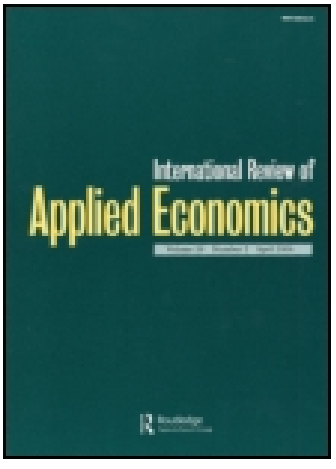

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The real exchange rate and economic growth: are developing countries different?

Martín Rapetti [a] , Peter Skott [b] & Arslan Razmi [b]
[a] Department of Economics , CEDES and University of Buenos Aires , Buenos Aires , Argentina
[b] Department of Economics , University of Massachusetts , Amherst , USA
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The real exchange rate and economic growth: are developing countries different?

Martín Rapetti[a,]*, Peter Skott[b] and Arslan Razmi[b]

[a]*Department of Economics, CEDES and University of Buenos Aires, Buenos Aires, Argentina;* [b]*Department of Economics, University of Massachusetts, Amherst, USA*

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Recent research has found a positive relationship between real exchange rate (RER) undervaluation and economic growth. Different rationales for this association have been offered, but they all imply that the mechanisms involved should be stronger in developing countries. Rodrik (2008) explicitly analyzed and found evidence that the RER–growth relationship is more prevalent in developing countries. We show that his finding is sensitive to the criterion used to divide the sample between developed and developing countries. Using alternative classification criteria and empirical strategies to evaluate the existence of asymmetries between groups of countries, we find that the effect of currency undervaluation on growth is indeed larger and more robust for developing economies. However, the relationship between RER undervaluation and per capita GDP is non-monotonic, and is limited largely to the least developed and richest countries. This discontinuity constitutes a puzzle that calls for closer analysis.

Keywords: real exchange rate; growth; undervaluation; growth econometrics; developing countries

JEL Classifications: F43, O24, O11

1. Introduction

In recent years, a significant body of research has focused on the relationship between real exchange rates (RERs) and economic growth. The studies have used different data sets and empirical strategies but a systematic finding appears common to almost all: undervalued, i.e., competitive, RERs are positively associated with higher economic growth. At least two explanations for such a relationship have been offered. One suggests that an undervalued exchange rate favors the re-allocation of resources towards the tradable sector, which is the locus of learning-by-doing externalities and technological spillovers. As Rodrik (2008) and Eichengreen (2007) indicate, this mechanism mostly applies to developing economies, where market failures are more conspicuous. The other explanation emphasizes the role of competitive RER in relaxing the foreign exchange constraint on growth.[1] In developing countries with substantial open or hidden unemployment, the argument goes, growth can be accelerated with policies that mobilize unemployed resources. However, the acceleration of growth and capital

*Corresponding author. Email: m.g.rapetti@gmail.com

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accumulation has an impact on the balance of payments, especially if the dependence on imported capital goods is high, as in the case of developing countries. In these conditions, a more competitive RER would help relax foreign exchange bottlenecks that otherwise could restrain the development process.

Both narratives share a common element: the mechanisms involved are characteristic of developing countries. Thus, regardless of the relative importance of each mechanism, the positive relationship between RER undervaluation and economic growth should be stronger in developing countries. To our knowledge, Rodrik (2008) is the only study that explicitly analyses and finds evidence that the RER–growth relationship is more prevalent in developing countries. It is unclear, however, whether this result depends on the precise specification of the regressions, including the criterion used to divide the sample between developed and developing countries. In this paper, we provide a more thorough analysis of differences between developed and developing countries, using a variety of methods and classification criteria. Our results show that the positive correlation between RER undervaluation and economic growth is indeed stronger in developing countries. Closer analysis, however, leads us to conclude that Rodrik's finding of a positive relationship between undervaluation and growth conceals an interesting non-monotonicity; the finding is significant only for the least developed and most advanced countries. In addition to calling into question the linearity that Rodrik derived from his analysis of the interaction between per capita GDP and the strength of the undervaluation-growth relationship, this result constitutes an interesting puzzle that needs to be addressed by future work.

The paper is organized as follows. Following this introduction, we briefly survey the literature analyzing the RER–growth relationship. In Section 3, we replicate Rodrik's result and show its sensitivity to different classification criteria. We then provide our results. The final section concludes.

2. Literature review

Many recent studies run standard growth regressions using some index of RER misalignment, i.e., undervaluation or overvaluation, as a right-hand variable. The construction of such indices requires comparing the actual with the equilibrium RER, and some estimation of the latter is needed. Two approaches have been followed. One of them defines equilibrium RER as the purchasing power parity level adjusted for the Balassa-Samuelson effect (*PPP-based*). The other approach relies on either single equation or general equilibrium macroeconometric models, in which the estimated equilibrium RER depends on economic fundamentals such as relative productivity, net foreign assets, terms of trade and government spending (*fundamentals-based*).

Razin and Collins (1999) construct a fundamentals-based index of RER overvaluation derived from a structural macroeconomic model and use it for a pooled sample of 93 developed and developing countries over 16- to 18-year periods since 1975. They find that their index correlates negatively with economic growth. Their results also suggest the existence of asymmetries; the negative effect of overvaluation on growth is stronger than the positive effect of undervaluation. Aguirre and Calderon (2005) construct three fundamentals-based indices of RER overvaluation for a panel of 60 developed and developing countries over 1965–2003 and find that they correlate negatively with GDP per

capita growth. The relationship also appears to be asymmetric and non-linear: the estimated coefficients are larger for cases of overvaluation than those of undervaluation and they tend to decrease in absolute terms with higher degrees of undervaluation. The negative relationship between overvaluation and growth continues to hold when the fundamentals-based indices are replaced by PPP-based indices. Prasad, Rajan, and Subramanian (2007) find that developing countries that rely less on foreign capital tend to grow faster. They also find that capital inflows are positively associated with a PPP-based index of RER overvaluation. Both results apply only to developing countries; for developed nations the relationships show the opposite sign. A possible explanation for these findings, they argue, is that capital inflows tend to appreciate domestic currencies, which hurts economic growth by lowering incentives to invest in manufactures. They directly test the relationship between their index of RER overvaluation and economic growth and find a negative correlation. They do not investigate, however, whether this association varies between developed and developing countries. Gala (2008) finds a negative relationship between GDP per capita growth and a PPP-based index of RER overvaluation in a panel of 58 developing countries for the period 1960–1999. The result is robust to changes in control variables and econometric techniques.

