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REAL EXCHANGE RATE AND ECONOMIC GROWTH: NEW EMPIRICAL EVIDENCE

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ABSTRACT

The article empirically analyses the relationship between real exchange rate (RER) and growth rate of output. We first estimate the effect of the index of RER undervaluation on the rate of output growth in two samples of countries from 1978 to 2007. Our contribution is the use of a different dataset that increases the number of countries in the sample, as well as the number of available control variables. In doing so, the article adds to the literature by applying a method that allows for the control of income levels (quantile regressions). So, we present new findings on a non-linear relationship the RER-growth nexus. We conclude that maintaining a competitive level of RER has positive effects on growth rate.

1. INTRODUCTION

The relationship between real exchange rate (RER) and economic growth has been the subject of great controversy in the economic literature. Theoretical approaches vary from the absence of any interaction between these variables, to a positive association, and even to a negative one. At the same time, econometric tests to date have provided ambiguous results, allowing for staunch support for any of the three stances. The topic has recently returned to the fore of academic debate following Rodrik's (2008) presentation of new

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transmission mechanisms between variations in the exchange rate policy and output growth. Since then, a series of empirical works motivated by the contrast between growth trajectories of Southeast Asian, African and Latin American countries have been published. They suggest a close connection between a competitive exchange rate and economic performance (Dollar, 1992; Eichengreen, 2007; Rodrik, 2008; Razmi et al., 2009).

We can identify at least two different approaches to establishing the relationship aforementioned. The first shows that an undervalued RER promotes resource reallocation from the non-tradable to the tradable sector, which is an important locus of learning-by-doing externalities and technological spillovers (Eichengreen, 2007; Rodrik, 2008; Rapetti et al., 2012). The other explanation emphasizes the role of competitive RER in relaxing the foreign exchange constraint on growth (FX).[1] The novelty in this article is to perform a series of growth regressions in order to shed light on this issue.

The literature that emphasizes the role of competitive RER in relaxing the FX highlights the fact that a competitive level of the RER spurs investment through structural change, which, in turn, relaxes the balance-of-payments constraints. Therefore, exchange rate policy can affect growth not only by improving short run competitiveness but also by increasing incentives to invest and to foster technological development. Indeed, as Missio and Jayme (2012), Ferrari et al. (2013) and Bresser-Pereira et al. (2015, chapter 4) highlighted, the level of RER can affect long run economic growth through its endogenous effects on income elasticities of exports and imports, as well as through changes in short run price elasticities.

From an empirical viewpoint, studies that run standard growth regressions using some index of RER misalignment have used two approaches. The first defines equilibrium RER as the purchasing power parity level adjusted for the Balassa–Samuelson effect (PPP-based). The second relies on either single equation or general equilibrium macroeconometric models, in which the estimated equilibrium RER depends on economic fundamentals.

This study uses the PPP-based approach and provides a comprehensive empirical assessment of the association between RER levels and economic growth. Thus, the first contribution of this article is to provide additional evidence, using quantile regressions, that competitive RER levels tend to be associated with faster economic growth. The main findings of many recent studies can be summarized as follows: (1) RER levels and growth are positively associated (Rodrik, 2008; Rapetti et al. 2012); (2) the relationship is

[1] Both narratives share a common feature: the mechanisms involved are characteristic of developing countries (Rapetti et al., 2012, p. 736).

stronger in developing countries (Rodrik, 2008; Rapetti et al., 2012); and (3) the relationship is non-linear, implying that moderated undervaluations spur growth but high undervaluations undermine it (Aguirre and Calderón, 2005; Rodrik, 2008; Bereau et al., 2012).

Regarding the relationship between growth and RER levels, our contribution is the use of a different dataset that increases the number of countries in the sample, as well as the number of available control variables. The larger sample enables improved estimates, particularly in regards to distinct interactions between the undervaluation index and growth rates between groups of countries. Moreover, the article undertakes painstaking efforts to apply econometric methods that ensure the robustness of the results.

In doing so, the article adds to the literature by applying a method that allows for the control of income levels, hence avoiding possible estimation bias stemming from *ad hoc* groupings of countries. Furthermore, it shows that the non-linear relationship between undervaluation and growth remains even when the fundamentals-based indices are replaced by PPP-based indices.

The article also presents new findings on a non-linear relationship among the variables of interest by performing quantile regressions. These findings are new to the literature because quantile regressions enable identification of sign changes in estimated coefficients. The non-linearities in the relationship between the RER and growth are important. For instance, depending on a country's income level, small devaluations may be linked with higher growth rates.

The article is divided into three sections, not including the introduction and conclusions. Section 2 reviews new research on the role of the exchange rate in the balance-of-payments constrained growth model (BPCG), highlighting the transmission mechanisms through which RER can affect the productive structure and, consequently, the income elasticity of demand exports and imports, relaxing the foreign constraint and stimulating economic growth. Section 3 presents the methodology, the database and the estimates of the undervaluation index. Finally, section 4 presents the results of the quantile regressions.

2. EXCHANGE RATE IN A BPCG MODEL: THE ENDOGENEITY OF INCOME TRADE ELASTICITIES

The post-Keynesian literature has largely neglected the relationship between RER and growth. In BPCG, originally developed by Thirlwall (1979), the long-term equilibrium growth rate depends on the ratio between the income elasticity of exports (ε) and imports (π) multiplied by the growth rate of the income of the rest of the world. Variations in RER are assumed to be irrelevant for long-term growth, because empirical evidence shows that either price elasticities of exports and imports are low, meaning that the impact of a real devaluation of the exchange rate on the growth rate of exports and imports is small, or that terms of trade do not show a systematic trend in the long run (McCombie and Roberts, 2002, p. 92).

In the long run, as Thirlwall (2002) points out, the solution to improving a country's growth rate compatible with the intertemporal balance of payments equilibrium is structural change that increases ε and reduces π. Indeed, in the canonical model, causality runs from elasticities to growth, which is the basic assumption of classical centre-periphery models, such as Prebisch (1950), Myrdal (1957), Seers (1962) and Kaldor (1970).

Pasinetti (1981, 1993) clarifies the idea of structural economic dynamics by demonstrating that changes in the production structure lead to variations in growth rates given different sectoral demand growth rates. Each sector has a particular capacity (different elasticities) of benefitting from the growth of the economy. Araújo and Lima (2007) integrated this idea into a formal model analogous to Thirwall's, which maintains Pasinetti's multi-sectoral dynamics. Its final result, the multi-sectoral Thirlwall's Law, shows that the growth rate of a country's per capita income is directly proportional to the growth rate of its exports (the sectoral income elasticity of demand multiplied by the growth rate of the world economy), and inversely related to the sectoral income elasticity of the demand for imports, with both elasticities weighted by the relative participation of the sectors in foreign trade.[2]

However, most of these analyses do not explore the effects that variations of RER might have on capital accumulation and technological innovation. They suppose that the channels that affect the production structure are given by the stimuli that variations in the RER produce on demand and/or the wage structure. Although important, we believe that they do not comprise all of the effects.

