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On the Role of Productivity and Factor Accumulation in Economic Development in Latin America and the Caribbean:

2017 Update

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Abstract[*]

This report combines development and growth accounting exercises with economic theory to estimate the relative importance of total factor productivity and the accumulation of factors of production in the economic development performance of Latin America. The region's development performance is assessed by contrast with various alternative benchmarks, both advanced countries and peer countries in other regions. The paper finds that total factor productivity is the predominant factor: low productivity and insufficient productivity growth, as opposed to impediments to factor accumulation, are the key to understanding Latin America's low income relative to developed economies and its stagnation relative to other developing countries. While policies easing factor accumulation would help somewhat in improving productivity, for the most part, closing the productivity gap requires productivity-specific policies.

JEL classifications: O11, O47
Keywords: Economic growth, Total factor productivity, Development

[*] This document updates Daude and Fernández-Arias (2010), IDB Working Paper No. 155.

1. Introduction

Most countries in Latin America and the Caribbean (LAC) have been growing slowly for a long time and by and large, despite some recent uptick in some countries, see themselves increasingly poor relative to the rest of the world, both advanced countries and peer countries in other regions. Actual declines in income per capita for substantial periods of time are common. However, as we show in this piece, it would be misleading to blame low investment for this failure. Low productivity and insufficient productivity growth, as opposed to impediments to factor accumulation, is the key to understanding LAC's low income relative to developed economies and its stagnation relative to other developing countries that are catching up. *A fortiori*, the main development policy challenge in the region involves diagnosing the causes of poor productivity and acting on their roots.

This document is organized in the following way. In Section 2 we explain how and why we use total factor productivity (TFP, henceforth) as our measure of productivity to understand growth and development in LAC. In the following two sections we establish the basic stylized facts of aggregate productivity using some of the traditional tools of development and growth accounting, and then test their robustness to technical assumptions. Finally, in Section 5 we conclude by discussing some policy implications of our findings.

2. Measuring Aggregate Productivity

The first question to deal with is how to measure aggregate productivity. Standard economic analysis estimates aggregate productivity, or *TFP*, by looking at the annual output Y (measured by the gross domestic product, GDP) that is produced on the basis of the accumulated factors of production, or capital, which are available as inputs. For any given stock of capital, the higher the output the more productive the economy. Capital is composed of physical capital, K, and human capital, H. Physical capital takes the form of means of production, such as machines and buildings. Human capital is the productive capacity of the labor force employed, which in turn corresponds to the headcount of the labor force or raw labor, L, multiplied by its average level of skill h, so that $H=hL$. TFP measures the effectiveness with which accumulated factors of production, or capital, are used to produce output.

Therefore, output Y results from the combination of factors of production K and H at a certain degree of TFP (A). Likewise, output growth over time results from accumulation of factors of production and productivity growth. The attribution of output level and growth to factors and productivity is done by using production functions mapping factors into output: what is not accounted for by factors of production as estimated by the production function is attributed to productivity. In particular, we use a standard Cobb-Douglas production function given by:

$$Y = AK^{\alpha}H^{1-\alpha} = AK^{\alpha}\left(hL\right)^{1-\alpha} \tag{1}$$

where *a* is the output elasticity to (physical) capital. The production function parameter *a* is set equal to approximately 0.43 (the 1960 average of the estimated elasticities in the Penn World Table 9.0).[1] Although there is some debate in the literature regarding the validity of this uniformity assumption, Gollin (2002) shows that once informal labor and household entrepreneurship are taken into account, there is no systematic difference across countries associated with level of development (GDP per capita), nor any time trend. Hence its uniformity across countries and time appears to be a reasonable assumption. Using this assumption also implies that any factor-augmenting technological change since 1960 is captured in our measure of productivity. We will relax this assumption for sensitivity analysis.

We construct the relevant series for output, physical capital and human capital (*Y*, *K*, and *H*, respectively) based on available statistics and following methods detailed in the Statistical Appendix.[2] It is important to note that we filter the raw annual data to obtain smooth series reflecting their trends, thus filtering out the business cycle. Using these series, we can compute our measure of TFP by:

$$A = \frac{Y}{K^{\alpha}\left(hL\right)^{1-\alpha}} \tag{2}$$

which is a comprehensive measure of the efficiency with which the economy is able to transform its accumulated factors of production *K* and *H* into output *Y*. In this way, as noted, we estimate trend TFP series for each country.[3]

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[1] This value is roughly equal to that calculated in the previous update of the database using the same method (Fernández-Arias, 2014). In the first version this parameter was set at 1/3, a standard value in the literature (see Klenow and Rodríguez-Clare, 2005). For more information about the variables used in these calculations, see the Statistical Appendix.

[2] Roughly speaking, we rely on Penn World Tables for data on output, physical capital and raw labor. Concerning the human capital index *h*, we model it on the basis of education (from Barro and Lee, 2013) using the approach of Bils and Klenow (2000).

[3] In this formulation, TFP would also reflect the natural resource base (natural capital) of each country. Resource- rich countries would tend to exhibit larger (but possibly less dynamic) measured TFP. Since LAC is a resource-rich region,

In terms of the sample of countries utilized, on top of the availability of all these data, we introduce as a further restriction a population size of at least 1 million as of 1960. The resulting sample of 79 countries with complete information between 1960 and 2014 is shown in Table 1.[4]

There are, however, other partial measures of productivity that are commonly used. One is a variant of this TFP measure defined with respect to employment L rather than total human capital H, so that labor skill is not considered a factor of production and, therefore, higher average skill level h would be reflected in higher productivity, given by:

$$Alt_1 = Ah^{1-\alpha} = \frac{Y}{K^{\alpha} L^{1-\alpha}} \tag{3}$$

Another partial measure of productivity is labor productivity, or Y/L. In this case, as shown in equation (4), physical capital K is also neglected as a factor of production, and therefore an economy whose labor force has more capital at its disposal would tend to exhibit higher productivity.

