OECD DEVELOPMENT CENTRE

Working Paper No. 313

DEVELOPMENT ACCOUNTING: LESSONS FOR LATIN AMERICA

by

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Research area:
Latin American Economic Outlook

June 2012

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ACKNOWLEDGEMENTS

I would like to thank Marcela Eslava and Daniel Ortega, as well as participants at the Economía of May 2011 in Washington DC for helpful suggestions and comments. Laura Alfaro, Mauricio Cárdenas, Francesca Castellani, Eduardo Fajnzylber, Eduardo Fernández-Arias, William Maloney and participants at the October 2009 INNOVALatino Experts Meeting in Buenos Aires gave insightful comments and suggestions on an earlier version of this paper. Arne Nagengast provided superb research assistance. Any remaining errors are my sole responsibility. The opinions expressed in this paper are personal and do not necessarily reflect those of the OECD or the governments of its member countries.

PREFACE

The factors and policies that make countries succeed or fail in their quest for economic growth and development have been the subject of analysis and debate since economics as a discipline came into existence. Even the less ambitious objective of a better understanding of the contribution of production factors -- such as physical capital, labour and human capital -- and productivity increases due to technological change or efficiency gains, are full of methodological and measurement complexities. Quantifying these relative contributions is a relevant first step to defining policy priorities, as policies that boost innovation and economic efficiency do not necessarily coincide with policies that promote faster capital accumulation (physical or human).

This paper makes a contribution to this debate on the measurement and relative contribution of production factors and total factor productivity to income per capita gaps of Latin American countries with respect to the frontier. Previous research has generally pointed towards productivity shortfalls as the main driver of the income gap of the average Latin American country. However, this paper shows that this conclusion depends critically on the production function and frontier benchmark, as well as how differences in the quality of education are treated. Using a data envelope analysis that allows for factor-dependent TFP frontiers, the paper shows that production factors tend to be more important than is usually considered in the literature. Furthermore, adjusting human capital for differences in cognitive skills significantly increases the contribution of human capital in explaining the income per worker gap. Finally, taking into consideration the endogeneity of physical capital and productivity shows that there are very heterogeneous realities within Latin America.

Overall, the results highlight the limitations of cross-country benchmarks to define policy priorities. This does not mean that the traditional accounting exercises are not informative in certain circumstances, but rather that they have to be complemented with a more country-specific approach that takes into account the existing heterogeneity as well as institutional characteristics that are often key to understanding the success or failure of policies.

In addition to contributing to the Development Centre's work on Latin America and its flagship report, the paper is also useful for the OECD Strategy on Development, endorsed at the OECD Ministerial Council Meeting in May 2012, as it highlights the need for careful benchmarking and a country-specific approach to understand the bottlenecks and constraints to sustainable and inclusive economic development.

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June 2012

RÉSUMÉ

Ce document de recherche présente des expériences analysant les facteurs à l'origine des écarts dans le niveau du PIB dont souffre l' Amérique latine, grâce à des méthodes et des bases de données nouvelles afin d'évaluer la robustesse des résultats déjà existants. Alors que la productivité globale des facteurs apparaît dans un premier temps comme le principal responsable des écarts de *l'output* par travailleur en Amérique latine et les Caraïbes, ce « fait » n'est pas robuste face aux formes fonctionnelles alternatives, aux ajustements dans la qualité du capital humain et aux considérations endogènes. Ce document souligne l'hétérogénéité entre les pays de la région et discute des démarches alternatives pour établir des liens entre le *benchmarking* macroéconomique et les politiques.

Classification JEL: O11, O47.

Mots clés: croissance économique, facteurs de croissance, productivité globale des facteurs, Amérique latine.

ABSTRACT

This paper presents development accounting exercises in Latin America using novel databases and methods to investigate the robustness of its results. While total factor productivity initially appears to be the most important driver of output per worker gaps in Latin America and the Caribbean, this "fact" is not robust to alternative functional forms, adjustments for the quality of human capital and endogeneity considerations. The paper also highlights the heterogeneity among countries in the region and discusses alternative ways to link macroeconomic benchmarking to policies.

JEL classification: O11, O47.
Keywords: economic growth; developing accounting; total factor productivity; Latin America.

I. INTRODUCTION

Despite some improvements in recent years, long-term economic growth in Latin America has been rather disappointing over the past decades. GDP per capita gaps have widened steadily since 1960, not only compared to developed economies but also other peers (see Table 1). While the typical Latin American country[1] was around 4.4 times poorer than the United States in 1960, as of 2008 the gap has increased to 5.5 times. The comparison to twin economies – countries that in 1960 had a similar level of GDP per capita to those in Latin America[2] – is even more remarkable. The average Latin American economy was just 20% poorer than its typical twin economy in 1960. In 2008, GDP per capita in Latin America was less than half compared to twin economies.

This persistent decline in relative GDP per capita has been rather common to all countries in the region, with some exceptions. Out of the 19 Latin American and Caribbean economies in our sample, 5 managed to grow faster than the United States during the period 1960-2008: Brazil, Chile, Colombia, the Dominican Republic and Panama. However, progress has been quantitatively modest. For example, if benchmarked to twin economies, only the Dominican Republic and Panama managed to grow faster over the same period. Furthermore, in several cases progress was made mainly during the 1960s and 1970s (*e.g.* Brazil), with growth being subpar from the debt crisis in the early 1980s onwards. While the 2000s have been good years in terms of the relative growth performance for the region, it would still take around 27 years to cut by 50% the GDP per capita gap with respect to the United States if the growth differential during 2000-2008 of around 1.5% per annum were to be maintained, while with respect to twin economies it would take around 108 years. Therefore, low potential growth continues to be a significant challenge for the region nowadays.

1 Throughout the paper, we use the terms "typical" or "average" country indistinctly to refer to the geometrical average across countries within a region.

2 Twin economies are those that were in the second and third quartile of the world's GDP per capita distribution in 1960 – a range where most Latin American countries were at that time – and for which all data used in this paper to perform the accounting exercises are available (investment, education, etc). The resulting group of countries is composed by: Cyprus, Greece, Iran, Ireland, Israel, Japan, Jordan, Korea, Mauritius, Portugal, South Africa, Spain and Turkey.

Table 1. **GDP per capita in Latin America relative to benchmarks**

Country	GDP per capita relative to United States					
	1960	**1970**	**1980**	**1990**	**2000**	**2008**
Argentina	0.395	0.370	0.331	0.234	0.234	0.272
Bolivia	0.175	0.138	0.133	0.089	0.084	0.087
Brazil	0.189	0.217	0.298	0.233	0.202	0.215
Chile	0.241	0.221	0.189	0.182	0.247	0.286
Colombia	0.160	0.146	0.165	0.147	0.153	0.176
Costa Rica	0.318	0.311	0.318	0.238	0.231	0.262
Dominican Republic	0.149	0.138	0.172	0.154	0.186	0.224
Ecuador	0.177	0.155	0.219	0.156	0.129	0.144
El Salvador	0.222	0.201	0.179	0.131	0.141	0.151
Guatemala	0.193	0.194	0.220	0.151	0.140	0.143
Honduras	0.146	0.118	0.132	0.100	0.078	0.085
Jamaica	0.367	0.351	0.256	0.232	0.227	0.211
Mexico	0.293	0.305	0.364	0.279	0.264	0.289
Nicaragua	0.173	0.180	0.127	0.070	0.053	0.050
Panama	0.139	0.165	0.201	0.186	0.177	0.228
Paraguay	0.121	0.099	0.141	0.119	0.089	0.088
Peru	0.243	0.247	0.218	0.136	0.130	0.165
Uruguay	0.307	0.226	0.246	0.202	0.213	0.246
Venezuela	0.449	0.413	0.391	0.261	0.212	0.220
Average LAC country relative to						
United States	0.225	0.213	0.222	0.167	0.161	0.182
Twin economies	0.834	0.670	0.632	0.486	0.448	0.462

Source: Own calculations based on Heston *et al.* (2011).

Note: GDP per capita is PPP adjusted and HP filtered with smoothing parameter 6.25.

This paper contributes to the understanding of what drives this poor performance by using new databases and analytical tools to explore the relative importance of productivity and factor accumulation across Latin America and the Caribbean. Regarding the analytical tools, the paper provides new evidence from three viewpoints. First, we perform a careful analysis of different ways of decomposing GDP per capita levels into total factor productivity (TFP), physical and human capital, under different assumptions regarding the production function and measurement. Second, we discuss endogeneity of factors and productivity jointly and present a detailed calibration exercise of an endogenous "varieties" growth model by Cordoba and Ripoll (2007). Third, we present non-parametric estimations of efficiency based on a data envelope analysis that does not rely on the traditionally used Cobb-Douglas production function. In terms of new datasets this paper uses three newly available sources. First, in contrast to previous studies focusing on Latin America, we use the new version of the Barro and Lee (2010) dataset on educational attainment which addresses several concerns on data quality with respect to its previous version (see Cohen and Soto, 2007; as well as De la Fuente and Domenech, 2006). Second, we also use the latest version of the Penn World Tables (version 7.0) extending our analysis until 2008, which allows us to cover the 2000's, a decade that has been quite successful for the region in terms of economic growth compared to its past. Third, we use the OECD's PISA 2009 test scores to analyse the importance of cognitive skills.

The paper focuses on the robustness of the decompositions of GDP per worker into productivity, physical and human capital using alternative methods, as policy recommendations might differ substantially according to the source of income disparities, in particular if policy makers have to establish priorities and have limited political capital to implement reforms. Furthermore, while recent work on Latin America has emphasised the importance of TFP (see Daude and Fernández-Arias, 2010) for the region as a whole, the present paper tries to go more in detail into the differences across countries within the region. The remainder of the paper is structured as follows. The second section presents the data sets and basic definitions used along the paper and some preliminary evidence using traditional development accounting techniques. The third section presents some robustness checks regarding these basic results considering among them different specifications within the standard Cobb-Douglas production function framework, the effects of terms-of-trade and natural resources and the quality of education. In the following section, we explore alternative production functions based on a non-parametric estimation of a production possibility frontier. The fifth section discusses the endogeneity issue of TFP and factor accumulation and presents different exercises, including the calibration of an endogenous growth model following Cordoba and Ripoll (2007). Finally, in last section we sum up our results discussing their main policy implications as well as future research needed.