The positive association between RER undervaluation and economic growth has also been found in studies that have not estimated equilibrium RER. Hausmann, Pritchett, and Rodrik (2005), for instance, identify 83 episodes of sustained growth acceleration in developed and developing countries between 1960 and 2000 and find that these tend to be preceded by RER depreciations. In a similar study, Berg, Ostry, and Zettelmeyer (2008) investigate the factors that make growth episodes sustainable in both developing and developed countries. They find that overvaluation affects the duration of growth spells adversely. Polterovich and Popov (2002) carry out a cross-country study for developing countries, in which foreign exchange (FX) reserve accumulation appears to be positively associated with GDP per capita growth and the level of the RER. Using data for developing countries, Levy-Yeyati and Sturzenegger (2009) build two indices of FX intervention and find that they are positively correlated (in independent regression analyses) with GDP growth and the level of RER. The results of these two studies are interpreted by the authors as evidence that FX reserve accumulation by central banks in developing countries is carried out to maintain undervalued RERs and thus to stimulate growth.

Unlike the above studies, Rodrik (2008) explicitly tests for asymmetries between developing and developed countries, using a PPP-based index of RER undervaluation in a fixed-effects model for a panel of 184 countries between 1960 and 2004. He defines developing countries as those with a GDP per capita less than $6,000 and finds that the positive relationship between RER undervaluation and economic growth is stronger and more significant for developing than developed countries. The robustness of Rodrik's results with respect to changes in the measure of RER misalignment has been examined (and confirmed) by MacDonald and Viera (2010).[2] Our study addresses another robustness issue. In the next section, we show that Rodrik's result depends on the delineation of the two groups of countries and that a significant relationship may also hold for high-income countries.

3. Econometric model and results

We follow the same three-step methodology as Rodrik (2008) to obtain a PPP-based index of RER undervaluation. Using data from the Penn World Tables 6.2, we first calculate the real exchange rate (RER) as the ratio between the nominal exchange rate (XRAT) and the purchasing power parity conversion factor (PPP). Because the real exchange rate can deviate from equilibrium in the short/medium run we use a 5-year frequency, in which each observation corresponds to the period average. Both variables are expressed as national currency units per US dollar.[3] Since PPP is calculated over the entire GDP, the basket includes non-tradables. Thus, in order to calculate equilibrium real exchange rates, in a second step we adjust for the Balassa-Samuelson effect, regressing RER on real GDP per capita (RGDPCH):

$$\ln RER_{it} = \rho + \beta \ln RGDPCH_{it} + f_t + \varepsilon_{it} \quad (1)$$

where i and t are country and time indices, respectively, f_t accounts for time fixed effects, and ε_t is the error term. Our estimate of $\hat{\beta} = -0.24$ is identical to Rodrik's; we get a t-statistic of 21.29 while Rodrik reports a t-statistic of 'around 20'. The sign of the coefficient is in line with the Balassa-Samuelson prediction; in this case, a 10% increase in RGDPCH is associated with a 2.4% real appreciation. Finally, we define the undervaluation index (*UNDERVAL*) as the ratio of actual to Balassa-Samuelson-adjusted real exchange rates: $UNDERVAL_{it} = \frac{RER_{it}}{\widehat{RER}_{it}}$. Defined this way, *UNDERVAL* is comparable across countries and over time; when it exceeds unity, the domestic currency is undervalued in real terms, i.e., domestic goods are cheap in international dollar terms. We use ln*UNDERVAL* as the main variable of interest; it has a zero mean and a standard deviation of 0.47.[4]

We conducted a series of standard growth regressions for a panel of a maximum of 181 countries and up to eleven 5-year time periods spanning 1950–2004.[5] The estimated fixed effects model is:

$$GROWTH_{it} = \alpha + \beta \ln RGDPCH_{it-1} + \delta \ln UNDERVAL_{it} + \gamma X_{it} + f_t + f_i + \varepsilon_{it} \quad (2)$$

The dependent variable is the average annual growth rate of real GDP per capita, $RGDPCH_{it-1}$ captures the convergence term, f_t time-specific effects, f_i country-specific effects, ε_{it} is the error term, and X is a vector of standard control variables, which includes government consumption, the inflation rate, gross domestic savings,[6] degree of trade openness, human capital (years of education), terms of trade, foreign debt, real exchange rate volatility, and an index of rule of law.[7] Table 1 lists the variable definitions and data sources. The specification in equation (2) estimates the effect of changes in RER undervaluation on changes in the rate of growth 'within' countries.[8]

Table 2 reports a series of estimations of equation (2) for the whole panel. In the baseline growth regression, the estimated coefficient of ln*UNDERVAL* is $\hat{\delta} = 0.015$ which is significant at 1%.[9] This implies that one standard deviation (0.47) in ln*UNDERVAL* boosts the rate of growth by almost 0.75 percentage points per annum. The coefficient, however, turns smaller and less significant as the number of control variables is increased (columns 2 to 6), and when the terms of trade and rule of law are added to the control group, ln*UNDERVAL* becomes insignificant. Overall, Table 2 provides some evidence of a positive relationship between

Table 1. Data definitions, sources and coverage.

