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ARTÍCULO

GROWTH AND THE REAL EXCHANGE RATE: THE ROLE OF TECHNOLOGY

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The aim of this paper is to assess the stability of the impacts of real exchange rate undervaluation and domestic technological capabilities on growth across development levels. Panel regressions with development-level interactions are used to test the stability of these variables' impact on growth. The results show that real undervaluation is a driver of growth across all development levels, once technological capabilities are accounted for; however, it is more important for developing and developed countries than for emerging countries.

Keywords: Development macroeconomics; growth; technological capabilities; undervaluation.
JEL: F43, O11, O19, O47.

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Márquez-Velázquez, A. (2023). Crecimiento y tipo de cambio real: el rol de la tecnología. *Cuadernos de Economía, 42*(90), 403-427.

Este artículo evalúa si los impactos de la subvaluación del tipo de cambio real y las capacidades tecnológicas nacionales sobre el crecimiento son estables en todos los niveles de desarrollo. Se utilizan regresiones de panel con interacciones a nivel de desarrollo para probar la estabilidad del impacto en el crecimiento de estas variables. Los resultados muestran que la subvaloración real es un motor de crecimiento en todos los niveles de desarrollo, una vez que se tienen en cuenta las capacidades tecnológicas; sin embargo, la subvaluación es más importante para los países desarrollados y en desarrollo que para los países emergentes.

Palabras clave: macroeconomía del desarrollo; crecimiento; capacidades tecnológicas; subvaluación cambiaria.
JEL: F43, O11, O19, O47.

INTRODUCTION

In a 2008 study, Rodrik provides empirical evidence and develops theories about how real exchange rate (RER) undervaluation can drive growth in developing countries. RER undervaluation (RERU) is one of two types of RER misalignment, the other being RER overvaluation (RERO). RER misalignment refers to situations in which a country's RER differs from its equilibrium value. In the context of RERU, the RER exceeds the equilibrium value, whereas under RERO, the RER falls below it. Therefore, under RERU, a country's tradable goods are relatively cheaper in international markets, and under RERO, the opposite is true.[1] Rodrik suggests that RERU incentivizes investment in modern tradable sectors due to the increase in the relative price of tradables it causes. These sectors are underdeveloped due to market and government failures. However, according to Rodrik, in developed countries, the growth impact of RERU is insignificant. Rapetti *et al.* (2012) replicate Rodrik's approach, finding that RERU has a significant impact on growth in developed and developing countries but not in emerging countries, *i.e.*, countries at an intermediate development level.

Early empirical studies that analyze the effect of depreciation on output could not detect a positive impact on growth because they failed to control for other factors affecting output during depreciation episodes (*e.g.*, Cooper, 1971; Díaz Alejandro, 1965). Agénor (1991) differentiates between expected and unexpected depreciations, attributing negative impacts on growth exclusively to expected depreciations resulting from high RERO.

This discussion overlooks domestic technological capabilities (DTCs) and the degree to which industries of different technological intensity are economically viable within a country. Technology is a major growth driver in most growth theories,[2] and a relative increase in the global competitiveness of a country's mid- and high-technology industries should increase its growth rate. Historically, economies that have been successful in catching up globally have shifted their economic structure towards mid- and high-technology sectors (Amsden, 1989, 2001).

The main objectives of this study are, firstly, to assess the impact RERU has on growth across countries at different levels of development while controlling for DTCs, and secondly, to understand the role of RERU and technology in shaping

1 This explanation adopts the perspective of developing countries, where exchange rates tend to be expressed in units of the domestic currency per USD. Therefore, a real exchange rate that makes domestic tradables more competitive is higher than its equilibrium level.

2 Lucas (1988, p. 15) criticizes Solow's growth model for "assigning so great a role to 'technology' as a source of growth." Romer (1994) criticizes Solow's neoclassical growth theory for explaining growth since the industrial revolution mainly as a consequence of unexplained technological change. The endogenous growth literature – pioneered by Romer – continues to underscore the central role of technology in growth yet endogenizes technological change (Romer, 1987). Authors studying the middle-income trap also emphasize the importance of knowledge and technology in overcoming the trap (e.g., Paus, 2020). Evolutionary literature studying growth emphasizes technological learning as the main driver for growth (*e.g.,* Nelson, 2008).

growth prospects for developing, emerging, and developed countries. To achieve these objectives, the main research question that this study seeks to answer is: How do the effects of RERU and DTCs on economic growth vary between developing, emerging, and developed countries?

To answer the main research question, two sub-questions need to be answered: 1) Is the impact that RERU has on growth the same for different development levels after controlling for DTCs? and 2) Does specializing in mid- and high-technology sectors improve growth prospects at different development levels? I contend that Rodrik (2008) did not find that RERU had a positive and significant impact on growth for his sample of developed countries because he used a low income level to classify a country as developed. If he had used a higher income level, he would have found a positive and significant growth impact, similar to that which Rapetti *et al.* (2012) obtained in their study. Additionally, I suggest that Rapetti *et al.* (2012) could not prove that RERU has a significant impact on growth in emerging countries because they did not control for DTCs. Controlling for DTCs is important, as RERU should be a more relevant growth driver for emerging countries specializing in mid- and high-technology sectors than those specializing in natural resources. Furthermore, testing this second hypothesis will provide evidence to support or undermine Lin's (2012) 'new structural economics' argument. This argument suggests that the type of industries that a government should promote must be related to their country's level of DTCs.

