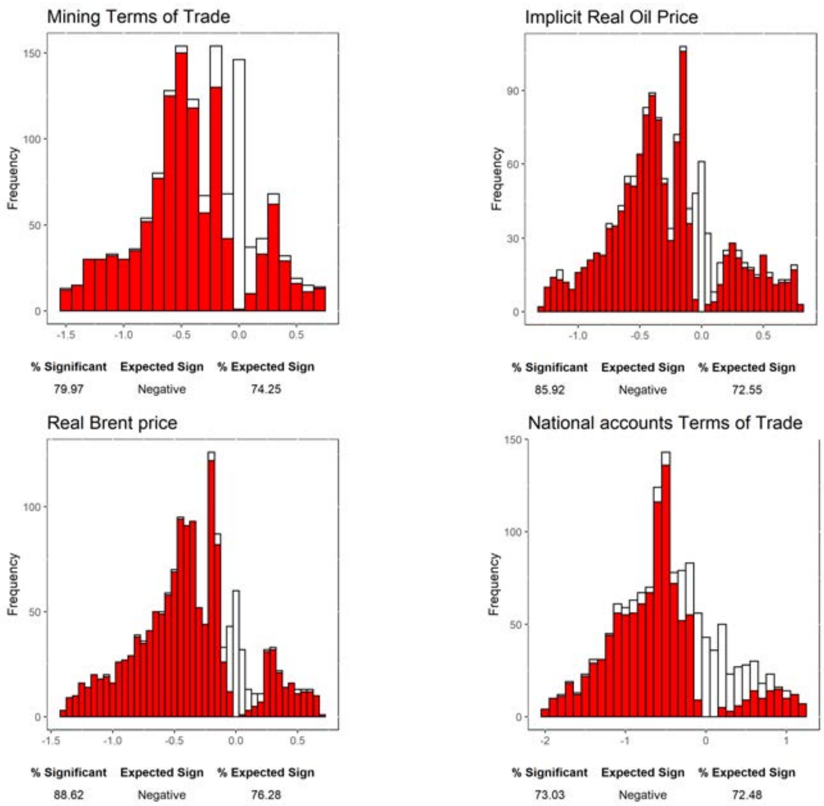
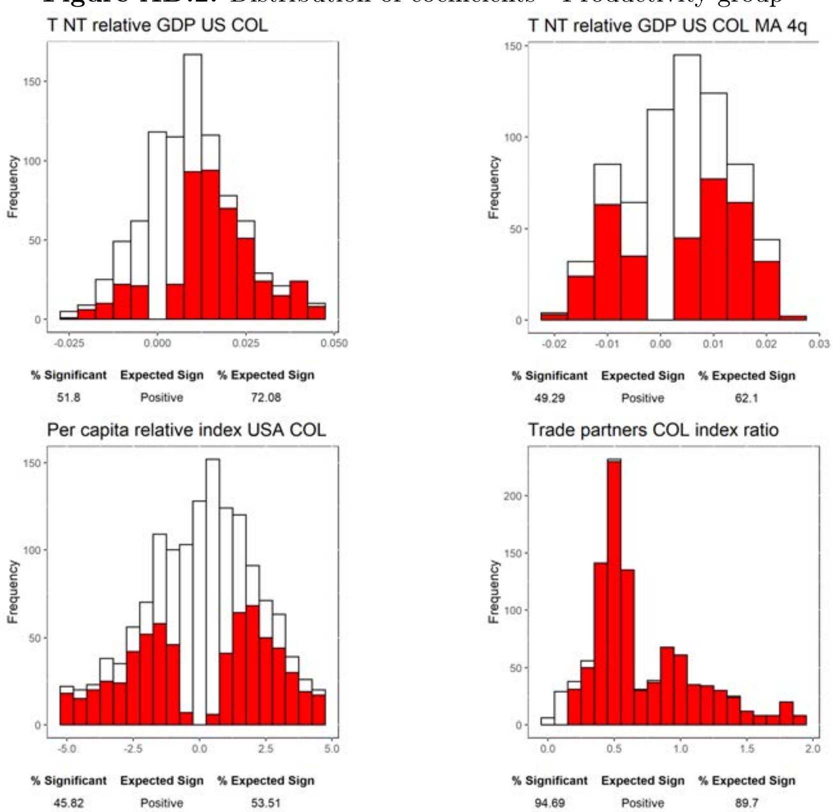