Name	Code	Definition	Source	Coverage
Real GDP per capita growth	GROWTH	GROWTH=[(RGDPCHt/RGDPCH$_{t-1}$)^(1/5)]-1	Authors' calculation	1955-2004
Real Exchange Rate	RER	RER=XRAT/PPP.	Authors' calculation	1950-2004
Real Exchange Rate Volatility	RERVOL	Calculated as the coefficient of variation of RER within each 5-year period	Authors' calculation	1950-2004
Average years of Education	TYR	Average years of education for the population aged 25 and over.	Barro and Lee (2001)	1960-1999
Rule of Law Index	ROL	Index elaborated based on responses on the quality of governance given by a large number of enterprise, citizen and expert survey. It is measured in units ranging from about -2.5 to 2.5, with higher values corresponding to better governance outcomes.	Kaufmann, Kraay, and Mastruzzi (2008)	1996-2004
Real GDP per capita	RGDPCH	Real GDP per capita in constant U.S. dollar in 2000. It is obtained using a chain index.	PWT	1950-2004
Nominal Exchange Rate	XRAT	National currency units per U.S. dollar.	PWT	1950-2004
Degree of Openness	OPENC	Exports plus Imports divided by GDP. All variables are expressed in current prices.	PWT	1950-2004
Purchasing Power Parity	PPP	Number of national currency units required to buy goods equivalent to what can be bought with one unit of U.S. It is calculated over GDP	PWT	1950-2004
Gross Domestic Savings	GDSGDP	Gross domestic savings is calculated as GDP less final consumption expenditure (total consumption). Data are as share of GDP and divided by 100.	WDI	1960-2004
Government Consumption	GOVGDP	It includes all government current expenditures for purchases of goods and services. Data are as share of GDP and divided by 100.	WDI	1960-2004
Consumer Price Index	CPI	Consumer price index.	WDI	1960-2004
Investment (Gross Fixed Capital Formation)	GFCF	It Includes land improvements; plant, machinery, and equipment purchases of goods and services.Data are as share of GDP and divided by 100.	WDI	1960-2004
External debt	DEBTGNI	Total external debt stocks to gross national income.	WDI	1960-2004
Terms of Trade	TT	The terms of trade effect equals capacity to import less exports of goods and services in constant prices. Data are in constant local currency.	WDI	1960-2004

Table 2. Panel Regression. All countries, 1950-2004.

	Dependent variable: GROWTH (GDP per capita growth)[a,b]						
	(1) Baseline	(2)	(3)	(4)	(5)	(6)	(7)
Ln $RGDPCH_{t-1}$	−0.030***	−0.047***	−0.051***	−0.059***	−0.038***	−0.100***	−0.032***
	(−6.57)	(−8.90)	(−9.29)	(−8.77)	(−4.61)	(−4.20)	(−7.07)
Ln UNDERVAL	0.015***	0.010***	0.007**	0.008**	0.003	0.025	0.089***
	(4.44)	(2.72)	(2.12)	(1.97)	(0.49)	(1.27)	(4.18)
Government consumption		0.011	0.010	0.091*	−0.119**	−0.155**	
(share of GDP)		(0.23)	(0.23)	(1.77)	(−2.15)	(−2.00)	
Ln (CPI_t/CPI_{t-1})		−0.005***	−0.004***	−0.005***	−0.003**	−0.013***	
		(−4.21)	(−4.04)	(−5.12)	(−2.24)	(−2.65)	
Gross domestic saving (Residuals)		0.126***	0.117***	0.111***	0.103***	0.103*	
		(5.76)	(5.61)	(6.13)	(2.60)	(1.89)	
Openness			0.025***	0.022**	0.020*	−0.009	
(Exports+Imports as share of GDP)			(3.16)	(2.46)	(1.75)	(−0.57)	
Ln (RER volatility)			−0.003**	−0.003**	−0.002	0.001	
			(−2.21)	(2.51)	(−1.50)	(0.31)	
Average years of education				0.004**			
				(2.13)			
Ln terms of trade					0.002		
					(0.29)		
Rule of law						−0.001	
						(−0.15)	
Ln ($RGDPCH_{t-1}$)xLn(UNDERVAL)							−0.0093***
							(−3.64)
Time dummies	yes	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes	yes	yes
Adjusted R-squared	0.34	0.52	0.53	0.58	0.55	0.69	0.35
Number of countries	181	155	155	98	117	151	181
Observations	1303	856	853	548	451	293	1303

[a]Robust *t*-statistics are in parentheses, *p<0.10, **p<0.05, ***p<0.01.
[b]All regressions exclude observations for Iraq, Democratic Rep. of Korea and Laos.

Table 3. Countries with varying level of GDP per capital: 1950-2004.

Dependent variable: GROWTH (GDP per capita growth)[a,b]										
	(1) RGDPCH <$2,500	(2) RGDPCH <$4,000	(3) RGDPCH <$6,000	(4) RGDPCH >$6,000	(5) RGDPCH >$8,000	(6) RGDPCH >$9,000	(7) RGDPCH >$11,000	(8) RGDPCH >$12,000	(9) RGDPCH >$15,000	(10) RGDPCH >$16,000
Ln $RGDPCH_{t-1}$	−0.052	−0.044	−0.039	−0.054	−0.059	−0.057	−0.065	−0.067	−0.073	−0.077
(p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ln UNDERVAL	0.035	0.030	0.024	0.002	0.012	0.016	0.030	0.031	0.027	0.025
(p-value)	(0.000)	(0.000)	(0.000)	(0.812)	(0.185)	(0.091)	(0.005)	(0.009)	(0.082)	(0.153)
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of countries	80	108	131	90	72	67	56	52	46	43
Observations	451	624	790	513	404	373	309	289	216	196

[a]Robust p-values are in parentheses.
[b]All regressions exclude observations for Iraq, Democratic Rep. of Korea and Laos.

ln*UNDERVAL* and economic growth for the entire panel.[10] We now investigate whether this relationship is stronger for developing countries.

As mentioned in the previous section, Rodrik (2008) classifies developing (developed) countries as those with a real GDP per capita of less (more) than $6000. Under this classification, he finds that the estimated coefficient of ln*UNDERVAL* in the baseline regression is low and not significant for developed countries, whereas it is large and significant for developing countries. Columns (3) and (4) in Table 3 reproduce those results, which are almost identical to Rodrik's. This is a key result that Rodrik uses to indicate that the positive relationship between currency undervaluation and economic growth 'is true particularly for developing countries' (Rodrik 2008, 365).