In terms of methodology, this study uses standard estimation techniques from the literature, based on Rodrik's (2008) seminal study measuring the impact of RERU on growth, albeit with a more recent version of the Penn World Table (Heston *et al.*, 2011). The sample comprises data from 191 countries covering the period 1985–2004. In this study, the countries are classified into three development categories: developing (low development level), emerging (mid-development level), and developed (high-development level).[3]

Following Rodrik (2008, p.377), this study classifies all countries with an average GDP per capita lower than USD 6,000 in purchasing-power-parity (PPP) 2005 terms for the period analyzed, as developing countries. Emerging economies are countries with an average GDP per capita equal to or above USD 6,000 and below USD 10,725. Finally, this study classifies countries above the upper bound of this income range as developed countries. The World Bank used this same threshold in 2005 for the high-income group (World Bank, 2012). The period of analysis is determined by the availability of the index of technological specialization (ITS) data (Alcorta & Peres, 1998), taken from ECLAC (2011). The ITS is the main DTC indicator used in the study. By adding interactions between RERU (ITS) and a country's development level, I test whether RERU (ITS) has the same growth

[3] Throughout this paper, the term developing countries will include the group of countries referred to as emerging economies, markets or countries, as well as low-income countries, unless a precise distinction needs to be made. In these cases, the term emerging economies will refer to developing countries with higher levels of income.

impact across development levels. The results show that RERU has a positive and significant impact on growth for the three development categories, although when controlling for DTCs, the impact is smaller for emerging economies. The results on the impact DTCs have on growth are less robust than those showing the impact of RERU on growth.

The following section comprises a literature review focusing on the growth impact of RER misalignments and technology. Subsequently, the study's results will be presented, followed by the conclusions inferred from the results.

THE IMPACT OF REAL EXCHANGE RATE MISALIGNMENTS ON GROWTH

Nominal devaluations are often perceived as a means to correct RERO, which is a RER misalignment often associated with low levels of growth (Sachs & Warner, 2001). In these cases, it is important to understand how RER misalignments can impact growth. The next subsection will provide a concise presentation and analysis of the main RER equilibrium theories, followed by a brief review of the literature examining the effects of RER misalignments on growth.

Theories of real exchange rate equilibrium

The analysis of RER misalignment is closely related to RER equilibrium theories, as RER misalignment occurs when the RER differs from its equilibrium value. The fundamentals approach — one of the most popular RER equilibrium theories— argues that the RER has reached its equilibrium when an economy has simultaneously reached its external and internal equilibria (Razin & Collins, 1999, p. 59). On the other hand, according to the purchasing power parity (PPP) theory — in either its strong or weak versions — equilibrium RER remains constant across time, whereby the law of one price prevails in accordance with its strong version or nominal devaluations equate with the difference between foreign and domestic inflation as its weak version holds (Dornbusch, 1985).

Naturally, the PPP approach to equilibrium RER has been subject to strong criticism; however, it has evolved by acknowledging that equilibrium RER may not necessarily remain constant. Balassa (1964) and Samuelson (1964) are often cited as the seminal works that provide empirical evidence and models which explain why the price levels of non-tradable goods relative to those of tradable goods— and thus the equilibrium RER — increase as countries attain a higher development level. Under the Balassa-Samuelson corrected PPP theory of equilibrium RER, RER misalignments will arise whenever the domestic price level of a country is either higher or lower than expected given its level of income per capita.

From the perspective of economic development, the fundamentals theory of RER equilibrium is problematic. This is because it considers at least part of the real appreciations resulting from commodity booms as a move towards a new equilibrium in a country's RER, given that the terms of trade are one of the determinants of a country's external equilibrium. The resulting RER misalignment caused by improvements in the terms of trade will, in principle, be lower when measured using the fundamentals theory than when applying the Balassa-Samuelson corrected PPP approach. A misalignment calculated using the latter will consider most RER appreciations as causes of RER misalignment, as long as the appreciations have a low impact on the country's income level. This means that a measurement of RER misalignment quantified using the corrected PPP approach will be better able to capture the growth slowdown related to RERO that has been highlighted in literature addressing Dutch disease and the resource curse, as will be discussed further in the next section.

Explaining the impact of real exchange rate misalignment on growth: Theories and evidence

There is an extensive body of knowledge concerned with Dutch disease which explains the short-term impact of RERO on growth, and the resource curse which explains its long-term impact on growth. Meanwhile, the literature analyzing the impact of RERU on growth is relatively recent and builds upon studies claiming that RERU can be sustained in the medium term (Levy-Yeyati & Sturzenegger, 2007). Rodrik (2008) expands the arguments of the Dutch disease and resource curse literature by arguing that RERU should have a positive impact on growth because under RERU, tradables will fetch a higher price relative to non-tradables than what is dictated by RER equilibrium. He argues therefore that RERU should incentivize investments in the tradables sector and especially in manufacturing, since, under RERU, the returns of investors in this sector are higher than what they would be under a RER equilibrium.

