A Panel Data Investigation of Real Exchange Rate Misalignment and Growth

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Abstract

The paper investigates the role of real exchange rate misalignment on long-run growth for a set of ninety countries using time series data from 1980 to 2004. We first estimate a panel data model (using fixed and random effects) for the real exchange rate, with different model specifications, in order to produce estimates of the equilibrium real exchange rate and this is then used to construct measures of real exchange rate misalignment. We also provide an alternative set of estimates of real exchange rate misalignment using panel cointegration methods. The variables used in our real exchange rate models are: real per capita GDP; net foreign assets; terms of trade and government consumption. The results for the two-step System GMM panel growth models indicate that the coefficients for real exchange rate misalignment are positive for different model specification and samples, which means that a more depreciated (appreciated) real exchange rate helps (harms) long-run growth. The estimated coefficients are higher for developing and emerging countries.

Key-Words: Long-run Economic Growth; Real Exchange Rate Misalignment; Panel Data Analysis and System GMM.

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Introduction

The real exchange rate does not normally feature in economic growth models, particularly those founded in the neoclassical tradition. Its role has, however, been highlighted by the literature on export-led growth since one of the policy recommendations in this literature is that it is crucially important that the price of export goods and services is at a level that makes it attractive to shift resources into their production. Other studies in the real exchange rate and growth literature are devoted to examining the effect of real exchange volatility on trade and investment and ultimately on growth. High real exchange rate volatility is also part of the investigation on the occurrence of currency crises episodes and how this can have a negative impact on growth.

The empirical literature on exchange rate misalignment and growth is not an extensive one but it has grown recently after the experience of several countries adopting pegged exchange rates as a key element in their disinflation policies. The outcome of such pegged exchange rate regimes is frequently associated with real exchange rate appreciation and the adverse impact this has on the external balance. One of the main arguments in favor of shifting from pegged to flexible exchange rates is that such a move is followed by a nominal and real depreciation, which helps foster long-run economic growth. Another reason for the growing interest in real exchange rate misalignment and growth is the experience of real exchange rate appreciation for many currencies over the recent past when the U.S. dollar has been on a trend depreciation path due to its fiscal and current account deficits.

This paper empirically investigates the relationship between real exchange rate misalignment and long-run economic growth for a set of almost one hundred countries using panel data techniques, including fixed and random effects, panel cointegration and system GMM. One of the main empirical contributions of the paper is to test different model specifications for the long-run equilibrium real exchange rate and then use these to obtain estimated real exchange rate misalignments and assess how robust the results are when they are included as an explanatory variable in the panel growth model. We have also estimated the growth models using System GMM and correct for the case of too many instruments which is an important econometric issue and has not to our knowledge been considered in this literature before.

The empirical results indicate that the coefficients for different measures of real exchange rate misalignment are positive for all estimated models and statistically significant for most model specifications and different samples, meaning that a more depreciated real exchange rate enhances long-run growth. The estimated coefficients for real exchange rate misalignment are higher for developing countries in most models, suggesting that the benefits for such countries are greater in terms of fostering long-run growth.

The paper is divided in two sections other than the introduction and concluding remarks. Section one develops a literature review on real exchange rate misalignment and growth. Section two is dedicated to the empirical results including the estimation of the real exchange rate misalignments and the panel growth models for the complete sample and for a set of developing and emerging economies.

1 – Real Exchange Rate Misalignment and Growth: A Literature Review

The literature on real exchange rate equilibrium goes back to the 1960s (Balassa, 1964) and the second half of the first decade of the new century has shown an increase in the number of empirical studies on real exchange rate misalignment and growth.[1] The notion of real exchange rate equilibrium is normally associated with the combination of external (current account sustainability) and internal (intertemporal equilibrium in the goods market) balance. The literature on exchange rate misalignment has not reached a consensus in terms of how misalignment is measured, since part of the literature is based on deviations from PPP while other studies focus on the deviation of the real exchange rate from some equilibrium level.[2] Another issue that is frequently examined in the literature on real exchange rate misalignment is the notion that overvaluation processes that last for a significant period of time are good indicators of possible currency crises (Frankel and Rose, 1996) and ultimately have an impact on relative price adjustment and create a negative correlation with growth.

One of the early studies on exchange rate misalignment and growth is Razin and Collins (1997) who argue that the policy of keeping the real exchange rate depreciated is generally associated with competitive devaluation policies to stimulate a country's export sector. Edwards (1989) investigates the relationship between real exchange rates and growth and one of the main findings is that inadequate (misaligned) real exchange rates are associated with relative price distortions in the tradable and non-tradable goods sectors and the outcome is a non-optimum allocation of resources among different sectors of the economy, which has a negative impact on growth.[3]

Rodrik (2008) is one of the recent studies on real exchange rate misalignment and growth, with estimation results for a set of 184 countries and time series data from 1950 to 2004. The author develops an index to measure the degree of real exchange rate undervaluation adjusted for the Balassa-Samuelson effect using real per capita GDP (RGDPCH - Penn World Table) data. The main empirical result is that growth is higher in countries with more undervalued real exchange rates and the effect is linear and similar for both under and overvaluation, implying that an overvalued real exchange rate hurts growth while an undervalued rate fosters growth. The magnitude and statistical significance of the estimated coefficient for real exchange rate undervaluation is higher for developing countries due to the fact that such countries are often characterized by institutional fragility and market failures.[4]

Berg and Miao (2010) develop an empirical investigation on real exchange rate misalignment and growth in order to compare the results with Rodrik (2008) and what they call the *Washington Consensus (WC)* view, which is based on a fundamental equilibrium exchange rate model (FEER).[5] Their main result suggests that both views are observationally equivalent for the main growth regressions but there are some identification problems since the determinants

[1] See Rodrik (2008), Eichengreen (2008), Berg and Miao (2010), Gala and Lucinda (2006), and Aghion et. al (2006) for recent panel data studies on real exchange rate misalignment and growth. On the role of exchange rate regimes and misalignments in developing countries, see Coudert and Couharde (2008).