Figure AD.2: Distribution of coefficients - Productivity group



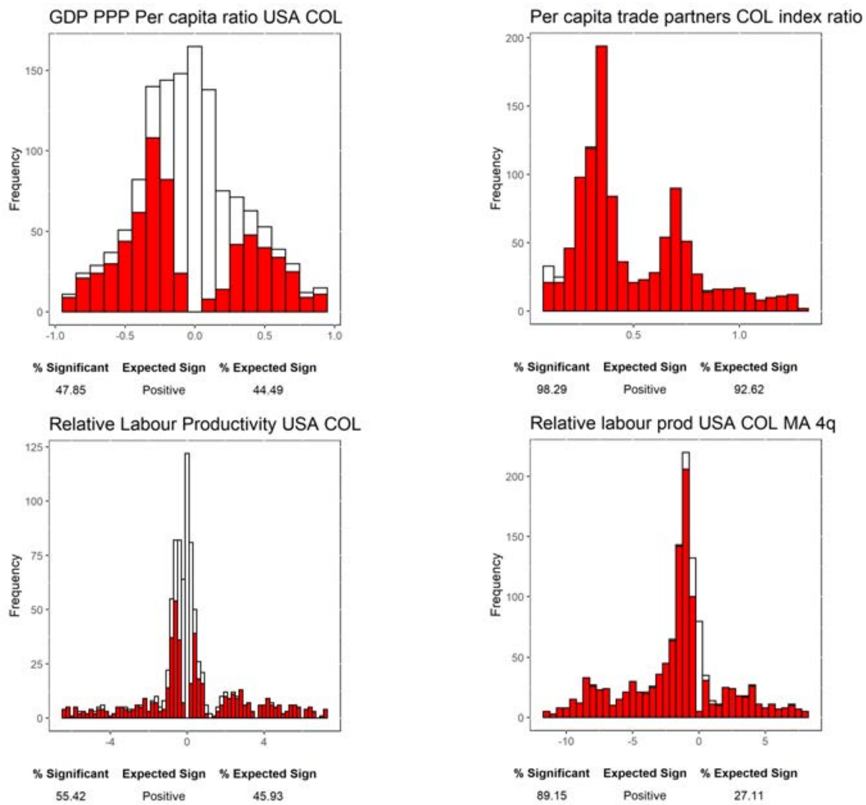
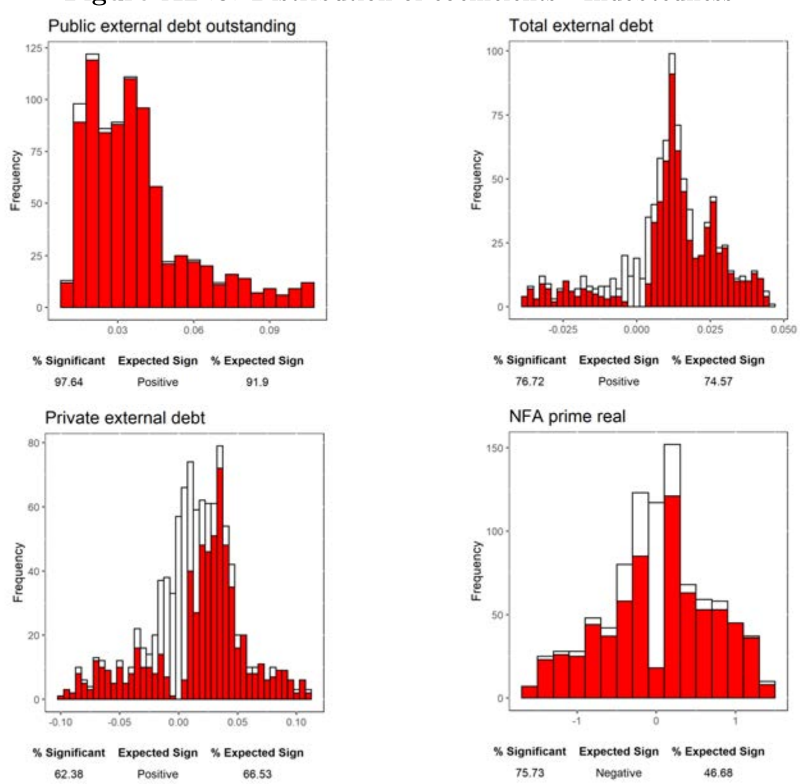