Rodrik (2008, p. 375) estimated a time-series–cross-section [TSCS] model of annual growth — averaged over five-year periods — on initial income and RERU. The empirical evidence he obtained supported the hypothesis that RERU had a positive impact on growth for developing countries between 1950 and 2004. By running Rodrik's (2008) growth regressions with different income thresholds defining developing countries, Rapetti *et al.* (2012) found evidence in favor of a changing relationship between RERU and growth, with RERU having a positive and significant impact for low- and high-income countries, but not for middle-income countries.

Rapetti *et al.* (2012) propose that the non-significant impact of RERU on growth in Rodrik's (2008) sample of richer economies seems to be driven by its lack of impact in the so-called emerging economies; a result that puzzles the authors. Nevertheless, Glüzmann *et al.* (2012) provide empirical evidence (similarly based on TSCS regressions) supporting the hypothesis that RERU has a positive and significant impact on growth in emerging markets. However, it is unclear what criteria the authors employed in classifying a country as an emerging market.

According to Rodrik's (2008) theory, it is expected that the impact of RERU on growth will be lower if the income threshold for the developing country category is increased, since his theoretical framework assumes that market and government failures affecting the modern tradable sector are less important for countries at higher income levels. Nevertheless, when using a higher income per capita threshold to define developed countries, Rapetti *et al.* (2012) found a significant impact on growth in developed countries and no significant impact on growth in middle-income countries. Regarding the transmission channel between RERU and growth, Rodrik (2008) could be criticized for his failure to match theory with evidence. It can be argued that in low-income countries, the industries promoted by RERU tend not to be part of the mid- or high-technology sectors. According to Rajan and Subramanian's (2011) findings, the manufacturing sectors promoted by RERU in these countries tend to be low-technology, labor-intensive sectors such as textiles, clothing, leather, and footwear.

The absence of a discernable impact of RERU on growth in emerging economies reported in Rapetti *et al.* (2012) can be interpreted as evidence for the idea that RERU does not noticeably boost the competitiveness of the industries in which these countries compete, which tend to be more technologically than the industries in which developing countries compete. The income differential between emerging and developed countries — the main players in the international market of mid- and high-technology manufacturing — is the base of emerging economies' cost competitiveness. Once their cost competitiveness erodes as incomes increase, a mastery of appropriate DTCs should reward emerging countries with sustainable growth.

Finally, Demir and Razmi (2022, p. 421) in their review of the literature, argue that there is a weak consensus on the positive impact of RERU on growth in developing countries. Many scholars are skeptical of this positive effect. In particular, there is an ongoing debate in the Brazilian strand of the literature regarding the significance attributed to the tradable sector channel of RERU by New Developmentalists. While authors such as de Medeiros (2020) criticize New Developmentalism for overemphasizing the importance of the exchange rate and underestimating the relevance of industrial policy, authors such as Oreiro (2020) argue that New Developmentalism does in fact recognize the importance of industrial policy for its capacity to prevent premature deindustrialization in middle-income countries.

Despite the different impacts on growth reported in the studies reviewed in this section, it could be argued that there is at least a consensus on which RER equilibrium theory to use, *i.e.*, the PPP approach corrected by the BSE. Similarly, all studies agree on using the econometric approach of TSCS regressions. The literature review in the next section will attempt to show how authors have highlighted the relationships between development, technology and trade patterns. The aim of exploring this literature was to find a justification for including DTCs together with RERU proxies in the growth regressions in Section 4.

DEVELOPMENT, TECHNOLOGY AND TRADE PATTERNS

Theories explaining trade patterns and technological change taking place within developing countries hold central importance for research such as the present study, focused on the topic of growth in the context of economic development. Economic development is understood as the structural change of a developing country's economic activities towards knowledge-intensive sectors (Amsden, 2001, p. 2). The following subsection outlines an example of a growth theory that considers the importance of technology for development and suggests an indicator for measuring DTCs.

Domestic technological capabilities as drivers of economic growth

DTCs are enhanced by implementing cost discovery activities (CDA), which Hausmann and Rodrik (2003, p. 605) define as activities related to the process of ascertaining what a country is good at producing. CDA hold greater significance in the developing world, as their role in assessing a country's capacity to produce goods already manufactured elsewhere requires technology assimilation-type innovations. Meanwhile, innovations that expand the technological frontier tend to occur in developed countries (Nelson, 2008, p. 16). The study of economic complexity examines the relationships between different economic activities in a country, while considering its potential for growth and development (Hidalgo & Hausmann, 2009). Economic complexity is particularly relevant to understanding the drivers of DTCs and their implications for economic growth.

Promoting CDA is one way of increasing the economic complexity of a country and thus its growth potential. However, in the absence of government intervention, CDA will be undersupplied because they generate positive externalities. This means that the value for society of uncovering production costs in new sectors of activity surpasses the benefits that the first investor in this sector (who conducted the CDA) can appropriate as benefits. This externality can be measured by assessing the advantages obtained by imitators once costs have been 'discovered' by pioneers. Hausmann *et al.* (2007) propose a model that links the expansion of CDA to economic growth, describing growth as a structural transformation in which producers shift from low- to high-productivity sectors. The authors argue that exported goods are vital for growth prospects, with developing countries that export high-productivity goods similar to those exported by rich countries experiencing faster growth.