[2] See MacDonald (2007), chapter 9 and Edwards and Savastano (1999) for a review of the literature on exchange rate misalignment.

[3] See Clark and MacDonald (1988) for a description of the BEER (Behavioral Equilibrium Exchange Rate) approach to measure real exchange rate misalignment. The idea is to estimate a long-run relationship between the real effective exchange rate and its fundamentals, where the equilibrium exchange rate is allowed to change over time based on changes in economic fundamentals and domestic policies. The BEER and the fundamental equilibrium exchange rate (FEER) provide useful information on the selection of the main determinants of the real exchange rate: per capita real GDP (Balassa-Samuelson effect), net foreign assets, the terms of trade and government consumption.

[4] Rodrik (2008) incorporates other variables in the growth models (panel and cross-section regressions), including: lagged growth, initial income level (convergence), institutions (Rule of Law), government consumption, terms of trade, inflation, gross domestic saving, years of education, time and country dummies.

[5] The first measure of real exchange rate misalignment (ε_{it}^{PPP}) is the same as in Rodrik (2008), using RGDPCH to capture the Balassa-Samuelson effect, while the second measure (ε_{it}^{FEER}) is based on the FEER view and incorporates additional variables (terms of trade, openness, investment and government consumption).

of real exchange rate misalignments are also likely to be explanatory variables in the growth regression. The empirical findings support those from Rodrik (2008) in the sense that undervaluation helps foster long-run growth and overvaluation has the opposite effect, a result that it is not consistent with the WC view. The authors argue that once they disentangle the direct and the indirect effects of the factors that drive growth the evidence is in favor of the WC view.

Eichengreen (2008) develops a historical review of the literature on real exchange rate and growth, focusing attention on possible channels through which the real exchange rate might have an impact on long-run economic growth. The author argues in favor of a more depreciated real exchange rate as long as this is not associated with higher exchange rate volatility. The combination of a depreciated real exchange rate and low volatility is regarded as a favorable combination for developing and emerging economies, where a more dynamic export sector is usually an important part of the process for achieving higher and sustained economic growth rates.[6] The main policy recommendation therefore is for such countries is to keep their real exchange rate at a competitive level and with lower volatility since they are relevant for jump-starting growth based on development experiences, such as the high growth East Asian economies.

The work developed by Aguirre and Calderón (2006) is among those using a measure of exchange rate misalignment based on the residuals from a FEER regression and they use dynamic panel and cointegration analysis for a set sixty countries with data from 1965 to 2003. The empirical evidence suggests that the effect of RER misalignment on growth is non-linear, which means that when real exchange rate depreciation is too high the impact on growth is negative but when it is small or moderate it can be growth enhancing.[7]

Gala e Lucinda (2006) developed a dynamic panel data analysis using Difference and System GMM techniques, for a set of 58 countries from 1960 to 1999, with a measure of real exchange rate misalignment incorporating the Balassa-Samuelson effect and other control variables for the growth regression such as physical and human capital, institutional environment, inflation, the output gap and terms of trade shocks. The main empirical evidence supports the argument that a real depreciated (appreciated) exchange rate is associated to higher (lower) growth rates.

One of the main contributions of our empirical estimates in the next section is to extend the determinants of real exchange rates including not only differences in per capita income but also the terms of trade, net foreign assets and government consumption.[8] We have also estimated the growth models using System GMM and correcting for too many instruments (tables 3 and 6) based on the Hansen-Diff test (p-value close to one) which has not been reported in recent studies (Rodrik, 2008; Berg and Miao, 2010).

[6] See Aghion et. al (2006) on real exchange rate volatility and factor productivity, which is different from the impact on factor accumulation (growth). The authors found that countries with a significant degree of real exchange rate variability experience slower productivity growth and the magnitude of such is negatively associated with the degree of financial development.

[7] Hausmann et. al (2005) also investigate a non-linear relationship for real exchange rate misalignment and growth for eighty episodes when growth accelerates by at least two percentage points and that acceleration lasts for at least eight years. Their main empirical finding is that real exchange rate depreciation is one of the factors associated with the occurrence of such growth accelerating episodes.

[8] Berg and Miao (2010) include terms of trade, openness, government consumption and investment as additional explanatory variables for growth but not net foreign assets.

2 – The Empirics of Real Exchange Rate Misalignment and Growth

In this section we outline the empirics of measuring real exchange rate misalignments and the estimation of per capita GDP growth models using System GMM.