$$Alt_2 = A\left(\frac{K}{L}\right)^{\alpha} = \frac{Y}{L} \tag{4}$$

The trends of these productivity measures differ substantially, so that which productivity measure is selected matters for the conclusions (Figure 1). Arguably, the use of the two alternative productivity measures may produce misleading conclusions. For example, an increase in the labor productivity measure is silent with respect to whether such improvement was produced by a more skilled labor force (better quality of the labor input), the accumulation of physical capital (unrelated to the labor input), or something else (unrelated to all factor inputs). In the case of the alternative productivity measure based on raw labor L, the effect of education becomes unnecessarily confounded with TFP. The discrimination of these different sources is relevant for diagnosis and policy action. Thus, our preferred measure of productivity is TFP, which is not contaminated by the evolution of factor inputs.

this observation implies that a symptom of low productivity would signal an even more serious ailment. (On the other hand, it could be argued that natural resources give rise to backward development and ultimately lower productivity (the "natural resource curse hypothesis"); see Lederman and Maloney, 2008, for a critical view.) In any event, the weight of natural resources-based production in GDP is only significant in very few countries and should not distort the overall picture shown in this paper.

[4] In this update, we also report results for 30 additional countries (shown in Table 1) with information starting after 1960. This information does not enter into the construction of the regional indexes that are used as benchmarks, which are only based on the 79 countries with complete information.

TFP measures the efficiency with which available factors of production are transformed into final output. This measure of productivity includes a technological component and tends to increase as the technological frontier expands and new technology or ideas become available and are adopted, but it is also affected by the efficiency with which markets work and are served by public services. For example, an economy populated by technologically advanced firms may produce inefficient aggregate results and therefore translate into low aggregate productivity. In particular, market and policy failures may distort the efficiency with which factors are allocated across sectors, and across firms within sectors, thus depressing efficiency at the aggregate level. The upshot is that, while increasing the stock of accumulated factors may require resources that are unavailable in low-income countries and may even be wasteful if productivity is low, boosting productivity directly may "simply" require willingness to reform policies and institutions by taking advantage of successful experiences elsewhere.

As noted, in order to minimize fluctuations in productivity induced by the business cycle, we filtered the annual series of output and factors to retain only their trends, thus obtaining trend productivity. Therefore, in our calculations, only structural features would be reflected in productivity. Because we measure labor input as employment, variations in the share of the population that is engaged in production (whether because of demographic reasons, the choice of working age population to participate in the labor force, or the rate of unemployment) are not reflected in productivity. On the other hand, as discussed above, the quality of education, which may differ significantly across countries, would be reflected in the productivity measure inasmuch as it impinges on the working capacity of the labor force.[5] Similarly, the age profile of the labor force would also entail differences in experience akin to the quality of education.

The above production function framework can be directly applied to account for output per worker Y/L (or "labor productivity") in terms of TFP and per-worker factor intensities: $k=K/L$ ("capital intensity") and $h=H/L$ (skill level of the labor force). It is useful to relate this production function framework to a welfare framework, such as the traditional measure of GDP per capita ($y=Y/N$), where N is the size of the population. This is an income measure commonly used to gauge welfare across countries. In this case, differences in income per capita, or in its growth, can be

[5] To the extent that quality differences affect uniformly the education spectrum, the aggregative measure h would not be distorted and they would only be reflected in TFP differences (see Appendix).

attributed to TFP and per-worker factor intensities, as before, and an extra term reflecting the share of the population in the employed labor force (*L/N*, denoted by *f*), given by:

$$y = \frac{Y}{N} = A\left(\frac{K}{L}\right)^{\alpha} h^{1-\alpha} \frac{L}{N} = Ak^{a}h^{1-\alpha} f \tag{5}$$

The enormous diversity of income per capita that exists across countries can be well explained statistically by differences in their aggregate productivity levels as measured by TFP. TFP and income per capita move in tandem (see Figure 2), with a correlation coefficient of 0.95. In statistical terms, 90 percent of the cross-country income variation in the world today would disappear if TFP gaps of less productive countries were closed. TFP appears central to understanding income per capita diversity across countries and to acting on the root causes of underdevelopment. In the remainder of the paper we will explore the economic determinants of this strong relationship.

In most of the analysis, we consider the productivity of the typical country in LAC, represented by a simple (logarithmic) average of country productivities, irrespective of whether the country is large or small. Thus, the typical LAC country's TFP is measured by:

$$A_{LAC} = \left(\prod_{i=1}^{n} A_i\right)^{\frac{1}{n}} \tag{6}$$

Similarly, we consider the simple (logarithmic) average of income per capita *(y)*, and the corresponding per-worker factor of production intensities (*k*, *h* and *f*).[6] To represent the region as a whole, however, where the productivity of larger countries is more influential because it applies to larger stocks of productive factors, we consider a synthetic region country summing up inputs and outputs over countries. For example, Figure 3 shows productivity in LAC (as opposed to the world's TFP shown in Figure 1) for both the typical country and the region as a whole.[7] (More generally, we represent various country groupings as the typical country and the region following similar methods for the analysis of a number of variables.)

[6] The use of a logarithmic transformation is needed to ensure that the TFP of the typical country so defined coincides with the typical TFP previously defined.
[7] Since technology in principle can only improve over time, we note in passing that a declining TFP over some periods reinforces the notion that TFP is only partially technologically determined.

Before embarking in the analysis of regional aggregates, it may be useful to keep in mind that there is substantial diversity in productivity levels across countries in the LAC region. Figure 4 shows our estimation of current productivity levels in each country relative to the typical country in Latin America (as of 2014).[8] The diversity within the region, as expected, is highly correlated with income per capita (with a correlation coefficient of 0.82; see Figure 2).

3. Stylized Facts of Aggregate Productivity in LAC

In this section we review the patterns of the evolution of aggregate productivity in the economic development of the LAC region, both in growth and levels.[9] This is done using traditional tools of growth and development accounting.