The undersupply of CDA will reduce the growth rate of countries, *ceteris paribus*. In order to exploit Gerschenkron's advantage of backwardness — achieving high growth rates thanks to innovations produced elsewhere — governments in developing countries need to manage the externality problem created by CDA. However, intervention should go beyond regulation of intellectual property rights. This is because the assimilation of standardized foreign technology plays an important part in CDA. Although this technology cannot be patented, it nevertheless requires high learning investments (Hausmann & Rodrik, 2003, p. 624). In order to gain a more inclusive and comprehensive understanding of innovation systems in developing countries, it is crucial to broaden the traditional definitions that focus solely on R&D investment and market-based approaches (Khan, 2022b).

A country's potential for innovation, economic development, and technology adoption is influenced by various factors, such as technological and social capabilities, institutions, policies, and economic stability (Fagerberg & Srholec, 2017; Khan, 2022a). An indicator such as the ITS could be suitable to measure increases in the relative importance of DTCs in mid- and high-technology sectors in the developing world. Alcorta and Peres (1998) define the ITS as the ratio between a country's revealed comparative advantage in mid- and high-technology-manufacturing sectors and its revealed comparative advantage in natural resource-intensive and low-technology manufacturing industries. A developing country that manages to increase the presence of CDA in its economy will set in motion a process of structural transformation that should increase the value of its ITS over time. This, in turn, should imply the declining importance of natural resource-intensive industries as well as low-technology manufacturing.

A key insight of the literature reviewed in this section is the importance of the production structure and the trade patterns that it reflects for the growth prospects of developing countries. This insight will be empirically analyzed in the next section, together with the potential of RERU to increase growth at different development levels. The main theoretical contribution of this research is the argument that RERU and DTCs should not be expected to produce consistent growth impacts across development levels. I hypothesize that, after controlling for DTCs, RERU should have significant and positive impacts on growth at different development levels, although these impacts will be of different magnitudes.

The relationship between growth and real exchange rate undervaluation is moderated by domestic technological capabilities

As stated above, Rodrik (2008) showed that the positive impact of RERU on growth disappears for developed countries defined with a relatively low threshold of GDP per capita. One possible explanation for this could be that many developing countries with incomes levels slightly above this threshold (the so-called emerging markets) compete in industries that are less influenced by the RER, as is the case with many natural resource-intensive activities.[4] Moreover, as emerging

[4] Literature on Dutch disease and the resource curse has developed theories and provided empirical evidence that proves and explains the claim that natural resource-intensive activities are less sensitive to RER (RERU or RERO). See Di John (2011) and van der Ploeg (2011) for reviews of this literature.

markets increase their presence in mid- and high-technology sectors, developed countries will need to depend more on RERU when competing against emerging countries.

Although there is evidence that developed countries seem to adjust to increased import competition in manufactured goods from developing or emerging countries by upgrading the quality of their products (Schott, 2008), there have been cases that disprove this. For example, developed Eurozone countries, including Greece, suffered in terms of reduced exports, tourism, and growth while under RERO (Papanikos, 2015). Accordingly, there is reason to believe that Eurozone countries, including Germany, better withstood competition in mid- and high-technology sectors from emerging countries because they experienced RERU and accumulated trade surpluses. As a result, it is justifiable to consider three development stages (low, mid and high) and control for DTCs when analyzing the impact of RERU on growth.

The combination of labor abundance — which in theory should facilitate successful competition in labor-intensive goods — and high RERU levels made low-income developing Asian economies super-competitive in low-technology manufactured goods. However, in high-growth, low-income developing countries, raising income levels can reduce price competitiveness in these sectors. Governments essentially have two choices for solving this problem, the first is to further repress wage growth to achieve high RERU levels, and the second is to intervene to foster DTCs in mid- and high-technology manufacturing sectors (Amsden, 2001, p. 6). Governments who choose to do the latter seem to have been able to achieve structural transformation and grow faster, but only when they have also monitored RERU and the balance of payments (BoP) constraint.

The upcoming section presents the results of the TSCS or panel data regressions, carried out following the established methodology in the literature. These were undertaken with the objective of reassessing the impact of RERU and DTCs on growth in developing, emerging and developed countries, while controlling for DTCs.

RELEVANCE OF REAL EXCHANGE RATE UNDERVALUATION AND DOMESTIC TECHNOLOGICAL CAPABILITIES

In this section, the results of TSCS models used to test the main hypotheses of this research are presented and discussed. One hypothesis is that RERU should have a positive impact on growth across all development levels (low, middle and high), once DTCs were controlled for. The second hypothesis posits that the higher the income level of a developing country, the more important the role that DTCs in mid- and high-technology sectors will play as drivers of growth.

Generating the real exchange rate undervaluation variable

The need to control for the BSE to obtain an equilibrium level of RER is illustrated by data supplied by *The Economist* (2013) concerning the Big Mac index. The data reveal that Big Macs tend to be more expensive in developed countries such as Belgium and Greece than in developing countries like Malaysia. Nonetheless, however illustrative of the BSE the price of a Big Mac might be (as a non-tradable good), it is necessary to use a proper RER index to accurately measure RERU. Following Rodrik (2008), I used the nominal exchange rate in local currency units per United States dollar over the PPP exchange rate in local currency units per international dollar to measure the RER. However, I took the data on these variables from a more recent version of the Penn World Table (version 7.0) (Heston *et al.*, 2011).