Table 3 reports a sensitivity analysis in which different GDP per capita thresholds are used. The results show that the asymmetric effect of undervaluation between countries is very sensitive to the choice of threshold. If the cut-off is selected from anywhere in the $9000–$15,000 range, the estimated coefficient is large (between 0.016 and 0.031) and highly significant for developed countries as well.[11] For GDP per capita greater than $16,000, the effect is not significant, but this could result from the small number of observations. On the other hand, the effect of undervaluation on growth appears to be high and robust for low-income countries. Columns (1) to (3) show that for countries with GDP per capita less than $6000 the effect of undervaluation tends to increase as income per capita decreases. Overall, the evidence in Table 3 suggests that the asymmetry between developed and developing countries may depend critically on the choice of the GDP per capita cut-off. We return to this issue shortly.

To analyze whether there is an asymmetry between developing and developed countries we use two alternative classifications. First, a relatively standard classification defines developed countries as those belonging to a group of 23 countries typically considered industrialized.[12] We refer to this as 'classification I.' One potential objection to this classification is its static nature: countries are classified as either developed or developing based on their current status. In our sample period that covers 55 years, it is not evident that a country that is now seen as developed would have been considered the same at the beginning of the sample; some European countries in the immediate post-war period come to mind in this regard. Similarly, there might be developing countries, which could have been considered developed at the beginning of the sample. An example is Argentina. In order to provide a more dynamic classification of countries, our second classification, termed 'classification II,' defines developed countries as those which, in a given 5-year period, were at a per capita GDP level at least half of that of the US, excluding those that had a population of less than a million in 2004. Under this classification, some countries are defined as developed (developing) at the beginning but not at the end of the sample.[13]

Table 4 presents estimates of equation (2) for developing countries under classification I. The effect of undervaluation on growth appears to be large and highly significant. The estimates are robust to the use of different control variables. The estimated coefficient reported in columns (1) to (4) remains stable in the range between 0.017 and 0.023 and is always significant at 1%. In regression (5) that includes the rule of law index, the coefficient becomes insignificant, but this seems to be a result of the small number of observations rather than the loss of explicative power due to the new control.[14] When we run the regression using the same control

Table 4. Developing countries (Classification I) : 1950-2004.

Dependent variable: GROWTH (GDP per capita growth)[a,b]							
	(1) Baseline	(2)	(3)	(4)	(5)	(6) 1950-1979	(7) 1980-2004
Ln RGDPCH (t-1)	−0.031***	−0.054***	−0.047***	−0.068***	−0.114***	−0.067***	−0.060***
	(−6.20)	(−8.08)	(−4.89)	(−6.74)	(−4.53)	(−5.68)	(−6.22)
Ln UNDERVAL	0.018***	0.023***	0.018***	0.017***	0.022	0.030***	0.013**
	(4.60)	(4.46)	(2.60)	(2.62)	(1.13)	(5.13)	(1.98)
Government consumption		−0.064	−0.088*	0.006	−0.176**		
(share of GDP)		(−1.65)	(−1.72)	(0.11)	(−2.10)		
Ln (CPI_t/CPI_{t-1})		−0.004***	−0.002**	−0.004***	−0.011**		
		(−3.58)	(−2.37)	(−3.80)	(−2.01)		
Gross domestic saving (Residuals)		0.118***	0.082**	0.144***	0.160***		
		(4.46)	(2.16)	(5.62)	(2.99)		
Openness		0.017**	0.022*	0.017	−0.007		
(Exports+imports as share of GDP)		(2.11)	(1.92)	(1.61)	(−0.40)		
Ln (RER volatility)		−0.003**	−0.001	−0.003	−0.002		
		(−2.24)	(−0.59)	(−1.61)	(−0.56)		
External debt		−0.018***	−0.022**	−0.020**	0.014		
(share of GNI)		(−3.15)	(−2.50)	(−2.28)	(0.99)		
Ln terms of trade			−0.001				
			(−0.13)				
Average years of education				−0.001			
				(−0.23)			
Rule of law					−0.004		
					(−0.59)		
Time dummies	yes	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes	yes	yes
Adjusted R-squared	0.32	0.55	0.58	0.56	0.72	0.58	0.40
Number of countries	158	112	85	66	110	128	158
Observations	1077	540	332	315	213	371	706

[a] Robust *t*-statistics are in parentheses, *p<0.10, **p<0.05, ***p<0.01.
[b] All regressions exclude observations for Iraq, Democratic Rep. of Korea and Laos.

variables as in column (2), but only for the periods for which there are data for the rule of law index, the coefficient and *t*-statistic ($\hat{\delta} = 0.023$ (1.27)) are similar to those from regression (5).[15] The effect of undervaluation is also robust to changes in the sample period. We split the sample in two sub-periods: 1950–1979 and 1980–2004. This split gives sub-periods of the same length; it also separates the pre- and post-financial globalization eras and the pre- and post-developing country debt crisis periods. The coefficient is significant in both sub-periods although it varies from 0.031 to 0.013.[16] Overall, the results in this table provide strong evidence that the effect of RER undervaluation on growth is large and significant for developing countries.

Table 5 reproduces the same analysis for developed countries under classification I. The results are not as conclusive as those for developing countries. This may partly result from the smaller sample size. In the baseline regression, ln*UNDERVAL* is significant at 1% and with an estimated coefficient of 0.017. Given the relatively small sample size, we introduced control variables one at a time. In the regressions reported in columns (2) to (8), ln*UNDERVAL* appears to be significant between 1% and 10% and its estimated coefficient remains stable in the 0.012–0.019 range, below that found for developing countries. When using terms of trade, i.e., column (9), and the rule of law index, i.e., column (10), as controls, ln*UNDERVAL* is not significant. When we control for changes in the terms of trade, the estimated coefficient actually turns negative. Finally, once we divide the sample into two periods, ln*UNDERVAL* is not significant although the estimates are within the range of previous estimations.