The hypothesis of the endogeneity of income elasticities of exports and imports goes further in a multi-sector Thirlwall's Law framework, by including the effects of RER level on growth. That is, it helps us to understand more precisely the determinants of the elasticities mentioned above because it shows that changes in the productive structure lead to changes

[2] Gouvêa and Lima (2010) investigate how structural change, seen as changes in the sectoral composition of exports and/or imports, affects the strength of the balance-of-payments constraint. They do so by estimating the Multi-sectoral Thirlwall's Law for eight countries during the 1962–2006 period, and demonstrate that it is not rejected by any country. In other words, the sectoral composition of exports and imports is important for growth.

in elasticities and, in turn, reduce external constraints. Therefore, policies that promote structural change can stimulate growth.

Accordingly, there is an increasing body of work incorporating endogenous elasticities in BPCG models, such as Palley (2002). In his model, income elasticity of the demand for exports is a negative function of excess capacity because imports are correlated with economic bottlenecks. Provided that excess capacity and unemployment decrease, these bottlenecks increase and the import share of income growth increases. Conversely, McCombie and Roberts (2002) include structural change in Thirlwall's framework by means of hysteresis in the parameters that govern the long run growth rate. In this case, the income elasticity of demand is a non-linear function of past growth rates. Botta (2009), in turn, allows income elasticities of exports (imports) in developing countries to be positively (negatively) correlated with the share of manufactures in domestic output. Therefore, income elasticities are endogenous and strictly connected to the share of manufactures and the pattern of industrialization in developing economies. Finally, Barbosa-Filho (2006), Missio et al. (2013) and Missio et al. (2014) point out the relationship between endogenous elasticities and RER level.

According to Missio and Jayme (2012), the starting point is observing that RER level can influence the productivity and the production structure of an economy, hence modifying specialisation and competitiveness patterns through other mechanisms. We argue that the 'new' mechanisms imply that maintaining a competitive RER might induce technical progress in the industrial sector. More specifically, currency devaluation—insofar as it increases the profits of companies and their self-financing capacity—affects funds available for these companies to carry out investment projects related to research and innovation.[3]

The argument states that overvaluation of RER is associated with income redistribution from profits to wages, which implies a decrease in the self-financing capacity of companies. This entails a decrease in the availability of funds for acquiring new technologies and greater restriction of access to third-party financing, due to the information asymmetry of financial markets that leads to credit rationing. Hence, even given the possibility of acquiring cheap technology from abroad, it is likely that many sectors will remain incapable of investing in modernization of their production

[3] The empirical literature shows that the main determinants of R&D expenditures and investment in physical capital are cash flow and number of sales (Hall, 1992; Himmelberg and Petersen, 1994; Bond et al., 1999). The point is that these are two variables positively affected by devaluations of the RER.

capacity. It is, therefore, by maintaining a competitive exchange rate that companies are expected to undertake innovative activities leading to a greater productive heterogeneity (e.g. a greater variety of produced goods), and also to structural homogenization, since sectors not connected to foreign markets now also incorporate technical progress. Given that the returns to innovative activities are greater in backward sectors, discontinuities are expected to be rapidly overcome.

In this approach, technological change is generated as a result of experience in production (thus, the importance of the connection with the foreign markets), as well as structural production. First, it is associated with the literature about learning-by-doing or cumulative learning as source of technological change, as well as the persistence of growth rate differentials between regions or countries (e.g. Dixon and Thirwall, 1975; Cimoli, 1988). Second, this is also consistent with the structural view and post-Keynesian literature. The industrial composition of an economy interacts with technological change, and may produce different macrogrowth patterns between countries (e.g. La Marca, 2007; Cimoli and Porcile, 2010). As Los and Verspagen (2006) point out, differences among industries may be related to income elasticities, since they present differences in technology. If industries are characterized by different rates of productivity growth or by different rates of demand growth (through income elasticities, e.g.), economic structure becomes important for aggregate economic growth. Missio and Jayme (2012) showed that income elasticities and technological change are dependent of RER.

Thus, despite being neglected in the literature, we suggest that channels that determine the endogeneity of income elasticities of foreign trade are very important. Indeed, to the extent that the income elasticities of exports and imports are endogenous to the RER we allow loosening the balance-of-payments constraints, which are essential for developing economies.

3. EMPIRICAL EVIDENCE ON THE UNDERVALUATION INDEX

In this section, we develop an empirical test that looks at the relationship between the level of RER and economic growth rate for a selected group of countries. In order to do so, we initially estimate an index for the undervaluation of RER, as proposed by Rodrik (2008). This procedure comprises three steps:

i. First, the RER is obtained as following:

$$lnRER_{it} = \ln(XRAT_{it}/PPP_{it}) \tag{3.1}$$

where RER_{it} is the real exchange rate; $XRAT_{it}$ is the nominal exchange rate expressed in the domestic currency; PPP_{it} is the conversion factor (purchasing power parity); ln is the natural logarithm and i and t are the indices for countries and time-periods, respectively. When RER_{it} is greater than unity, the current value of the currency is smaller (undervalued) than the value indicated by purchasing power parity.

ii. Second, the RER estimated by the Balassa–Samuelson effect is adjusted, which means that equation (3.1) needs to be corrected by the difference in factor endowments. The *per capita* GDP in dollars (*pibpcd*) is a *proxy* variable for these endowments.

$$\ln RER_{it} = \alpha_1 \ln(pibpcd_{it}) + \mu_t + \eta_i \varepsilon_{it} \tag{3.2}$$

where μ_t is the fixed effect for the time-periods; η_t is the fixed effect for the countries and ε_{it} is the error term.

iii. Last, the undervaluation index is calculated by taking the difference between the actual exchange rate and the exchange rate adjusted for the Balassa–Samuelson effect.

$$Undervalued_{it} = \ln RER_{it} - \ln \overline{RER}_{it} \tag{3.3}$$

where $Undervalued_{it}$ is the exchange rate undervaluation index and $\ln RER_{it}$ is the values obtained in equation (3.2).
The index, thus, defined is comparable across countries and over time. If its value exceeds unity, the exchange rate is such that domestic prices are cheaper than in the currency of reference (the dollar)—i.e. the domestic currency is undervalued. However, since we use the logarithmic transformation, this index is centred at zero.

Based on this index, it is possible to explore the relationship between the level of the RER and the *per capita* growth rate of the selected countries, through the econometric exercise presented below.

3.1 Data and methodology

The sources for the following data analysis are the statistical databases of the International Monetary Fund (IMF), the *World Economic Outlook Database* (WEO) of 2008 and the *International Financial Statistics* of March 2008, available on the IMF website. Data from *Penn World Table* and New York University's *Development Research Institute* (DRI) (2008) was also used. The estimation strategy involves a selection of two different samples of countries, based on data available from 1980 to 2008. More specifically, we used an *unbalanced panel* for a *broad sample* of 103 countries (n) during 29 years (t), and a *balanced panel* for a *reduced sample* comprising 63 countries during the same period.[4] The frequency of data is annual.