II. DEVELOPMENT ACCOUNTING: BASIC RESULTS

II.1. Data

For aggregate production in our baseline results, we use PPP adjusted series at 2005 prices from the latest Penn World Tables 7.0 available for nineteen Latin American and Caribbean economies in a consistent way from 1957 to 2008 (see Heston *et al.*, 2011).[3] The workforce and physical capital investments (at constant 2005 prices) are also from this database. We use the workforce instead of hours worked to proxy labour inputs, as the latter are available only for seven countries. However, we use output per hour worked as an alternative series in our robustness checks. For the construction of physical capital stocks, we follow the usual perpetual inventory method approach (see *e.g.* Caselli, 2005). The initial capital stock (K_0) is given by $K_0 = \frac{I_0}{g+\delta}$, where I_0 is aggregate investment in the first available year, g is the geometric average of GDP growth rates between the first year available and 1960, and the depreciation rate (δ) is set equal to 0.07. From the initial date onwards the capital stock is updated using the following equation: $K_t = I_t + (1-\delta)K_{t-1}$.

We use the average years of schooling of the population over 15-years old from Barro and Lee (2010) to construct the human capital series according to Hall and Jones (1999). In particular, we map the years of schooling (s) into human capital (h) using: $h = e^{\phi(s)}$, where $\varphi(.)$ is a piecewise linear function equal to $0.134 \cdot s$ if $s \leq 4$, $0.536 + 0.101 \cdot s$ if $4 < s \leq 8$ and $0.94 + 0.068 \cdot s$ if $s \geq 8$. It is important to point out that this measure of human capital is based on the average quantity of formal education in population. Therefore, it ignores differences in the quality of education as well as skills that are acquired through work experience and other types of training of the workforce.

Finally, as we are interested in analysing long-term trends rather than business cycle fluctuations, we focus on Hodrik-Prescott filtered GDP, workforce, as well as physical and human capital series, using a smoothing parameter of 6.25 as suggested by Ravn and Uhlig (2002).

3 In particular, we consider the Laspeyres series "rgdpl" (per capita) and "rgdpl2wok" (per worker). The countries in our sample are: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay and Venezuela.

II.2. Standard development accounting

Differences in GDP per capita of LAC countries with respect to the United States are mainly driven by differences in output per worker. GDP (Y) per capita can be written as: $\frac{Y}{N}=\frac{Y}{L}\frac{L}{N_{15-64}}\frac{N_{15-64}}{N}$, where N is the population, L the labour force and $N_{15\text{-}64}$ the working-age population. Therefore, differences in GDP per capita could be driven by differences in output per worker, differences in labour force participation rates or by demographic factors (share of the working-age population -- between 15 and 64 years old -- in the total population). In 2008, for the average LAC country, around 92% of the GDP per capita gap with respect to the United States is explained by the GDP per worker gap, while differences in labour participation and demographics explain less than 8% of the development gap.[4] Therefore, in what follows we focus on decomposing output per worker gaps.

The standard developing accounting approach consists in adjusting a Cobb-Douglas production function such as:

$$Y = AK^{\alpha}(hL)^{1-\alpha}, \qquad (1)$$

where Y is aggregate GDP, A is TFP, K the aggregate physical capital stock and hL the human capital adjusted workforce. In our baseline analysis, the capital-share production function parameter α, is set equal to 1/3, as usual in the literature.[5] In per worker terms, this yields:

$$y = Ak^{\alpha}h^{1-\alpha}. \qquad (2)$$

Dividing (2) by the benchmark's GDP per worker – denoted by y^* – and taking logs yields a decomposition of output per worker gaps given by:

$$\log y - \log y^* = (\log A - \log A^*) + \alpha(\log k - \log k^*) + (1-\alpha)(\log h - \log h^*). \quad (3)$$

Applying this decomposition to the 2008 data across countries in the region with respect to the United States shows that on average TFP accounts for around 52% of the output per worker gap, followed by physical capital with a contribution of nearly 36% and finally with human capital accounting for the remaining 12% (see Figure 1). However, there are significant differences regarding the relative contribution of each factor within the region. While TFP explains just around one third of the gap in Guatemala, its contribution amounts to almost two-thirds for the case of Jamaica. There is no clear pattern in terms of the level of development and the contribution of the different factor to the output per worker gap. For example, within Central America in Guatemala and El Salvador factors (physical and human capital) contribute between 63.5% and 53%, while in Nicaragua and Honduras TFP is the main factor (60.2% and 56.7%,

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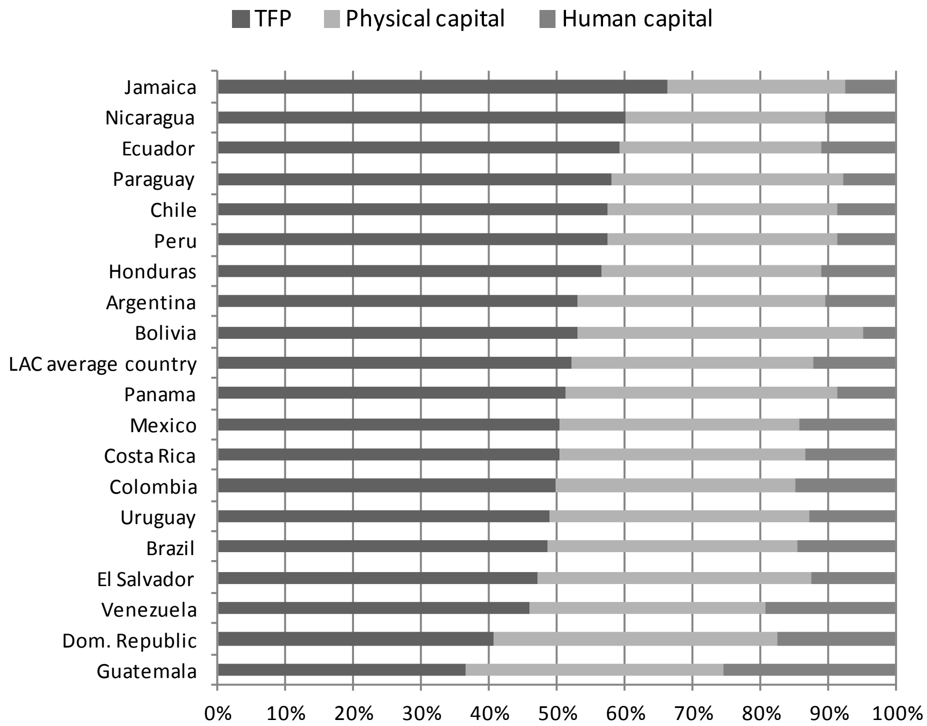
4 However, there are differences within the region. For some economies in the region labour participation and demographic differences are more significant in contributing to the GDP per capita gap. For example, in Mexico they account for almost 16% of the gap (mainly due to low female labour force participation). Meanwhile, in the case of Brazil the contribution of these factors is actually slightly negative (*i.e.* they narrow the GDP per capita gap with respect to the United States), contributing -1.7 in 2008.

5 While Gollin (2002) shows a large variation across countries in this parameter, once adjusting for informal labour markets and self employment, there are no significant trends in terms of economic development (GDP per capita levels) and labour income shares. Thus, the assumption of a constant and equal parameter across countries does not seem too restrictive to begin with. However, some authors argue that capital shares are higher in developing countries (see *e.g.* Rodriguez and Ortega, 2006).

respectively). Finally, Costa Rica and Panama – two economies with higher income per capita levels than the rest of the region – are in the middle in terms of the relative contribution of TFP and factors. In the southern cone a similar picture emerges. For example, countries like Chile and Paraguay have very similar relative contributions of TFP, physical and human capital to their gaps with respect to the United States, despite the fact that Chile's GDP per capita is more than 3 times that of Paraguay.

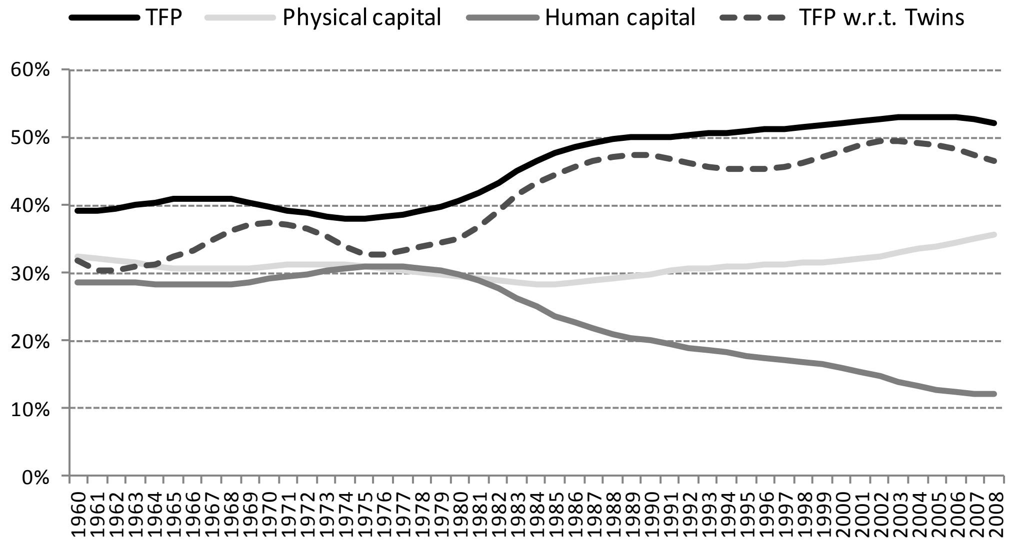
Figure 1.**GDP per worker decomposition relative to United States in 2008**



Source: Own calculations based on Barro and Lee (2010) and Heston *et al.* (2011).