2.1 – Real Exchange Rate Misalignment and Growth: Panel Data Estimation

In calculating the real exchange rate we follow the procedure suggested by Rodrik (2008) and use data from the Penn World Tables 6.2 for the nominal exchange rates (XRAT) and PPP conversion factors (PPP) to calculate a real exchange rate (RER): [9]

$$\mathrm{LRER}_{it} = L(\mathrm{XRAT}_{it} / \mathrm{PPP}_{it}), \qquad (1)$$

where i is a country index and t is an index for (5-year) time periods; XRAT and PPP are expressed as national currency units per U.S. dollar; L indicates that the variable is in logs.

When RER is greater than one it means that the value of the currency is lower (more depreciated) than is indicated by purchasing-power parity. Given the so called Balassa-Samuelson (BS) effect, we know that non-traded goods are also cheaper in poorer countries, which requires an adjustment to take this into account. In order to capture the BS effect we run a regression of RER on per-capita GDP (RGDPCH):

$$\mathrm{LRER}_{it} = \alpha + \beta L\mathrm{RGDPCH}_{it} + \mathrm{f}_t + \mathrm{u}_{it}, \qquad (2)$$

where f_t is a time fixed effect and u_{it} is the error term.

The estimation of equation (2) provides the estimated coefficient for β and if the coefficient is negative and statistically significant this can be taken as an indication of the relevance of the BS effect (Table 1, model 1). The final step in constructing an index of undervaluation (misalignment) is to calculate the difference between the actual real exchange rate from equation (1) and the exchange rate adjusted by the BS effect from equation (2), which we call Mis1.

We have used other model specifications in order to obtain additional measures of RER misalignment and we use the Hausman test to select which one is the preferred estimation. The data refers to a set of ninety countries, where twenty four are developed countries and the remaining sixty six countries are developing and emerging countries. The time series dimensions of our data set are 1980-2004.

Table 1 reports the estimated real exchange rate for seven different model specifications, where in five of them the Hausman test indicates the fixed effect model as the preferred one (models 2, 3, 5, 6 and 7) while the random effect model was selected for models 1 and 4. The coefficient on real per capita GDP (LRGDPCH) is statistically significant in model 1, when it is the only explanatory variable, and it appears with a negative estimated coefficient (-0.301). This is higher than when it is included with other variables (models 2, 3 and 5), although in these cases the coefficient is insignificant. All the other estimated coefficients for NFAGDP, LTT and LGOV are statistically significant in different model specifications and with the expected coefficient signs.

We consider this first set of results as an indication that empirical studies such as Rodrik (2008), who uses only LRGDPCH as an explanatory variable to estimate the equilibrium real exchange

[9] The definition of real exchange rate as units of domestic currency relative to the U.S. dollar means that a higher (lower) value is associated to real exchange rate depreciation (appreciation).

rate and then calculate the real exchange rate misalignment (undervaluation), should be extended to include other determinants of the real exchange rate.

Table 1 - Model Estimation for Real Exchange Rate (log)

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Hausman (FE x RE)	RE	FE	FE	RE	FE	FE	FE
LRGDPCH	-0.301***	-0.109	-0.043		-0.019		
	(-11.51)	(-1.59)	(-0.62)		(-0.26)		
NFAGDP		-0.100 ***	-0.089 **	-0.135 ***	-0.106 ***	-0.121 ***	-0.1087 ***
		(-2.93)	(-2.43)	(-4.51)	(-2.87)	(-3.68)	(-3.08)
LTT			-0.281 ***		-0.259 ***		-0.2613 ***
			(-4.38)		(-3.98)		(-4.04)
LGOV					-0.135 **	-0.200 ***	-0.1385 **
					(-2.05)	(-3.29)	(-2.14)

Notes: t-stat (FE) and z-stat (RE) in parenthesis.

RE and FE refers to Random and Fixed effect estimation.

*, ** and *** indicates significance at 10%, 5% and 1%

In order to measure real exchange rate misalignment we then subtract the actual real exchange rate from its estimated value using the coefficients from table 1 (Mis1, Mis2, Mis3, Mis4, Mis5, Mis6 and Mis7). The main purpose of this transformation is to investigate the role of such measures of RER misalignment in our growth models for the complete (table 2) and developing and emerging (table 3) samples, based on a two-step robust System GMM estimation.

The option to use System GMM is based on the argument that the existence of weak instruments implies asymptotically that the variance of the coefficient increases and in small samples the coefficients can be biased. To reduce the potential bias and inaccuracy associated with the use of Difference GMM (Arellano and Bond, 1991), Arellano and Bover (1995) and Blundell and Bond (1998) develop a system of regressions in differences and levels. The instruments for the regression in differences are the lagged levels of the explanatory variables and the instruments for the regression in levels are the lagged differences of explanatory variables. These are considered as appropriate instruments under the assumption that although there may be correlation between the levels of explanatory variables and the country specific effect, there is no correlation between those variables in differences and the country specific effect.

The objective here is to first estimate a simple growth model for each of our seven measures of RER misalignment and then include the lagged dependent variable and initial income level. The next step is to estimate an extended model for each measure of RER misalignment including other variables such as: years of education (human capital), law and order (institutions), government consumption (fiscal discipline) and inflation (macroeconomic stability).