Finally, the approach I used here to deal with missing data differs from Rodrik's (2008, p. 373), which involved taking five-year averages of his variables of interest, resulting in only eleven time periods. There are several limitations of this approach, including the acute loss of degrees of freedom and the fact that it causes the new averaged dependent variable to lose variability (Honaker & King, 2010, p. 562). For these reasons, I applied the multiple imputation model suggested by Honaker and King (2010) to handle missing data in both the dependent and independent variables.

Table 1.
The effect of gross domestic product per capita increases on the real exchange rate, 1985-2004

Independent Variable	
Intercept	1.535***
	(0.082)
Gross domestic product per capita (in logarithm, purchasing-power-parity 2005 United States dollars)	-0.129***
	(0.01)
% of significant year fixed effects	53%
Observations	3,820
	(N = 191, T = 20)
Adjusted R^2	0.105
Lagrange multiplier test p-value	0

Notes: Panel corrected standard errors in parenthesis; *** p-value < 0.01; ** 0.01 < p-value < 0.05; * 0.05 < p-value < 0.10. Year fixed effects reported as significant when their p-value < 0.10. Source: Own calculations based on data from Heston *et al.* (2011).

The results presented in Table 1 were estimated by applying the following equation, which was originally proposed by Rodrik (2008, p. 371) and later used in other studies, such as that of Glüzmann *et al.* (2012) and Rapetti *et al.* (2012):

$$\ln \mathrm{RER}_{i,t} = \beta_0 + \beta_1 \ln \mathrm{RGDPCH}_{i,t} + y_t + \varepsilon_{i,t} \tag{1}$$

Here, the RERU measure is obtained with the error term $\varepsilon_{i,t}$, which constitutes the unexplained level of RER that cannot be accounted for from a country's income level ($\ln \mathrm{RGDPCH}_{i,t}$) nor from time-specific shocks (y_t). One salient feature of the results presented in Table 1 is that the BSE estimate ($\hat{\beta}_1 = -0.1291$) is almost half of the magnitude reported in other, related studies (Glüzmann *et al.*, 2012; Rodrik, 2008). This difference in the estimation results could be due to disparities between the studies in terms of the period sampled, the approach used for dealing with missing data, as well as the use of a more recent data set. Moreover, the results in Table 1 could be criticized due to the model's low goodness of fit (0.1046). However, adding more covariates to improve the goodness of fit of the RER model (as conducted in the RER fundamentals literature) may give the impression that the RER of some countries is close to equilibrium for given periods, when in fact it might be over- or undervalued, as argued above..

Results and discussion

The main hypothesis of this study asserts that RERU is a relevant driver of growth across development levels. Additionally, the progression of a country's DTCs is expected to play a more important role as a growth driver in emerging markets compared to developing countries. The baseline growth model used to test these sub-hypotheses is as follows:

$$\mathrm{GROWTH}_{i,t} = \beta_0 + \beta_1 \ln \mathrm{RGDPCH}_{i,t-1} + \beta_2 \mathrm{ITS}_{i,t} + \beta_3 \mathrm{RERU}_{i,t} + \beta_4 \mathrm{ITS}_{i,t} \times \mathrm{DEV}_i + \beta_5 \mathrm{ITS}_{i,t} \times \mathrm{EME}_i + \beta_6 \mathrm{RERU}_{i,t} \times \mathrm{DEV}_i + \beta_7 \mathrm{RERU}_{i,t} \times \mathrm{EME}_i + c_i + y_t + \varepsilon_{i,t} \tag{2}$$

in which $\mathrm{GROWTH}_{i,t}$ is defined as the year-on-year percentage change in RGDPCH for country *i* in year t; Ln. $\mathrm{RGDPCH}_{i,t-1}$ is country *i*'s lagged natural logarithm of its real GDP per capita level, *i.e.*, the usual convergence term used in growth regressions; $\mathrm{ITS}_{i,t}$ is the country's ITS in year *t*; $\mathrm{RERU}_{i,t}$ is its real undervaluation measure for the same year; DEV_i and EME_i are binary variables if country *i* is a developing or emerging country respectively, and zero otherwise; c_i is country *i*'s fixed effect; y_t is the fixed effect for year *t*; and $\varepsilon_{i,t}$ is an idiosyncratic error term.

The inclusion of the fixed effects of both country and year allows β_2 and β_3 to be interpreted as the impact that changes in RERU and the ITS have had on the growth rate in each country. By incorporating interaction terms, I can determine whether the impact of these variables varies in comparison to the reference group of developed countries. This means that the impact of RERU on growth in developing countries is given by $\beta_3 + \beta_6$. The data for these equations were provided by an Economic Commission for Latin America and the Caribbean database with ITS values for up to 210 countries and territories between 1985 and 2004 (ECLAC 2011). The remaining necessary variables were obtained from the Penn World Table 7.0 (Heston *et al.*, 2011).