Concerning growth accounting, the growth rate of TFP ($\hat{A}$) is obtained as a residual after accounting for the growth rates of output and factor inputs (measured as their logarithmic increase from equation (5):[10]

$$\hat{y} = \hat{A} + \alpha\hat{k} + (1-\alpha)\hat{h} + \hat{f} \tag{7}$$

The above equation can also be used to account for the growth gaps between two countries or groups of countries, so that the growth gap in income per capita can be decomposed into the sum of the growth gap in TFP, the (weighted) factors' growth gaps, and the gap in the growth of labor force intensity:

$$Gap(\hat{y}) = Gap(\hat{A}) + \alpha Gap(\hat{k}) + (1-\alpha)Gap(\hat{h}) + Gap(\hat{f}) \tag{8}$$

Development accounting looks at levels rather than growth rates. It utilizes equation (5) to compare the components behind the income per capita gap between an economy of interest and a benchmark economy taken as a development yardstick, denoted by "*", or level gaps:

$$y = \frac{y}{y^*} = \frac{A}{A^*}\left(\frac{k}{k^*}\right)^{\alpha}\left(\frac{h}{h^*}\right)^{1-\alpha}\frac{f}{f^*} = \overline{A}\overline{k}^{\alpha}\overline{h}^{1-\alpha}f \tag{9}$$

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[8] Country TFP estimations may be subject to measurement errors of the underlying economic variables which would tend to cancel out in regional TFP estimation. Therefore, we regard estimations for the typical country as substantially more reliable.

[9] The 17 LAC countries included in the sample are Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala, Honduras, Jamaica, Mexico, Panama, Paraguay, Peru, Uruguay and Venezuela.

[10] We follow the convention of denoting the growth rate of a variable x by $\hat{x}$.

A logarithmic transformation of the above equation can then be used to account for the contribution of the TFP gap and that of factor intensities to the overall income per capita gap at a point in time:

$$\log(\bar{y}) = \log(\bar{A}) + \alpha \log(\bar{k}) + (1-\alpha)\log(\bar{h}) + \log(\bar{f}) \tag{10}$$

In order to highlight LAC's weaknesses and anomalies, these gaps (the growth gaps in equation (8) and the log-level gaps in equation (10)) are computed against the rest of the world (ROW) and selected groups of countries, such as the East Asian tigers (EA) and currently Developed countries (DEV). Unless noted, comparisons are made between the typical countries of each one of the regions. Following convention, we take the U.S. economy as the technological frontier against which "absolute" gaps in productivity are estimated.

It is worth noting that equation (10) contains all the information needed for these analyses. The time difference over a period of *p* years (say from *t-p* to *t*) yields a decomposition of how the level gaps opened during the period, to be interpreted as a decomposition of the accumulated growth gap in the period, found in equation (11). In fact, for a period of one year (*p=1*, so that the period runs between *t-1* and *t*), the time difference yields the annual growth gap in equation (8).

$$\Delta_p \log y_t = \log\left(\frac{y_t}{y_{t-p}}\right) = \log\left(\frac{\bar{A}_t}{\bar{A}_{t-p}}\right) + \alpha \log\left(\frac{\bar{k}_t}{\bar{k}_{t-p}}\right) + (1-\alpha)\log\left(\frac{\bar{h}_t}{\bar{h}_{t-p}}\right) + \log\left(\frac{\bar{f}_t}{\bar{f}_{t-p}}\right) \tag{11}$$

In what follows, we highlight three stylized facts of total factor productivity in Latin America and the Caribbean that are central to diagnosing some of the main weaknesses in the region's economic development.

Fact 1: The growth gap in LAC is driven by the gap in productivity growth.

The first stylized fact is that the gap in income per capita growth can be largely attributed to the gap in TFP growth, rather than to differences in the pace of factor accumulation. The growth gaps since 1960 in GDP per capita and in TFP relative to the rest of the world appear equally large and systematic (Panel A of Figure 5). Factor accumulation in Latin America was in line with the rest of the world; what sets apart Latin American growth is subpar TFP growth.[11] This finding coincides with the analysis in Blyde and Fernández-Arias (2006). While a gap in the rate of factor

[11] In our sample, similar to the regional statistics, most of the variability in growth gaps in individual Latin American countries can be explained by their TFP growth gaps.

accumulation with respect to the typical East Asian country was important until about a decade ago (Panel C of Figure 5), this pattern is more a peculiarity of East Asian development than a Latin American weakness.

Fact 2: LAC productivity is not catching up with the frontier, in contrast with East Asia.

Endogenous growth theory suggests that less productive countries should be able to increase their productivity faster because they can adopt technologies from more advanced economies, benefitting from advances at the frontier without incurring the costs of exploration. While it is true that TFP is not just technology—for example, it also reflects inefficiencies in how markets work, as we argued above—the catching-up argument works just as well for policies and institutions: backward countries have the benefit of being able to improve by learning, rather than inventing.

Figure 6 shows the evolution of productivity in LAC and other regions relative to the frontier, customarily taken as the United States (normalizing the indexes to 1 by 1960). Until the debt crisis of the 1980s, catching up in the typical LAC country was slower than in the rest of the world. Since then, catching up turned on its head, especially in LAC. This divergent pattern in recent decades holds true not only for the typical LAC country but also for the region as a whole (LAC Region in the figure) as Brazil's earlier dynamism during the 1960s and 1970s slowed down. Other benchmarks further highlight LAC's poor productivity trends even when compared to the ROW, which also failed to catch up.

The failure to catch up on productivity is widespread across LAC countries. Figure 7 shows all countries in the sample ranked by overall TFP catch-up (relative to the United States) in the period examined (1960-2014). Only Argentina and Panama, and marginally Bolivia, show some degree of convergence with the United States in that period.

Fact 3: LAC's productivity is about half its potential.

Current levels of estimated TFP for Latin American countries relative to that of the United States, taken as the frontier, are uniformly subpar (see Figure 8). In particular, in 2014 the aggregate productivity of the typical LAC country (which being an average is subject to less statistical error than that of individual countries) is about half (56 percent).