The estimated results for the complete sample reported in table 2 shows that all estimated coefficients for the RER misalignment are positive, meaning that a more depreciated real exchange rate helps foster long-run growth. The results are robust since most of the coefficients are statistically significant for different measures of RER misalignment and model specification. For the models where misalignment is an explanatory variable with lagged growth and initial income, the estimated coefficients range from 0.204 to 0.085 and the average is 0.146, while for the extended models the range is from 0.103 to 0.026 with an average RER misalignment of 0.071, which is half of the average for the simple models. If we consider the average coefficients for RER misalignment for the simple and extended models, a 10% increase in real exchange rate misalignment increases growth from a range of 0.7% to 1.4% over a five year period, which means that the average annual increase in growth varies from 0.14% to 0.28%.[10]

Table 2: Real GDP Growth and Real Exchange Rate Misalignment (Complete Sample) System GMM

Models	1	2	3	4	5	6	7	8	9	10	11	12	13	14
GrowthPPPlag	0.194***	0.105	0.189***	0.099	0.228***	0.097	0.193***	0.09	0.233***	0.163**	0.197***	0.177**	0.234***	0.163**
	(2.88)	(1.55)	(2.69)	(1.45)	(3.06)	(1.38)	(2.67)	(1.22)	(3.19)	(2.07)	(2.83)	(2.16)	(3.18)	(2.07)
Initial Income	0.053***	0.003	0.087***	0.014	0.068**	-0.002	0.101***	0.022	0.072**	-0.025	0.097***	0.009	0.073**	-0.025
	(2.87)	(0.09)	(3.15)	(0.42)	(2.17)	(-0.09)	(3.14)	(0.73)	(2.39)	(-0.63)	(3.32)	(0.34)	(2.39)	(-0.62)
Mis 1	0.204***	0.103*												
	(3.82)	(1.83)												
Mis 2			0.196***	0.100*										
			(3.72)	(1.83)										
Mis 3					0.085*	0.026								
					(1.69)	(0.53)								
Mis 4							0.185***	0.092*						
							(3.58)	(1.80)						
Mis 5									0.089*	0.041				
									(1.80)	(1.13)				
Mis 6											0.179***	0.096**		
											(3.50)	(2.36)		
Mis 7													0.088*	0.041
													(1.78)	(1.13)
Educ		0.078		0.085		0.092**		0.084*		0.063		0.045		0.064
		(1.42)		(1.50)		(1.98)		(1.73)		(1.07)		(0.81)		(1.08)
Law		0.034		0.034*		0.033**		0.034*		0.039***		0.032***		0.039***
		(1.64)		(1.70)		(2.04)		(1.67)		(2.66)		(2.74)		(2.66)
Gov		-0.111**		-0.103*		-0.127***		-0.106**						
		(-2.15)		(-1.92)		(-2.85)		(-2.14)						
Inf		-1.60E-05		-1.10E-05		-2.40E-05		-1.10E-05		-2.50E-05		-8.76E-06		-2.00E-05
		(-0.68)		(-0.4)		(-0.9)		(-0.42)		(-0.67)		(-0.25)		(-0.68)
AR(2)	0.59	0.403	0.533	0.392	0.45	0.263	0.516	0.405	0.417	0.259	0.538	0.313	0.417	0.258
Hansen	0.151	0.207	0.142	0.299	0.125	0.363	0.143	0.292	0.13	0.296	0.17	0.442	0.126	0.295
Hansen-Diff	0.721	0.433	0.705	0.48	0.928	0.806	0.73	0.459	0.828	0.675	0.85	0.85	0.815	0.675
Number of Groups	80	71	80	71	80	71	80	71	80	71	80	71	80	71
Number of Instruments	37	73	37	73	37	73	37	73	37	64	37	64	37	64

Note: t-stat in parenthesis. *, ** and *** indicates significance at 10%, 5% and 1% respectively.

System GMM 2-step Robust Estimation with Time Dummies

Table 3 reports the estimated results for developing and emerging countries and it shows that all estimated coefficients for RER misalignment are positive, indicating that a more depreciated real exchange rate helps foster long-run growth. The estimated coefficients for RER misalignment are all statistically significant for the models where misalignment is an explanatory variable with lagged growth and initial income, and the estimated coefficients range from 0.253 to 0.120 with an average value of 0.172. For the extended models the estimated coefficients for RER misalignments are not statistically significant, except for Mis6, where they range from 0.18 to 0.05, with an average of 0.112. The lack of statistical significance for the extended models are associated with the fact that for such models we have to deal with instrument proliferation (Roodman, 2009b), which was not the case when estimating the extended model for the complete sample in table 2. If we consider the average coefficients for RER misalignment for

[10] Rodrik (2008) uses annual per cent growth in GDP per capita as the dependent variable and observations are averages over five-year while our growth models use the log difference of per capita GDP growth over a five year period. Rodrik's (2008) two-step System GMM estimation for the LNUNDERVAL (equivalent to our MIs1 variable) coefficient for 1950-2004 is 0.011 (full sample) and 0.013 (developing countries) meaning that a 10% undervaluation is associated with an increase in annual growth of real income per capita during the same five-year period of 0.11% to 0.13%, which is similar to our estimation for post-1980 ranging from 0.14% to 0.28%.

the simple and extended models, a 10% real exchange rate depreciation increases growth from a range of 1.1% to 1.7% over a five year period, which means that the average annual increase in growth varies from 0.22% to 0.34%.[11]

