CHARACTERIZING REAL EXCHANGE RATE MISALIGNMENTS IN LATIN-AMERICA: The case of Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Mexico, Peru, Uruguay and Venezuela.

Zarzosa Valdivia, Fernando
zarzosa.fernando@gmail.com
National University of Córdoba

Catalano, María Victoria
mvictoriacatalano@gmail.com
National University of Córdoba

Abstract

Based on monthly data, this research finds that the persistence of the real exchange rate misalignment varies between Latin-American countries and for different real exchange rate measures, such as the purchasing power parity real exchange rate, the quotient between the wholesale and consumer price indices and the relative tradable to non-tradable price (based on goods included in the basket of the consumer price index).

Real exchange rate misalignments are calculated as deviations from the Hodrick and Prescott long-run series and do not show unit root behaviour in any of the analysed countries. Nonetheless, regressing them against their lagged variable (by the ordinary least square method) gives statistically significant coefficients close to one; the lowest (0.66) and the largest (0.94) correspond to Peru and Argentina, respectively. These results suggest a persistence behaviour of the real exchange rate misalignment.

Instead of regressing real exchange rate misalignments against their lagged variables, we assume that the error term follows an autoregressive process of order p, $AR(p)$. We find evidence that the purchasing power parity real exchange rate misalignments exhibits an AR process of order a) two in Argentina, Colombia, Ecuador, El Salvador and Peru, b) four for Chile, Costa Rica, Uruguay and Venezuela, c) five in Mexico and d) seven in Brazil, with a zero coefficient for the fifth autoregressive coefficient. Misalignments based on the quotient between the wholesale and consumer price index suggest an AR process of order a) five in Argentina, of order b) three in Brazil and c) two elsewhere. Misalignments based on the relative tradable to non-tradable price imply an AR process of order two for all countries.

Our results show additionally that in most of the cases, the $AR(1)$ and $AR(2)$ coefficients are positive and negative, respectively, which could reflect the overshooting behaviour in the adjustment process.

JEL Codes: C13, F31, F41

Keywords: Real exchange rate, Hodrick and Prescott filter, misalignment, persistence, unit root, autoregressive process of order *p*.

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A. Introduction

This research aims to determine the degree of persistence of the real exchange rate misalignments for different measures of real exchange rates and for eleven Latin-American countries; Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Mexico, Peru, Uruguay and Venezuela.

The real exchange rate is a relative price that can be measured in different manners; e.g. a) the purchasing power parity real exchange rate, b) the quotient between the wholesale and consumer price indices as a proxy of the relative tradable and non-tradable price, and c) the ratio between the tradable and non-tradable price indices.

After gathering the relevant data, its adjustment by seasonalities or the presence of outliers is considered. The seasonal adjusted data is used for the construction of the different real exchange rate measures. Real exchange rates values for the long-run are estimated by the Hodrick and Prescott filter. The difference between the observed and the long-run real exchange rate refers to the so-called real exchange rate misalignment. Following Rusek (2012, p. 534), the real exchange rate misalignments are perceived to be the causes of the loss of a competitiveness, growth slowdowns and currency crises (in cases of overvaluation), overheating and inflation in cases of undervaluation, sectoral misallocations of resources and global economic imbalances.

The persistence of the real exchange rate misalignment for each country is considered by assuming that they follow an autoregressive process of order *p*. regressed against their lagged variables. The influence of the devaluation (or depreciation) rate and the inflation rate on the real exchange rate misalignments is also analysed. Policy recommendations regarding competitiveness of an economy can focus on reducing or eliminating real exchange rate misalignments, especially those associated with large overvaluation processes.

The next section presents the real exchange rate concepts and proxy measures, the data sources, the estimation methodology and results. Thereafter some conclusion as well as the policy recommendations are drawn.

B. Theoretical Framework and Estimations

1. Real exchange rate concepts and measures

The purchasing power parity (PPP) real exchange rate is a relative price that measures the value of domestic goods in terms of foreign goods, and it is calculated as the quotient between two price indexes, the foreign and domestic goods, adjusted by the nominal real exchange rate; see equation (1). The multilateral or effective real exchange rate is a PPP real exchange rate that resumes all foreign price indexes in an aggregate price index weighted by the trade shares of the country analysed with its main trade partners, see equation (2).

$$RER_{PPP} = \frac{EP^*}{P} \tag{1}$$

$$RER_{PPP} = \frac{\prod_{i=1}^{n} \left(E_i P_i^* \right)^{w_i}}{P} \tag{2}$$

where *E* is the nominal exchange rate, *P* and *P** are the domestic and foreign price indexes, which could be consumer or wholesale price indexes. P_i^* refers to the price index of the foreign country *i*.

The PPP real exchange rate is also known as the external real exchange rate; external because it compares the relative price of a basket of goods produced (or consumed) in different countries (Hinke & Nsengiyumva, 1999). If the domestic price level rises faster than the foreign price level, then for a given level of *E*, the real price of the domestic currency will be falling (real appreciation) and the foreign price competitiveness improving against the home country (Pentecost, 1993, p. 5). Note also that the PPP real exchange rate is constant when the law of one price holds.

Even when countries engage in trade, not all goods and services are necessarily traded internationally. Indeed, some products or services are non-tradable.[1] The price ratio between tradable and non-tradable goods is known as the structural real exchange rate (StRER); and is defined as follows:

$$StRER = P_T / P_N \tag{3}$$

where P_T and P_N are the domestic prices of tradable and non-tradable goods, respectively

The relevant real exchange rate measure for developing countries is the structural real exchange rate, also known as the internal real exchange rate. It is so because it divides the economy in its two broad sectors: tradable and non-tradable sectors. It is, then, "appropriate for assessing the real exchange rate within countries" (Driver & Westaway, 2004, p. 17).