If factor inputs are kept constant, income per capita would move together with TFP. Therefore, if TFP increased to its potential, the income per capita of the typical LAC country would almost double (to about 40 percent of the U.S. level). In this thought experiment, a better combination of the same inputs emulating what is feasible in other economies, using existing technologies, would render an output substantially larger.

The sizable room for improvement associated with productivity catching-up is in some sense good news for LAC to the extent that rapid progress in income per capita (i.e., high growth) may be unlocked by economic policy reform even in the absence of the burden of increased investment. The potential for improving productivity in the typical LAC country by around 81 percent is not available to the typical East Asian country (45 percent) or developed country (only 18 percent).

Fact 4: LAC's productivity gap is becoming the key reason behind the income gap.

One way to gauge the importance of the productivity gap in explaining the income gap is to note what would have been the evolution of LAC income per capita if its historical production inputs had been applied with U.S. productivity at each point in time. This direct income effect of closing the productivity gap provides a measure of the relevance of that gap. Figure 9 shows the counterfactual scenarios of relative income per capita in which the TFP gap is closed for both the typical LAC country and the region as a whole.[12]

Figure 10 shows the evolution over time of the development accounting exercise based on equation (10) to show how the relevance of the productivity gap is increasing. From 1975 onwards, the contribution of TFP to the income gap has been increasing steadily to reach a level of 40 percent. Physical capital accounts for a comparable portion of the income per capita gap but with a stable contribution over time, while the contribution of human capital is substantially smaller and has gradually declined. In contrast, the contribution of labor employment intensity has collapsed. It explained an important share (over 20 percent) of the income gap during the early 1980s, but today its contribution to the income per capita gap between the typical LAC country and the United States is negligible. In summary, productivity is increasingly important in explaining income gaps. Figure 11 shows this decomposition country-by-country in 2014.

[12] There are also important indirect effects because productivity and factor accumulation are interlinked and changes in productivity are bound to have indirect effects on factor accumulation (and vice versa). See Daude and Fernández-Arias (2010) and Fernández-Arias and Rodríguez Apolinar (2016) for a further analysis.

4. Robustness of the Stylized Facts

The use of alternative methodologies confirms the robustness of the previous key stylized facts. In particular, we consider first the following three variations of the standard methodology employed:

a) A production function giving less weight to physical capital and more weight to human capital. In this alternative we use a lower capital share, a=1/3, the standard value in the literature.

b) A time-variant value for a, which might account for technological change altering the elasticity of substitution of factors of production. This time series is obtained calculating the cross-country average of factor income shares estimated in the Penn World Table version 9.0 (PWT 9.0).[13]

c) A human capital index h based on Hall and Jones (1999) method. This is what is used in the calculations by Feenstra, Inklaar and Timmer (2013) for PWT 9.0.

In order to test Fact 1: The growth gap in LAC is driven by the gap in productivity growth, the annual TFP growth gap between LAC and ROW based on equation (8) shown in the previous section is contrasted with the annual TFP growth gaps produced by the three alternative methodological variations (Figure 12). The contrast demonstrates that the TFP growth gap under alternatives (a), (b) and (c) is similar to the baseline case.

The robustness of Fact 2: LAC productivity is not catching up with the frontier, in contrast to East Asia, is tested by looking at the evolution of the typical LAC country's TFP relative to the frontier under the various alternative methodologies (Figure 13). The remarkable lack of convergence persists under the alternative scenarios.

The alternative methodologies broadly confirm Fact 3: Latin America's productivity is about half its potential, as shown in Figure 14, where the TFP gap between the typical Latin American country and the frontier is estimated under the various alternatives.

Finally, not only LAC is not catching up with the technological frontier, but also the productivity contribution to explaining the income gap has been increasing in recent years; the

[13] As explained in the previous version of this document, a country-specific, time-variant value for a estimated in the Penn World Table version 8.0 (PWT 8.0) was also considered, which allows technology to differ across countries in the output elasticity dimension (Feenstra, Inklaar and Timmer, 2013). However, these estimations were very volatile and strongly suggested the presence of measurement error.

three methodologies support this statement (Figure 15). Consequently, Fact 4 is robust to the three alternatives.

5. Conclusions

Low productivity and insufficient productivity growth as measured by total factor productivity, rather than impediments to factor accumulation, are the key to understanding Latin America's low income relative to developed economies and its stagnation relative to other developing countries that are catching up, as summarized by the following stylized facts:

a) The growth gap in LAC is driven by the gap in productivity growth.

b) LAC's productivity is not catching up with the frontier, in contrast to East Asia.

c) LAC's productivity is about half its potential.

d) LAC's productivity gap is gradually becoming the dominant factor behind the income per capita gap.

Therefore it is clear that the key to the economic development problematic in the region is how to close the productivity gap. The main development policy challenge in the region involves diagnosing the causes of poor productivity and acting on its roots. While impediments to technological improvement at the firm level is part of the problem, aggregate productivity depends on the efficiency with which private markets and public inputs support individual producers. Since firms' productivities may be heterogeneous, aggregate productivity also depends on the extent to which the workings of the economy allocate productive factors to the most productive firms. These considerations open up a rich agenda for productivity development policies.

Statistical Appendix

Gross output (Y) is computed as PPP-adjusted real GDP from the Penn World Table Version 9.0 (PWT 9.0). In the latest release, two versions of GDP have been published. The first is expenditure-based and coincides with the one in previous versions of the PWT. The second is an output-based version of the GDP (*cgdpo*), which is more suitable to our purposes of comparative development accounting across countries and is the one we used to calculate the baseline TFP.

Labor input (L) is measured by the total labor force engaged also from the PWT (*emp*).[14] It is often argued that hours worked is a more accurate measure. However, these data are not available for a large number of countries over a long period of time, limiting the possibility of a broad and structural comparison across countries in Latin America. However, it is known that such refinement does not substantially alter measured TFP (see Restuccia, 2008). Furthermore, short-run fluctuations in labor market conditions would not have an influence on the TFP measure because we focus on HP-filtered trends. Population (N) is taken from PWT as well (*pop*).