The sample ended in 2008 in order to avoid the effects of the 2008 financial crisis on estimation. The volatility of the variables used in this work can affect the estimates and overshadow the results, since the 1987–2008 is much more stable than the subsequent period. In addition, the literature has shown evidence that higher RER levels tend to be associated with higher GDP per capita growth rates. This appears robust to changes in the estimation technique [cross-sectional Ordinary Least Squares (OLS), panel data (fixed and random effects), dynamic panel data (GMM), non-linear panels and panel cointegration techniques]; the number of control variables; and the data sources for both the dependent and independent variables [Penn World Tables, International Financial Statistics, World Development Indicators, Maddison Historical Statistics] (Rapetti, forthcoming).

It must be noted that for some countries the number of observations is severely limited, i.e. the series present many missing values. This traditionally requires the adoption of one of the following strategies: focusing on a restricted sample of countries for a relatively long period, or focusing on a short time span for a large sample of economies. Both alternatives offer challenges, because the former prevents the study of the relationships of interest in the developing and less-developed economies, while the latter neglects the dynamics and the evolution of these relationships. Furthermore, as the missing observations are not taken into consideration when estimating a regression, excluding these observations may cause estimation bias.[5] If there are systematic differences between countries that report data and those that do not, then there is an identification problem. The existence of a sample selection bias means that it may not be possible to make inferences for the totality of countries. Hence, the interpretation of the econometric results must take these limitations into account. Nevertheless,

[4] In the broad sample missing data is under 5 per cent. The countries comprising the samples can be requested by email to authors.

[5] It is possible that presence (or absence) of missing values is not random, which could lead to a specification bias. As mentioned above, in the reduced sample the number of developed countries decreases only very slightly, whilst the number of developing countries is considerably reduced. This suggests that the 'most' adequate sample is the reduced one, which is to say that the emphasis must be put on the results of the estimations based on this sample, since the presence of missing values is, usually, associated with developing countries.

Box 1

Composition of the broad and reduced sample

	Broad sample		*Reduced sample*	
	Number of countries	*Number of Observations (n)*	*Number of countries*	*Number of Observations (n)*
(A) Advanced economies	22	638	20	580
(i) Eurozone	22	638	20	580
(B) Emerging and developing economies	81	2349	43	1247
(i) Latin and Central America	29	841	14	406
(ii) Developing Asia	13	377	10	290
(iii) Sub-Saharan Africa	18	522	11	319
(iv) Central and Eastern Europe	5	145	1	29
(v) Middle East and North Africa	16	464	7	203
Total (A + B)	103	2987	63	1827

Note: classification according to WEO – World Economic, 2010.

it can be considered that the samples are sufficiently encompassing and are representative of different types of international specialization.

Box (1) presents a detailed description of the number of countries, and the number of countries per group, that compose each sample, according to the classification of the *World Economic Outlook*.

The exercise is carried out based on econometric techniques appropriate for this type of data. More specifically, different techniques for panel data (fixed and random effects) are used, as well as the conventional specification and identification tests of the model, namely the F test for the presence of fixed effects, the Breush–Pagan test for the presence of random effects, the Hausman test for the choice of the fixed and random effects models, the Wooldridge serial correlation test[6] and the modified *Wald* test for panel data heteroskedasticity, and the test for including time effects.[7]

[6] A test discussed by Wooldridge (2000) and developed in Stata by Drukker (2003).

[7] For more details on the employed econometric methodology, see Cameron and Trivedi (2005), Greene (2003) and Wooldridge (2000).

The general form of the equation to be estimated is given below. It represents the growth model for panel data:

$$tpibpc_{i,t} = \beta_0 + \beta_2 Undervalued_{it} + \sum_{j=3}^{K} \beta_j Z_{i,tj} + \mu_t + \eta_i + \varepsilon_{i,t} \tag{3.4}$$

where $i = 1,\ldots,N$, $t = 2,\ldots,T$, $j = 3,\ldots K$. The dependent variable (*tpibpc*) is the growth rate of the *per capita* GDP of each country i in the period; *Undervalued* is the undervaluation index of the RER calculated according to Rodrik (2008); Z are the control variables ($K = 6$); $\beta' s$ are the parameters to be estimated; μ_t is the time-specific effect; η_t captures the non-observed effects of each country i that are invariant over time; ε_{it} is the idiosyncratic error term; and the i and t subscripts refer to countries and time-periods, respectively. The time-specific term aims at controlling international conditions that change over time and affect the growth performance of the countries, whereas the non-observable country-specific term captures factors that influence the growth of income and are potentially correlated with the explained variables.[8] table 1 shows variables and data sources used in the econometric exercise.

The control variables used to estimate equation (3.4) follow the literature on this issue (Aguirre and Calderón, 2005; Gala, 2008; Rodrik, 2008; Chen, 2012, McDonald and Vieira, 2014) and can be classified according to the following groups: (i) openness to foreign trade: trade volume divided by the GDP (*openc*); (ii) government liabilities: we use the share of government expenditure in *per capita* GDP (*expend*) as a proxy; and (iii) stabilisation policies: the average inflation rate (*tinfla*).

In addition, following Verspagen (1993), we use the ratio between its *per capita* GDP and that of the United States as proxy for *technological gap* (*gap*). More specifically, the value of the *per capita* GDP of the United States is considered, for defining the *gap*, as the productivity of the technological leader. Thus, countries close to the technological frontier should grow at slower rates. Moreover, we use as control variables the growth rate of the population (*tcpop*) and the savings rate (*save*). A positive relationship between the dependent variable and *openc* is expected, which would mean that countries that are more open to foreign trade grow at a relatively faster rate.[9] Conversely, the expected sign for the variables *gap*, *expend* and *tcpop*

[8] For capturing the time-specific effect we used dummy variables that, for simplicity, will not be reported.

[9] However, a large number of studies have yielded different empirical findings and various explanations (see Dufrénot et al., 2010).

Table 1. List of the variables in the research

Abbreviation	*Comment*	*Source*
pibpcd	*Per capita* GPD in American dollars	WEO/IMF
Tpibpc	Growth rate of *per capita* GDP	DRI/NYU
Save	Savings as a percentage of GDP (gross national savings/GDP)	WEO/IMF
Xrat	Exchange rate (units of domestic currency for American dollars)	PWT 7.0
Ppp	Purchasing power parity in relation to GDP (in domestic monetary units for American dollars)	PWT 7.0
Undervalued	Undervaluation of the level of the RER index, calculated according to Rodrik (2008)	Own elaboration based on data from PWT 7.0
Openc	Openness percentage (current prices)	PWT 7.0
Gap	*Per capita* GDP converted by PPP in relation to the United States (US=100)	PWT 7.0
expend	Government Consumption Share of PPP Converted GDP Per Capita at 2005 constant prices.	PWT 7.0
Tinfla	Inflation rate (average annual change of the Consumer Price Index)	WEO/IMF
Tcpop	Population growth rate	DRI/NYU
n	Number of observations	_____

Source: Own elaboration.

Notes: DRI, Development Research Institute; NYU, New York University; WEO, World Economic; IFS, International Financial Statistics; and IMF, International Monetary Fund.

is negative, indicating that countries close to the technological frontier, that maintain a higher government consumption share or with high population growth rates tend to grow more slowly.