In line with Faruque (1995), Hinkle and Montiel (1999) and Harberger (2004), consumer and wholesale price indices are assumed to be the geometric average of the price of tradable and non-tradable goods with the tradable weight of the wholesale price index (*l*) larger than the tradable weight of the consumer price index (γ). Formally:

$$CPI = P_T^{\gamma} P_N^{1-\gamma} \tag{4}$$

$$WPI = P_T^{\ell} P_N^{1-\ell} \tag{5}$$

where CPI and WPI are the consumer and wholesale price indexes, and *l* > γ

In this paper, two alternative measures for the structural real exchange rate are considered: a) the quotient between the wholesale and domestic price indices and b) the ratio between the tradable and the non-tradable price indexes of the consumer price index basket. Formally:

$$SRER = \frac{WPI}{CPI} \tag{6}$$

$$SRER_1 = \frac{TPI}{NPI} \tag{7}$$

where, while *TPI* and *NPI* are the price indexes of trabable and non-tradable goods of the consumer price index basket.

Following Bastourre, Carrera and Ibarlucia (2008b), the wholesale to consumer price index ratio serves as a practical proxy of the relative price structure of an economy. Equation (8) shows that this ratio does not measure the structural real exchange rate, but is positively related to it.

[1] Following Sachs and Larrain Larrain (1993, p. 659), two main factors determine tradability or non-tradability. The first one refers to the transport costs, which create natural barriers to trade. The lower transport cost as a proportion of the total cost of a good, the more likely it is that the good will be internationally traded. Goods with very high value per unit weight, such as gold, tend to be highly tradable. Technological progress in communication has recently allowed for the international trade of several kinds of financial services. The second factor is related to the extent of trade protectionism. Tariffs and trade quotas can limit the free flow of goods across borders, even when transport costs are low. The higher these artificial barriers to trade, the less likely it is that a good will be traded. The category of what is tradable and what is non-tradable is not immutable; technological improvements can offset the limitations imposed by artificial barriers.

$$\frac{WPI}{CPI} = \left(SRER\right)^{(\ell-\gamma)} \quad \Rightarrow \quad \frac{\partial(WPI/CPI)}{\partial SRER} > 0 \tag{8}$$

Faruque (1995, p. 90) states a similar relationship to equation (8). MacDonald and Stein (1999, p. 10) suggest that the wholesale to consumer price index ratio is not a direct measure of the relative tradable to non-tradable price, although its use may be justified by arguing it captures both demand and supply side influences.

The ratio between the tradable and the non-tradable price indexes of the consumer price index basket is useful as a direct measure of the structural real exchange rate, but its shortcoming lies in including only goods of the consumer price index.

The structural and the PPP real exchange rates are different measures of competitiveness which are, however, related. Thus, in a two-country setting with the same preferences and technologies, the consumer price index PPP real exchange rate can be re-expressed as follows:

$$RER_{PPP} = S\frac{CPI^*}{CPI} = \left(\frac{SP_T^*}{P_T}\right).\left(\frac{SRER}{SRER^*}\right)^{(1\text{-}\gamma)} = \frac{1}{v}\left(\frac{SRER}{SRER^*}\right)^{(1\text{-}\gamma)} \tag{9}$$

where a star denotes the foreign variable.

Edwards (1988) and Monacelli and Perotti (2010) present a similar decomposition of equation (9), which implies that PPP real exchange rate depends on the tradable goods real exchange rate and the cross-country ratio of the relative price of traded (to non-traded) goods. The structural and the PPP real exchange rate move in line when the law of one price holds and the foreign structural real exchange rate is constant. Next the real exchange rate behaviour of various Latin-American countries will be evaluated.

2. Data sources and stylized facts

Monthly data regarding price indices as well as the effective real exchange rate are obtained from ECLAC data base for the period 1990 - 2015. Argentinean multilateral real exchange rate is provided by the Argentinean Central Bank (BCRA); these series have been corrected by the BCRA in order to reduce the effects of unreliable data since 2007.

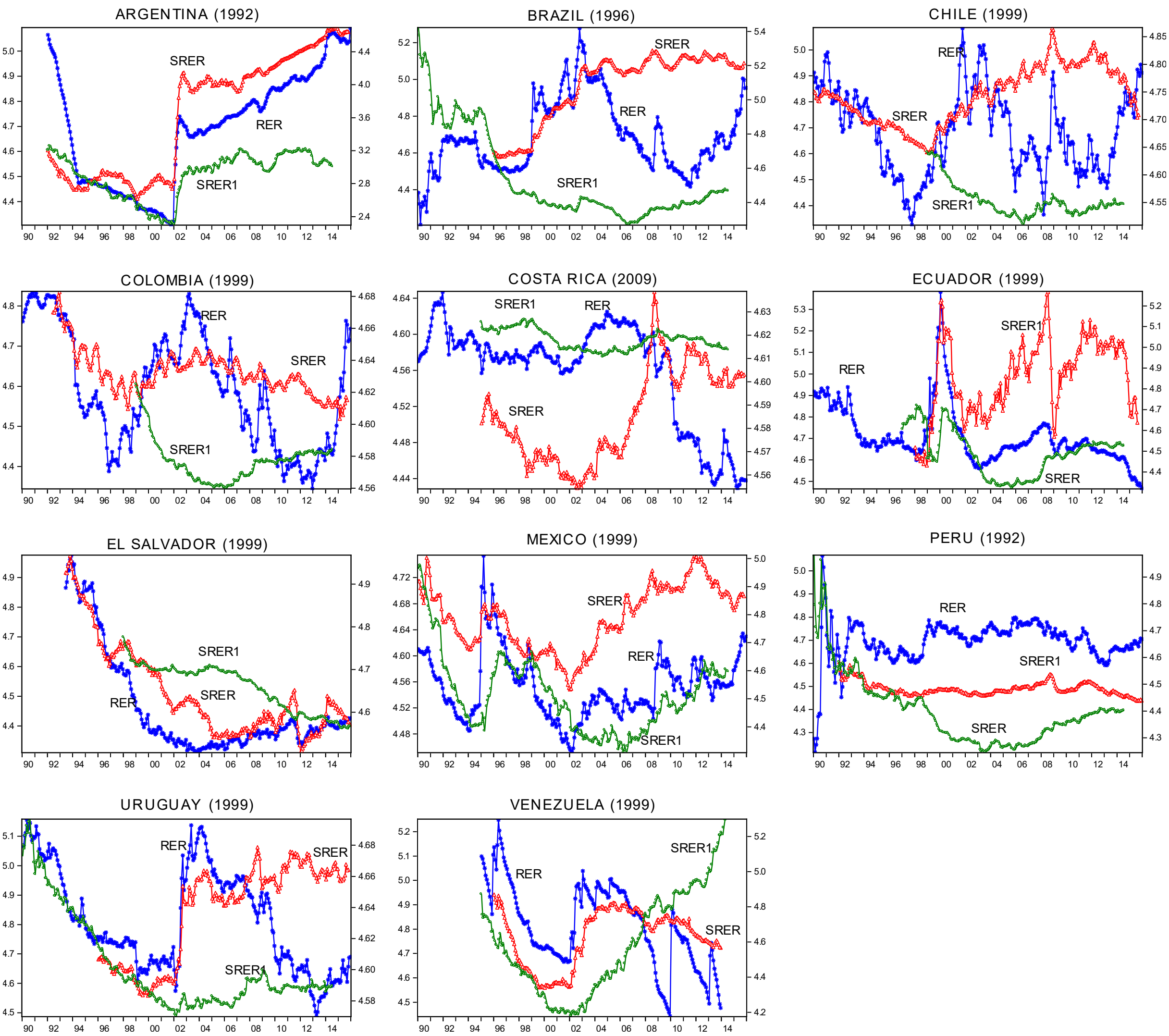
Price indexes are adjusted by the ARIMA XI seasonality adjustment method. Where seasonality was found, price indexes were adjusted. Thereafter the different real exchange rate measures were calculated. Tabla 1 provides information regarding the period for which different real exchange rate measures have been calculated