Figure AD.3: Distribution of coefficients - Indebtedness



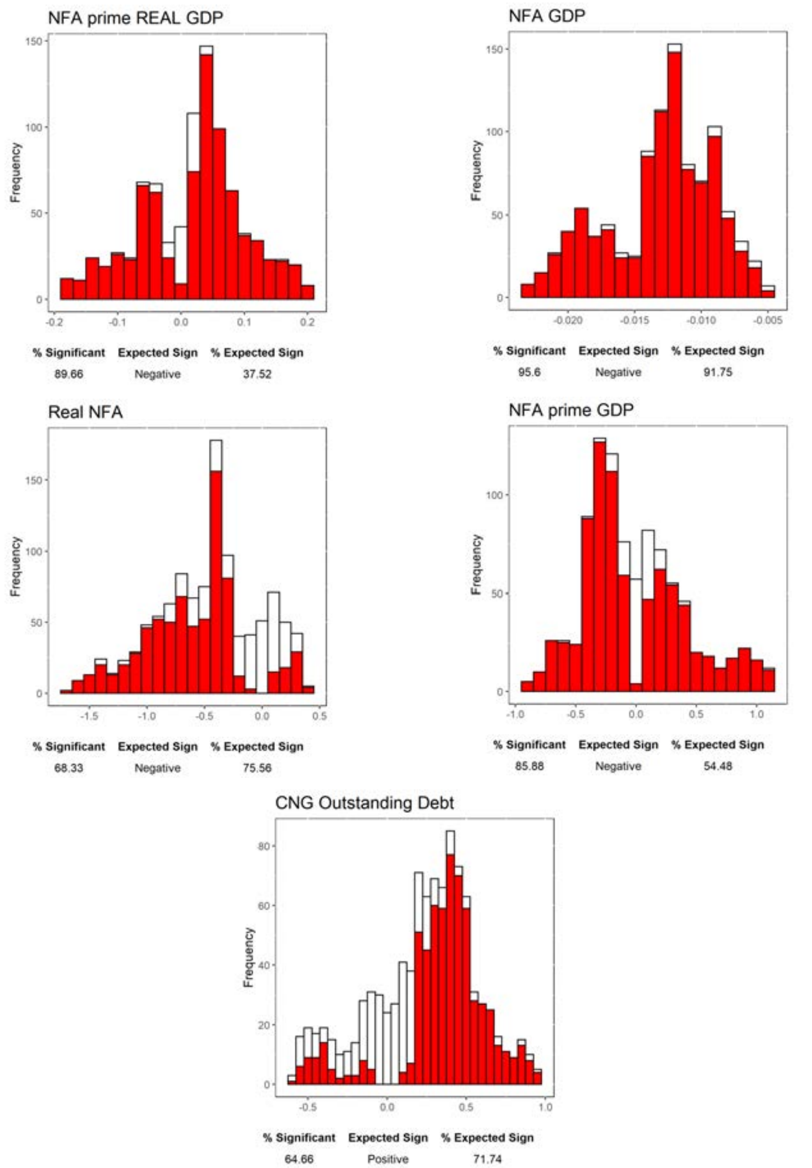