Table 6 reports robustness checks for the presence of outliers and endogeneity/simultaneity. The positive relationship between ln*UNDERVAL* and economic growth observed in previous tables could be driven by some extreme observations of the undervaluation index. Columns (1)–(3) and (6)–(8) show growth regressions for successively narrower ranges of ln*UNDERVAL* for both developing and developed countries under classification I. For the former, we used a regression including relevant control variables; for the latter we opted for the baseline growth regression that provides more degrees of freedom. In both groups of countries, the estimated coefficient is robust to changes in the range of ln*UNDERVAL*, although for developing countries the coefficient is higher and more significant.

The real exchange rate is arguably determined jointly with other variables, and simultaneity problems could potentially make the estimated coefficients inconsistent. Ideally this problem could be ameliorated with the use of instrumental variables, but it is difficult to imagine regressors that affect the real exchange rate without having at the same time an impact on the rate of growth. To address the issue of endogeneity we therefore follow a dynamic panel approach using the generalized method of moments (GMM), which is common practice in growth regressions. Columns (4)–(5) and (9)–(10) in Table 6 report both the difference and system GMM estimates for both groups of countries under classification I.[17] Reassuringly, the coefficients of ln*UNDERVAL* are in line with those reported in previous tables. For developing countries, the estimated coefficient lies in the 0.022–0.025 range and is always significant at 1%. For developed countries, it lies in the 0.014–0.019 range and is significant at 5–10%.

We reproduced the same analysis using classification II and obtained very similar results to those presented in Tables 4 to 6. The only noteworthy difference is that, for developed countries, the coefficient on ln*UNDERVAL* appears statistically

Table 5. Developed countries (Classification I): 1950-2004.

	Dependent variable: GROWTH (GDP per capita growth)[a,b]											
	(1) Baseline	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11) 1950-1979	(12) 1980-2004
Ln RGDPCH (t-1)	−0.037***	−0.040***	−0.037***	−0.048***	−0.041***	−0.049***	−0.049***	−0.045***	−0.026	−0.048	−0.034***	−0.025
	(−5.38)	(−6.08)	(−5.31)	(−5.64)	(−5.87)	(−6.84)	(−6.75)	(−3.68)	(−0.77)	(−1.37)	(−3.05)	(−1.00)
Ln UNDERVAL	0.017***	0.012*	0.016**	0.017**	0.014**	0.019***	0.017***	0.017**	−0.012	0.032	0.018	0.017
	(2.76)	(1.91)	(2.51)	(2.28)	(2.20)	(3.21)	(2.66)	(2.33)	(-1.02)	(1.43)	(1.64)	(1.51)
Openness (Exports+imports as share of GDP)		0.038*** (3.44)										
Ln (RER volatility)			−0.001 (−0.47)				−0.001 (−0.72)					
Government consumption (share of GDP)				−0.178*** (−2.63)			−0.056 (−1.06)					
Average years of education					−0.001 (−0.57)							
Gross domestic saving (Residuals)						0.142*** (6.16)	0.136*** (6.01)					
Ln (CPI_t/CPI_{t-1})								−0.003 (−0.41)				
Ln terms of trade									−0.032* (−1.70)			
Rule of law										0.033*** (3.97)		
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Adjusted R-squared	0.55	0.60	0.55	0.60	0.64	0.72	0.72	0.52	0.27	0.80	0.71	0.25
Number of countries	23	23	23	23	22	23	23	23	18	23	23	23
Observations	226	226	223	202	194	182	179	178	86	46	111	115

[a] Robust *t*-statistics are in parentheses, *p<0.10, **p<0.05, ***p<0.01.
[b] All regressions exclude observations for Iraq, Democratic Rep. of Korea and Laos.

Table 6. Robustness checks for outliers and simultaneity (Classification I): 1950-2004.

Dependent variable: GROWTH (GDP per capita growth)[a,b]										
	Developing countries (classification I)					Developed countries (classification I)				
	(1) −1.0<lnUnd<1.0	(2) −0.8<lnUnd<0.8	(3) −0.6<lnUnd<0.6	(4) D-GMM	(5) S-GMM	(6) −1.0<lnUnd<1.0	(7) −0.8<lnUnd<0.8	(8) −0.6<lnUnd<0.6	(9) D-GMM	(10) S-GMM
Ln RGDPCH (t-1)	−0.057***	−0.057***	−0.056***	−0.108***	−0.047***	−0.037***	−0.037***	−0.040***	−0.091***	−0.044***
	(−8.67)	(−8.35)	(−7.79)	(−8.84)	(−6.68)	(−5.38)	(−5.15)	(−5.99)	(−5.48)	(−6.15)
Ln UNDERVAL	0.023***	0.022***	0.016**	0.022***	0.025***	0.017***	0.011*	0.017***	0.019*	0.014**
	(4.13)	(3.37)	(2.43)	(3.77)	(5.07)	(2.76)	(1.88)	(3.00)	(1.92)	(2.02)
Government consumption	−0.058	−0.055	−0.067*	−0.051	−0.069*					
(share of GDP)	(−1.50)	(−1.41)	(−1.77)	(−1.13)	(−1.88)					
Ln (CPI_t/CPI_{t-1})	−0.003***	−0.003***	−0.003***	−0.002**	−0.003***					
	(−3.24)	(−3.22)	(−3.17)	(−2.09)	(−3.30)					
Gross domestic saving (Residuals)	0.129***	0.131***	0.126***	0.110***	0.092***					
	(5.23)	(5.10)	(4.61)	(3.46)	(3.87)					
Openness	0.015*	0.015*	0.009	0.011	0.018**					
(Exports+imports as share of GDP)	(1.89)	(1.80)	(1.06)	(0.68)	(1.97)					
Ln (RER volatility)	−0.003**	−0.003*	−0.002	−0.001	−0.002					
	(−2.06)	(−1.74)	(−1.05)	(−1.24)	(−1.38)					
External debt	−0.020***	−0.021***	−0.021***	−0.019**	−0.023***					
(share of GNI)	(−3.52)	(3.56)	(3.48)	(−2.48)	(−3.87)					
GROWTH (t-1)				−0.014	0.026				−0.080	0.031***
				(−0.30)	(0.53)				(−1.07)	(3.90)
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	–	–	yes	yes	yes	–	–
Instrument rank	–	–	–	20	47	–	–	–	18	18
J-statistic	–	–	–	8.37	36.51	–	–	–	10.90	10.58
Sargan test (p-value)	–	–	–	0.14	0.27	–	–	–	0.14	0.16
Adjusted R-squared	0.56	0.55	0.56	–	–	0.55	0.55	0.64	–	–
Number of countries	110	109	101	95	95	23	23	23	23	110
Observations	527	515	470	405	405	226	219	190	180	213