Table 3: Real GDP Growth and Real Exchange Rate Misalignment (Developing and Emerging) System GMM

Models	1	2	3	4	5	6	7	8	9	10	11	12	13	14
GrowthPPPlag	0.193***	0.164	0.175**	0.148	0.208***	0.134	0.183***	0.143	0.201***	0.139	0.181**	0.168*	0.202***	0.139
	(2.64)	(1.26)	(2.31)	(1.23)	(2.73)	(1.22)	(2.33)	(1.23)	(2.76)	(1.53)	(2.36)	(1.77)	(2.77)	(1.52)
Initial Income	0.017	0.095*	0.06	0.116*	0.051	0.131**	0.074*	0.127*	0.053	0.058	0.079*	0.093	0.054	0.058
	(0.50)	(1.69)	(-1.52)	(1.88)	(1.27)	(2.04)	(1.73)	(1.89)	(1.34)	(0.93)	(1.84)	(1.44)	(1.35)	(0.92)
Mis 1	0.253***	0.18												
	(3.61)	(1.31)												
Mis 2			0.220***	0.16										
			(3.60)	(1.26)										
Mis 3					0.127**	0.063								
					(2.10)	(0.67)								
Mis 4							0.198***	0.14						
							(3.31)	(1.18)						
Mis 5									0.122**	0.051				
									(2.32)	(0.67)				
Mis 6											0.169***	0.143*		
											(3.09)	(1.67)		
Mis 7													0.120**	0.05
													(2.28)	(0.65)
Educ		-0.095		-0.028		0.002		-0.001		-0.035		-0.061		-0.033
		(-0.57)		(-0.15)		(0.01)		0.00		(-0.25)		(-0.46)		(-0.23)
Law		0.006		0.01		0.026		0.013		0.057**		0.034		0.058**
		(0.21)		(0.36)		(1.23)		(0.46)		(2.34)		(1.15)		(2.34)
Gov		-0.231*		-0.229*		-0.263*		-0.234*						
		(-1.82)		(-1.68)		(-1.90)		(-1.67)						
Inf		-3.00E-05		-3.00E-05		-4.20E-05		-3.00E-05		-2.00E-05		-1.00E-05		-2.00E-05
		(-0.52)		(-0.45)		(-0.81)		(-0.48)		(-0.46)		(-0.33)		(-0.47)
AR(2)	0.586	0.696	0.633	0.609	0.52	0.519	0.637	0.578	0.533	0.83	0.795	0.813	0.534	0.831
Hansen	0.121	0.226	0.125	0.201	0.142	0.176	0.114	0.188	0.131	0.189	0.151	0.192	0.128	0.188
Hansen Diff	0.658	0.228	0.55	0.103	0.711	0.027	0.442	0.044	0.646	0.639	0.758	0.404	0.628	0.648
Number of Groups	58	49	58	49	58	49	58	49	58	49	58	49	58	49
Number of Instruments	37	35	37	35	37	35	37	36	37	31	37	31	37	31

Note: t-stat in parenthesis. *, ** and *** indicates significance at 10%, 5% and 1% respectively.

Models 2, 4, 6, 8, 10, 12 and 14 are estimated with the Collapse Command from Stata 10 in order to deal with too many instruments

System GMM 2-step Robust Estimation with Time Dummies

Comparing the results for the complete sample and the developing and emerging countries, it is clear that the estimated coefficients for RER misalignment are higher for developing and emerging countries, suggesting that a policy based on sustaining a depreciated real exchange rate has a long-run impact on growth that is magnified for such countries.

Our first set of empirical results on the role of RER misalignment for long-run growth supports the findings from other recent studies, such as Rodrik (2008), Berg and Miao (2010), Aguirre and Calderón (2006), Gala and Lucinda (2007) and Eichengreen (2008) in the sense that an undervalued real exchange rate is beneficial for long-run growth, while the opposite is true for

[11]The baseline panel regression from Rodrik (2008) using only developing countries and data for 1980 to 2004, which is the same time period used in our study, provides an estimated coefficient for LNUNDERVAL of 0.028 and a 10% undervaluation will increase annual growth by 0.28%, which is within our estimated range.

an overvalued real exchange rate. On the other hand, our estimated models have provided additional empirical evidence that long-run equilibrium exchange rates should not be modeled only as a function of real per capita GDP (Rodrik, 2008), but should include other determinants, such as the terms of trade, net foreign assets and government consumption.

2.2 – Real Exchange Rate Misalignment and Growth: Panel Unit Roots and Cointegration

The aim of this section is to use panel cointegration analysis to calculate the RER misalignment and then estimate the panel growth models to see how robust the results are when compared to those from the previous section in terms of the magnitude and significance of the estimated coefficients.