Another interesting finding is that the contribution of human capital is rather limited, on average just 12% of the output per worker gap with respect to the United States. As Figure 2 shows, the relative contributions of TFP, physical capital and human capital have changed significantly over time. While during the 1960s and 1970s human capital accounted for almost one-third of the gap, physical capital at a similar level and TFP only slightly above, during the 1980s TFP increased its contribution to around 50%, while human capital started to decline steadily from 30% in 1980 to just above 12% in 2008. TFP's contribution to the gap has remained slightly above 50% since the 1980s, while physical capital has increased its contribution from around 29% to around 36%. Again, there are different patterns across countries within the region over time. During the period 1980-2008, TFP's contribution has remained relatively the same for Argentina, Bolivia, Chile, Dominican Republic, Ecuador, Panama, Peru and Uruguay, while it increased significantly in the remaining countries. The increase has been particularly steep in Brazil and Mexico, where the contribution of TFP to the output per worker gap with respect to the United States was negative or minor in 1980 and accounts for around half of the gap in 2008. While it could be argued that these trends are specific to the counterfactual – the United States economy – the dotted line in Figure 2 shows that this is not the case. Considering the contribution of TFP of LAC with respect to twin economies a similar trends emerge.

Figure 2.**Evolution of contributions to the GDP per worker gap relative to United States for the typical LAC country**



Source: Own calculations based on Barro and Lee (2010) and Heston *et al.* (2011).

Table 2.**Contributions to the output per worker gap vis-à-vis the United States by country**

	1980			2008			2008-1980		
	TFP	Physical Capital	Human Capital	TFP	Physical Capital	Human Capital	TFP	Physical Capital	Human Capital
Argentina	0.56	0.20	0.24	0.53	0.36	0.10	-0.03	0.16	-0.13
Bolivia	0.46	0.35	0.19	0.53	0.42	0.05	0.07	0.07	-0.14
Brazil	0.14	0.31	0.56	0.49	0.37	0.15	0.35	0.06	-0.41
Chile	0.53	0.28	0.19	0.58	0.34	0.09	0.04	0.06	-0.10
Colombia	0.37	0.33	0.29	0.50	0.35	0.15	0.13	0.02	-0.15
Costa Rica	0.22	0.41	0.37	0.50	0.36	0.14	0.29	-0.05	-0.24
Dominican Republic	0.38	0.36	0.25	0.41	0.42	0.18	0.03	0.05	-0.08
Ecuador	0.56	0.17	0.27	0.59	0.30	0.11	0.03	0.13	-0.16
El Salvador	0.28	0.37	0.35	0.47	0.40	0.12	0.20	0.03	-0.23
Guatemala	0.18	0.36	0.46	0.36	0.38	0.25	0.18	0.02	-0.21
Honduras	0.38	0.34	0.29	0.57	0.32	0.11	0.19	-0.01	-0.18
Jamaica	0.54	0.22	0.24	0.66	0.26	0.07	0.12	0.05	-0.17
Mexico	-0.07	0.33	0.74	0.50	0.35	0.14	0.57	0.02	-0.59
Nicaragua	0.46	0.25	0.29	0.60	0.29	0.11	0.14	0.04	-0.19
Panama	0.47	0.31	0.22	0.51	0.40	0.09	0.04	0.09	-0.13
Paraguay	0.44	0.35	0.21	0.58	0.34	0.08	0.14	-0.01	-0.14
Peru	0.51	0.24	0.25	0.57	0.34	0.09	0.06	0.10	-0.16
Uruguay	0.50	0.29	0.20	0.49	0.38	0.13	-0.02	0.09	-0.07
Venezuela	0.29	0.08	0.64	0.46	0.35	0.19	0.17	0.27	-0.44
LAC – typical country	0.41	0.30	0.30	0.52	0.36	0.12	0.12	0.06	-0.18

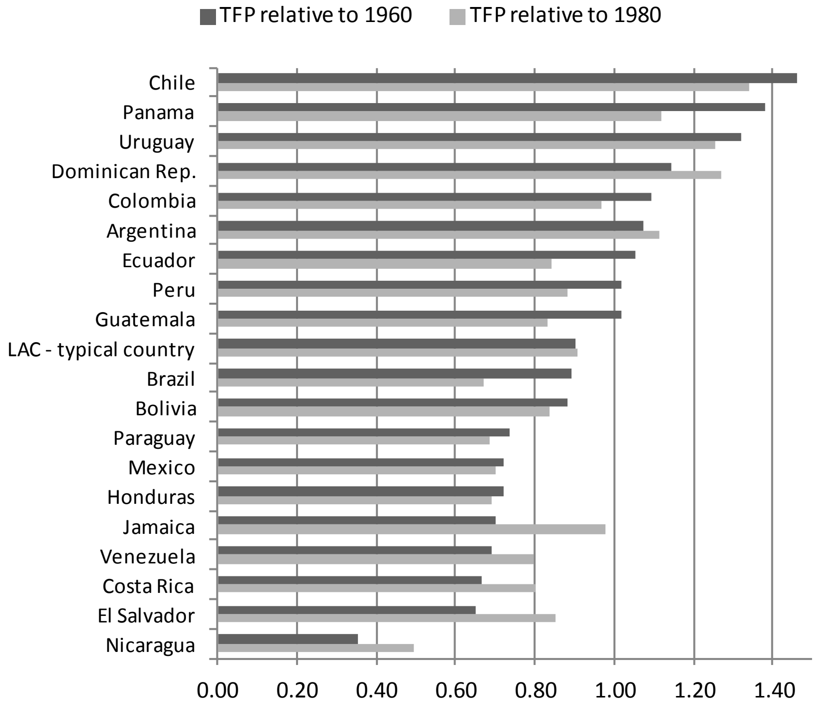
Source: Own calculations based on Barro and Lee (2010) and Heston *et al.* (2011).

Note: GDP per capita is PPP adjusted and HP filtered with smoothing parameter 6.25.

Not only did TFP grow relatively slower in LAC than in benchmark countries – as shown by the widening income per capita gaps (Table 1) and the increasing contribution of TFP to this gap (Figure 2) – but in many countries of the region TFP levels in 2008 are actually below those of the early 1980s.[6] While nine countries present higher or similar TFP in 2008 than in 1960, only three countries (Chile, Panama and Uruguay) managed to have in 2008 TFP levels 20% -- the cumulative growth rate of TFP in the United States during the same period -- or more above their levels of 1960 (Figure 3). On average TFP in 2008 was around 10% lower than the level of 1960. Furthermore, for many countries the picture is more acute when compared with 1980s. For example, Brazil's TFP level in 2008 is just two-thirds that of 1980. This contrasts somewhat with other economies in the Southern Cone, such as Argentina, Chile and Uruguay, who managed to raise their TFP levels. In Central America and the Caribbean, Panama and the Dominican Republic – and to some degree Jamaica -- stand out as the relatively successful economies in terms of raising their TFP levels from 1980 onwards, with other economies reaching levels of TFP of just half of that of 1980 (Nicaragua). Declines in TFP levels are difficult to understand if TFP is given a narrow technological interpretation. Alternative interpretations, which can be grouped into two, could be offered. First, TFP -- as measured here -- captures the overall efficiency at which inputs map into aggregate output, therefore distortions in the allocation of factors across sectors or firms can result in lower levels of output per units of input if resources are reallocated to inefficient sectors or firms. This would be also in line with the finding by McMillan and Rodrik (2011) that in Latin America structural change – the reallocation of resources across sectors of economic activity – has had a negative contribution to output per worker growth. The question here is what drives these distortions – which policies, politics, market failures or structural characteristics. The second group of interpretations is that measured TFP just captures all measurement and specification errors in equation 2. We will address these concerns below.

6 Daude and Fernández-Arias (2010) also highlight this fact.

Figure 3.Total Factor Productivity levels in 2008 relative to 1960 and 1980



Source: Own calculations based on Barro and Lee (2010) and Heston *et al.* (2011).

Next, we investigate what drives the dispersion in income per worker across countries in the region. In particular, we emphasise the role of TFP versus physical and human capital. Let $y_{kh} = k^{\alpha}h^{1-\alpha}$ be the level of income if all countries had the same level of efficiency (TFP), such that difference across countries would only be explained by differences in factors. We can compute the following indicator to quantify the explanatory power of production factors to explain the differences in GDP per worker within the region (see Caselli, 2005):

$$VR_1 = \frac{var(\log(y_{kh}))}{var(\log(y))}. \qquad (4)$$

Alternatively, as TFP and factors are correlated, Klenow and Rodriguez-Clare (1997) propose to use the following measure:

$$VR_2 = \frac{var(\log(y_{kh}))+cov(\log A, \log y_{kh})}{var(\log(y))}. \qquad (5)$$

Table 3.**Evolution of variances across LAC countries**

	1960	1970	1980	1990	2000	2008
GDP per worker	0.150	0.180	0.129	0.138	0.176	0.209
Factors (y_{kh})	0.067	0.064	0.045	0.038	0.036	0.038
TFP	0.092	0.089	0.064	0.071	0.088	0.100
Covariance (TFP, factors	-0.005	0.014	0.010	0.014	0.026	0.036
Variance ratio 1 (VR_1)	***0.445***	***0.353***	***0.346***	***0.276***	***0.207***	***0.183***
Variance ratio 2 (VR_2)	***0.415***	***0.430***	***0.425***	***0.380***	***0.353***	***0.353***

Source: Own calculations based on Barro and Lee (2010) and Heston *et al.* (2011).

Note: The first three rows refer to the variance of the logs between the 19 LAC countries in the sample.

Table 3 shows the evolution over time of the components of equations (4) and (5), as well as the variance of TFP (in logs). The dispersion within the region in output per worker has increased significantly (by 60%) since the 1980s. This has not been the case for the dispersion in factors, which declined somewhat during the 1980s and has remained constant throughout the 1990s and 2000s. In the meantime, there is an increase in the dispersion of TFP levels (by around 56% between 1980 and 2008) and also the covariance between TFP and factors. Regarding the relative importance of factors and TFP in explaining the dispersion in output per worker, according to the indicator VR_1, physical and human capital have been continuously losing ground, falling from a ratio of 44% in 1960 (35% in 1980) to below 19% in 2008. If we consider VR_2, the ratio is around 35% in 2008, below the 43% in 1980, but still significantly above the VR_1 measure.[7] Thus, the conclusion on what explains income per worker differences within the region depends to a certain degree on the treatment of the covariance term. The VR_1 indicator points clearly towards a declining importance of physical and human capital with more than 80% of the variation in output per worker in 2008 being explained by other drivers (TFP and the covariance term). The VR_2 indicator would still assign two-thirds of the output per worker gap to differences in TFP and just one third to physical and human capital. Therefore, TFP does not only contribute to explaining a large share (52% in 2008) of the average output per worker gap with respect to the United States, but it also seems to account for a significant share of the differences of output per worker within the region. We explore next the robustness of these and the previous results.