[a] Robust *t*-statistics are in parentheses, *p<0.10, **p<0.05, ***p<0.01.
[b] All regressions exclude observations for Iraq, Democratic Rep. of Korea and Laos.

indistinguishable from zero in both the difference and system GMM estimations. Table 7 presents a summary of the results using classification II; the whole set of results using this classification is available on request.

So far, the findings based on our two classification criteria provide evidence that the effect of undervaluation on growth is stronger for developing countries. A potential problem with our results, however, is that the sample size is substantially larger for developing countries under both classifications rendering the comparison between countries not entirely reliable. An alternative strategy to evaluate asymmetric results between countries and avoid the sample-size problem is to introduce interaction terms between undervaluation and income. Rodrik (2008) makes ln*UNDERVAL* interact with real GDP per capita (*RGDPCH*) and finds that the effect of undervaluation decreases monotonically with income level. Column (7) in Table 2 replicates Rodrik's finding. Our estimated coefficients are almost identical to those obtained by Rodrik. According to these, the effect of ln*UNDERVAL* turns negative at levels of GDP per capita above $17,548.

Table 3, however, suggests a closer look. Recall that the effect of undervaluation on growth in developing countries increases as we reduce the upper limit on income from $6000 to $2500. Recall also that something roughly similar happens for developed countries as we raise the lower bound on income from $6000 to $16,000. Is it possible that the finding of linear interaction is masking underlying discontinuities?

Tables 8 and 9 split the countries into three categories. Table 8 does this by dividing countries evenly into the low, middle, and high-income terciles. Columns (2)–(4) present the estimates obtained in the absence of control variables other than lagged per capita GDP and ln*UNDERVAL*. The coefficient on the latter variable is significant (and much larger) only for the lowest tercile. Columns (6)–(8) repeat the same analysis but now with additional controls. The pattern still holds, although the coefficient on the middle tercile is now significant (if small) at the 10% level. Columns (9)–(11) present results based on a slightly different classification. Instead of dividing the countries evenly into three groups, we now define the lowest 25% of countries by income as low income, the top 25% as high income, and the middle 50% ones as middle income. The coefficients on ln*UNDERVAL* for the low and high income countries are now significant (at the 1 and 5% levels, respectively), and of a similar magnitude.

Table 9 repeats the exercise but now makes the split between countries according to their income relative to the US. The results are similar to those discussed for Table 8 but stronger in the sense that the coefficients on ln*UNDERVAL* are always significant at the 5% level for the highest income group and larger and significant at 1% for the poorest. For the middle income group the effect is statistically indistinguishable from zero.

In sum, contrary to our (and Rodrik's) finding of a linear interaction between *RGDPCH* and undervaluation, closer analysis suggests a non-monotonic relation with the effect of undervaluation on growth being strongest for the low-income countries but also significant for high-income countries. It appears to be non-existent for middle-income countries. Given that, to our knowledge, no previous paper has predicted such a pattern, this non-monotonocity presents both a theoretical and empirical puzzle.

Table 7. Developed and developing countries (Classification II) : 1950-2004.

Dependent variable: GROWTH (GDP per capita growth)[a,b]										
	Developing countries (classification II)					Developed countries (classification II)				
	(1) Baseline	(2)	(3) -0.8<lnUnd<0.8	(4) D-GMM	(5) S-GMM	(6) Baseline	(7)	(8) -0.8<lnUnd<0.8	(9) D-GMM	(10) S-GMM
Ln RGDPCH (t-1)	−0.032***	−0.055***	−0.057***	−0.109***	−0.047***	−0.053***	−0.059***	−0.056***	−0.078***	−0.041***
	(−6.04)	(−8.09)	(−8.35)	(−8.88)	(−6.74)	(−7.83)	(−8.53)	(−7.73)	(−5.45)	(−6.50)
Ln UNDERVAL	0.018***	0.023***	0.022***	0.023***	0.025***	0.016***	0.013**	0.011**	0.008	−0.001
	(4.57)	(4.48)	(3.40)	(3.86)	(5.13)	(3.19)	(2.26)	(2.17)	(0.82)	(−0.13)
Government consumption		−0.065*	−0.055	−0.056	−0.069*					
(share of GDP)		(−1.66)	(−1.42)	(−1.23)	(−1.86)					
Ln (CPI_t/CPI_{t-1})		−0.004***	−0.003***	−0.002*	−0.003***		0.002			
		(−3.53)	(−3.16)	(−1.88)	(−3.26)		(1.32)			
Gross domestic saving (Residuals)		0.117***	0.131***	0.109***	0.092***		−0.004			
		(4.43)	(5.08)	(3.39)	(3.87)		(−0.08)			
Openness		0.017**	0.015*	0.011	0.018*					
(Exports+imports as share of GDP)		(2.10)	(1.79)	(0.68)	(1.96)					
Ln (RER volatility)		−0.003**	−0.003*	−0.002	−0.002		0.106***			
		(−2.27)	(−1.78)	(−1.30)	(−1.42)		(4.63)			
External debt		−0.018***	−0.021***	−0.019**	−0.023***					
(share of GNI)		(−3.16)	(−3.57)	(−2.51)	(−3.86)					
GROWTH (t-1)				−0.014	0.029				−0.173**	0.252**
				(−0.30)	(0.60)				(-2.05)	(2.52)
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	–	–	yes	yes	yes	yes	yes
Instrument rank	–	–	–	20	47	–	–	–	18	31
J-statistic	–	–	–	7.70	38.42	–	–	–	15.01	24.44
Sargan test (p-value)	–	–	–	0.17	0.20	–	–	–	0.04	0.22
Adjusted R-squared	0.32	0.55	0.55	–	–	0.55	0.74	0.67	–	–
Number of countries	165	112	109	95	95	28	26	28	26	26
Observations	1093	538	513	403	403	210	174	203	173	173

[a] Robust *t*-statistics are in parentheses, *p<0.10, **p<0.05, ***p<0.01.
[b] All regressions exclude observations for Iraq, Democratic Rep. of Korea and Laos.