TABLE 1: Period of analysis for different countries

RER	Argentina (1991M1-2015M10), Venezuela (1990M1- 2013M12) and the rest of countries (1990M1-2015M12).
SRER	Argentina and Mexico (1990M1-2015M10), Brazil and Uruguay (1996M1-2015M10), Colombia (1992M6-2015M9), Chile (1990M1-2015M9), Costa Rica (1995M1-2015M10), Ecuador (1998M1-2015M8), El Salvador (1990M1-2014M10), Peru (1992M1-2015M12) and Venezuela (1996M1 -2013M12)
SRER1	Argentina, Brazil, Mexico, Peru and Uruguay (1990M1-2014M7), Colombia and Chile (1999M1-2014M7), Costa Rica and El Salvador (1995M01-2014M7), Ecuador (1997M1- 2014M7) and Venezuela (1995M1-2014M5)
where Mi (i=1,12) refers to the month of the respective year	

Figure 1 displays the evolution of the logarithm of the different real exchange rate measures; the left axis refers to both structural real exchange rate measures while the right axis refers to the PPP real exchange rate. Although they all indicate certain degree of competitiveness, they do not exhibit similar behaviour.

Figure 1: Real exchange rates measures (base year for each country in brackets)



3. Methodology

The smoothing method proposed by Hodrick and Prescott, a widely method used among macroeconomists, is applied to estimate long-run trends for the logarithm of the different measures of real exchange rates; the selected penalty parameter λ is 14400. Misalignments are formally defined as follows:

$$y_{mis_t} = \left(\frac{y_t - y_{HP_t}}{y_{HP_t}} \right) * 100 \qquad (10)$$

where y is a variable that can be *RER*, *SRER* or *SRER1*. y_{mis} refers to the misalignment of the y variable. y_{HP} reflects the Hodrick and Prescott long-run value of the variable *y*.

Real exchange rate misalignments measure relative deviations of the observed real exchange rate from its long-run value; positive and negative values represent periods of real depreciations and appreciations, respectively.

Due to the definition and measurement of the misalignments, they are stationary and their mean is zero. Table 2 presents the observed Dickey-Fuller statistic corresponding to the unit root test on the real exchange rate misalignments based on the Hodrick and Prescott filter.

Table 2: Real exchange rate Misalignments' Unit Root Tests (Ho: There is a unit root)

Country	Augmented Dickey-Fuller statistic: Observed Values		
	RER	SRER	SRER1
Argentina	-5.81***	-5.376***	-5.828***
Brazil	-7.116***	-5.162***	-5.397***
Colombia	-6.057***	-5.656***	-3.715***
Chile	-7.389***	-7.146***	-4.221***
Costa Rica	-6.954***	4.31***	-5.099***
Ecuador	-4.624***	-4.29***	-5.577***
El Salvador	-8.976***	-4.172***	5.495***
Mexico	-5.815***	-6.537***	-5.662***
Peru	-9.431***	-6.643***	-7.056***
Uruguay	-6.261***	-3.547***	-7.216***
Venezuela	-6.049***	-4.466***	-5.539***

*** indicates that the null hypothesis of the existence one-unit root is rejected at the 1% level

Persistence of the real exchange rate misalignments

The stationarity behaviour only tells us that real exchange rate misalignments do no exhibit a random walk pattern, but their evolution in a period might be influenced by their change in previous periods. Based on the ordinary least squares, Table 3 provides estimations of the real exchange rate misalignments against their lagged variable. Although, the null hypothesis of coefficients equal to one are rejected in all cases, the corresponding estimates are statistically significant and quite high; in the PPP real exchange rate misalignment case the lowest 0.8 and the highest 0.94 estimates correspond to El Salvador and Argentina, respectively; in the wholesale to consumer price ratio the lowest 0.85 and the highest 0.94 correspond to Colombia and Brazil, respectively; in the case of the ratio between the non-tradable to tradable price, the lowest 0.667 and the highest 0.913 correspond to Peru and Colombia, respectively.