We also obtained the series for the real capital stock (K) from PWT (*ck*). In this version, the authors of the PWT have estimated capital stocks, recognizing the differences in depreciation rates among the types of assets that add up to the total capital stock.

Concerning the skill level, we follow the approach by Bils and Klenow (2000) by constructing the human capital index h as a function of the average years of schooling given by:

$$h = e^{\phi(S_{it})} \tag{A.1}$$

where $\phi(S)$ is such that $\phi(0) = 0$ and $\phi'(S)$ is the Mincerian return on education. In particular, we approximate this function by a log-linear function shown in equation (A.2). We estimated the parameters θ and ψ from the data in Psacharopoulos and Patrinos (2004)[15] and using the corresponding average schooling years (population older than 15 years) in Barro and Lee (2013) database. The data in Barro-Lee extend to 2010.

$$\phi(S_{it}) = \frac{\theta}{1-\psi} S_{it}^{1-\psi} \tag{A.2}$$

[14] Blyde and Fernández-Arias (2006) show that the use of employed labor instead of labor force to measure factor input makes little difference in LAC.

[15] Both Caselli (2005) and Feenstra, Inklaar and Timmer (2013) use the approach by Hall and Jones (1999), which is in turn based on the estimations by Psacharopoulos (1994). We considered these estimations out-of-date and not representative of schooling progress throughout the world.

Clearly, differences in the quality of human capital across countries could affect our measure of human capital. However, if the differences in the quality of education are the same for all levels of education, they would be adequately captured in TFP comparisons. It is straightforward to show this. Suppose that the returns depend on quality adjusted years of education defined as $j\ (qS)$. Given the function in (A.2) and $\phi(0)=0$, $\phi(.)$ is homogeneous of degree *1-ψ*, which implies that *h* can be written as $h=e^{\phi(qxS)}=e^{q^{1-\psi}}e^{\phi(S)}$.

Finally, in order to obtain the structural series, we considered the logarithms of the series of output, physical capital, skill level and labor headcount (*Y*, *K*, *h* and *L*, respectively), filtered them with a Hodrick-Prescott filter with smoothing parameter $\lambda=7$, and then inverted the logarithmic transformation. Using these filtered series, we computed our measures of productivity.

Projections of *Y*, *K*, *pop*, *h* and *emp* for 2015-2017 are used to avoid end-point problems in the filtering process. WEO reports projections of real GDP at current PPP, investment as percentage of GDP, population, employment, and unemployment rate. We assume that *Y*, *pop* and *emp* (when available) grows at the same rate as the PPP-adjusted real GDP, population and employment reported on WEO, respectively. For countries without employment projections, we follow two strategies. We use unemployment rate (when available) and then construct the growth rate of *emp* as the sum of the average employment growth rate between 2000 and 2014 and the change of the employment rate implied by the unemployment rate; for the remaining countries we assume that *emp* grows at the same rate as *pop*. We obtain investment by assuming that the ratio (investment / GDP) also holds on PPP terms; then, using investment, lagged capital and a constant as regressors, we estimate a simple equation for the variation of capital and use the estimated parameters to obtain one-point-ahead projections of the variation of capital. Finally, we assume a constant growth rate for *h*, equal to its average growth rate between 2000 and 2014.

GDP Per Capita and Prices in PWT 8.0 and PWT 9.0

It is important to keep in mind that there are substantial differences in GDP in PPP terms between PWT 9.0 and PWT 8.0 that sometimes lead to significant variations between this 2017 update and the previous 2014 version of our database.

This update is based on PWT 9.0, which used price information from the International Comparison Program 2011 (ICP 2011). In contrast, the 2014 update was based on PWT 8.0, which used price information from ICP 2005. As explained in Feenstra, Inklaar and Timmer (2016), the common global list used for price comparison in ICP 2005 included many products that were typical in the consumption baskets of high-income countries but high-priced luxury items in low-income countries. As a consequence, prices in these countries were overestimated and, as a consequence, GDP per capita calculations were underestimated.

In order to see the magnitude of these changes, in Figure A.1 we show the ratio between GDP per capita reported in PWT 9.0 and GDP per capita in PWT 8.0 for the United States and three groups of countries, East Asia, Latin America and the Caribbean and developed countries. In the United States and developed countries, the evolution of this ratio remains around 1, suggesting few adjustments in the data for these countries. In the case of LAC, this ratio remains around unity until the mid-1990s and starts increasing thereafter. Differences are strikingly higher for East Asia, where this ratio diverts from unity during the entire sample.