Table 8. All countries: 1950-200. Grouping based on actual GDP per capita.

Dependent variable: GROWTH (GDP per capita growth)[a,b]											
	All sample (1)	Low <0.33 (2)	Middle (3)	High >0.66 (4)	All sample (5)	Low <0.33 (6)	Middle (7)	High >0.66 (8)	Low <0.25 (9)	Middle (10)	High >0.75 (11)
Ln RGDPCH (t-1)	−0.030***	−0.054***	−0.060***	−0.056***	−0.051***	−0.056***	−0.078***	−0.073***	−0.058***	−0.062***	−0.088***
	(−6.57)	(−4.27)	(−5.25)	(−6.44)	(−9.29)	(−4.99)	(−8.16)	(−6.31)	(−4.25)	(−8.26)	(−6.98)
Ln UNDERVAL	0.015***	0.035***	0.007	0.007	0.007**	0.036***	0.013*	0.005	0.035***	0.005	0.032**
	(4.44)	(5.37)	(1.04)	(0.83)	(2.12)	(5.13)	(1.74)	(0.40)	(4.43)	(0.90)	(2.43)
Government consumption (share of GDP)					0.010	−0.002	−0.005	0.144*	0.003	−0.059	0.145
					(0.23)	(−0.06)	(−0.08)	(1.85)	(0.08)	(−1.06)	(1.52)
Ln (CPI_t/CPI_{t-1})					−0.004***	−0.004**	−0.004**	−0.000	−0.004*	−0.005***	0.002
					(−4.04)	(−2.69)	(−2.58)	(−0.12)	(−1.94)	(−3.86)	(0.40)
Gross domestic saving (Residuals)					0.117***	0.0.81***	0.130***	0.133***	0.108***	0.140***	0.166***
					(5.61)	(2.80)	(4.06)	(3.62)	(3.79)	(5.94)	(2.75)
(Exports+imports as share of GDP)					(3.16)	(0.16)	(−0.15)	(3.65)	(0.25)	(1.27)	(2.87)
Ln (RER volatility)					−0.003**	−0.005***	−0.002	0.002	−0.004	−0.002	0.002
					(−2.21)	(−2.73)	(−1.09)	(0.80)	(−1.45)	(−1.32)	(0.57)
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Adjusted R-squared	0.34	0.38	0.47	0.51	0.53	0.57	0.62	0.64	0.58	0.61	0.61
Number of countries	181	75	96	78	155	70	75	59	50	97	43
Observations	1303	434	435	434	853	284	285	284	213	427	213

[a]Robust *t*-statistics are in parentheses, *p<0.10, **p<0.05, ***p<0.01.
[b]All regressions exclude observations for Iraq, Democratic Rep. of Korea and Laos.

Table 9. All countries: 1950-200. Grouping based on GDP per capita relative to the US.

	Dependent variable: GROWTH (GDP per capita growth)[a,b]										
	All sample	Low <0.33	Middle	High >0.66	All sample	Low <0.33	Middle	High >0.66	Low <0.25	Middle	High >0.75
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Ln RGDPCH (t-1)	−0.030***	−0.046***	−0.050***	−0.059***	−0.051***	−0.058***	−0.070***	−0.078***	−0.051***	−0.056***	−0.091***
	(−6.57)	(−4.16)	(−5.25)	(−6.63)	(−9.29)	(−6.35)	(−7.73)	(−8.86)	(−4.10)	(−8.34)	(−8.66)
Ln UNDERVAL	0.015***	0.031***	0.003	0.018**	0.007**	0.036***	0.009	0.022**	0.037***	0.003	0.027**
	(4.44)	(4.82)	(0.46)	(2.51)	(2.12)	(5.10)	(1.23)	(2.22)	(4.44)	(0.57)	(2.42)
Government consumption (share of GDP)					0.010	−0.021	−0.091	0.123*	−0.004	−0.072	0.095
					(0.23)	(−0.52)	(−1.37)	(1.87)	(−0.10)	(−1.44)	(1.23)
Ln (CPI_t/CPI_{t-1})					−0.004***	−0.004**	−0.005***	−0.004**	−0.003*	−0.005***	0.002
					(−4.04)	(−2.43)	(−2.77)	(−2.11)	(−1.83)	(−3.71)	(0.52)
Gross domestic saving (Residuals)					0.117***	0.0.96***	0.143***	0.129***	0.0.84***	0.143***	0.134***
					(5.61)	(3.26)	(4.48)	(4.34)	(2.81)	(5.77)	(3.10)
Openness (exports+imports as share of GDP)					0.025***	0.029*	-0.001	0.036***	0.012	0.010	0.029**
					(3.16)	(1.85)	(-0.11)	(3.34)	(0.76)	(1.33)	(2.26)
Ln (RER volatility)					−0.003**	−0.005**	−0.001	0.002	−0.002	−0.002	0.002
					(−2.21)	(−2.37)	(−0.74)	(1.27)	(−0.78)	(−1.13)	(1.02)
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Adjusted R-squared	0.34	0.36	0.41	0.50	0.53	0.57	0.62	0.64	0.50	0.61	0.64
Number of countries	181	75	94	65	155	66	70	51	51	90	39
Observations	1303	434	435	434	853	284	285	284	213	427	213

[a] Robust *t*-statistics are in parentheses, *p<0.10, **p<0.05, ***p<0.01.
[b] All regressions exclude observations for Iraq, Democratic Rep. of Korea and Laos.