7 Interestingly, these latter levels of relative dispersion are similar to those found by Caselli (2005) for the whole world.

III. ROBUSTNESS

This section presents robustness checks regarding the production function parameters and specifications that might affect the results of the standard developing accounting presented so far. We do not focus on every possible source of variation, but rather on new ones or some not highlighted in the literature so far.[8] In particular, we analyse four different topics. First, we consider country-specific labour shares instead of a uniform share across countries. Second, we investigate the influence of the terms-of-trade on our measures of TFP. Third, we test the robustness of our results when considering output per hour worked instead of output per worker. Finally, we explore the importance of differences in the quality of education.

III.1. Country-specific labour shares

A first consideration is to relax the assumption that all capital/labour shares are the same across countries. We do so by considering the country-specific estimates of labour share from Bernanke and Gürkaynak (2002) that follows the methodology proposed by Gollin (2002).[9] The resulting sample of LAC countries are presented in the appendix (Table A.1). In terms of decomposing the output per worker ratios, equation (3) would now look like:

$$\log y - \log y^* = (\log A - \log A^*) + \alpha \log k - \alpha^* \log k^* + (1-\alpha)\log h - (1-\alpha^*)\log h^* \quad (6)$$

The previous decompositions into factors and TFP are not that straightforward anymore. While the contribution of TFP could in principle be computed focusing the first term on the right-hand side of (6), the other terms are a mix of differences in the production function (*i.e.* technological differences) and factor gaps. For example, we could rewrite the right-hand side as the TFP gap plus two factor gaps if all countries had the same production function and a last term due to the differences in the production function as:

$$\log \frac{A}{A^*} + \alpha^* \log \frac{k}{k^*} + (1-\alpha^*)\log \frac{h}{h^*} + (\alpha - \alpha^*)\log \frac{k}{h}. \quad (7)$$

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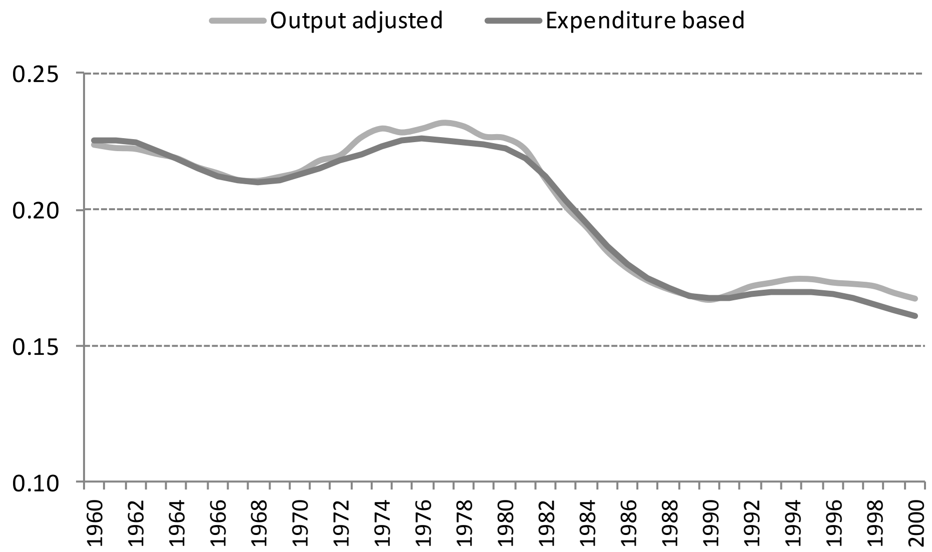
8 For an overall survey on these issues from a global perspective, see Caselli (2005). Daude and Fernández-Arias (2010) show that decompositions are not very sensitive to changing the capital share from 1/3 to 0.5 and alternative ways to compute the physical capital stock.

9 Although in principle one could also consider changes over time in the shares, the evidence provided by Bernanke and Gürkaynak (2002) and Gollin (2002) shows that in general there are no time trend or important fluctuations in labour shares over time for a large sample of developed and developing countries.In order to maximise coverage we consider first the labour share adjusting it for the operating surplus and private unincorporated enterprises (OSPUE). If this information is not available, we use the imputed OSPUE. Finally, if the required information to compute the imputed OSPUE is not available we use the labour-force corrected share (see Bernanke and Gürkaynak (2002) for more details).

Thus, the last term could be considered a technology factor which depends on the country's relative factor endowments and therefore it could be attributed to the "Solow residual" or part of the gap driven by factors. As shown in Table 4, this term makes a significant contribution to the output per worker gap. On average, it accounts for -53% of the output per worker gap. However if we combine it with the increased TFP contribution of 110%, the contribution attributable to TFP and differences in technology is on average 55%. Therefore, the difference with respect to the model with equal labour shares is just a 3% increase. As the exercise country-by-country shows, for all economies we get a somewhat similar increase. Thus, while under this interpretation differences in the production function parameters seem not to make a significant difference with respect to the results presented in Table 2, this conclusion depends on the idea that the last term in equation (7) could be thought of as differences in productivity induced by the difference in technologies related to the relative factor endowments $\frac{k}{h}$. Therefore, again the issue of how efficiency and productive factors interact seems to be important to understand further what drives output per worker gaps. In the next section, we will go beyond the Cobb-Douglas function and the uniform frontier implicitly used here to further explore these issues.

Figure 4. **GDP per worker gap relative to the United States according to alternative deflators**



Source: Own calculations based on Feenstra *et al.* (2009) and Heston *et al.* (2011).

III.2. Terms of trade

Another concern is the influence of commodity prices on TFP measurement. In our sample, the simple correlation coefficient for the average LAC economy between changes the terms-of-trade and TFP for the period 1980-2008 is 0.64 and statistically significant. This positive correlation between TFP and terms-of-trade growth could be driven by economic fundamentals or simply due to a measurement problem, such that price effects account for part of the increase in GDP growth (in PPP).[10] This problem relates to the issue of how GDP is measured in the PWT database –following the "expenditure side" rather than "output side" as Feenstra *et al.* (2009) put it. The PWT data measure real (PPP adjusted) income with deflators constructed using expenditure data which are influenced by the terms-of-trade rather than output-based deflators. These expenditure and output deflators can be very different, especially in small open economies, due to the terms-of-trade. Unfortunately, the required deflators are not available from 2001 onwards. Therefore, to assess the robustness of results, we look at the differences in trends from 1960 to 2000. Figure 4 plots the GDP per worker ratio of the average LAC country versus the United States using both alternative deflators.[11] As it can be seen, despite some differences between both series, the trends coincide and deviations never above 4%. Such small differences can therefore not affect the overall trends and facts we presented above for the LAC region as a whole.

Table 4. **Decomposition of output per worker gap in 2008 versus United States with country specific labour shares**

Country	A/A*	k/k*	h/h*	Interaction A/A* term	+ interaction term/a	Equal labour shares = 1/3 /b	Difference /a - /b
Bolivia	0.72	0.37	0.05	-0.14	0.58	0.53	0.05
Chile	1.40	0.29	0.09	-0.78	0.62	0.58	0.04
Colombia	0.91	0.31	0.16	-0.38	0.54	0.50	0.04
Costa Rica	0.30	0.31	0.14	0.24	0.54	0.50	0.04
Ecuador	2.05	0.26	0.12	-1.43	0.62	0.59	0.03
El Salvador	1.24	0.35	0.13	-0.73	0.51	0.47	0.04
Mexico	1.70	0.31	0.15	-1.16	0.54	0.50	0.03
Panama	0.21	0.35	0.09	0.34	0.55	0.51	0.04
Paraguay	1.33	0.30	0.08	-0.72	0.62	0.58	0.04
Peru	1.28	0.30	0.09	-0.67	0.61	0.57	0.04
Uruguay	1.38	0.34	0.14	-0.85	0.53	0.49	0.04
Venezuela	1.63	0.31	0.21	-1.15	0.48	0.46	0.02
Average LAC	***1.11***	***0.32***	***0.13***	***-0.56***	***0.55***	***0.52***	***0.03***

Source: Own calculations based on Barro and Lee (2010) and Heston *et al.* (2011).

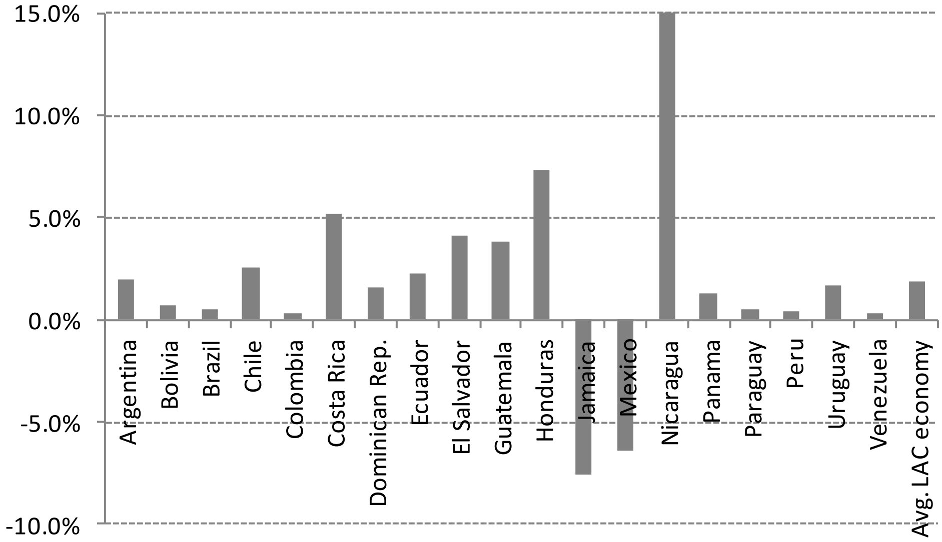
However, Figure 5 shows that the differences for individual countries can be significant. In fact, for Nicaragua the contribution of TFP to the output per worker gap in 2000 increases by more than 15% from around 51% to above 66%. The differences in TFP contributions are also significant for Honduras, Jamaica, Mexico and Costa Rica. Although we cannot infer from this that the influence of terms-of-trade in TFP measurement invalidates our results presented above, terms-of-trade seem likely to have first-order effects and should therefore be taken into account. For example, while overall regional trends seem to be relatively robust to this problem, country-

10 For example, if resources are very difficult to move across sectors, fluctuations in the terms-of-trade can induce fluctuation in aggregate measured TFP, as the movements in relative prices could induce fluctuations in factor utilisations. However, as we focus here on trends, *i.e.* filtered series, such effects should not be driving the correlation. See also Kehoe and Ruhl (2008) on this issue.