2.2.1 – Unit Roots and Panel Cointegration Tests

The first step is to use apply a range of panel unit root tests (the Levin, Lin and Chu 2002 test; the Im, Pesaran and Shin, 2003 W-Stat; and two Fisher-type tests using ADF and PP tests from Maddala and Wu, 1999; and Choi, 2001). The results for each one of our five variables are reported in table 4, where all the tests have a unit root under the null hypothesis. We note that for real per capita GDP and net foreign assets there is no contradiction among the unit root tests as both are non-stationary. For the real exchange rate, terms of trade and government consumption there are mixed results regarding the non-stationarity of each variable.[12]

Table 4: Panel Unit Roots Tests

Variables	Method	Statistic	Prob.*	Obs	Non-Stationary or Stationary
LRER	Levin, Lin & Chu	-1.0739	0.1414	2144	NST
	Im, Pesaran and Shin W-stat	-1.39674	0.0812	2144	NST
	ADF - Fisher Chi-square	280.064	0.000	2144	ST
	PP - Fisher Chi-square	254.367	0.0002	2160	ST
LRGDPCH	Levin, Lin & Chu	1.25344	0.895	2134	NST
	Im, Pesaran and Shin W-stat	4.11483	1.000	2134	NST
	ADF - Fisher Chi-square	133.638	0.996	2134	NST
	PP - Fisher Chi-square	154.707	0.914	2160	NST
NFAGDP	Levin, Lin & Chu	3.59056	0.9998	2126	NST
	Im, Pesaran and Shin W-stat	4.95657	1.000	2126	NST
	ADF - Fisher Chi-square	113.564	1.000	2126	NST
	PP - Fisher Chi-square	129.845	0.9981	2159	NST
LTT	Levin, Lin & Chu	-54.9557	0.000	1796	ST
	Im, Pesaran and Shin W-stat	-3.14395	0.0008	1796	ST
	ADF - Fisher Chi-square	167.119	0.5908	1796	NST
	PP - Fisher Chi-square	221.803	0.0062	1857	ST
LGOV	Levin, Lin & Chu	-0.3778	0.3528	2117	NST
	Im, Pesaran and Shin W-stat	1.47413	0.9298	2117	NST
	ADF - Fisher Chi-square	164.954	0.7825	2117	NST
	PP - Fisher Chi-square	260.206	0.0001	2143	ST

* Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality

Im, Pesaran and Shin; ADF - Fisher and PP - Fisher - Null Hypothesis: Unit Root (Individual Unit Root process)

Levin, Lin & Chu Test - Null Hypothesis: Unit Root (common Unit Root process)

Automatic lag length selection based on Modified Schwarz Criteria and Bartlett kernel

The recent literature has focused on tests of cointegration in a panel setting and we provide the results in table 5 for two panel cointegration tests based on Pedroni (1999) (2004) and Kao (1999), where both are Engle-Granger based tests.

[12] We have also used the Hadri (2000) unit root test, where stationarity is the null hypothesis and we reject the null for all five variables.

The cointegration tests proposed by Pedroni (1999) (2004) allow for heterogeneous intercepts and trend coefficients across cross-sections, with different methods of constructing statistics for testing the null hypothesis of no cointegration. There are two alternative hypotheses: the homogenous alternative which is called the within-dimension test, or panel statistics test, and the heterogeneous alternative referred to as the between-dimension, or group statistics test. This type of panel cointegration test has the advantage over others that it allows for heterogeneous variances across countries at each point in time allowing to pool the long-run information contained in the panel, while permitting the short-run dynamics to vary among different groups. The Kao (1999) test follows the same basic approach but specifies cross-section specific intercepts and homogeneous coefficients in the first-stage regressors.

The panel cointegration results from table 5 provide us with evidence of cointegration since most of Pedroni test statistics reject the null hypothesis of no cointegration for the two estimated models and the same interpretation can be drawn from the Kao test statistics where the null is rejected in both cases.

Table 5: Panel Cointegration Tests: Pedroni and Kao

Model 1: LRER, LRGDPCH and NFAGDP	Pedroni	Statistics	Prob.
Alternative hypothesis: common AR coefs. (within-dimension)			
	Panel v-Statistic	3.482	0.000
	Panel rho-Statistic	-0.890	0.187
	Panel PP-Statistic	-5.997	0.000
	Panel ADF-Statistic	-7.576	0.000
Alternative hypothesis: individual AR coefs. (between-dimension)			
	Group rho-Statistic	3.907	1.000
	Group PP-Statistic	-1.999	0.023
	Group ADF-Statistic	-7.216	0.000
	Kao	Statistics	Prob.
	ADF	-8.473	0.000
Model 2:LRER, LRGDPCH, NFAGDP, LTT and LGOV	Pedroni	Statistics	Prob.
Alternative hypothesis: common AR coefs. (within-dimension)			
	Panel v-Statistic	-0.048	0.519
	Panel rho-Statistic	9.363	1.000
	Panel PP-Statistic	-2.686	0.004
	Panel ADF-Statistic	-3.655	0.000
Alternative hypothesis: individual AR coefs. (between-dimension)			
	Group rho-Statistic	13.788	1.000
	Group PP-Statistic	-0.416	0.339
	Group ADF-Statistic	-3.568	0.000
	Kao	Statistics	Prob.
	DF	-6.6135	0.000
	DF*	-6.4649	0.000

Null Hypothesis: No Cointegration

Pedroni Test: Automatic lag length selection based on SIC with a max lag of 4

Kao Test: Automatic lag length selection based on SIC: 5 for model 1 and 0 for model 2

Pedroni and Kao Tests: Newey-West automatic bandwidth selection and Bartlett kernel

Pedroni and Kao Tests - Trend assumption: No deterministic trend

Having estimated the panel unit root and cointegration tests we then estimate a vector error correction model (VECM) for the two model specifications reported in table 5 (Model 1 and 2) in order to obtain the two measures of real exchange rate misalignment (MisCoint 1 and MisCoint 2) as the difference between the actual and predicted real exchange rate.[13]

2.2.2 - Growth and Real Exchange Rate Misalignment: System GMM Estimation

The results for our two-step System GMM growth model are reported in table 6 using the two measures of RER from the VECM and they indicate that the estimated coefficients are positive and the results are robust for different models and sets of countries. This evidence therefore supports the previous estimated results (tables 2 and 3) that a more depreciated real exchange rate enhances long-run growth.