3.2 Results

We now perform a series of econometric exercises to explore the relationship between the level of the RER and economic growth.[10] The results are reported in table 2. First, we adjusted the model of equation (3.4) using the

[10] The estimation of equation (3.2) suggests a significant presence of the Balassa–Samuelson effect ($\alpha_1 = -0, 505$, $t = -\ 38, 35$).

Table 2. Undervaluation and growth—OLS (pooled regression) × fixed effects × random effects, 1980–2008

	OLS with pooled data (robust)		Panel data (fixed effects)		Panel data (random effects)	
Dependent variable: tpibpc	Broad sample (I)	Reduced sample (II)	Broad sample (III)	Reduced sample (IV)	Broad sample (V)	Reduced sample (VI)
Undervalued	0.46	1.10**	1.09*	1.33**	0.607	1.23**
	(1.26)	(2.88)	(2.26)	(2.62)	(1.75)	(3.01)
save	0.094***	0.10***	0.080***	0.93***	0.85***	0.097***
	(8.40)	(6.98)	(6.31)	(6.41)	(8.27)	(8.0)
openc	0.009***	0.007***	0.016**	0.02***	0.012***	0.012***
	(5.08)	(4.09)	(3.32)	(3.57)	(4.34)	(3.97)
gap	−0.02***	−0.035***	−0.037*	−0.037	−0.028***	−0.035***
	(−5.44)	(−8.44)	(−2.30)	(−1.82)	(−4.66)	(−5.12)
expend	−0.01	−0.036*	−0.175***	−0.24***	−0.045*	−0.086***
	(−0.82)	(−1.73)	(−4.82)	(−5.20)	(−2.26)	(−3.47)
tinfla	−0.0007*	−0.057***	−0.0009***	−0.06***	−0.0008***	−0.058***
	(−2.59)	(−5.73)	(−3.7)	(−7.06)	(−3.40)	(−7.02)
tcpop	−0.64***	−0.79***	−0.425*	−0.62***	−0.56*	−0.73***
	(−6.63)	(−6.41)	(−3.07)	(−4.02)	(−5.91)	(−5.83)
Constant	1.92**	3.46***	3.73***	5.11***	2.37***	3.72***
	(2.68)	(4.09)	(3.93)	(4.52)	(3.58)	(4.79)
n	2987	1827	2897	1827	2987	1827

Tests for choosing the right model	Broad sample	Reduced sample	Decision
F-test	3.65	4.08	Fixed
Prob > *F*	0.0000	0.0000	effects
Breusch–Pagan (valor x^2)	197.85	177.03	Random
Prob>x^2	0.0000	0.0000	effects
Hausman (valor x^2)	23.57	18.52	**Fixed**
Prob>x^2	0.0006	0.0098	**effects**

Notes: *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$. The values of the t-statistic are in parenthesis. (i) OLS pooled estimate are already corrected for potential heteroskedasticity; (ii) *F*-test: H_0: all errors are independent and identically distributed (iid); (iii) Breusch-Pagan test: H_0: the errors of the random effects model are iid; (iv) Hausman test: H_0: the differences in the coefficients of the tested models is not systematic.

OLS method with pooled data, so as to establish a comparison. The results (columns I and II) show that the variables of interest and the control variables have the expected signs. The *Undervalued* index is significant in the estimate that employs the reduced sample. Based on these results, we reject the null hypothesis that the level of the RER does not affect the growth rate, i.e. the evidence suggests that this effect exists and is positive.

Nevertheless, the preceding model assumes contemporary exogeneity of the explanatory variables. This requires regressors to be uncorrelated with the idiosyncratic error in the same period. However, this condition, necessary for the consistency of this estimator, may not be met due to the omission of relevant variables in the regression model.[11] One way of solving this problem is using panel data and explicitly considering non-observed individual effects, which can be identified when the temporal dimension is considered in the analysis. For this reason, we investigated the relationship of interest using panel data techniques.

Estimation results for the panel data model (fixed and random effects) are shown in columns III–VI of table 2. It can be seen that the control variables have the expected signs and are statistically significant. Additionally, the variable of interest—the undervaluation index—has the expected sign (and is significant) in the fixed effects estimation. Estimates using random effects have the expected sign; although only significant in the regression employ the reduced sample. Consequently, we once more reject the null hypothesis that the level of the RER does not affect growth.

We tested the hypothesis that time *dummies* must be included as fixed effects in the regression. The results (not shown) reject the null hypothesis that these variables are jointly not significant—i.e. they must be included in the model. All models include time *dummies*, except when otherwise specified.

Table 2 also presents the results of model selection tests. We first tested for the presence of fixed effects. In this case, we performed the *F*-test, and rejected the null hypothesis that the idiosyncratic errors are independent and identically distributed, which allows for the conclusion that the fixed effects model is more appropriate than the OLS model with pooled data. We then tested for the presence of random effects. For this, we used the Lagrange multiplier test proposed by Breusch and Pagan (1980), which indicated the presence of random effects. Finally, to choose between fixed and random effects we used the Hausman (1978) test. The results show that the null hypothesis of the non-systematic coefficients is rejected for both samples, indicating the fixed effects model.

[11] The Ramsey RESET test (F-test = 4.50, Prob > F = 0.0037) indicates problems with omitted variables. H0 is, thus, rejected (H0: the model has got no omitted variables).

The next step is to check robustness. In order to do so, we used the *modified Wald* test for heteroskedasticity in regression models with fixed effects and the Wooldridge test for serial correlation in the panel model.[12] Results indicate that the errors of the model are serially correlated and heteroskedastic. Given this, we use a series of estimation methods that seek to correct these problems.[13]

We first used the Generalized Least Squares (GLS) method, which corrects for heteroskedasticity. Second, we estimated the fixed effects model (within) correcting for serial correlation when the idiosyncratic error is autoregressive of the first order (the estimate does not include the time *dummies*). Third, we ran a model with Driscoll and Kraay (1998) corrections for the standard errors of the coefficients estimated via fixed effects. The structure of the idiosyncratic error is assumed to be heteroskedastic, serially correlated, and, possibly, correlated between groups (panels). In this case, the standard errors are robust to various forms of cross-sectional ('spatial') and temporal (when the temporal dimension becomes large) dependency. Fourth, we used the method of Fixed Effects Generalized Least Squares (FEGLS), considering the presence of serial correlation of the first order within the panels and cross-sectional correlation, as well as heteroskedasticity in the panels. Last, we used the Cochrane-Orcutt method with the Prais-Winsten transformation to correct for problems of serial correlation and heteroskedasticity. As Greene (2003) shows, the Prais–Winsten transformation removes these problems, and the results are unbiased coefficients and consistent panel corrected standard errors (PCSE's). Furthermore, when calculating the standard errors and the variance-covariance matrix it is assumed that the errors are heteroskedastic and contemporaneously correlated between panels. The results are presented in table 3.[14]

[12] The broad sample has missing values, which makes it impossible to run a cross-section-dependent serial correlation test and/or Pesaran's test for contemporary serial correlation. We can, however, use the Wooldridge test for serial correlation, since, according to Drukker (2003, p. 01), the test has got good properties in moderate-sized samples. This result was reached 'from simulations for both fixed and random-effects designs, with and without conditional homoskedasticity in the idiosyncratic error term, with balanced data, and with unbalanced data with and without gaps in the individual series' (our emphasis).