11 The data were downloaded from Feenstra's website: http://www.econ.ucdavis.edu/faculty/fzfeens/papers.html

specific diagnosis – a fundamental tool for evidenced-based policy – seems more sensitive to this issue and should therefore carefully review this issue in detail.

Figure 5. **Difference in the contribution of TFP to the output per worker gap versus the United States in 2000 between (Output-based minus baseline data)**



Source: Own calculations based on Barro and Lee (2010), Feenstra *et al.* (2009) and Heston *et al.* (2011).

III.3. Differences in labour intensity

Significant differences in labour intensity could affect our results regarding trends as well as levels of TFP differences across countries. To address this issue, we compare the contribution of TFP to the gap in output per worker and output per hour worked with respect to the United States for the seven countries where the information on hours is available in the PWT database. Table 5 shows that changing the measure of labour input does not have significant consequences for the relative importance of TFP versus physical and human capital. On average the impact for 1980 and 2008 is almost negligible, while in 1960 it accounted for a marginal increase in 2 percentage points of TFP's contribution to the gap. The main differences can be observed for Mexico in 1960 (with hours increasing the contribution of TFP by 5 percentage point), but as of 2008 for all countries the impact is not greater than one percentage point.[12]

12 These results are similar to Restuccia (2008) who finds that labour intensity and participate are not a major driver of the output gap with respect to the United States for the aggregate LAC region.

Table 5. **Contribution of TFP to output per hour or per worker versus United States**

Country	1960		1980		2008	
	Hours	Workers	Hours	Workers	Hours	Workers
Argentina	0.54	0.54	0.56	0.56	0.53	0.53
Brazil	0.32	0.31	0.16	0.14	0.49	0.49
Chile	0.67	0.66	0.53	0.53	0.57	0.58
Colombia	0.45	0.43	0.39	0.37	0.50	0.50
Mexico	0.08	0.03	-0.05	-0.07	0.51	0.50
Peru	0.62	0.60	0.52	0.51	0.58	0.57
Venezuela	0.10	0.10	0.29	0.29	0.46	0.46
Average	***0.44***	***0.42***	***0.38***	***0.38***	***0.52***	***0.52***

Source: Own calculations based on Barro and Lee (2010) and Heston *et al.* (2011).

III.4. Differences in the quality of education

The analysis so far has been considering human capital as a mapping of the quantity of formal skills (average years of schooling) via the returns to education into the index h that affects the productivity of labour. We are assuming that for all countries an additional year of education will increase the productivity of labour by the same amount. However, this assumption seems very unrealistic considering the international evidence of large differences in cognitive skills suggested by international tests such as the OECD's PISA test scores. For example, in the 2009 PISA test, the average score for the eight LAC countries is 408 points almost 100 points below the OECD average (500 points). Such a difference is large, equivalent to a gap in knowledge of more than two years of schooling (OECD, 2009). Thus, a significant part of measured TFP might be capturing shortfalls in the quality of education. Next, we consider estimates of how adjusting for differences in the quality of the labour force can change our results. As there are no sufficiently long time series of comparable test score to adjust the working-age population's human capital accordingly, we use the 2009 PISA score to adjust the average years of schooling.[13] Table A.2 presents the PISA test score for the eight countries in LAC that participated in the 2009 PISA round. For the adjustment, we consider the equivalence of 39 points to one year of schooling to map test score gap with respect to the United States (which has a score of 500) into years of schooling. Then, we subtract the resulting years from the original Barro and Lee (2010) data. For example, while Chile had 9.99 years of schooling in 2008, given Chile's PISA score of 449, the quality-adjusted years of schooling would be 8.69.[14]

13 Therefore, we are implicitly assuming that the differences in quality were the same in the past.

14 8.69 = 9.99 – (500 – 449)/39.

Table 6. Decomposition of output per worker gap versus United States in 2008 adjusting for differences in the quality of education

Country	Decomposition with quality adjusted years of schooling			Change in TFP vs. baseline
	TFP	Physical capital	Human capital	
Argentina	0.31	0.37	0.32	-0.22
Brazil	0.27	0.37	0.37	-0.22
Chile	0.47	0.34	0.19	-0.11
Colombia	0.28	0.35	0.37	-0.22
Mexico	0.28	0.36	0.36	-0.22
Panama	0.27	0.41	0.33	-0.25
Peru	0.35	0.34	0.31	-0.22
Uruguay	0.30	0.39	0.31	-0.19
Average	***0.31***	***0.36***	***0.32***	***-0.21***

Source: Own calculations based on Barro and Lee (2010), Heston *et al.* (2011) and OECD (2010).

The adjustment for differences in the quality of schooling has a significant impact on the relative importance of TFP and human capital. Table 6 presents the decomposition of the output per worker gap for the eight LAC countries that participated in the PISA 2009 round. On average, human capital shortfalls now explain almost one third of the output per worker gap. TFP now accounts on average for approximately the just same fraction of the gap as physical or human capital. This result is also consistent with recent regression-based evidence, which argues that LAC's disappointing growth performance can be explained by the low quality of schooling (Hanushek and Woessmann, 2009). These differences in the quality of education also help explaining the puzzle that while education attainment has been increasing in most countries of the region, it has added little to close the income per capita gap. Thus, the conclusion that TFP is the single most important variable explaining LAC's development gap would not hold anymore. The results have also important policy implications. Almost two-thirds of human capital's contribution to the income gap of Latin America with respect to the United States is driven by the lower quality of education and just one third due to lower "quantity". Therefore, a focus of growth policies in this area of educational quality -- putting emphasis on increasing skills and knowledge -- rather than just expanding coverage would bring the biggest payoff in terms of GDP growth.[15]

Summing up, this section has shown that traditional development accounting techniques might mask very different realities and policy implications, as they are particularly sensitive to changes in the terms-of-trade and the quality of schooling. Therefore, their results should be taken with a caution and to better understand the drivers of country-specific income gaps they should be complemented with an in-depth analysis of these issues at the country level.

15 Of course, in the short tem extending education to lower income households often brings with it a reduction in the average test scores as students from weaker family backgrounds are incorporated into the system. The challenge for Latin American schools is therefore to become more inclusive while increasing also their effectiveness.

IV. BEYOND COBB-DOUGLAS

So far, we have used Cobb-Douglas production functions to decompose GDP per worker gaps. Nevertheless, the previous section revealed that once we consider differences in the production function across countries – even within the Cobb-Douglas framework – the division between productivity and productive factors becomes less clear cut. As discuss above, equation (7) implies that in the presence of differences in the parameter α, output per worker gaps will depend on the country's relative factor endowments of k and h. There is a long debate about the theoretical and empirical validity of factor-neutral technological change (see Caselli, 2005). In order to explore the implications of relaxing the Cobb-Douglas assumption, we use a non-parametric estimation using data envelope techniques (DEA). This approach pioneered by Koopmans (1951) and Farell (1957) has been recently used by Färe *et al.* (1994) and Kumar and Russell (2002) to growth accounting and Jermanowski (2007) to developing accounting across countries. It allows us to impose fewer constraints on the elasticity of substitution between factors and move away from the factor-neutral technological frontier we have been considering up to this point. In this regard, we have been assuming that all countries could operate at the same TFP level as the frontier (United States), independently of their level of development or factor endowments. The reason for such a benchmark is that – at least in the long run – less developed countries can in principle copy/adopt technologies and institutions that deliver efficiency from the developed world and there for catch up to the frontier.[16] However, this depends critically on the assumption that technological change is factor neutral. If there is directed technological change, for example if new technologies are skilled biased, they might increase divergence in income per capita across countries as well as increase income inequality within countries.[17] Above, we have used the twin economies as an alternative benchmark of countries that in the 1960s had a similar level of development. However, this group of countries might have still had different factor endowments and possibilities to upgrade their technologies. The DEA estimation of production possibility frontiers enables us therefore to consider country-specific benchmarks.

16 See Bernard and Jones (1996) on this issue.

17 See Acemoglu (2002).

We assume that output in a given country can be written as $Y=E\ F(K,H)$ where $F(.)$ has constant returns to scale. Therefore, country n could in principle replicate the economies of the whole universe of countries at scale λ as long as the required aggregate factor inputs in this combination do not exceed the available stocks of factor inputs (K_n,H_n). Consequently, the frontier is the linear combination that would yield the highest output. Given N countries and inputs in per worker terms (k, h), country n's maximisation program is given by:

$$\begin{aligned}&\max_{\theta_n,\lambda_1,\ldots\lambda_N} \theta_n\\ &\text{subject to}\\ &\theta_n y_n \leq \lambda \cdot y,\ k_n \geq \lambda \cdot k,\\ &h_n \geq \lambda \cdot h,\ \lambda_{1\times N} \geq 0\end{aligned} \tag{8}$$

The resulting efficiency estimates are generally upward biased, given that they are based on the actual levels observed within the sample. Therefore, we also present a bias-corrected estimate of the efficiency index (E) using the bootstrapping procedure proposed by Simar and Wilson (1998).[18] The main advantage of DEA techniques is its non-parametric nature which allows accommodating for differences in the elasticity of substitution between physical and human capital and therefore reduces the potential of misspecification. However, DEA techniques also share with parametric production function or frontier models the disadvantage of potential endogeneity biases, as causality between physical and human capital and productivity can go both ways. Although it could be argued that the non-parametric nature reduces in part these problems, simulations shows that the endogeneity bias can also be large in DEA analysis, in particular in the presence of measurement errors and small samples (Orme and Smith, 1996).