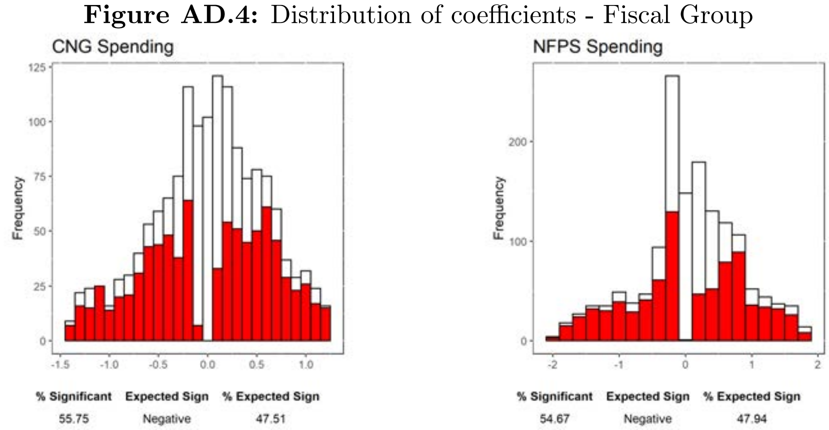
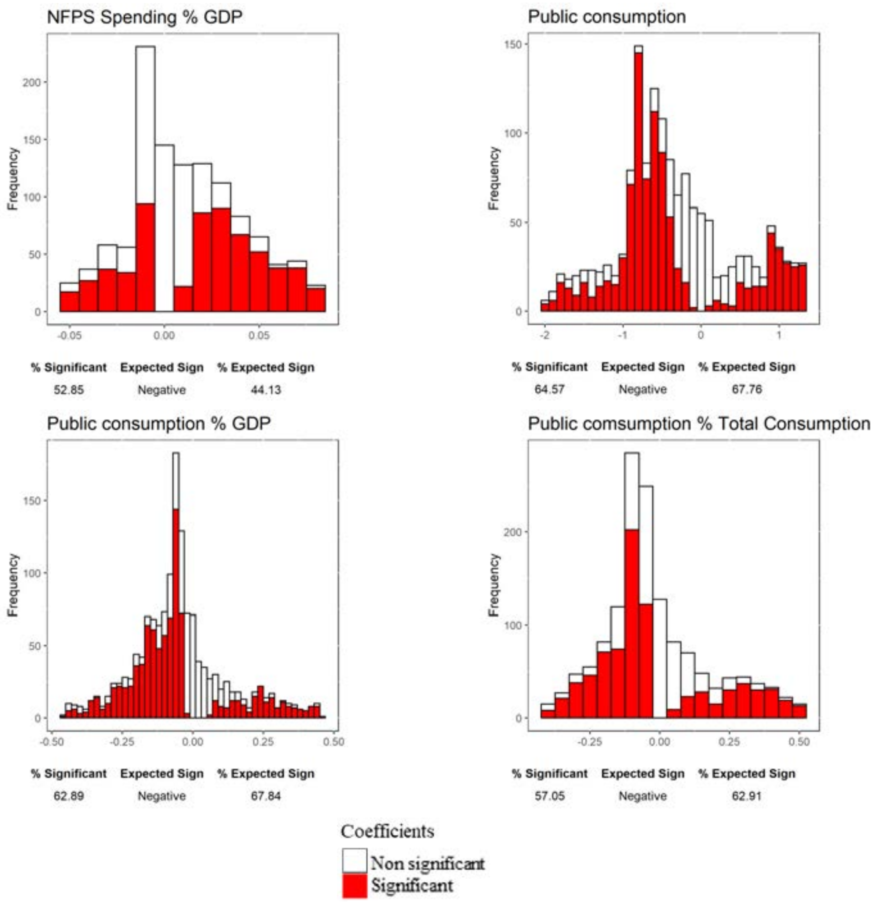