[13] We performed robustness tests for different designs of model (3.4), involving the broad and reduced sample. Nevertheless, throughout the work we will present different tests for a single model that we believe is better specified. In other words, we first define a standard model and then we present tests for this model using different econometric techniques.

[14] Regarding the tests performed, we believe that the most reliable results are those arising from the method of FEGLS and of the Cochrane-Orcutt method with the Prais-Winsten transformation, because these estimation methods seek to correct the problems of heteroskedastic and autocorrelation of the errors.

Table 3. Robustness tests, 1980–2008

Tpibpc	GLS		EF com AR (1)		FE/Driscoll e Kraay.		FEGLS		Prais-Winsten	
	Broad sample	Reduced sample	Broad sample	Reduced sample	Broad sample	Reduced sample	Broad sample	Reduced sample	Broad sample	Reduced sample
Undervalued	0.37	1.11	1.21	1.42	1.09	1.33	1.16	1.81	0.92	1.35
	(1.90)	(4.35)***	(2.12)*	(2.30)*	(2.14)*	(1.77)	(2.76)**	(3.07)**	(2.25)*	(3.02)**
	0.10	0.11	0.82	0.085	0.08	0.09	0.075	0.087	0.081	0.08
save	(14.64)***	(12.98)***	(5.83)***	(5.11)***	(5.58)***	(4.51)***	(6.43)***	(5.60)***	(6.01)***	(5.12)***
	0.008	0.005	0.026	0.017	0.01	0.017	0.017	0.024	0.010	0.007
openc	(5.85)***	(3.63)***	(4.96)***	(3.02)**	(1.63)	(1.69)	3.87***	(4.22)***	(3.86)***	(2.99)**
	−0.03	−0.04	−0.03	−0.031	−0.03	−0.03	0.005	0.013	−0.027	−0.037
gap	(−11.25)***	(−12.4)***	(−0.19)	(−1.18)	(−1.45)	(−1.89)	0.36	(0.85)	(−4.41)***	(−6.44)***
	−0.02	−0.048	−0.09	−0.22	−0.17	−0.24	−0.10	−0.23	−0.019	−0.035
expend	(−1.84)	(−3.26)**	(−2.15)*	(−3.95)***	(−2.20)*	(−3.41)**	(−3.23)	(−4.15)***	(−1.08)	(−1.39)
	−0.0005	−0.06	−0.001	−0.067	−0.0009	−0.06	−0.0005	−0.09	−0.007	−0.062
tinfla	(−3.19)**	(−8.94)***	(1.27)	(−7.07)***	(−2.20)*	(−5.53)***	(−3.05)**	(−9.81)***	(−3.92)***	(−6.21)***
	−0.70	0.74	−0.62	−0.59	−0.42	−0.62	−0.67	−0.78	−0.66	−0.81
tcpop	(−10.97)***	(−8.56)***	(−4.10)***	(−3.36)**	(−3.30)**	(−4.71)***	(−5.38)***	(−5.36)***	(−6.39)***	(−5.61)***
	1.89	3.44	0.54	3.75	3.73	5.11	3.41	5.37	2.05	4.0
Cons	(4.90)***	(7.44)***	(0.78)	(4.19)***	(2.21)*	(3.14)**	(5.05)	(6.37)***	(3.16)**	(4.83)***
n	2987	1827	2987	1827	2987	1827	2987	1827	2987	1827
Solve Problems	Heteroscedasticity		Autocorrelation		Autocorrelation and Heteroscedasticity		Autocorrelation and Heteroscedasticity		Autocorrelation and Heteroscedasticity	

Notes:*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$. * AR (1) indicates to first-order autocorrelation. The values of the t-statistic are in parenthesis. In the estimates for EF with AR (1) were not included temporal dummies variables.

With the corrections for heteroskedasticity and serial correlation, the estimations of the coefficients of interest in the proposed model maintain the expected sign and are, for the most part, statistically significant. This indicates that the expected relationships between the dependent variable and the explanatory variables are still valid, thereby demonstrating the robustness of the model. The variables *undervalued*, *save* and *expend* were the most sensitive to the robustness tests. Conversely, the regression results have higheconomic significance. All estimates suggest that the effect of undervaluation on economic growth is sizable. For example, in the GLS model with the reduced sample, the estimates show that an undervaluation of roughly 50 per cent is associated with a growth increase of 5.55 per cent points (0.50×1.11). Different behaviour patterns may be observed in the variables of interest. We, thus, use the fixed effects model, based on the previous tests (table 2), to investigate the existence of such patterns amongst the different groups of countries. Thus, we estimate the model of equation (3.4) by groups of countries.

The results are reported in table 4 and show that, for developed as well as developing countries, the undervaluation index has the expected sign, even if it is only significant for the second group. This result empirically supports the hypothesis that the level of RER is important for the growth of developing countries. It also supports the hypothesis that the level of RER influences growth in different manners. Moreover, one can observe that there are differences between the groups of *developing countries*. In this case, it can be seen that the effect is positive (and significant) for the Sub-Saharan African countries, positive and statistically significant (reduced sample) for the Latin American countries and ambiguous for the Middle Eastern and North African countries. These results suggest that the effect of the exchange rate on growth may be conditioned by the presence other structural-economic specificities in the selected countries.

Finally, we should point out that the panel regressions performed above accept the (strong) hypothesis of strict exogeneity of the regressors with respect to the idiosyncratic errors. Under the violation of this condition, both estimators are inconsistent. However, it is possible to relax strict exogeneity by assuming that the regressors are sequentially exogenous with respect to the idiosyncratic errors, conditional to the unobserved effects. Formally we have the following moment condition:

$$E[\varepsilon_{i,t}/x_{i,t}, x_{i,t-1}, \ldots, x_{i,t-1}, \eta_i)] = 0 \text{ for all } t = 1, \ldots, l. \qquad (3.5)$$

Namely, we assume the non-correlation of the errors with contemporaneous and future explanatory variables. That is, the present values of the

Table 4. Undervaluation and growth—fixed effects model for groups of countries, 1980–2008