We estimated equation (8) using a sample of 65 economies – which are all countries that have all data available for the period 1960-2008. We excluded two outliers Luxemburg and Iran as they influenced the estimation of the frontier heavily due to its extremely high income and the 1970s oil price hikes, respectively. To increase the accuracy of our estimates, we compute the annual frontiers using all year available observations up to that date (*e.g.* for 1970 we use 650 observations: 65 countries times 10 years). Table 7 presents the resulting contributions of efficiency E to the output gap relative to the frontier compared to the contribution of TFP for the baseline with respect to the United States. Clearly, abandoning the Cobb-Douglas production function has important implications in terms of the diagnostic. On average, bias-corrected efficiency gaps contribute around one third to the distance to the frontier, almost 20 percentage points less than the contribution of TFP to the output per worker gap with respect to the United States according to our baseline results. Therefore, it seems that the conclusion that TFP is the main culprit of the GDP per worker gap is rather sensible to the production function specification.

18 Daude and Fernández-Arias (2010) present similar estimates, but for the aggregate of Latin America and without considering the bias correction.

Table 7. **Contributions of Efficiency to output per worker distance to frontier (2008)**

Country	Efficiency	Bias Adjusted Efficiency /1	Cobb-Douglas (United States benchmark) /2
Argentina	0.42	0.37	0.53
Bolivia	0.35	0.34	0.53
Brazil	0.35	0.30	0.49
Chile	0.37	0.30	0.58
Colombia	0.35	0.30	0.50
Costa Rica	0.32	0.26	0.50
Dominican Republic	0.29	0.23	0.41
Ecuador	0.48	0.44	0.59
El Salvador	0.29	0.24	0.47
Honduras	0.44	0.40	0.57
Jamaica	0.52	0.46	0.66
Mexico	0.33	0.25	0.50
Nicaragua	0.48	0.45	0.60
Panama	0.39	0.37	0.51
Paraguay	0.45	0.42	0.58
Peru	0.47	0.44	0.57
Uruguay	0.37	0.32	0.49
Venezuela	0.32	0.27	0.46
Average LAC	***0.39***	***0.34***	***0.52***

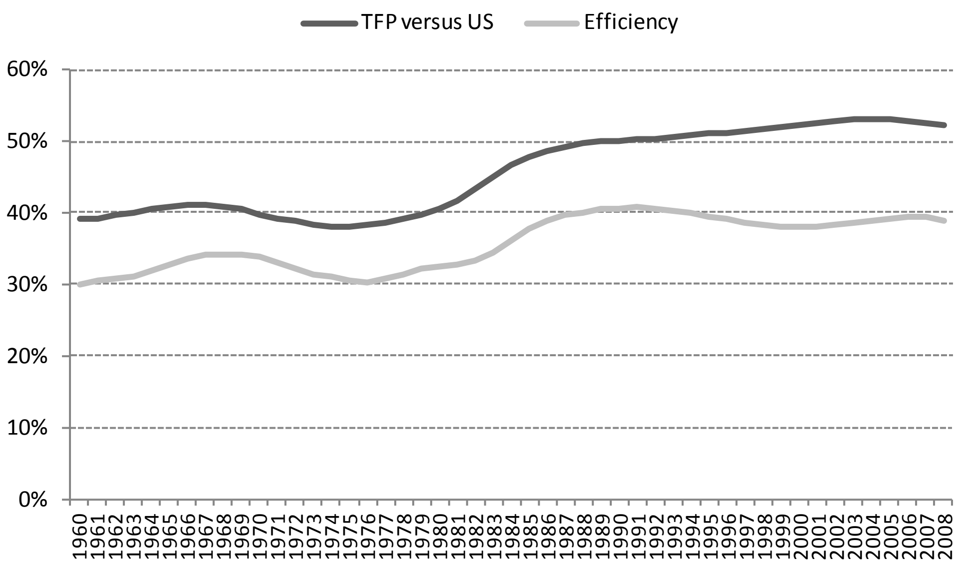
Source: Own calculations based on Barro and Lee (2010) and Heston *et al.* (2011).

There are differences at the country level, but in general the reduction in the contribution of efficiency is between 15 and 27 percentage points. In no country is the contribution of bias-corrected inefficiency above 50%. However, it continues to represent around a 40% or more of the gap in several economies like Jamaica, Nicaragua, Peru, Ecuador and Honduras. Mexico and Chile are the countries with the largest difference between the efficiency and TFP gaps. These differences are economically significant. For example, in the case of Mexico, according to the DEA estimates, output per worker would increase by 30% if the economy would operate on the production frontier. Meanwhile, according to the TFP decomposition versus the United States, if Mexico were to operate at the same level of efficiency as the United States it would almost double it output per worker. Of course, the DEA tells us that the United States level of TFP is not attainable for Mexico at its current factor endowments. This does not mean that TFP or technology does not matter in explaining this large gap, but rather that given its factors – physical and human capital – Mexico actually has a low potential output, probably because it cannot produce more sophisticatedly products with its current fix of factors.

In terms of the dispersion, we also observe a decline in the importance of productivity. Efficiency explains 29% of the variance in GDP per worker within the region in 2008 according to equation (4), while when considering the second measure VR_2 it increases to 47%. Thus, for both measures the explanatory power of factors increases by around 10 percentage points, compared to the Cobb-Douglas baseline (Table 3).

Figure 6 plots the contribution according to the DEA estimation and the baseline TFP contribution to the GDP per worker gap relative to the United States for the average LAC economy over time. Interestingly, the time series are very similar, with a simple correlation between both series of 0.94. On average, the TFP contribution is 10% above the efficiency-based estimation. As discussed above, TFP under the Cobb-Douglas formulation is the main explanation for the decline in GDP per worker from the early 1980s onwards. However, according the DEA measure while the decline in relative GDP per worker during the 1980s was explained by a relative loss of efficiency, from the 1990s onwards, efficiency's contribution to the gap has declined somewhat constant, which means that factors have been gaining ground again in explaining absolute gaps. Interestingly, this period coincides also with the increase in the correlation between TFP and factors reported in Table 3. It has also been associated with skill-biased technological change and an increasing complementarity between capital and skilled labour (*e.g.* computers).[19]

Figure 6. **Contribution of Efficiency to gap to the frontier and TFP with respect to United States**



Source: Own calculations based on Barro and Lee (2010) and Heston *et al.* (2011).

Thus, low levels of potential output might be explained by technological change that is not factor neutral, as put forward by the theory of appropriate technology in developing countries (Atkinson and Stiglitz, 1969; Basu and Weil, 1998). Following Jermanowski (2007), one way to explore this issue in our current set-up is to decompose TFP (A) into the product of a pure efficiency term E, which is captured by our estimate from the DEA, and a term that depends on factors, as follows: $A = E \times T(k/h)$, such that the technological frontier for country i can be estimated as: $T_i = A_i/E_i$. Figure 7 presents potential and observed TFP in terms of the relative endowments of physical and human capital for 2008 and 1980.

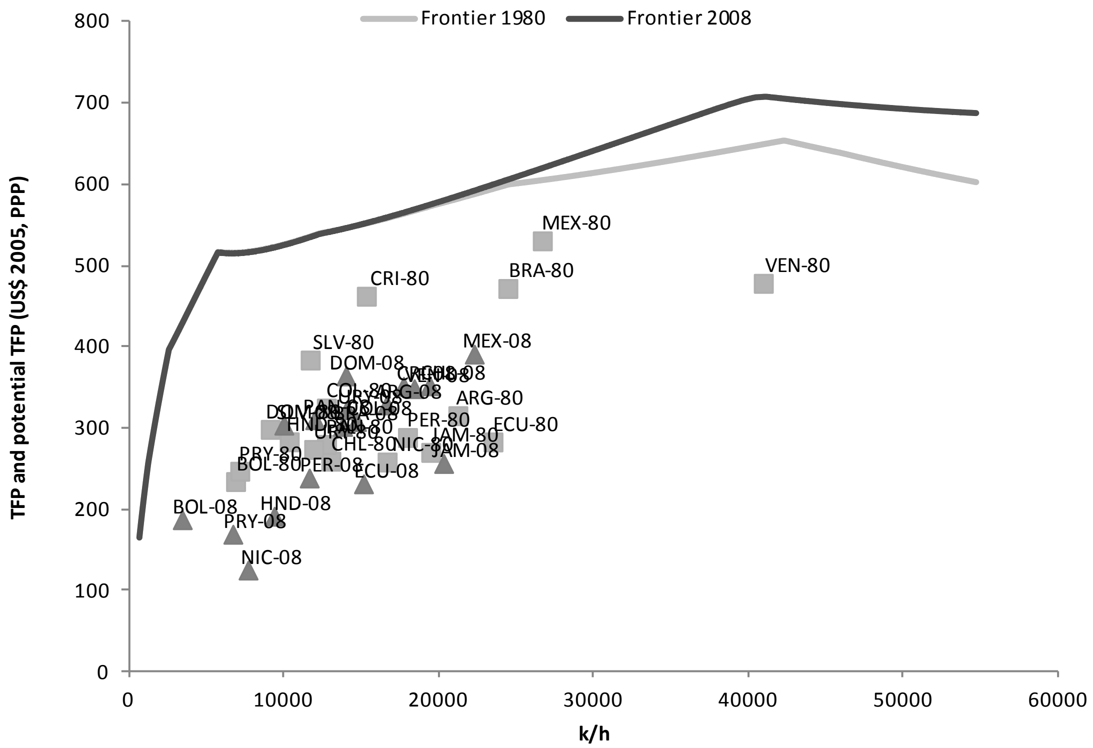
There are several interesting findings related to Latin America in this graph. First, the technological frontier for the countries with low relative physical capital has virtually not changed as the frontier has expanded outwards at the higher end only.[20] This implies that for most countries in LAC – in addition to the observed decline in TFP – the potential level of TFP has not changed significantly between 1980 and 2008. For example, while measured TFP declined

19 See Acemoglu (1998), Bekman *et al.* (1998) and Caselli and Coleman (2006).

20 This result is in line with Jermanowski (2007) analysis which covered just up to 1995.

around 12.5% on average during that period, potential TFP fell by just 3%. Second, despite different experiences across countries there is a positive correlation between the changes in measured TFP and in the potential TFP. For example, within the group of countries which increased their TFP levels between 1980 and 2008 (Chile, the Dominican Republic and to some extent Uruguay, Panama and Argentina) all countries -- with the exception of a slight decline in Argentina -- have experienced an increase in their potential TFP. Third, this increase is mainly driven by an upgrading in the relative factor endowments than an expansion of the technological frontier. For example, while for Chile and the Dominican Republic potential TFP increased by around 6% and 5%, respectively, this increase would have been basically nil if they had preserved their 1980's factor mix. However, these increases in potential TFP are small compared with the overall increases in measured TFP of 36% and 22%, respectively. Thus, these countries have raised TFP mainly by increasing factor-independent efficiency, rather than by accessing to new technological opportunities due to altering their factor mix.