Finally, a recent technique at time of writing was chosen to deal with missing data: the multiple imputation model. A common approach to reducing the bias created by missing data used in empirical studies investigating the impact of RERU on growth is to use five-year averages of the variables of interest in the TSCS regressions (Rodrik, 2008; Glüzmann *et al.*, 2012; Rapetti *et al.*, 2012). However, using average values strongly reduces the number of observations available for running regressions. Since the ITS data available only cover a period of 20 years, this would have reduced my T to five, which is too low for TSCS analysis. Given this relatively short time span for the ITS, I had to run TSCS regressions with annual data. I therefore chose to use the multiple imputation model for TSCS data proposed by Honaker and King (2010), to address missing data under these parameters.

After removing growth outliers from the sample, the overall findings from specifications 5 and 6 in Table 2 align with the hypothesis that RERU has a positive and significant impact on growth across all development levels, once DTCs are controlled for. Growth outliers were defined as countries with average growth rates higher than that of Equatorial Guinea. Equatorial Guinea is a sparsely populated country that had a low income per capita at the beginning of the period, but managed to reach a high-income status by the end of the period thanks to the discovery of oil fields (Frynas, 2004). No similar circumstances could be found for countries with growth rates above that of Equatorial Guinea. The existence of these growth outliers might be due to the multiple imputation algorithm performing poorly for some countries' growth rates due their having a high level of missing data on GDP per capita.

Although specification 5 is more parsimonious, specification 6 is preferred for several reasons. In Table 2, the Lagrange multiplier test of specification 5 yields a p-value of zero, which rejects the null hypothesis of no serial correlation. This means that specification 5 violates the Gauss-Markow assumption of no serial correlation, and so ordinary least squares no longer produce the best linear unbiased estimators, and its test statistics lose validity. To address this issue, Beck and Katz (2011, p. 339) suggest including the lagged dependent variable, which I integrated on the right-hand side in specification 6. I then applied a Lagrange multiplier test to verify the presence of serial correlation. As shown in Table 2, the resulting p-value does not provide evidence to reject the null hypothesis of no serial correlation.

Countries were categorized following Rodrik's (2008, p. 377) parameters, that defined as developing economies all countries with an average GDP per capita lower than USD 6,000 in PPP according to 2005 levels, for the period analyzed. Emerging economies are countries with an average GDP per capita equal to or above USD 6,000 and below USD 10,725. Countries above the upper bound of this income range — which was the threshold used by the World Bank in 2005 to define the high-income group (World Bank, 2012) — are classified as developed countries. The results of specification 6 contrast with the impacts of RERU on growth reported by Rodrik (2008, p. 375). In his study, Rodrik reported a positive yet not significant coefficient for developed countries, as well as a much larger positive and significant coefficient for developing countries.

Furthermore, after removing the growth outliers and controlling for the lagged dependent variable (growth) to avoid serial correlation problems, in the present study, the impact of ITS on growth was found to be insignificant for all country groups, as can be seen in Table 2. This lack of significance could be due to the existence of some degree of multicollinearity between GDP per capita and the ITS, which have a correlation coefficient of 0.36. To investigate further, I performed a multicollinearity analysis using a one-dimensional generalized variance inflation factor ($GVIF^{1/(2*df)}$), as recommended by Fox and Monette (1992) for regressions involving categorical variables. This metric is equivalent to the square root of the variance inflation factor (VIF). According to these authors, if the $GVIF^{1/(2*df)}$ associated with one regressor is larger than 2, a regression might suffer from serious multicollinearity problems (Fox & Monette, 1992, p. 182). This is the case with the regressors of lagged gross domestic product per capita ($GVIF^{1/(2*df)} = 7.988$), index of technological specialization ($GVIF^{1/(2*df)} = 2.828$), the developing country dummy ($GVIF^{1/(2*df)} = 2.633$), and the emerging economy dummy ($GVIF^{1/(2*df)} = 3.071$).

To mitigate the multicollinearity problem, it could be beneficial to generate an ITS that takes into account a country's development level. This transformation would also address endogeneity issues between GDP per capita growth and the ITS, since, according to Kaldor-Verdoorn's law, growth is a factor that drives technological change (Porcile & Lima, 2010). Therefore, a development-level corrected ITS (DCITS) will indicate the ITS of a country disassociated from its development level.

The results of specification 8 in Table 3 provide statistical evidence supporting the hypothesis that increases in the development-level corrected ITS (DCITS) adversely affect growth in developing countries, *ceteris paribus*.[5] To better understand this result, I will reiterate the definition of the ITS, as mentioned in the section "Domestic Technological Capabilities as Drivers of Economic Growth". Alcorta and Peres (1998) define the ITS as the ratio between the revealed comparative advantage of a country in mid- and high-technology manufacturing sectors and its revealed comparative advantage in natural resource-intensive and low-technology manufacturing industries. Moreover, the authors classified exports according to their deriving from high-, mid-, or low-technology sectors depending on the research and development intensity occurring in that sector in the Global North.

One drawback of the index is its tendency to overestimate the DTCs of countries of the Global South that are highly integrated into global value chains, and which therefore possess a high proportion of processed exports (Alcorta & Peres,

[5] The DCITS was generated following a similar method to that used for the RERU variable (see Appendix 1).