Another feature from the System GMM growth model is that for the complete sample the estimated coefficients for the two measures of RER misalignment are statistically significant, regardless of which model specification is used, while this is not the case for the developing and emerging market countries sample due to the fact that the Hansen-Diff statistics on previously estimated models suggest that we need to collapse the number of instruments.[14]

In terms of the magnitude of the estimated coefficients for the two measures of RER misalignment, there are significant differences for the complete and developing / emerging samples, where for the former the coefficients for MIsCoint1 varies from 0.111 to 0.096 and from 0.138 to 0.147 for the latter. For MisCoint2 the estimated coefficients vary from 0.038 to 0.029 for the complete sample and from 0.025 to 0.027 for developing and emerging economies.

In general, we can infer from our results that a 10% increase in real exchange rate misalignment increases GDP growth over a five year period in the range of 0.29% to 1.1% for the complete sample, which translates into annual increases in growth of 0.06% and 0.22%. For developing and emerging market countries a 10% increase in RER misalignment increases growth over a five year period in the range of 0.25% to 1.4%, resulting in annual increases in growth in the range of 0.05% to 0.28%.[15]

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[13] Figure 1A (appendix) shows the estimated coefficients and significance for a panel regression (fixed effects) of real GDP growth and each one of our nine measures of RER misalignment and it is clear that the coefficients are positive and statistically significant for all estimated models.

[14] We did not report the results for developing and emerging countries without collapsing the number of instruments but they are available on request from the authors. See Roodman (2009b) for a further discussion on the consequences of instrument proliferation.

[15] One comparison that can be made for the estimated coefficients of RER misalignments relates to two sets of estimates which use the same model specification: one is between Mis2 and MisCoint1 and the second is for Mis5 and MisCoint2. . See tables 2, 3 and 6.

Table 6: Real GDP Growth (Using Painel Cointegration to Estimate Real Exchange Rate Misalignment) System GMM

	Complete Sample				Developing and Emerging			
Models	1	2	3	4	1	2	3	4
GrowthPPPlag	0.223***	0.116	0.210***	0.136*	0.254***	0.200*	0.231***	0.138
	(2.96)	(1.47)	(2.93)	(1.73)	(2.70)	(1.72)	(3.08)	(1.36)
Initial Income	0.033**	0.004	0.024*	0.002	0.003	0.105	0.012	0.138**
	(2.15)	(0.14)	(1.90)	(0.10)	(0.09)	(1.58)	(0.48)	(2.07)
MisCoint 1	0.111**	0.096**			0.138**	0.147		
	(2.45)	(2.37)			(2.20)	(1.24)		
MisCoint 2			0.038**	0.029**			0.025	0.027
			(2.00)	(2.07)			(0.89)	(1.10)
Educ		0.081		0.077		-0.125		-0.009
		(1.41)		(1.55)		(-0.76)		(-0.05)
Law		0.028**		0.031**		0.002		0.024
		(1.99)		(2.06)		(0.08)		(1.22)
Gov		-0.137***		-0.164***		-0.276**		-0.343**
		(-3.10)		(-3.11)		(-1.96)		(-2.32)
Inf		-3.9E-05*		-1.90E-05		-7.20E-05		-2.30E-05
		(-1.66)		(-0.69)		(-0.96)		(-0.44)
AR(2)	0.802	0.4	0.963	0.36	0.886	0.835	0.924	0.624
Hansen	0.172	0.484	0.516	0.431	0.124	0.191	0.191	0.204
Hansen Diff	0.773	0.732	0.833	0.575	0.541	0.101	0.592	0.04
Number of Groups	80	71	77	68	58	49	57	48
Number of Instruments	37	73	37	73	37	35	37	35

Note: t-stat in parenthesis. *, ** and *** indicates significance at 10%, 5% and 1% respectively.
Mis Coint 1 includes LRER and two non-stationary variables (LRGDPCH and NFAGDP)
Mis Coint 2 includes LRER and four variables (LRGDPCH, NFAGDP, LTT and LGOV)
Models 2 and 4 for Developing and Emerging use the Collapse command from Stata 10 to correct for too many instruments
System GMM 2-step Robust Estimation with Time Dummies

One final task is to test for non-linearity, taking the same growth regression from table 6 for our two measures of RER misalignment, and using the squared values of misalignment. The resulting estimated coefficients are negative suggesting that higher levels of RER misalignment reduce long-run growth, but there is no statistical significance in either sample of countries and model specification.[16] We have not found evidence of non-linearity in the relationship between RER misalignment and growth, which corroborates recent results (Rodrik, 2008) but there is no consensus in the empirical literature since previous studies such as Aguirre and Calderon (2006) and Razin and Collins (1997) have found the existence of non-linearities.

[16] The estimated coefficients for MisCoint 1 and MisCoint 2 squared are not reported due to lack of statistical significance but they are available from the authors on request.