Figure 7. **Technological frontier in 1980 and 2008**



Source: Own calculations based on Barro and Lee (2010) and Heston *et al.* (2011).

In terms of the relative contribution of pure efficiency (*E*) and factor-related technology (*T*) to the output per worker gap with respect to the United States, Basically, the contribution of TFP (52% in 2008; Table 2) would be composed by a pure efficiency term (32%) and a factor-related gap in *T* (20%) in we use the bias-corrected DEA estimates. This would imply that factors would be responsible for more than two thirds of the output per worker gap. Again, this exercise casts doubt on the idea that TFP – or efficiency *per se* regardless factor endowments – is the major culprit of the development gaps observed in the region.

Overall, the DEA presented here adds arguments in the direction that a development policy agenda for the region should definitely be country-focused, as the proximate causes of low labour productivity across countries differs significantly. Furthermore, conclusions regarding the main factors driving relative GDP per worker levels for Latin America depend heavily on the functional form assumed in standard development accounting exercises. Of course, just as the Cobb-Douglas framework has its flaws, the DEA approach also suffers from the same potential measurement problems in human and physical capital. Furthermore, it does not solve the causality problems discussed earlier. We turn to this issue in the next section.

V. ENDOGENEITY OF FACTOR AND PRODUCTIVITY

The analysis so far has not included considerations regarding the endogeneity of production factors or TFP. Clearly, this is a major limitation of using an accounting approach. For policy purposes, one would like to act on the underlying causes and take into account the different causal links between factors and productivity. The DEA analysis as well as the above documented rising correlation between TFP and factors point towards an interaction between TFP and factors that needs to be understood better, as it can have a significant impact on the diagnostic and the consequent definition of policy priorities. For example, it is clear that an increase in TFP raises the marginal return to physical capital investment and therefore part of the gaps in physical capital per worker is actually driven by differences in TFP levels. If one would consider this effect of TFP on physical capital, the average contribution of TFP to the output per worker gap in LAC versus the United States for 2008 would be almost 78%, significantly above the 52% from the standard accounting exercise (Table 2). Similarly, with respect to Twin Economies, TFP would contribute now 75% of the gap. In a similar way, it can be argued that – at least private – human capital investment also reacts to changes in TFP (at least in the long run). If this endogeneity is taken into account, the literature shows that almost the entire output per worker gap could be attributed to TFP.[21] However, causality can obviously run also in the opposite direction. For example, enhancements in productivity could be embodied in new capital goods (see Hulten, 1979 and 1992; and Greenwood *et al.* 1997). Thus, even physical capital replacement investments would cause TFP to increase.[22] Similarly, human capital might be needed to adapt new technologies and would also raise the returns to R&D investments.

To address these issues jointly in this section we use a "varieties" endogenous growth model by Córdoba and Ripoll (2008) to analyse further the importance of productive factors versus aggregate inefficiencies to explain the relatively low levels of GDP per worker in LAC versus the frontier. It is clear that advances in productivity in general depend on a deliberate investment effort in R&D and the allocation of physical and human capital do produce ideas and new goods. Therefore, in a similar way to Maloney and Rodríguez-Clare (2007), we use an endogenous growth model to calibrate some wedges and parameters that allow us to assess the contribution of low levels of innovation to the development gap in terms of GDP per worker. The model includes learning externalities and international spillovers, such that cost of introducing a new variety depends by R&D investments at home, but it is also a decreasing function of the

21 See Daude and Fernández-Arias (2010) and Restuccia (2008).

22 As we are using investment ratios in constant prices, we are already accounting for part of the technology specific advancement or improvement in the quality of capital goods -- which would be reflected in changes in the relative price of capital goods (see Caselli, 2005).

existing stock of varieties (learning externality) and the distance to the technological international frontier (advantage of backwardness). Thus, two key parameters in the model are the size of these externalities and the speed of convergence to the frontier. R&D investment and physical capital are endogenous in the model and depend on two deep parameters -- p and q -- that represent patent protection (more specifically the average duration of monopoly on a new variety) and an implicit tax or expropriation risk premium on physical capital, respectively.

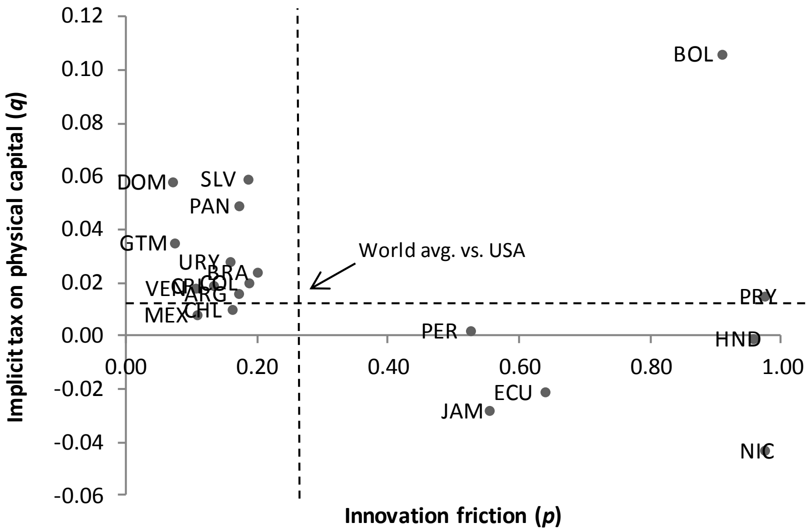
We present the decomposition of output per worker implied by the model for the case of Latin America in Table 8. Once we take into account the joint endogeneity of TFP and factor accumulation, TFP explains just around 29% of output per worker gap with respect to the U.S. for the average Latin American economy in 2008, as significant reduction from the 52% that standard accounting techniques suggest. With the exception of Nicaragua, in all LAC countries factor gaps seem to be the most important driver of output per worker gaps. Therefore, once we take into account the endogeneity of TFP, factors gaps seem to be the primary drivers of output per worker gaps in the region.

Table 8. **Contributions of TFP and factors to the output per worker gap versus United States in 2008 based considering endogeneity of factors and TFP**

Country	TFP	Factors
Argentina	0.31	0.69
Bolivia	0.32	0.68
Brazil	0.26	0.74
Chile	0.33	0.67
Colombia	0.26	0.74
Costa Rica	0.27	0.73
Dominican Rep.	0.16	0.84
Ecuador	0.38	0.62
El Salvador	0.24	0.76
Guatemala	0.14	0.86
Honduras	0.35	0.65
Jamaica	0.44	0.56
Mexico	0.28	0.72
Nicaragua	0.55	0.45
Panama	0.27	0.73
Paraguay	0.41	0.59
Peru	0.37	0.63
Uruguay	0.27	0.73
Venezuela	0.21	0.79
Average LAC	0.29	0.69

Source: Own calculations based on Barro and Lee (2010), Cordoba and Ripoll (2007) and Heston *et al.* (2011).

Figure 8.**Physical capital and innovation frictions in 2008**



Source: Own calculations based on Barro and Lee (2010) and Heston *et al.* (2011).

Figure 8 presents the resulting country-specific calibration of the two key parameters in the model: the innovation friction (p) and the implicit tax on physical capital (q) compared to the world average relative to the United States. The figure shows several interesting results. First, nine countries present distortions on the innovation side that are below the world average but some evidence of distortions on physical capital above average (Argentina, Brazil, Colombia, Costa Rica, Dominican Republic, Guatemala, Panama, Uruguay and Venezuela), while six countries Ecuador, Honduras, Jamaica, Paraguay, Peru and Nicaragua present mainly innovation shortfalls but no evidence on high distortions to physical capital. Chile and Mexico present somewhat less friction on both dimensions – compared to the rest of the world, such that along these dimensions there is no smoking gun to explain the output per worker differences. Combining these results with the analysis of Table 6 on the quality of human capital, it seems that differences along this dimension might be important drivers for Mexico and Chile. Finally, Bolivia is the only country that presents large distortions along both dimensions. Again this shows that there are significant differences among countries in the region. There is a negative correlation of p with the level of development – a simple correlation coefficient of -0.82 -- with countries in the region that exhibit a smaller gap in output per capita versus the United States present smaller distortions, while in terms of the physical capital distortions there is no correlation (a correlation coefficient of 0.05). However, the latter result depends critically on the inclusion or not of Nicaragua. If Nicaragua is excluded physical capital distortions q are also negatively correlated with the level of development. In relative terms, the contribution of TFP to the output per worker gap tends to be smaller in the more developed economies of the region, but again this depends on Bolivia and Nicaragua which might be outliers not only for economic reasons but also data quality problems.

Of course, the results presented depend on a series of parameters that are not easy to determine, such as the speed of convergence to the frontier or the size of learning externalities. Nevertheless, the calibrations show that conclusions regarding the proximate causes of output per worker gaps in the region depend crucially on endogeneity considerations, with TFP accounting on average just for less than one third of the gap. Furthermore, significant differences across countries remain important, such that a unique regional diagnostic and reform agenda might be misleading.