The Lagrange multiplier (LM) tests is applied to test for higher order *AR* errors. The autoregressive model is estimated as follows: if the null hypothesis of no serial correlation up to lag order p of the LM test is not rejected, an additional order is added to the real exchange rate misalignment regression until the null of the consequent LM test is not rejected.

Because real exchang rate misalignments are also affected by the devaluation (or depreciation) and inflation rate, these variables are also introduced as explanatory variables of the real exchange rate misalignments. Variables that are not significant at the 10% confidence level are, in general, dropped.

Table 3: Real exchange rate misalignments regressed against their lagged variable

Country	Variable	RER_{t-1}	R^2	Variable	$SRER_{t-1}$	R^2	Variable	$SRER1_{t-1}$	R^2
Argentina	**RER**	0.942 0.018 ***	0.902	**SRER**	0.9 0.02 ***	0.82	**SRER1**	0.841 0.026 ***	0.777
Brazil	**RER**	0.85 0.03 ***	0.724	**SRER**	0.94*** 0.02	0.89	**SRER1**	0.883 0.025 ***	0.813
Colombia	**RER**	0.877 0.027 ***	0.77	**SRER**	0.85 0.03 ***	0.72	**SRER1**	0.913 0.028 ***	0.852
Chile	**RER**	0.844 0.03 ***	0.712	**SRER**	0.86 0.03 ***	0.73	**SRER1**	0.885 0.034 ***	0.786
Costa Rica	**RER**	0.874 0.028 ***	0.765	**SRER**	0.9 0.03 ***	0.82	**SRER1**	0.824 0.036 ***	0.696
Ecuador	**RER**	0.893 0.026 ***	0.797	**SRER**	0.88 0.03 ***	0.78	**SRER1**	0.902 0.029 ***	0.82
El Salvador	**RER**	0.8 0.03 ***	0.703	**SRER**	0.89 0.03 ***	0.8	**SRER1**	0.815 0.036 ***	0.683
Mexico	**RER**	0.872 0.028 ***	0.759	**SRER**	0.89 0.03 ***	0.8	**SRER1**	0.882 0.028 ***	0.777
Peru	**RER**	0.82 0.031 ***	0.693	**SRER**	0.87 0.03 ***	0.78	**SRER1**	0.667 0.04 ***	0.489
Uruguay	**RER**	0.856 0.029 ***	0.735	**SRER**	0.9 0.03 ***	0.81	**SRER1**	0.728 0.038 ***	0.56
Venezuela	**RER**	0.845 0.032 ***	0.71	**SRER**	0.86 0.03 ***	0.75	**SRER1**	0.789 0.039 ***	0.638

RER_{t-1}, *$SRER_{t-1}$* and *$SRER1_{t-1}$*, refers to the corresponding real exchange variable lagged one period. In each cell, the first row refers to the estimated parameter, while values in the second row to its standard errors. (*), (**) and (***) indicate statistical significances at the 10%, 5% and 1% levels, respectively. R^2 refers to the R-square statistic.

To estimate an autoregressive model of order *p* by the E-views software, the following linear model is transformed:

$$y_{mis_t} = x_t^{'}\beta + u_t \tag{11}$$

$$u_t = \sum_{i=1}^{p} \rho_i u_{t-i} + \varepsilon_t \tag{12}$$

into the non-linear model:

$$y_{mis_t} = \sum_{i=1}^{p} \rho_i y_{t-i} + \left(x_t - \sum_{i=1}^{p} \rho_i x_{t-i} \right)' \beta + \varepsilon_t \tag{13}$$

where y_{mis} refers to the misalignment of the *RER*, *SRER* or *SRER1*. x_t refers to variables such as the devaluation (or depreciation) and the inflation rate, u_t is the unconditional errors and ε_t is the one-period ahead forecast errors

The unconditional errors are estimated using the original variables and the estimated β parameters. The one-period ahead forecast errors represent the forecast errors computed using a prediction of the residuals based upon past values of the data, in addition to the contemporaneous information. The coefficients ρ and β are estimated simultaneously by applying a Marquardt nonlinear least square algorithm to the transformed equation.

Following Greene (559, p), lagged variables are theoretically justified when it is expected that there will be long lags between policy changes and their impacts. Real exchange rate misalignments are deviations from long run trends and therefore are not expected to hold in the long-run. Instead of regressing real exchange rate misalignments against their lagged variables, we assume that the error term follows an autoregressive process of order *p*, *AR*(*p*).

Table 4, 5 and 6 show the estimated results. They suggest that the purchasing power parity real exchange rate misalignments exhibits an *AR* process of order a) two in Argentina, Colombia, Ecuador, El Salvador and Peru, b) four for Chile, Costa Rica, Uruguay and Venezuela, c) five in Mexico and d) seven in Brazil, with a zero coefficient for the fifth autoregressive coefficient. Misalignments based on the quotient between the wholesale and consumer price index suggest an *AR* process of order a) five in Argentina, of order b) three in Brazil and c) two elsewhere. Misalignments based on the relative tradable to non-tradable price imply an *AR* process of order two for all countries.

As expected, changes in the nominal exchange rate affect negatively the PPP real exchange rate misalignments in all countries under analysis. Thus, if there is a period of real overvaluation (observed real exchange rates lower than their long-run values), a devaluation (or depreciation) can faster the adjustment process to the PPP real exchange rate equilibrium path. We also find that nominal exchange rates of Argentina, Colombia, Chile, Mexico, Peru and Uruguay reduce the SRER (wholesale to consumer price) real exchange rate misalignments. Devaluation or depreciations do not impact on the real exchange rate based on non-tradable and tradable price indexes; long-run improvements in competitiveness cannot occur by simply adjusting the nominal exchange rate.