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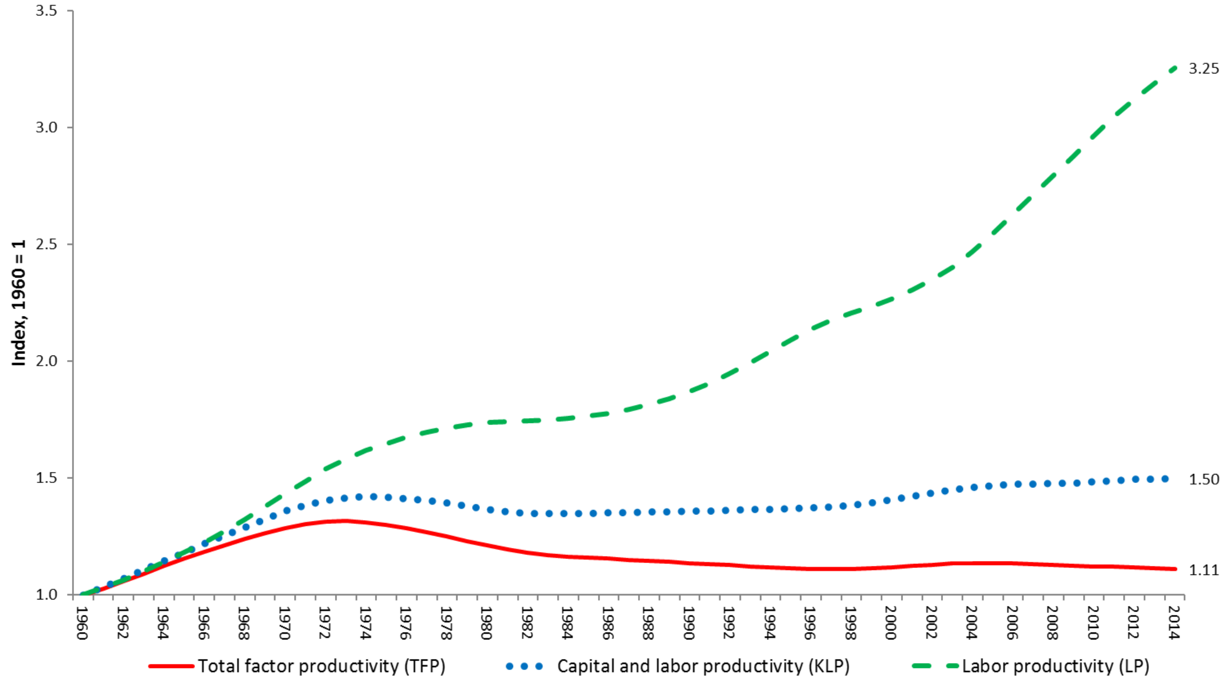
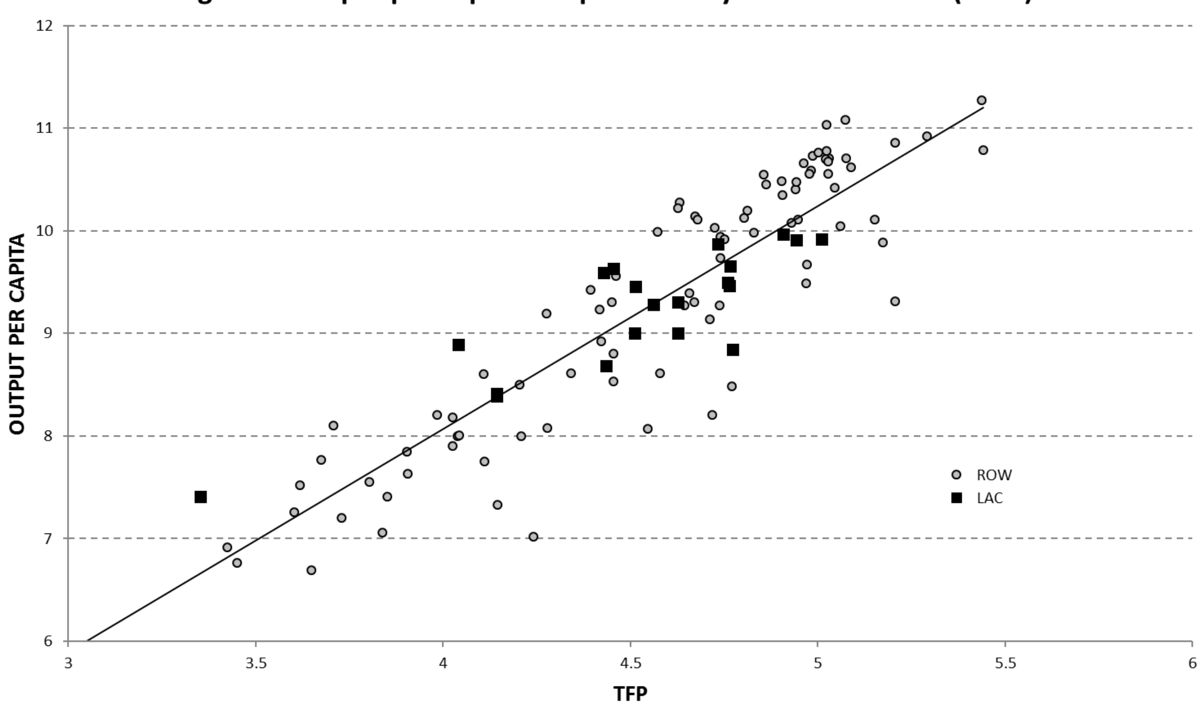
Figure 1. Alternative productivity measures (Typical world economy)