VI. CONCLUDING REMARKS

The present paper has presented a series of exercises of development accounting in Latin America. The results show that conclusions regarding the relative importance of TFP, physical capital and human capital depend critically on the assumptions regarding functional forms and benchmarks. Furthermore, issues such as the quality of education of the labour force and changes in terms-of-trade tend to be captured by measured TFP, although they would have very different implications for policy. In addition, these exercises in general do not take into account the endogeneity of TFP and factor demands. Our discussion in the previous section shows that considering just factor demands overestimates the importance of TFP in driving output per worker differences of Latin America with respect to developed economies. If the endogeneity of TFP to factors is considered, alternative production functions are considered or if one accounts for the differences in the quality of education, production factors tend to explain a larger fraction of the development gaps than TFP. While all these exercises also have their shortcomings and limitations, we think that they provide solid evidence on the pitfalls of standard development accounting techniques to make robust prediction on the relative importance of TFP and production factors in Latin America. Therefore, while they can be a useful exploratory tool to identify some trends, policy recommendations in terms of priorities should be based on more solid evidence. For example, traditional techniques tend to underestimate the role of human capital in explaining Latin American income gaps *vis-à-vis* the developed world and other developing countries, because they focus only on the quantity of education rather than taking into account cognitive skills. This paper has shown that cognitive differences are large and therefore human capital formation should be high on the agenda in most countries of the region. In particular, an emphasis on outcomes in terms of quality, knowledge and skills would bring larger payoffs that focusing on just extending coverage.

Of course, development accounting also has limitations in terms of its usefulness for policy purposes because the proximate causes are somewhat abstract and not directly related to policies.[23] There exist efforts such as the OECD's Going for Growth framework which try to remediate this issue by developing databases to benchmark policies and regulations, and have an estimate of the expected impact on productivity and growth of each policy. Combined with such an approach, developing accounting would be part of the toolbox for a diagnosis, but would be complemented by an in-depth analysis of policy gaps which could guide a prioritisation and suggestions for reform. Nevertheless, such a framework should be adapted to the stages of development of LAC countries, as countries might face different constraints to development and growth at different stages and phases of development. For example, many policies might be

23 The cross-country growth regressions popular during the 1990s have received similar criticism as they often include indirect proxies of outcomes but not policies.

growth- and productivity-enhancing in developed economies – as they allow for more innovation and reallocation of resources to leading sectors – such as competition policies and financial liberalisation, but they do little in economies which are far away from the frontier where institutions and policies that facilitate absorption and adoption might be more important (Acemoglu *et al.*, 2006). There is some evidence in the literature that these differential and non-linear effects of policies do exist (*e.g.* Wölfl *et al.*, 2010; Vandenbussche *et al.*, 2004). Thus, in addition to policy benchmarking and developing accounting, a careful country-level assessment is definitely needed to understand the constraints to economic growth in each country in the region, especially given the significant heterogeneity that, even at a very aggregate and abstract level as the results presented here, seems to exist within Latin America and the Caribbean. Studies based in the Growth Diagnostics methodology proposed by Hausmann *et al.* (2005) seem to be a more fruitful way to guide policy (see *e.g.* Agosin *et al.*, 2009). Combined with country-specific microeconomic evidence, this approach is flexible enough to take into account the complexity of interactions and institutions that matter for a good diagnosis to guide growth-enhancing policies, but also provide a framework to systematically assess development constraints.

APPENDIX

Table A.1. **Alternative labour shares by country**

Country	Labour share
Bolivia	0.67
Chile	0.62
Colombia	0.65
Costa Rica	0.74
Ecuador	0.45
El Salvador	0.58
Mexico	0.59
Panama	0.76
Paraguay	0.52
Peru	0.59
Uruguay	0.59
Venezuela	0.55
United States	0.71

Source: Bernanke and Gürkaynak (2002).

Table A.2. **PISA 2009 scores (OECD average = 500)**

Country	Score
Argentina	398.3
Brazil	411.8
Chile	449.4
Colombia	413.2
Mexico	425.3
Panama	370.7
Peru	369.7
Uruguay	425.8
United States	499.8

Source: OECD (2010).

Cordoba and Ripoll (2007) model

While a complete explanation and derivation of the model can be seen in Córdoba and Ripoll (2007), here we outline just the major ingredients necessary for our quantitative calibration exercises. Aggregate output (Y) is produced using a variety of inputs (x) using a CES aggregator:

$$Y_t = \left(\sum_{j=1}^{N_t} x_{jt}^{\gamma} \right)^{1/\gamma}, \quad 0 < \gamma < 1 \tag{9}$$

where each intermediate good is produced using a Cobb-Douglas production function combining physical and human capital: $x_j = k_j^{\alpha} h_j^{1-\alpha}$.

Factor markets are competitive, but new intermediate goods are produced under monopolistic competition with market power disappearing according to a Poisson process with parameter p.[24] This parameter can be interpreted as the degree of intellectual property rights protection. Afterwards, the variety is produced under competitive conditions such that at all times there is a fraction of intermediate goods N_m produced under monopolistic conditions and a fraction $N_c = N - N_m$ produced under competitive conditions.

The cost of introducing a new variety is given by: $\lambda_t = N_t^{-\phi}\left(N_t^*\right)^{-\eta} L_t$, where the first term on the right-hand side captures externalities in the research process, being the cost of innovation a decreasing function of these externalities ($\phi > 0$). Furthermore, the cost of R&D is also a decreasing function of the international frontier denoted by N^*, such that for countries that are far away from the frontier it is easier to adopt existing technologies.[25]

Risk neutrality and free entry imply that innovators have to breakeven in expected terms, such that:

$$\lambda_t = \int_t^{\infty} \pi_m(v) e^{-(r+p)(v-t)} dv,$$

where the right-hand side is the present discounted value of expected profits.

Returns on physical capital can be taxed or expropriated, such that a wedge (represented by q) between the return on capital (r_k) and the risk free interest rate on assets (r) might exist: $1 + r = (1 + r_k - \delta)(1-q)$, where δ is the rate of depreciation. Along the balanced growth path, aggregate output is given by:

$$Y_t = K_t^{\alpha}\left(A_t^{\beta} H_t\right)^{1-\alpha}, \tag{10}$$

where $A_t = \left[\left(\frac{g+\theta^{\gamma} p}{g+p}\right)^{1/\gamma} \frac{g+p}{g+\theta p}\right]^{\gamma/1-\gamma} N_t, \quad \beta = \frac{1-\gamma}{\gamma(1-\alpha)}$.

The parameter θ is the ratio of intermediate goods produced by competitive versus monopolistic firms in equilibrium, and g is the growth rate of the frontier $A^* = N^*$. For TFP growth, we have that:

$$\dot{A}_t = dA_t^{\phi}\left(A_t^*\right)^{\eta} s_R y_t, \tag{11}$$

24 The expected lifetime of monopolistic power is therefore given by 1/p.

25 The linear dependence on the labour force is included to eliminate scale effects.

where $d = \left[\left(\frac{g + \theta^{\gamma} p}{g + p} \right)^{1/\gamma} \frac{g + p}{g + \theta p} \right]^{\gamma(1-\phi)/1-\gamma}$ and $s_R = \frac{R}{Y}$ is the R&D investment rate as a ratio of GDP.

To rule out strange dynamics, we assume that the following parameter restriction holds: $1 - \phi - \beta = \eta$. In terms of the physical capital, the equilibrium capital-output ratio of the model is then given by:

$$\kappa = \alpha\gamma \frac{g + \theta p}{g + \theta^{\gamma} p} \frac{1 - q}{r + q + \delta(1 - q)} \quad (12)$$

Finally, the remaining key equation is the R&D investment ratio, given by:

$$s_R = \frac{(1 - \gamma)g}{r + p + (\phi + \eta)g - g_L} \frac{g + p}{g + \theta^{\gamma} p} \quad (13)$$

These two last equations imply that increasing patent protection (lowering *p*) increases the R&D investment ratio but decreases the capital-output ratio, because an increase in *p* lowers the expected return on capital.[26] In addition, distortions to capital accumulation (*q*) have no effect on R&D investment ratios, but lower the capital output ratio.

Based on these equations, output per worker can be decomposed according to a "pure" TFP component and a factor component:

$$y = \tilde{A}(p)\tilde{X}(p, q, h), \quad (14)$$

where:

$$\tilde{A}(p) = \Omega(p) \left(\frac{(1 - \gamma)d}{r + p + (\phi + \eta)g - g_L} \frac{g + p}{g + \theta^{\gamma} p} \right)^{\beta/\eta} (A_t^*)^{\beta} \quad (15)$$

$$\tilde{X}(p, q, h) = \Omega(p)^{-1} \left[\left(\alpha\gamma \frac{g + \theta p}{g + \theta^{\gamma} p} \frac{1 - q}{r + q + \delta(1 - q)} \right)^{\frac{\beta}{\eta}} h \right]^{1 + \frac{\beta}{\eta}} \quad (16)$$

$$\Omega(p) = \left(\frac{g + p}{g + \theta^{\gamma} p} \right)^{\frac{\alpha}{1-\alpha}\left(1 + \frac{\beta}{\eta}\right)} \quad (17)$$

The data regarding output per worker, physical and human capital are the same that we have used so far. Furthermore, as Córdoba and Ripoll (2008) we assume a risk free interest rate (*r*) of 2% and calibrate η to match a speed of convergence of 3% per annum (such that η=0.5), which represents an intermediate value of estimates reported by Parente and Prescott (1994). We use Klenow and Rodríguez-Clare (2005) for parameter values of α=1/3, β=0.21, δ=0.08, g=0.015 and g_L=0.011, respectively. The parameters ϕ and γ are deduced from the values of α, β and η, such that ϕ = 0.09 and γ =0.75. The solution procedure for the key parameters we use is the following.

26 However, if g is close to zero, then the effect of p on the capital-output ratio will be very small.

We can calibrate p from equation (15) if the frontier A^* is known. Therefore, we assume that the maximum value of TFP in our sample for the year 2008 is associated with a value of p equal to 1/100. Then, we can solve for the frontier and calibrate p for each country using (15). Given the value of p we can infer q from equation (16).

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