			Emerging and developing economies		
Dep. variable: tpibpc	Advanced economies	Emerging and developing economies	Middle East and North Africa	Sub-Saharan Africa	Latin and Central America
Broad Sample					
Undervalued	3.02 (1.77)	1.56** (2.83)	1.32 (1.12)	5.76*** (5.28)	1.42 (1.10)
save	0.12*** (4.07)	0.046** (3.36)	0-004 (0.15)	0.12*** (4.44)	0.001 (0.04)
openc	0.013* (2.18)	0.024** (3.88)	−0.027 (−0.95)	0.027* (2.44)	0.037** (3.33)
gap	−0.02 (−1.68)	−0.03 (−1.59)	−0.028 (−0.67)	−0.21** (−2.73)	0.007 (0.15)
expend	−0.14 (−1.21)	−0.211***(−5.03)	−0.199 (−0.63)	−0.31*** (−5.02)	−0.17* (−2.22)
tinfla	−0.008 (−1.68)	−0.001*** (−3.97)	−1.014 (−0.63)	−0.002* (−2.49)	−0.0009*** (−3.5)
tcpop	−0.194 (−0.96)	−0.34** (−1.96)	−0.39 (−0.86)	−0.11 (−0.31)	−0.83** (−2.68)
Constant	2.18 (1.10)	3.70** (3.20)	8.61* (2.12)	4.15 (1.90)	2.96 (1.24)
n	638	2349	464	522	841
Reduced Sample					
Undervalued	1.93 (1.27)	0.90 (1.42)	−2.18 (−1.79)	3.79** (2.68)	4.21* (2.55)
save	0.13*** (4.06)	0.07*** (4.53)	−0.002 (−0.05)	0.12*** (3.67)	0.012 (0.40)
openc	0.10 (1.88)	0.022** (3.30)	0.031 (0.80)	0.023 (1.41)	0.04** (3.09)
gap	−0.034** (-.14)	−0.028 (−0.65)	0.24 (1.34)	−0.17* (−2.07)	0.12 (1.49)
expend	−0.89***(−5.94)	−0.21 (−3.84)	−0.704 (−4.17)	0.30* (−2.56)	−0.16 (−1.83)
tinfla	−0.12*** (−7.18)	−0.059 (−5.59)	−0.054 (−1.21)	−0.05 (−1.59)	−0.04** (−3.71)
tcpop	−0.29 (−1.42)	−0.60** (−2.91)	−1.39** (−2.77)	0.08 (0.19)	−0.91** (−2.86)
Constant	−3.75*** (−5.62)	4.13** (3.10)	9.57 (1.87)	3.11 (1.0)	0.96 (0.32)
n	580	1247	203	319	406

Notes: $*P < 0.05$, $**P < 0.01$, $***P < 0.001$. The values of the t-statistic are in parenthesis.

regressors can be correlated with past errors (Arellano and Bond, 1991; Wooldridge, 2000; Greene, 2003). The assumption of sequential exogeneity is consistent with the presence of the lagged dependent variable among the regressors (dynamic models of panel data). These models control the existence of a correlation between past values of the dependent variable and the contemporaneous values of other explanatory variables, thus, eliminating potential sources of bias of the estimators associated with this type of correlation (Blundell and Bond, 1998; Wooldridge, 2000). Following Blundell and Bond (1998), we estimate the following regression:

$$tpibpc_{i,t} = \beta_0 + \beta_1 tpibpc_{i,t-1} + \beta_2 Undervalued_{i,t} + \sum_{j=3}^{K} \beta_j Z_{i,tj} + \eta_i + \varepsilon_{i,t} \qquad (3.6)$$

where $i = 1, ..., N,\ t = 2, ..., T, j = 3, ..., K$.

The results for the equation (3.6) are presented in table 5. The coefficient associated with *Undervalued* index is positive for both samples, although only significant for the reduced one. Moreover, the value of this coefficient is significantly higher in both estimates, implying that previous studies have underestimated the effect of exchange rate on the growth rate of GDP.

The control variables also have the expected signs and are generally significant in both samples. The Hansen test of overidentifying restrictions and the Arellano-Bond test for the correlation of the second order error term are as expected, showing that the model is correctly specified.[15]

4. THE QUANTILE REGRESSION

Having identified distinct coefficients for the undervaluation index, one potential estimation issue remains to be investigated. The classification adopted for the different groups of countries, adopted by the WEO, does not necessarily control for income levels. For example, the group of developing countries can include countries with low *per capita* income. This indicates that the generalisation of the conclusions, that the level of RER

[15] According to Roodman (2006; 2007), there is no clear rule about the number of instruments, although some rules and signals can be observed. First, the number of instruments should not exceed the number of observations, as is the case of the econometric exercise performed. Second, a telltale is the sign of Hansen's J statistic with *P*-value equal to 1.00. The estimates show that this is a possible sign that there are many instruments. Accordingly, we used a number of other regressions, increasing and decreasing the number of instruments, in particular, using the command in Stata collapse to decrease the number of instruments, but any other limits worsen the diagnosis.

Table 5. Undervaluation and growth—system-GMM (two-step robust)

Dependent Variable: tpibpc	Large Sample	Reduced Sample
L.tpibpc	0.29** (2.58)	0.28*** (6.09)
Undervalued	2.33 (1.29)	2.40* (2.52)
save	0.12** (5.37)	0.12*** (5.04)
openc	0.007** (2.68)	0.007* (2.10)
gap	−0.04* (−2.25)	−0.03*** (−4.69)
expend	−0.02 (0.84)	0.14 (0.52)
tinfla	−0.0003* (−2.14)	−0.04** (−3.18)
tcpop	−0.31*** (−1.55)	−0.24 (−1.13)
n	2987	1827
Arellano-Bond test for AR (1) in first difference	$z = -4.08$	$z = -3.96$
H0: There is no first order correlation in residuals	Pr > z = 0.000	Pr > z = 0.000
Arellano-Bond test for AR (2) second difference	$z = 1.33$	$z = 0.84$
H0: There is no second order correlation in residuals	Pr > z = 0.185	Pr > z = 0.404
Hansen test for overidentification	chi2 (161) = 101.3	chi2 (161) = 59.96
H0: The model is well specified and all overidentification are correct	Prob>chi2 = 1.000	Prob > chi2 = 1.000

Notes: $^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$. t statistic in brackets. The regressions do not include constant. Independent variables possible non-exogenous: *over, save e tinfla*.

impacts the growth rate of developing countries, may be incorrect. Consequently, the regressions estimated with the samples of countries that follow this classification may not be representative of what we call *developing countries*.

One way of avoiding this problem is to use quantile regression methods (Koenker and Basset, 1978; Koenker and Hallock, 2001). This method allows for the analysis of the association between the dependent and the explanatory variables in the various quantiles of the conditional distribution, which permits a fuller mapping of the influence of the RER on the income level of the selected countries. In the present exercise, the technique has the advantage of: (i) allowing us to test if the previous results hold for the countries of middle-range income (quantiles 0.5 and 0.75); (ii) allowing identification of sign changes between quantiles—i.e. whether the level of RER differently impacts the income of the countries when the quantiles are taken into account; (iii) enabling us to assess if the magnitude of this impact varies, which might determine, for example, a growing (decreasing) influence between quantiles of the previously estimated relationship; (iv) allowing the use of non-parametric bootstrapping approach, which uses the actual sample distribution in place of an assumed statistical distribution. It is recommended as a correction method when normality of the residuals is not observed. Using Generalized Least Squares, we estimate the regression model with the new dependent variable (the income level) for the different samples and run the Jarque-Bera test for normality of the residuals. In all cases, we reject the null hypothesis that the idiosyncratic errors following a normal distribution. It should also be noted that in this approach the variance-covariance matrix calculated via bootstrapping includes inter-quantile blocks, which makes it possible to conduct tests and build confidence intervals comparing the coefficients associated to the different quantiles.