Increments of the inflation rate, measured by the consumer price index change ratio, increases the PPP real exchange rate misalignments in Argentina, Brazil, Chile, Costa Rica, Peru and Uruguay as well as the SRER real exchange rate of Colombia, Costa Rica, El Salvador, Peru and Uruguay.

TABLE 4: Autoregressive estimations of the PPP real exchange rate misalignments

	Δ(E)	Δ(CPI)	μ_1	μ_2	μ_3	μ_4	μ_5	μ_6	μ_7	i	ii	Statistics	
	-14.543	7.378	1.674	-0.732						-5.107	-4.259	**R2**	0.973
ARGENTINA	1.424	3.186	0.036	0.035						0.564	0.502	**R2-adj**	0.973
	***	**	***	***						***	***	**LM**	2.024
	-9.459	2.63	1.77	-1.363	0.706	-0.27		0.138	-0.127	-1.519	-1.361	**R2**	0.924
BRAZIL	0.398	0.609	0.061	0.12	0.122	0.075		0.052	0.04	0.28	0.279	**R2-adj**	0.922
	***	***	***	***	***	***		***	***	***	***	**LM**	0.1
	-7.656		1.351	-0.486						0.382	-0.584	**R2**	0.876
COLOMBIA	0.7		0.053	0.052						0.224	0.215	**R2-adj**	0.875
	***		***	***						*	***	**LM**	2.41
	-8.76	6.068	1.514	-0.91	0.322	-0.107						**R2**	0.867
CHILE	0.523	2.763	0.061	0.111	0.108	0.058						**R2-adj**	0.865
	***	***	***	***	***	*						**LM**	0.488
	-10.34	10.838	1.562	-1.028	0.52	-0.217						**R2**	0.885
COSTA RICA	0.799	1.146	0.059	0.108	0.107	0.057						**R2-adj**	0.884
	***	***	***	***	***	***						**LM**	0.017
	-9.873		1.342	-0.408						-0.575		**R2**	0.936
ECUADOR	0.437		0.06	0.06						0.229		**R2-adj**	0.935
	***		***	***						**		**LM**	0.156
	5.932		0.856	0.049						8.933		**R2**	0.905
EL SALVADOR	0.87		0.026	0.025						0.391		**R2-adj**	0.904
	***		***	*						***		**LM**	2.606
	-11.177		1.879	-1.578	0.944	-0.485	0.159			0.515	-0.226	**R2**	0.941
MEXICO	0.279		0.06	0.128	0.152	0.128	0.06			0.119	0.117	**R2-adj**	0.939
	***		***	***	***	***	***			***	*	**LM**	2.443
	-12.446	10.68	1.658	-1.211	0.397					-6.735	-2.634	**R2**	0.924
PERU	0.498	0.565	0.056	0.089	0.053					0.617	0.339	**R2-adj**	0.923
	***	***	***	***	***					***	***	**LM**	0.934
	-10.379	4.698	1.503	-0.961	0.456	-0.133				0.57		**R2**	0.853
URUGUAY	0.754	1.266	0.06	0.103	0.099	0.056				0.19		**R2-adj**	0.85
	***	***	***	***	***	**				***		**LM**	0.396
	-6.381		1.348	-0.719	0.334	-0.116				-4.707		**R2**	0.837
VENEZUELA	0.679		0.062	0.102	0.101	0.061				0.53		**R2-adj**	0.834
	***		***	***	***	*				***		**LM**	1.112

In each cell, the first row in each cell refers to the estimated parameter, while values in the second row to its standard errors. (*), (**) and (***) indicate statistical significances at the 10%, 5% and 1% levels, respectively. i and ii refer to the dummy variables with one in the specified period and zero elsewhere (Argentina: 2002M1&2, 2002M3&4, Brazil: 1999M2 and 1999M3, Colombia: 1994M3 and 2009M2, Ecuador: 2000M2, El Salvador: 1990M3&4, Mexico: 1995M5, 2008M10, Peru 1990M9&10, 1990M11, Uruguay 2002M8, and Venezuela: 2010M1)

TABLE 5: Autoregressive estimations of the SRER (wholesale to consumer price index) real exchange rate misalignments

	Δ(E)	Δ(CPI)	μ_1	μ_2	μ_3	μ_4	μ_5	i	ii	iii	Statistics	
ARGENTINA	-3.012	-7.458	1.424	-0.378	-0.112	0.087	-0.108	1.726	1.01		**R2**	0.955
	0.33	0.706	0.06	0.103	0.072	0.043	0.032	0.154	0.141		**R2-adj**	0.953
	***	***	***	***	-1.565	***	***	***	***		**LM**	1.075
BRAZIL	0.607		1.453	-0.404	-0.143			-0.47	-0.411		**R2**	0.94
	0.17		0.07	0.121	0.069			0.091	0.09		**R2-adj**	0.939
	***		***	***	**			***	***		**LM**	0.013
COLOMBIA	-1.192	6.279	1.192	-0.361				-0.158	0.574		**R2**	0.796
	0.252	2.459	0.058	0.058				0.086	0.08		**R2-adj**	0.793
	***	**	***	***				*	***		**LM**	0.129
CHILE	-1.676		1.204	-0.41							**R2**	0.781
	0.506		0.053	0.053							**R2-adj**	0.78
	***		***	***							**LM**	0.486
COSTA RICA		7.755	1.174	-0.272							**R2**	0.856
		1.253	0.063	0.063							**R2-adj**	0.855
		***	***	***							**LM**	0.921
ECUADOR		-14.796	1.016	-0.178				-1.478			**R2**	0.806
		4.445	0.046	0.046				0.671			**R2-adj**	0.804
		***	***	***				**			**LM**	0.328
EL SALVADOR		7.424	1.066	-0.167				-0.465	0.612	-0.912	**R2**	0.838
		1.636	0.06	0.06				0.187	0.186	0.186	**R2-adj**	0.835
		***	***	***				**	***	***	**LM**	1.778
MEXICO	-0.944	-2.332	1.338	-0.494							**R2**	0.858
	0.148	1.292	0.051	0.051							**R2-adj**	0.857
	***	*	***	***							**LM**	0.906
PERU	-1.219	3.971	1.37	-0.517				-0.162			**R2**	0.868
	0.365	0.918	0.051	0.049				0.059			**R2-adj**	0.866
	***	***	***	***				***			**LM**	0.023
URUGUAY	-1.268	7.226	1.16	-0.251				-0.409	-1.92		**R2**	0.872
	0.651	2.533	0.065	0.065				0.217	0.215		**R2-adj**	0.869
	**	***	***	***				*	***		**LM**	2.089
VENEZUELA			1.033	-0.186				-0.605			**R2**	0.77
			0.068	0.068				0.167			**R2-adj**	0.768
			***	***				***			**LM**	1.093