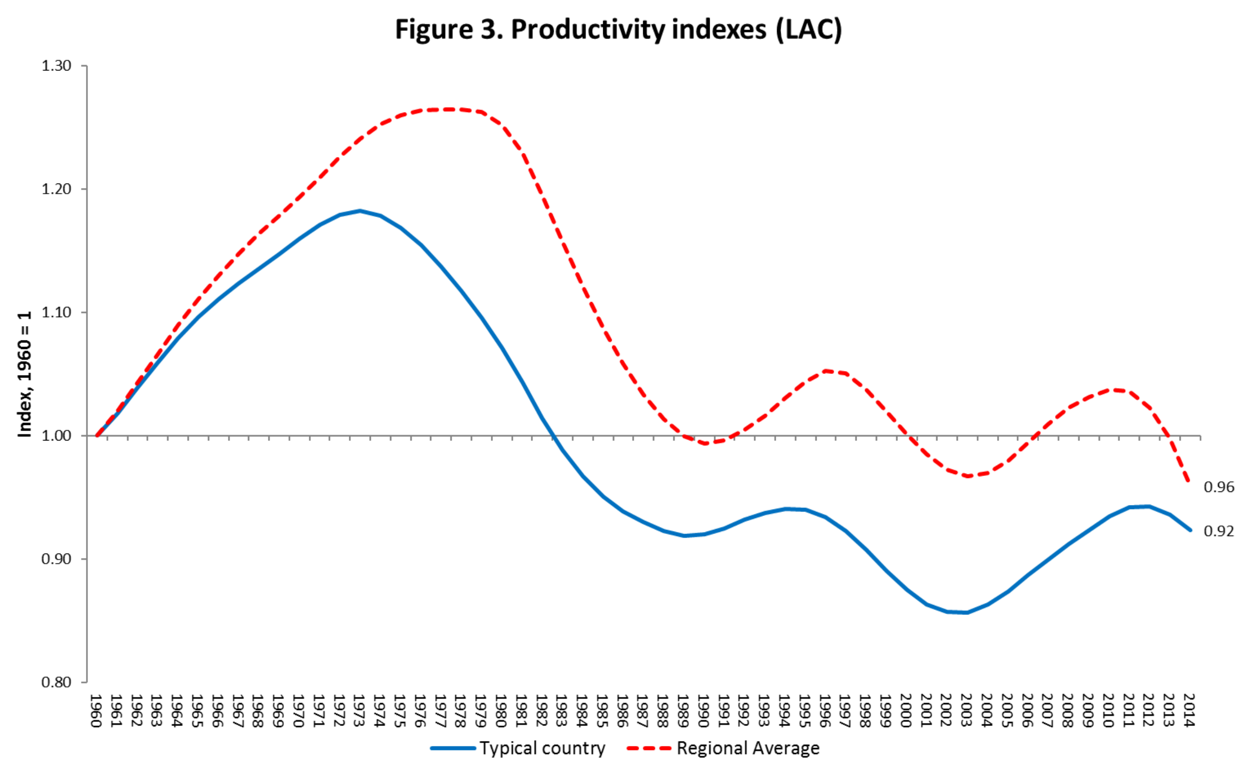


Source: Authors' Calculations based on Penn World Table 9.0 (2016) and Barro and Lee (2016).

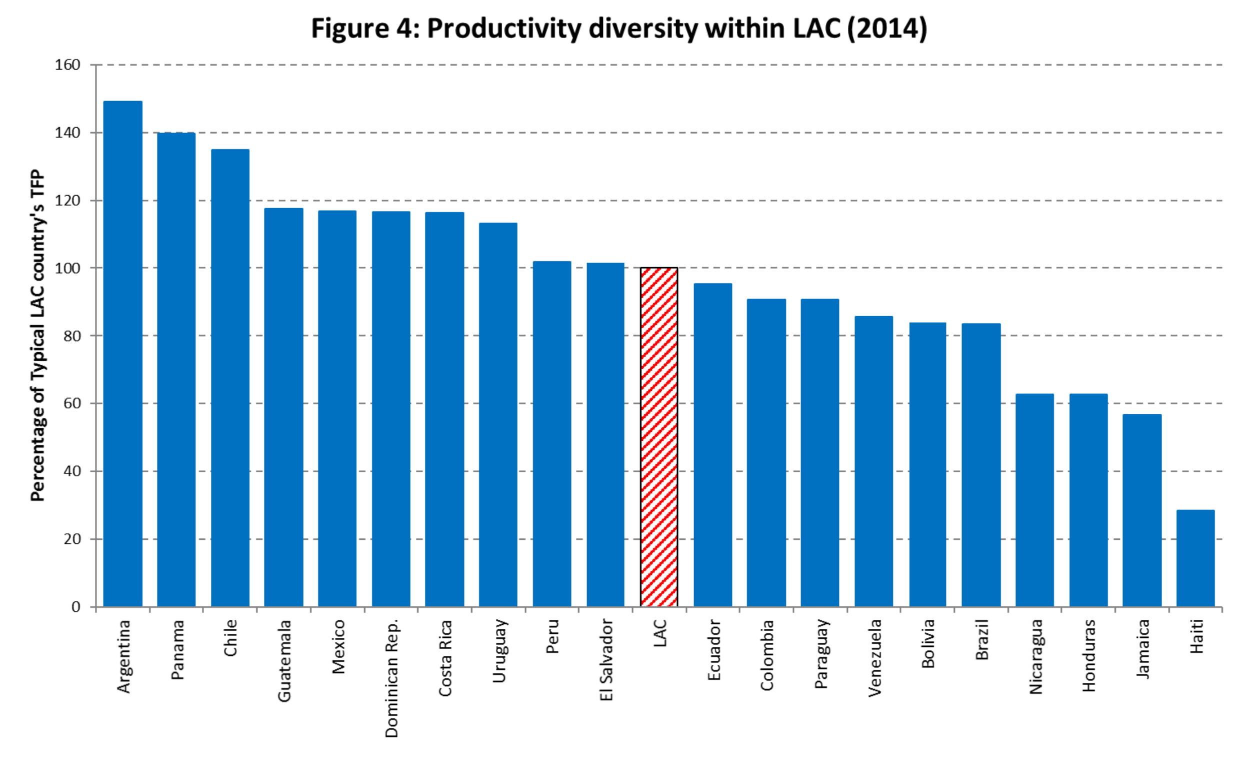
Figure 2. Output per capita and productivity across countries (2014)



Note: Income per capita and TFP measured in logarithmic scale
Source: Authors' Calculations based on Penn World Table 9.0 and Barro and Lee (2016)