Using the quantile regression technique for pooled data we adjust new estimations according to capture the effect of the level of the RER on the income level (logarithm of *per capita* GDP, in dollars), applying the bootstrapping approach. We also define one new sample in order to sidestep the econometric problems associated to the presence of *missing* values and the small variability of the data. The third sample comprises a balanced panel with 87 countries during seven four-year periods (each period corresponds to the mean observed values during four years, for the period ranging from 1980 to 2007). The inclusion of this new sample is justified by the fact that using average periods avoids problems related to business cycles and measurement errors. Box 2 presents the number of countries per group that compose this new sample.

In order to further understand how the level of RER can influence growth, we test the hypothesis that the keeping an undervalued RER has a non-linear (quadratic) effect on growth. We assess the square of the exchange rate undervaluation index (*Undervalued2*) and run new estimations.[16] It is important to highlight that, although a linear specification can capture the distinguished effect of RER misalignments depending on the sign of the deviation, that estimate is not able to capture other

[16] The negative sign on Undervalued2 implies that the RER growth relationship becomes negative beyond a certain threshold. Different to the literature on this issue, the test does not find a unique threshold, since the value will depend on the quantile of the income. Therefore, once the quantile regressions allow to collect the variability of the parameters, the threshold is different for low income countries (quantile 0,25) compare to middle income countries (quantile 0,75). For more about the test for a U-shaped relationship, see Thori Lind and Mehlun (2010).

Box 2

Composition of the third sample

	Sample (3)	
	Number of countries	*Number of Observations (n)*
(A). Advanced economies	22	154
(i). Eurozone	22	154
(B). Emerging and developing economies	65	455
(i). Latin and Central America	24	168
(ii). Developing Asia	11	77
(iii). Sub-Saharan Africa	16	112
(iv). Central and Eastern Europe	4	28
(v). Middle East and North Africa	10	70
Total (A+B)	87	609

Note: Classification according to the WEO –World Economic, 2010.

features, such as size effects. For Bereau et al. (2012, p. 3508), 'a linear specification has several drawbacks that are worth mentioning. First, by definition, in a linear equation, the growth–misalignment elasticity is constant. Second, the threshold value that divides positive from negative effects is, by construction, zero. Third, and related to the previous points, there is symmetric—but opposite in sign—effect of under and overvaluations. Finally the higher the misalignment, the more positive (in the case of undervaluations) or negative (in the case of overvaluations) the final effect on growth'. However, there is no reason to think that this is necessarily the case, and such effects may come from the restrictive nature of the linear specification.[17]

[17] We use the fixed effects model to investigate the existence of non-linearity. Therefore, we estimate the square of the exchange rate undervaluation index (Undervalued 2) and run new estimates the model of equation (3.4) by groups of countries. The objective here is to test the hypothesis that the effect on growth of maintaining an undervalued RER level is non-linear (quadratic). Accordingly, we expect the sign of this new term to be negative, in an indication that after a certain level further undervaluation would reduce the rate of economic growth. The results show that, in general, for developing countries, this term has the correct sign although the statistical significance is weak. As Bereau et al. (2012) suggest, the existence non-linear specification shows that exchange rate policy may play a key role in economic growth, i.e. appropriate exchange rate policies that limit currency overvaluation could be used to promote economic growth.

The general form of the equation to be estimated by quantile regression is:

$$\ln pibpcd_{i,t} = \beta_0 + \beta_2 Undervalued_{i,t} + \beta_3 Undervalued2_{i,t} + \sum_{j=4}^{K} \beta_j Z_{i,tj} + \varepsilon_{i,t} \tag{4.1}$$

where $j = 4,\ldots K$. The dependent variable (ln*pibpcd*) is the income level (logarithm of *per capita* GDP, in dollars).[18]

The results of the quantile regressions are presented in tables 6 and 7. It can be seen that the coefficients capturing the effect of the undervaluation index on level of income are significant and have the expected signs in the first three quantiles of the broad sample (higher quantiles are associated with higher income levels). Despite the linear term associated with the *Undervalued* index not being significant, these coefficients also have the expected signs in the last quantile. It can also be seen that the magnitude of the coefficients associated with the linear and quadratic terms of the *Undervalued* index decrease, going from the lower to the higher income levels. This implies that the positive and negative effects of exchange rate are stronger in fewer developed countries. The significance and non-linearity are confirmed in two quantiles of the reduced sample. In the third quantile, the coefficients associated with the *Undervalued* index have the expected signs, although the linear term is not significant. Finally, the linear term is negative in the last quantile, which indicates that an undervalued RER negatively affects the income level of the countries with the highest income levels.

The estimates for sample (3) once more present evidence in support of the hypothesis that non-linearity in the relationship between the level of RER and the level of *per capita* income. As in previous estimates, the coefficients adjusted for the *Undervalued* index have positive and negative signs, respectively for the linear and quadratic terms of the sample (3). Furthermore, these coefficients decrease in magnitude from the first to the third quantile. The estimations for the fourth quantile are not significant. As a result, we conclude that, for developed countries, the effects of an undervalued RER are ambiguous and tend to be negative.

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[18] We assume the same controls in the model, because we believe that they are also relevant when GDP per capita level is the dependent variable. In other words, we believe that there is not any reason for any of the controls to be removed or that any others should be included in the model. In addition, when using the same model, it is possible to identify and compare the results obtained with the others presented in the work.

Table 6. Quantile regressions (1980–2008), bootstrap (100)—broad and reduced sample

Dependent variable: lnpibpcd	*Quantile 0,25*	*Quantile 0,5*	*Quantile 0,75*	*Quantile0,95*
Broad sample				
Undervalued	0.37*** (7.47)	0.24*** (5.87)	0.18*** (4.13)	0.08 (1.07)
Undervalued2	−0.89*** (−12.61)	−0.80*** (−12.16)	−0.64*** (−8.16)	−0.42*** (−5.10)
save	−0.008*** (−4.70)	−0.004** (−2.63)	−0.002* (−1.98)	−0.004*** (−3.40)
openc	0.001*** (5.08)	0.001*** (3.56)	0.0003 (1.20)	−0.0001 (−0.40)
gap	0.03*** (65.05)	0.037*** (67.95)	0.035*** (58.75)	0.032*** (33.42)
expend	−0.01*** (−3.49)	−0.007*** (−3.89)	−0.0034 (−1.89)	−0.0008 (−0.32)
tinfla	−0.0001 (−0.94)	−0.00001 (−0.26)	−0.00003 (−0.72)	−0.000009 (−0.19)
tcpop	−0.07*** (−2.61)	−0.024 (−1.24)	0.010 (0.72)	0.005 (0.63)
Constant	6.48*** (61.86)	6.63*** (74.81)	6.92 (84.27)	7.38*** (69.89)
Pseudo R^2	0.64	0.68	0.69	0.67
n	2987	2987	2987	2987
Reduced sample				
Undervalued	0.52*** (9.02)	0.18** (3.22)	0.06 (1.08)	−0.19** (−2.84)
Undervalued2	−0.89*** (−9.47)	−0.79*** (−5.54)	−0.66*** (−4.63)	−0.52*** (−5.34)
save	−0.012*** (−5.72)	−0.003* (−1.68)	−0.003 (−0.17)	−0.002 (−1.07)
openc	0.001*** (4.54)	0.001** (2.82)	0.0006* (2.06)	−0.0004 (−1.56)
gap	0.037*** (60.12)	0.036*** (49.50)	0.036*** (51.51)	0.034 (41.51)***
expend	−0.0052 (−1.55)	−0.002 (−1.34)	−0.0003 (−0.17)	0.001 (0.40)
tinfla	−0.006*** (−4.11)	−0.004* (−2.1)	0.0004 (0.30)	0.003 (1.34)
tcpop	−0.041* (−2.17)	−0.057** (−3.10)	−0.033* (−1.52)	−0.05** (−2.60)
Constant	6.53*** (53.67)	6.63*** (52.04)	6.84*** (52.80)	7.23*** (42.80)
Pseudo R^2	0.69	0.72	0.73	0.71
n	1827	1827	1827	1827