Figure AD.4: Distribution of coefficients - Fiscal Group




NFPS Spending % GDP
Frequency
% Significant
Expected Sign
% Expected Sign
52.85
Negative
44.13
Public consumption
Frequency
% Significant
Expected Sign
% Expected Sign
64.57
Negative
67.76
Public consumption % GDP
Frequency
% Significant
Expected Sign
% Expected Sign
62.89
Negative
67.84
Public comsumption % Total Consumption
Frequency
% Significant
Expected Sign
% Expected Sign
57.05
Negative
62.91
Coefficients
Non significant
Significant

Annex E: Description variables

Variable name	Description	Source
RERI CPI NT	Real exchange rate index (Details in Annex C)	Banrep
Diff Assets Prime	Difference between Colombian real interest rate and Fed's real prime interest rate.	Banrep-FRED Economic Data
Diff FTD 90 days	Difference of 90-day real fixed-term certificate of deposit (CD) rates betweeen Colombia and the US	Banrep-FRED Economic Data
Relative Labour Productivity USA COL	Relative labour productivity USA/COL (industry sector/manufacturing sector)	DANE-FRED Economic Data
Terms of Trade CE [a]	Terms of Trade index (2010=100) according to trade methodology	Banrep
Terms of Trade PPI [b]	Terms-of-Trade according to the producer price index (PPI) methodology index (2010=100)	Banrep
Mining Terms of Trade	Mining sector Terms-of-Trade index (2010=100)	Banrep
Public consumption	Public consumption (moving average four quarters)	DANE
Public comsumption % Total Consumption	Public consumption as percentage of total consumption (moving average four quarters)	DANE
CNG Spending	Central National Government (CNG) Spending (moving average four quarters)	MinHacienda.
CNG Outstanding Debt	CNG Outstanding Debt (moving aveage four quarters)	MinHacienda.
NFPS Spending	Non-Financial Public Sector (NFPS) spending (moving average four quarters)	MinHacienda.
TNT relative GDP US COL	Tradables/Non-tradables relative GDP of US vs. COL, Tradables/Non-tradables relative GDP of US vs. COL	DANE-BEA
Diff FTD360 Prime	Difference of 360- day real fixed term certificate of deposit (CD) rates between Colombia and the US (Diff FTD360-Prime)	Banrep-FRED Economic Data
Diff FTD Prime	Difference between real Fixed-term Deposit (FTD) interest rate and the real prime interest rate (Diff FTD-Prime)	Banrep-FRED Economic Data
Diff FTD 3mlibor	Difference between real Fixed-term Deposit (FTD) interest rate and the 3-month real libor interest rate (Diff FTD-3mlibor)	Banrep-FRED Economic Data
Public external debt outstanding	Public external debt outstanding as percentage of nominal GDP in USD (moving sum four quarters)	Banrep
Total external debt	Total external debt outstanding as percentage of nominal GDP in USD (moving sum four quarters)	Banrep
Trade partners COL index ratio	Trade partners/COL index ratio (Ratio between the quarterly GDP PPP index of the trading partners, weighted by trade, and the PPP GDP index of COL)	DANE-IMF
Per capita trade partners COL index ratio	Per capita trade partners/COL index ratio (Ratio between the quarterly GDP per capita in PPP of the trading partners, weighted by trade, and the index of the GDP per capita in PPP of COL)	DANE-IMF
Implicit Real Oil Price	Implicit Real Oil price (deflated by US CPI)	FRED Economic Data
Real Brent price	Real Brent price (deflated by US CPI)	FRED Economic Data
NFA prime REAL GDP	NFA times prime interest rate as percentage of real GDP (all deflated by US CPI)	Banrep-FRED Economic Data
NFA GDP	NFA as percentage of nominal GDP in USD (moving sum four quarters)	Banrep-FRED Economic Data
Real NFA	NFA deflated by US CPI	Banrep-FRED Economic Data
NFA prime GDP	NFA times the prime interest rate divided by total GDP (sum four quarters)	Banrep-FRED Economic Data
National accounts Terms of Trade	Terms-of-Trade using implicit deflator by Colombian National Accounts	DANE
Private external debt	Private external debt outstanding as percentage of nominal GDP in USD (moving sum four quarters)	Banrep
Per capita relative index USA COL	Per capita relative index USA/COL (Ratio between the quarterly GDP per capita of the US and the index of the GDP per capita of COL)	DANE-FRED Economic Data
GP PPP Per capita ratio USA COL	GDP PPP Per capita ratio USA/COL (Ratio between the quarterly GDP per capita in PPP of the US and the index of the GDP per capita in PPP of COL)	DANE-IMF
NFA prime real	NFA times the prime interest rate deflated by US CPI	Banrep-FRED Economic Data
Public consumption % GDP	Public consumption as percentage of GDP (moving average four quarters)	DANE
NFPS Spending % GDP	Non-Financial Public Sector (NFPS) spending as percentage of total GDP (moving average four quarters)	MinHacienda.
Relative labour prod USA COL MA 4q quarters)	Relative labour productivity USA/COL (industry sector/manufacturing sector) (moving average four DANE-FRED Economic Data	
TNT relative GDP US COL MA 4q	Tradables/Non-tradables relative GDP of US vs. COL, Tradables/Non-tradables relative GDP of US vs. COL (moving average four quarters)	DANE-FRED Economic Data

[a] Source: DIAN-DANE customs statistics. For more details on the methodology see Garavito et al. (2011). "Aproximación a los índices de valor unitario y quantum del comercio exterior colombiano," Borradores de Economía, Banco de la República, 680.

[b] It is calculated as the quotient between the price index of exported goods and the price index of imported goods. These indices are obtained by adding the price indices of different economic activities, according to ISIC Rev.4 at two digits, weighted by foreign trade figures. For more details, check the calculation methodology at https://www.banrep.gov.co/sites/default/files/paginas/Nota_metodologica_terminos_intercambio_IPP.pdf. Source: Banco de la República (Central Bank of Colombia).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