Table 2.
The impact of real exchange rate undervaluation and the index of technological specialization on growth, 1986-2004[a]

Independent variables	Specification number					
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	24.2***	25.16***	25.11***	25.58***	1.083**	0.92*
	(3.42)	(3.35)	(3.38)	(3.45)	(0.483)	(0.499)
Lagged gross domestic product per capita (in logarithm, purchasing-power-parity 2005 United States dollars)	-3.91***	-4.07***	-4.07***	-4.12***	-0.173**	-0.151*
	(0.55)	(0.55)	(0.55)	(0.58)	(0.078)	(0.081)
Index of technological specialization		2.24**	2.25**	2.82*	0.026*	0.021
		(1.12)	(1.14)	(1.12)	(0.015)	(0.016)
Real exchange rate undervaluation	0.2		0.28	-0.1	0.057**	0.067**
	(0.69)		(0.71)	(1.56)	(0.027)	(0.027)
Index of technological specialization x developing country dummy				-2.73	-0.028*	-0.024
				(1.52)	(0.016)	(0.017)
Index of technological specialization x emerging economy dummy				0.91	0.012	0.007
				(2.89)	(0.011)	(0.012)
Real exchange rate undervaluation x developing country dummy				0.35	-0.029	-0.027
				(1.26)	(0.036)	(0.034)

(Continued)

Independent variables	Specification number					
Real exchange rate undervaluation x emerging economy dummy				0.68	-0.04	-0.052*
				(1.43)	(0.029)	(0.028)
Lagged growth						-0.007
						(0.123)
% of significant country fixed effects	94	93	93	89	85	78
% of significant year fixed effects	6	6	6	6	6	59
Observations	3,629	3,629	3,629	3,629	3,002	2,844
	(N=191, T=19)	(N=191, T=19)	(N=191, T=19)	(N=191, T=19)	(N=158, T=19)	(N=158, T=18)
Adjusted R-square	0.18	0.2	0.2	0.2	0.12	0.13
Lagrange multiplier test p-value	0.17	0.35	0.35	0.27	0	0.22

Notes: Panel corrected standard errors in parenthesis; *** p-value<0.01; ** 0.01<p-value<0.05; * 0.05<p-value<0.10. Country and year fixed effects reported as significant when their p-value<0.10. [a] specifications 5 and 6 were regressed for 158 countries and the period of specification 6 was 1987–2004. Source: Own calculations based on data from ECLAC (2011) and Heston *et al*. (2011).

Table 3.
The impact of real exchange rate undervaluation and the development-level corrected index of technological specialization on growth in 158 countries between the mid-1980s and mid-2000s

Independent Variables	**Specification Number**	
	(7)	(8)
Intercept	1.103** (0.485)	0.941* (0.503)
Lagged gross domestic product per capita (in logarithm, purchasing-power-parity 2005 United States dollars)	-0.176** (0.078)	-0.155* (0.081)
Development-level corrected index of technological specialization	0.015 (0.01)	0.011 (0.011)
Real exchange rate undervaluation	0.058** (0.027)	0.068** (0.027)
Development-level corrected index of technological specialization x developing country dummy	-0.051* (0.02)	-0.045* (0.022)
Development-level corrected index of technological specialization x emerging economy dummy	0.02 (0.013)	0.015 (0.014)
Real exchange rate undervaluation x developing country dummy	-0.033 (0.036)	-0.03 (0.034)
Real exchange rate undervaluation x emerging economy dummy	-0.04 (0.042)	-0.054* (0.028)
Lagged growth		-0.009 (0.122)

(Continued)

Independent Variables	**Specification Number**	
% of significant country fixed effects	85	78
% of significant year fixed effects	6	59
Observations	3,002 (N = 158, T = 19)	2,844 (N = 158, T = 18)
Adjusted R-square	0.12	0.13
Lagrange multiplier test p-value	0.002	0.329
Timeframe	1986-2004	1987-2004

Notes: Panel corrected standard errors in parenthesis; *** p-value < 0.01; ** 0.01 < p-value < 0.05; * 0.05 < p-value < 0.10. Country and year fixed effects reported as significant when their p-value < 0.10. Source: Own calculations based on data from ECLAC (2011) and Heston *et al*. (2011).

1998, p. 879). Vertical specialization is an indicator of integration into global value chains (Hummels *et al.*, 2001). When calculating the correlation between the ITS and vertical specialization in 35 developing countries (out of the 95 in the sample), between 1994 and 2001, the result is 0.713, which is a high correlation coefficient.[6] The correlation between DCITS and vertical specialization was also positive and moderate — albeit weaker —, with a coefficient of 0.625 for the same group of countries and during the same period. It can therefore be speculated that the negative interactions between the DTCs indicator and the developing country dummy obtained in specifications 6 (Table 2) and 8 (Table 3) reflect the notion that participation in North-South global value chains hurts growth at lower development levels. However, the growth impact of the interactions between the DTCs variables and the emerging country dummy are positive as shown in Tables 2 and 3. These results align with those produced by Fagerberg *et al.* (2018).

The short-term growth impact of increases in the DCITS in developed countries is positive but not statistically significant, with a coefficient of 0.011, as shown in Table 3. Additionally, this coefficient is approximately half the size of the equally non-significant coefficient of the ITS for developed countries. shown in Table 2. This means that correcting the ITS for the development level of countries, did not result in increased DTCs in mid- and high-technology sectors with significant impacts on growth in developed countries. Moreover, in specifications 6 and 8, in Tables 2 and 3, respectively, the interaction between the dummy variable representing developing countries and the proxies for DTCs is negative. However, this interaction is only significant when DCITS is used. Finally, the interaction between the DTC proxies and the emerging market dummy is positive and not significant in both specifications, although its magnitude in specification 8 is double that of specification 6.