Concluding Remarks

The empirical literature on growth and real exchange rate misalignment using panel data analysis has developed substantially in the recent past and the evidence suggests that the more depreciated is a country's real exchange the faster is its long-run growth. This result seems to be more significant and robust for emerging and developing countries where institutional fragility and lack of macroeconomic stability is a common feature over the past decades.

The main empirical contribution of our work has been to expand the determinants of the real exchange rate in order to calculate different measures of misalignment and to use two different econometric methodologies (fixed / random effects and panel cointegration analysis) for a set of almost one hundred countries with time series data from 1980 to 2004.

Our empirical estimation of the System GMM panel growth models has shown that all estimated coefficients for the real exchange rate misalignment are positive, which means that a more real depreciated exchange rate helps real GDP growth while the opposite is true for a real exchange rate appreciation. The results are robust in terms of statistically significant coefficients for different samples and models and the estimated coefficients are higher for developing and emerging market economies. The estimated coefficients from all of our nine measures of real exchange rate misalignment suggest that a 10% increase (depreciation) in real exchange rate misalignment can increase annual per capita GDP growth by up to 0.3%.

Finally, we can say that our results are in accordance with those reported in recent studies, such as Rodrik (2008) and Berg and Miao (2010), although we find that exchange rate misalignment has a bigger impact on economic growth than that reported in these studies. The crucial policy recommendation to stem from our work, which is especially relevant for developing and emerging market economies, is that such economies should avoid periods of long lasting real exchange rate appreciation and instead adopt economic policies that are able to keep the real exchange rate at a competitive level, which most of the time should be associated with a more depreciated real exchange rate relative to its equilibrium level.

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Appendix

Table 1A: Variables - Definition, Source and Number of Observations

Variable	Definition	Source	Obs
LRER	Bilateral real exchange (units of domestic currency relative to the U.S. dollar and using CPI)	IFS	450
LRGDPCH	Real GDP per capita	Penn World Table	450
NFAGDP	Net foreign assets as % of GDP	Lane and Milesi-Ferretti (2007)	450
LGOV	Government consumption as % of GDP	WDI	446
LTT	Ratio of export to import prices (2000 = 100)	WDI	386
GROWTHPPP	Log difference of Real GDP per capita (PPP) growth.	WDI	447
Initial Income	Real GDP per capita (PPP) level in 1980, 1985, 1990, 1995 and 2000	WDI	447
LEDUC	Average number of years of schooling of the population aged above 15 years in 1980, 1985, 1990, 1995, and 2000	Barro and Lee (2000)	394
INF	Inflation measured by the consumer price index (annual %).	WDI	439
LTRADE	Sum of exports and imports of goods and services as a % of GDP	WDI	445
LAW	The "law" sub-component assesses the strength and impartiality of the legal system, and the "order" sub-component assesses popular observance of the law (scale from zero to six).	International Country Risk Guide	444
Mis 1	Measure of RER misalignment using LRGDPCH		450
Mis 2	Measure of RER misalignment using LRGDPCH and NFAGDP		450
Mis 3	Measure of RER misalignment using LRGDPCH, NFAGDP and LTT		450
Mis 4	Measure of RER misalignment using NFAGDP		450
Mis 5	Measure of RER misalignment using LRGDPCH, NFAGDP, LTT and LGOV		450
Mis 6	Measure of RER misalignment using NFAGDP and LGOV		450
Mis 7	Measure of RER misalignment using NFAGDP, LTT and LGOV		450
MisCoint 1	RER misalignment - Panel Cointegration (LRER, LRGDPCH and NFAGDP)		450
MisCoint 2	RER misalignment - Panel Cointegration (LRER, LRGDPCH, NFAGDP, LTT and LGOV)		389

All measures of RER misalignment are in log L = variable in log

A positive misalignment indicates that real exchange rate is undervalued relative to the equilibrium level.

Table 2A: List of Countries - Complete Sample

Countries	Countries	Countries	Countries	Countries
Algeria	Costa Rica	Iceland	Mexico	Singapore
Argentina	Cote D Ivoire	India	Morocco	South Africa
Australia	Denmark	Indonesia	Netherlands	Spain
Austria	Dominican Republic	Iran	New Zealand	Sri Lanka
Bahrain	Ecuador	Ireland	Nicaragua	Sudan
Bangladesh	Egypt	Israel	Niger	Sweden
Belgium	El Salvador	Italy	Nigeria	Switzerland
Bolivia	Ethiopia	Jamaica	Norway	Syria
Botswana	Finland	Japan	Oman	Thailand
Brazil	France	Jordan	Pakistan	Togo
Burkina Faso	Gabon	Kenya	Panama	Trinidad & Tobago
Cameroon	Germany	Korea, South	Papua New Guinea	Tunisia
Canada	Ghana	Kuwait	Paraguay	Turkey
Chile	Greece	Madagascar	Peru	Uganda
China	Guatemala	Malawi	Philippines	United Kingdom
Colombia	Haiti	Malaysia	Portugal	Uruguay
Congo	Honduras	Mali	Saudi Arabia	Venezuela
Congo, DR	Hong Kong	Malta	Senegal	Zambia

Figure 1A: Growth and RER Misalignment – Panel Regression (Fixed Effects)