Conclusion

Recent research has found a positive relationship between RER undervaluation and economic growth. Different rationales for this association have been offered, but they all imply that the mechanisms involved should be more prevalent in developing countries. Rodrik (2008) finds evidence that the RER–growth relationship is indeed more prevalent in developing countries and that, interacting the index of RER undervaluation with the level of GDP per capita, the effect of currency undervaluation tends to decrease linearly with the latter.

In this paper we show that Rodrik's findings are sensitive to the criterion for dividing the sample between developed and developing countries. Overall, using alternative classification criteria and empirical strategies to evaluate the existence of asymmetries between groups of countries we confirm that the effect of currency undervaluation on growth is larger and more robust for developing countries. But further analysis also suggests that this finding masks an important non-monotonicity. Although, the effect of undervaluation on growth appears to be largest for very poor countries, it is significant for the highest-income countries as well. The contrasting behavior of middle-income countries presents a puzzle, which, if it proves robust to alternative specifications and variable definitions, must be addressed by future theoretical and empirical analysis.

Notes

1. See, for instance, Porcile and Lima (2010) and Razmi, Rapetti, and Skott (2012).
2. Berg and Miao (2010) also test the robustness of Rodrik's result to an alternative specification of the real exchange rate and derive similar estimates. Their classification criterion for developing and developed is the same as Rodrik's.
3. Ideally, one would like to use effective real exchange rates because they provide a more precise measure of the degree of international competitiveness of a country. We decided to use bilateral rates against the US dollar due to data availability issues: there are no large data sets of effective RERs. This choice should not be problematic. Effective RERs and bilateral RERs against the US are highly correlated in developing countries. Moreover, effective RERs are typically less volatile than bilateral RER against the US. This is the case because shocks affecting the latter tend to affect trade partners in the same region similarly (e.g., a shock that makes the Argentine peso depreciate against the US dollar will typically generate depreciation pressures on the Brazilian real against the US dollar). This makes bilateral rates against regional trade partners (and, hence effective RERs) less volatile. Given the lower volatility of effective RERs, the use of bilateral RERs against the US will – if anything – underestimate the effect of exchange rate undervaluation on growth. Thus, our results could be interpreted as a lower bound on the effect of RER undervaluation on growth.
4. Rodrik reports that ln*UNDERVAL* has a zero mean and standard deviation of 0.48.
5. Also following Rodrik, we exclude from the sample three countries with extreme values of ln*UNDERVAL*: Iraq, the Democratic Republic of Korea and Laos. Former COMECON countries and Eurozone countries are included within this group of 181 countries. For Eurozone countries, RERs are calculated using relative prices and individual exchange rates for the pre-euro period and the euro exchange rate for the post-euro period. For former COMECON countries data on bilateral RERs begin in the following five-year periods: 1955–59 (Romania), 1965–69 (Hungary), 1970–74 (Bulgaria and Poland), 1980–84 (Czech Republic) and 1990–94 (Russia). Our results are not affected if the early (pre Soviet collapse) observations for COMECON countries are excluded from the data set.
6. Since saving decisions are likely to be affected by the real exchange rate, *UNDERVAL* and the saving rate (*GDSGDP*) are expected to be highly collinear. To correct for multicollinearity, we estimated the effect of undervaluation on the saving rate

($GDSGDP_{it} = \alpha + \beta\ lnUNDERVAL_{it} + f_t + f_i + \varepsilon_{it}$) and then used the residuals of this regression as a control variable. With this methodology the coefficient on ln*UNDERVAL* captures its direct effect on the dependent variable (*GROWTH*) and its indirect effect through the saving rate. The coefficient on the residuals captures the effect of the saving rate on the dependent variable, net of the effect of ln*UNDERVAL*.

7. We also explored lagged effects of ln*UNDERVAL* but found these to be insignificant in the baseline regression.
8. As pointed out by a referee, the inclusion of country fixed effects can lead to problems of interpretation. Country fixed effects are needed to capture the incidence of idiosyncratic time invariant factors on the dependent variable. Together with the constant term (α), the fixed effect (f_i) in equation (2) provides an estimation of each country's average trend growth rate over the sampling period. Since trend or potential growth rates are unobservable, econometric studies have typically used five-year averages (or even lower frequencies) to get a proxy of trend GDP growth rates, and thus 'clean' the series from short-run cyclical movements (see Durlauf, Johnson, and Temple 2006, for a detailed discussion of this issue). The presence of an intercept term and country fixed effects in combination with the five-year averages enables us to identify the effect of changes in the degree of RER undervaluation on long-term or potential GDP per capita growth on the basis of within country variation.
9. Rodrik's estimated coefficient of ln*UNDERVAL* is $\hat{\delta} = 0.017$ and it is significant at 1%.
10. Rodrik does not add control variables to the regression using the whole sample; hence, no direct comparison is possible.
11. For countries with GDP per capita less than a cutoff in the range of $6000–$16,000, the estimated coefficient is between 0.024 and 0.017 and always significant at 1%. An appendix with details is available on request.
12. The countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States. Other studies have followed a similar classification. See, for example, Prasad, Rajan, and Subramanian (2007).
13. According to classification I, there are (11×23=) 253 observations for developed countries. The number changes to 226 under classification II. Of these, 196 are common. The lists of developed countries according to both criteria are presented in the available-on-request appendix.
14. Data for the rule of law index are available only for two periods: 1995–99 and 2000–2004.
15. Given the lack of explanatory power of the rule of law variable, one could simply decide not to include it in the regression analysis. We report the result because it is a control variable that is commonly used in growth regressions (Durlauf, Johnson, and Temple 2006).
16. We obtained the same coefficients at the same significance level when dividing the sample in an alternative split for the pre- and post-globalization eras: 1950–74 and 1975–2004.
17. For the difference (D-GMM) and system (S-GMM) estimators we followed Arellano and Bond (1991) and Arellano and Bover (1995), respectively. In both cases, we used 2-step period seemingly unrelated regressions (SUR) weights to correct for period heteroskedasticity and general correlation of observations within cross-sections.

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