In each cell, the first row in each cell refers to the estimated parameter, while values in the second row to its standard errors. (*), (**) and (***) indicate statistical significances at the 10%, 5% and 1% levels, respectively. i and ii refer to the dummy variables with one in the specified period and zero elsewhere (Argentina: 2002M1&2, 2002M3&4, Brazil: 1999M2 and 1999M3, Colombia: 1994M3 and 2015M2, Ecuador: 2009M3, El Salvador: 2008M7, 2008M10 and 2011M2, Peru 1992M10, Uruguay 2002M8 and 2002M9, and Venezuela: 1996M5)

TABLE 6: Autoregressive estimations of the SRER (non-tradable to tradable price index of the consumer price basket) real exchange rate misalignments

	Δ(CPI)	μ_1	μ_2	i	ii	iii	Statistics	
ARGENTINA		1.044	-0.196	0.644	0.988	0.885	**R2**	0.789
		0.057	0.054	0.232	0.285	0.231	**R2-adj**	0.787
		***	***	***	***	***	**LM**	0.272
BRAZIL		1.152	-0.3	1.381			**R2**	0.846
		0.053	0.052	0.212			**R2-adj**	0.845
		***	***	***			**LM**	2.616
COLOMBIA	-5.675	1.118	-0.234	0.159			**R2**	0.872
	1.837	0.07	0.069	0.037			**R2-adj**	0.87
	***	***	***	***			**LM**	0.447
CHILE	13.098	1.125	-0.259				**R2**	0.824
	2.594	0.07	0.069				**R2-adj**	0.822
	***	***	***				**LM**	0.107
COSTA RICA	4.372	0.978	-0.172				**R2**	0.72
	1.432	0.061	0.06				**R2-adj**	0.718
	***	***	***				**LM**	0.094
ECUADOR		1.284	-0.387	1.859			**R2**	0.885
		0.064	0.064	0.184			**R2-adj**	0.884
		***	***	***			**LM**	0.03
EL SALVADOR	-8.848	1.164	-0.337	-0.453	-0.18		**R2**	0.792
	1.138	0.061	0.06	0.089	0.092		**R2-adj**	0.789
	***	***	***	***	*		**LM**	0.572
MEXICO		1.127	-0.286				**R2**	0.797
		0.055	0.055				**R2-adj**	0.796
		***	***				**LM**	1.596
PERU	-3.101	1.235	-0.423	-0.459			**R2**	0.84
	0.125	0.047	0.047	0.162			**R2-adj**	0.838
	***	***	***	***			**LM**	1.224
URUGUAY	6.964	0.936	-0.166				**R2**	0.601
	1.23	0.058	0.057				**R2-adj**	0.599
	***	***	***				**LM**	0.527
VENEZUELA	-6.199	1.016	-0.229	0.662			**R2**	0.718
	1.577	0.06	0.058	0.178			**R2-adj**	0.714
	***	***	***	***			**LM**	0.778

In each cell, the first row refers to the estimated parameter, while values in the second row to its standard errors. (*), (**) and (***) indicate statistical significances at the 10%, 5% and 1% levels, respectively. i and ii refer to the dummy variables with one in the specified period and zero elsewhere (Argentina: 2002M1, 2002M2, 2002M3, Brazil: 1991M3, Colombia:2000M2, Ecuador: 1999M1, El Salvador: 1996M8, 1998M11, Peru 1990M6, and Venezuela: 1996M5)

In general, the estimated of the first order autoregressive process (ρ_1) is larger than one while the second order estimate (ρ_2) is negative. The impulse response function of most of the estimations suggests overshooting effects of exogenous shocks on the real exchange rate misalignments. Figure 2, 3 and 4 depicts the trajectory of the real exchange rate misalignments after an exogenous shock has hit the economy, the one standard error deviation is also drawn.