Notes: *P <0 .05, **$P < 0.01$, ***$P < 0.001$. The values of the t-statistic are in parenthesis.

Table 7. Quantile regressions (1980–2007), bootstrap (100)—samples (3)

Dependent variable: lnpibpcd	Quantile 0,25	Quantile 0,5	Quantile 0,75	Quantile 0,95
Sample 3				
Undervalued	0.57***	0.37***	0.24**	0.24
	(5.91)	(3.70)	(2.61)	(1.44)
Undervalued2	−0.71***	−0.707***	−0.65***	−0.39
	(−5.02)	(−6.81)	(−4.74)	(−1.80)
save	−0.009*	−0.004	−0.0002	−0.006
	(−2.17)	(−1.06)	(0.01)	(−1.46)
openc	0.001*	0.0007	0.0006	−0.0002
	(2.56)	(1.06)	(0.96)	(−0.37)
gap	0.037***	0.036***	0.036***	0.031***
	(30.39)	(27.93)	(26.67)	(15.04)
expend	−0.009	−0.008*	−0.007	−0.004
	(−1.7)	(−2.02)	(−1.84)	(−0.68)
tinfla	0.00006	−0.00001	0.00006	0.000007
	(−0.22)	(−0.10)	(0.38)	(0.02)
tcpop	−0.0002	0.005 (0.15)	0.023	−0.008
	(−0.08)		(0.74)	(−0.35)
Constant	6.37***	6.59	6.78***	7.44
	(35.92)	(43.37)	(48.7)	(39.89)
Pseudo R^2	0.68	0.70	0.72	0.67
n	609	609	609	609

The control variables, in general, have the expected signs and are significant, especially in the first and the second quantile—except for the variable *gap*, whose sign was the opposite of expected in all estimates. The explanation for this result may lie in how the variable is defined; it is possible that it causes certain endogeneity, because its numerator is equal to the dependent variable.[19]

We then run a specification test for the model, testing for the necessity of including more variables. We do so by running a regression of the observed values of the dependent variable against the predicted values (*hat*) and the square of the predicted values (*hatsq*). The first term must be significant since it contains the predicted values, whilst the second one must not be significant; if the model is correctly specified, the square of the predicted values must not be of explanatory value. The test therefore consists of

[19] Nevertheless, the dependent variable is transformed by the natural logarithm.

Table 8. Tests for model specification errors

Dependent variable lnpibpcd	*Broad Sample* coef.	*Broad Sample* $P>\|t\|$	*Reduced Sample* coef.	*Reduced Sample* $P>\|t\|$
hatsq	−0.004	0.715	0.03	0.831

Table 9. Wald test for the difference between the coefficients

	Undervalued		*Undervalued2*	
Hypothesis	[q25] – [q95]= 0	[q50] – [q95]= 0	[q25] – [q95] = 0	[q50] – [q95]= 0
Broad Sample	$F(1, 2709) =$ 10.01 Prob > F = 0.0016	F (1, 2709) = 3.03 Prob > F = 0.0820	F (1, 2709) = 19.3 Prob > F = 0.0000	$F(1, 2709) =$ 14.92 Prob > F = 0.0001
Reduced Sample	$F(1, 1790) =$ 85.30 Prob > F = 0.0000	$F(1, 1790) =$ 23.70 Prob > F = 0.0000	$F(1, 1790) =$ 11.89 Prob > F = 0.0006	$F(1, 1790) =$ 3.85 Prob > F = 0.0499

verifying the significance of *hatsq*, under the null hypothesis that there are no specification errors. If this term is significant, then the null hypothesis is rejected, and the conclusion is that the model is incorrectly specified. table 8 shows the test statistics. The null hypothesis that the model does not present specification errors cannot be rejected.[20]

Finally, we test the difference between coefficients. More specifically, we test whether the coefficients associated with the *Undervalued* index in the first quantile, as well as those in the second quantile, are statistically different from the coefficients in the last quantile. The results show that we cannot reject the null hypothesis that the coefficients are statistically different. This implies that the effect of the level of the RER on *per capita* income is different and statistically significant between the estimated quantiles (table 9).

In summary, the results of the econometric tests indicate the existence of a significant non-linear relationship between RER and growth, especially for developing countries.

[20] The result is also valid for the sample (3).

5. CONCLUSIONS

This article presented empirical evidence on the relationship between RER level and growth. We first conducted tests to show the relationship between growth and an undervaluation index calculated according to Rodrik (2008). The results show a positive and significant relationship between the variables, indicating that countries that maintain a higher undervaluation index (a more undervalued RER) grow faster. The results are robust to different econometric techniques.

We additionally explored this relationship for different groups of countries, finding that it is positive and significant for developing countries. Moreover, we presented evidence that it is not linear (but quadratic), in the sense that keeping an undervalued currency increases growth during a first moment and then acts in the opposite direction. The results of the quantile regression better represent this relationship, for two reasons. First, because they control for the income level and, thus, avoid problems related to the classification of countries. Second, they allow for detecting changes in the coefficients' signs. The results show that the non-linear relationship holds for developing countries of average income.

A tentative explanation for the fact that the relationship does not hold for developed countries is related to the proposition that, for these countries, technological progress is 'less' dependent on the stimuli of RER. More specifically, it can be considered that technology is more diversified in these countries. This makes technological progress much more a result of production alone, rather than dependent on stimuli from exchange rate policy.

Regarding economic policy, the main conclusion is that keeping a competitive RER for developing countries can create important effects on the productive structure. It changes their specialisation pattern, relaxing the balance-of-payments constraint and, thus, allowing for a higher long-term growth rate. This result means that RER depreciation can affect the long-term growth of an economy via an increase (decrease) in its income elasticity of the demand for exports (imports), which would spur the growth of exports for any given growth rate of world income. In this sense, the variations in competitiveness the RER brings about are not spurious, but, rather, authentic.

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