These results show that, between the mid-1980s and mid-2000s, increases in DTCs in mid- and high-technology sectors were slightly more relevant for growth in emerging markets than in developed countries. Moreover, the results suggest that developing countries that specialized in natural resource-intensive and low-technology manufacturing sectors had slightly higher growth rates, *ceteris paribus*. In specifications 6 and 8, the growth impact of RERU was found to be positive and significant for developed countries. However, its impact on growth in developing and emerging countries, while still significant, was comparatively weaker. In emerging markets especially, its impact was significantly weaker.

Before concluding, I will comment on the results of the multicollinearity analysis performed on regression specification 8, shown in Table 3. In specification 8, the equivalent regressors from specification 6 exhibited $GVIF^{1/(2*df)}$ values greater than 2. Specifically, the lagged gross domestic product per capita showed a $GVIF^{1/}$

[6] The selected period for calculating the correlation coefficient coincided with both the data used in the paper (1986–2001) and the data from the UNCTAD-Eora Global Value Chain database (1994–2017), which was used to construct the vertical specialization variable (Lenzen *et al.*, 2012, 2013). A similar rationale was applied in the selection of countries for analysis.

$^{(2*df)}$ value of 8.019, development-level corrected index of technological capabilities had a value of 2.528, the developing country dummy had a value of 2.535, and the emerging economy dummy had a value of 2.908. Based on these results, multicollinearity could still present an issue. However, in line with O'Brien's (2007) cautionary advice, it is important not to rely too heavily on general rules of thumb regarding variance indicators of regressors, without considering the specific context.

Given the results obtained from specification 6, a valid concern regarding multicollinearity emerged due to the high $GVIF^{1/(2\ df)}$ value associated with the ITS was accompanied by a failure to reject the null hypothesis of no growth impact of this variable, despite the extensive literature theorizing the existence of such growth impact and partly reviewed in the section on "Development, Technology and Trade Patterns". I therefore decided to adjust this variable according to the theory behind Kaldor-Verdoorn's law, which argues that growth drives technical change. This transformation led to a somewhat lower $GVIF^{1/(2\ df)}$ value for the development-level corrected ITS in specification 8 than for ITS in specification 6 ($2.528 < 2.828$). Furthermore, although the development-level corrected ITS interaction with the developing country dummy still exceeded the conventional threshold of 2 for multicollinearity, it was statistically significant. As a result, there is no reason to question the validity of this result on concerns of multicollinearity (O'Brien, 2007, p. 682).

CONCLUSION

The results provide stronger support for the hypothesis related to the growth impacts of RERU across development levels than the hypothesis regarding the different growth impacts of DTCs. This shows the robustness of the empirical evidence in favor of the hypothesis that RERU should also be positive and significant for the case of emerging markets. By contrast, the evidence supporting the hypothesis that increases in DTCs in mid- and high-technological manufacturing sectors should have a greater impact on growth in emerging economies with respect to developing countries was less conclusive. Nonetheless, the results support the idea that RERU should play an important role in the development strategies of emerging markets. Finally, the results indicate that processed exports of mid- and high-technology manufactured goods have a negative impact on the growth of developing countries. This finding highlights the potential for future research analyzing the trade direction of these types of manufactured goods for developing and emerging countries. This could contribute to understanding the relevance of trade direction as a determining factor in establishing the significant impact of DTC proxies on economic growth.

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APPENDIX 1

The ITS corrected for a country's development level is defined as the residual obtained from the following equation:

$$ITS_{i,t} = \beta_0 + \beta_1 \ln RGDPCH_{i,t} + y_t + \varepsilon_{i,t} \quad (3)$$

in which the dependent variable is the $ITS_{i,t}$ of country i in year t, $\ln RGDPCH_{i,t}$ is the respective natural log of real GDP per capita, y_t the fixed effect for year t and, $\varepsilon_{i,t}$ is an idiosyncratic error term. If the error term is a positive value, it means that a country has a level of the ITS above what is expected given its development level. Table 4 reports the results of the regression estimation based on Equation 3.

As can be seen in Table 4, the coefficient estimate of GDP per capita displays the expected sign and is significant at 1%. This is statistical evidence that supports the hypothesis that — *ceteris paribus* — a 10% increase in a country's GDP per capita level was accompanied by an average increase of 0.018 points in its ITS. This finding is based on the sample of data from 191 countries spanning 1985 and 2004.

Table 4.
The effect of gross domestic product per capita increases on the index of technological specialization, 1985-2004

Independent variable	
Intercept	-1.123***
	(0.049)
Gross domestic product per capita (in logarithm, purchasing-power-parity 2005 United States dollars)	0.184***
	(0.006)
% of significant year fixed effects	0%
Observations	3,820
	(N=191, T=20)
Adjusted R^2	0.124
Lagrange multiplier test p-value	0

Notes: Panel corrected standard errors in parenthesis; *** p-value<0.01; ** 0.01<p-value<0.05; * 0.05<p-value<0.10. Year fixed effects reported as significant when their p-value<0.10. Source: Own calculations based on data from ECLAC (2011) and Heston *et al*. (2011).

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