Figure 2: Impulse Response of the PPP Real Exchange Rate Misalignments

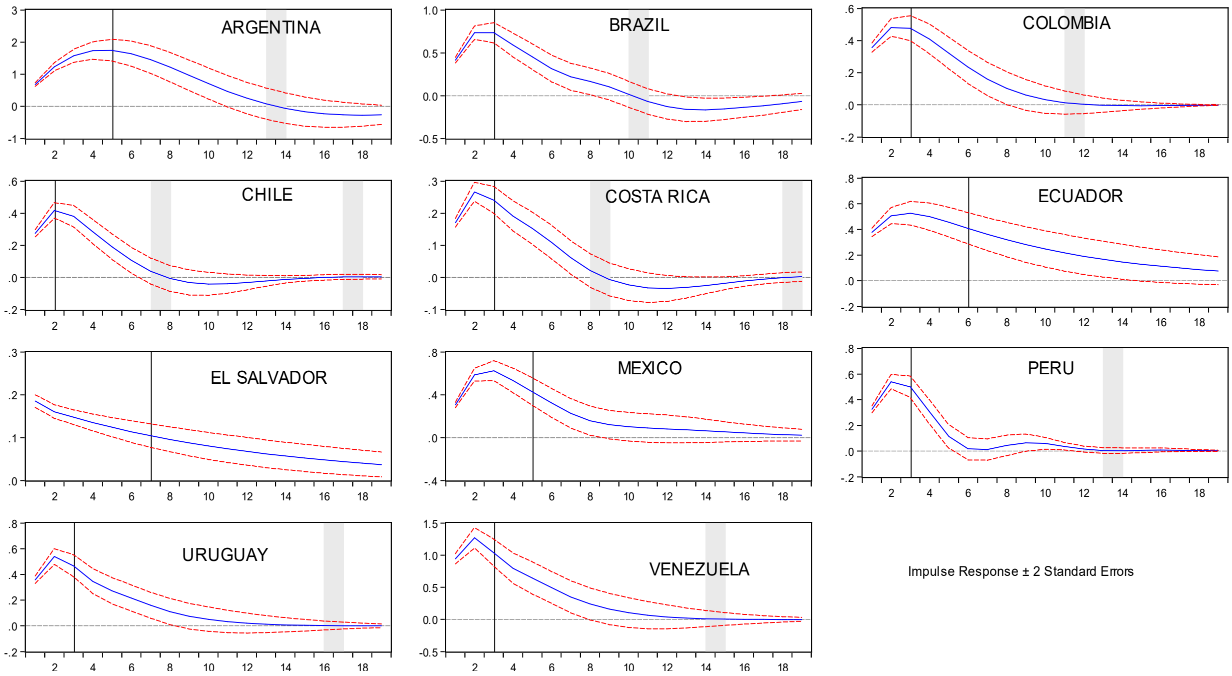


Figure 3: Impulse Response of the SRER1 (Wholesale to Consumer Price Index) Misalignments

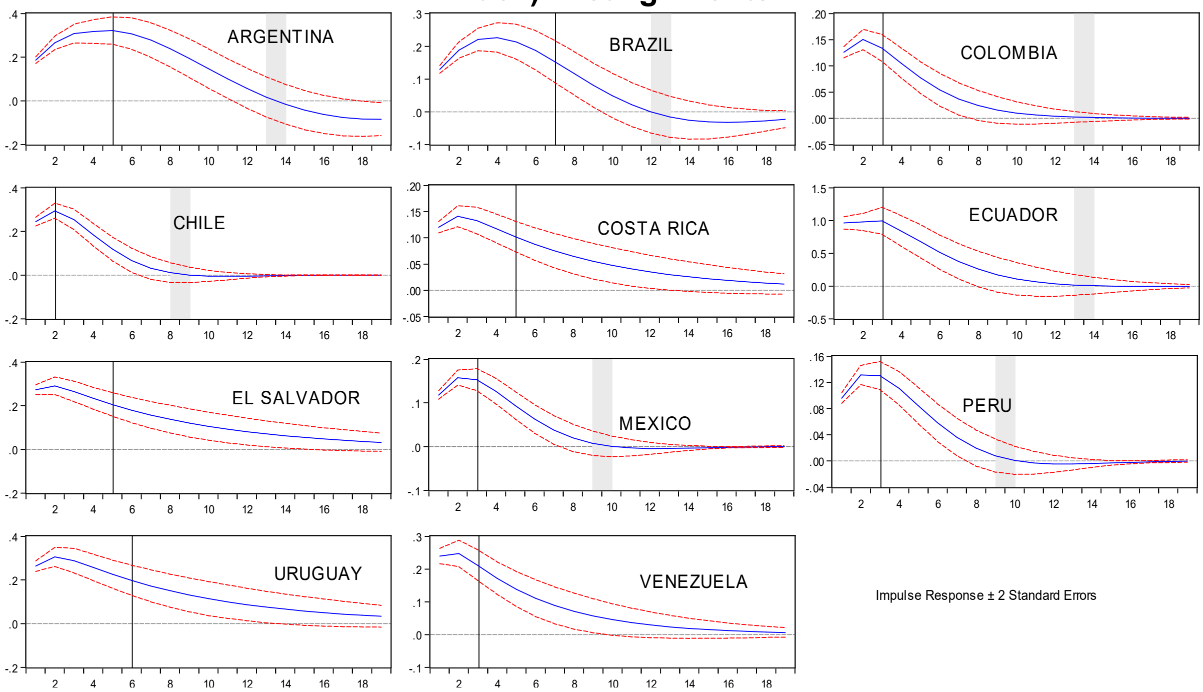
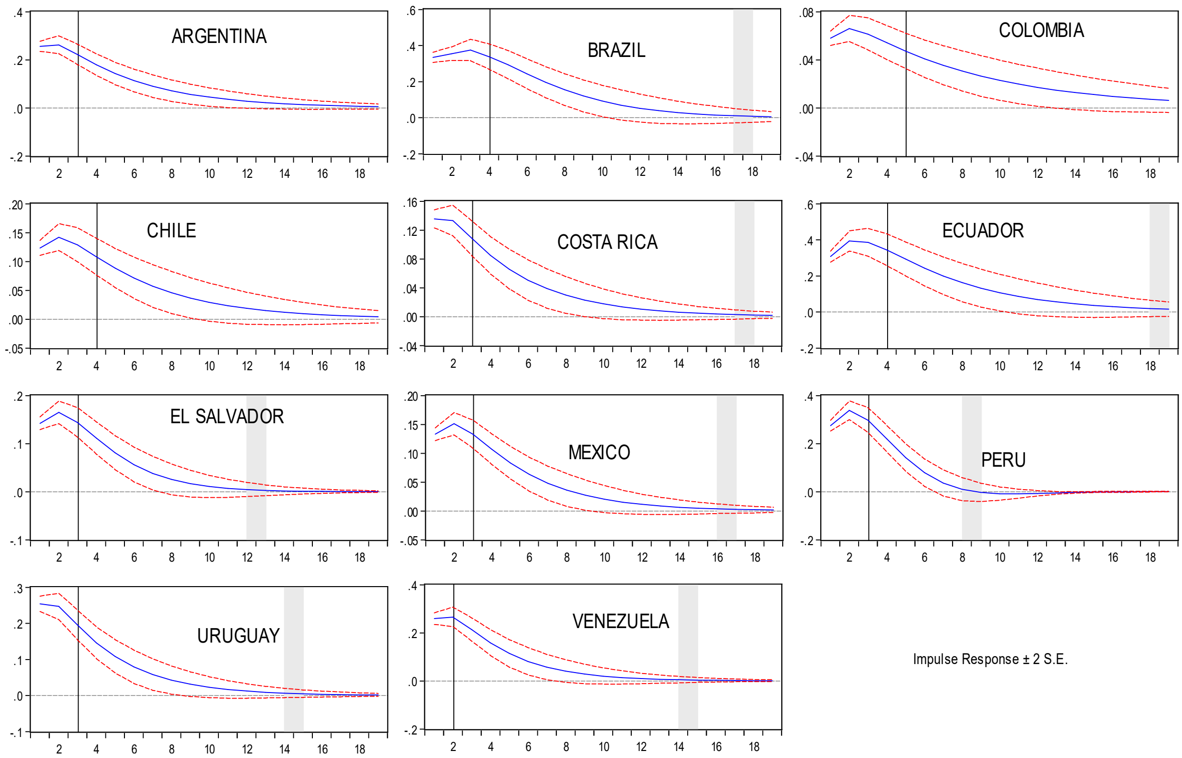


Figure 4: Impulse Response of the SRER1 (Non-tradable to Tradable Price Indexes Ratio) Misalignments



As expected, the roots associated to all estimates are inside the unit circle. Although the adjustment process of real exchange rate generated by an exogenous shock disappears, our results show a highly persistent behaviour with an overshooting behaviour; a pattern showing an up and down movement after a shock has hit the economy. In general, the adjustment process of the three real exchange rate measures is similar, but the period to reach the long-run equilibrium differs. The period in which 50% of the adjustment process (after a shock has hit the economy) occurs also differs between countries and real exchange rate measures.

For instance, after a shock has hit the economy the PPP, the *SRER* and the *SRER1* real exchange rates of Argentina reach their long-run levels after 13, 14 and 19 months, respectively. The shadow areas in each chart of Figures 2, 3 and 4 indicates approximately the period in which the misalignment of the respective real exchange rate measure disappears, while the horizontal line shows the periods in which 50% of the adjustment occurs after a shock hits the respective economy.

C. *CONCLUSIONS*

Based on monthly data, this research finds that the persistence of the real exchange rate misalignment varies between Latin-American countries and for different real exchange rate measures, such as the purchasing power parity real exchange rate, the quotient between the wholesale and consumer price indices and the relative tradable to non-tradable price (based on goods included in the basket of the consumer price index).

Real exchange rate misalignments are calculated as deviations from the Hodrick and Prescott long-run series and do not show unit root behaviour in any of the analysed countries. Nonetheless, regressing them against their lagged variable (by the ordinary least square method) gives statistically significant coefficients close to one; the lowest (0.66) and the largest (0.94) correspond to Peru and Argentina, respectively. These results suggest a persistence behaviour of the real exchange rate misalignment.

Instead of regressing real exchange rate misalignments against their lagged variables, we assume that the error term follows an autoregressive process of order p, $AR(p)$. We find evidence that the purchasing power parity real exchange rate misalignments exhibits an *AR* process of order a) two in Argentina, Colombia, Ecuador, El Salvador and Peru, b) four for Chile, Costa Rica, Uruguay and Venezuela, c) five in Mexico and d) seven in Brazil, with a zero coefficient for the fifth autoregressive coefficient. Misalignments based on the quotient between the wholesale and consumer price index suggest an AR process of order a) five in Argentina, of order b) three in Brazil and c) two elsewhere. Misalignments based on the relative tradable to non-tradable price imply an AR process of order two for all countries.

Our results also show, in most of the cases, an overshooting behaviour in the adjustment process after a shock has hit the economy. Consequently, the adjustment path is not always monotonic, but cyclical. Table 7 shows the overshooting behaviour of real exchange rate misalignments and the periods that are necessary for the real exchange rate to reach its long-run value as well as the periods in which the 50% of the adjustment after a shock has hit the economy occurs.

Table 7: Real Exchange Rate Misalignments Adjustment Process

	RER			SRER			SRER1		
Country	**Over-shooting**	**t_{Lr}**	**50%t**	**Over-shooting**	**t_{Lr}**	**50%t**	**Over-shooting**	**t_{Lr}**	**50%t**
Argentina	Yes	13	5	Yes	14	5	Yes	19	3
Brazil	Yes	10	4	Yes	11	7	Yes	18	4
Colombia	Yes	12	3	Yes	10	3	Yes	28	5
Chile	Yes	14	2	Yes	9	2	Yes	18	4
Costa Rica	Yes	18	4	Yes	19	5	Yes	19	3
Ecuador	Yes	36	6	Yes	10	3	Yes	19	4
El Salvador	No	36	7	Yes	19	5	Yes	13	3
Mexico	Yes	16	5	Yes	10	3	Yes	18	3
Peru	Yes	13	3	Yes	10	3	Yes	9	4
Uruguay	Yes	12	3	Yes	32	6	Yes	17	3
Venezuela	Yes	17	4	Yes	19	3	Yes	15	2

where: Overshooting indicates that a shock generates a pattern showing an up and down movement, t_{Lr} refers to the months in which the misalignment disappears after a shock has hit the economy (long-run), and 50% shows the periods in which the 50% of the adjustment takes place after a shock has hit the economy.

Table 7 suggests that policymakers should take into account the different adjustment processes and periods for the different real exchange rate concepts when adopting measures oriented to affect the competitiveness of an economy.

Further extensions of this paper could focus on the fundamentals that determine the behaviour of the long-run real exchange rates instead of calculating them by the Hodrick and Prescott filter.

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