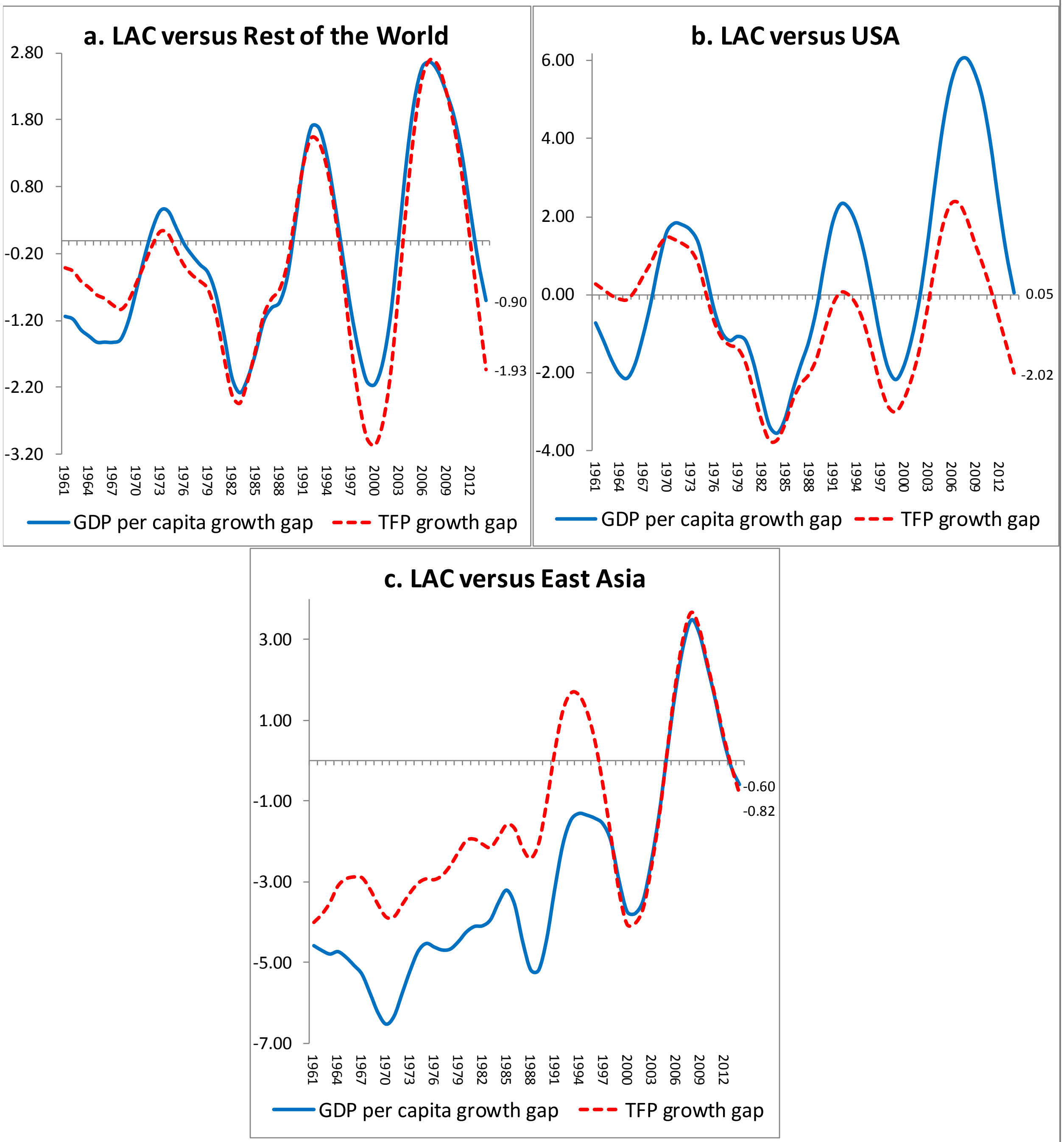


Source: Authors' Calculations based on Penn World Table 9.0 and Barro and Lee (2016)



Source: Authors' Calculations based on Penn World Table 9.0 and Barro and Lee (2016)

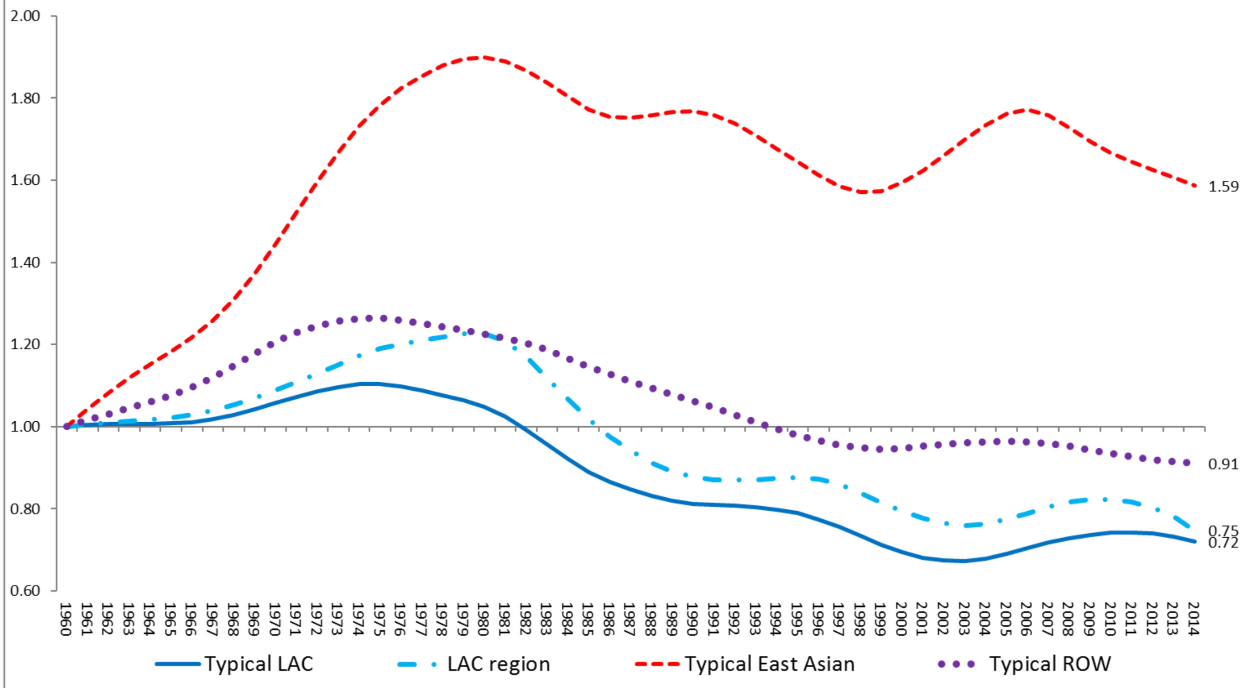
Figure 5. TFP and GDP per capita growth gaps (%)



Source: Authors' Calculations based on Penn World Table 9.0 and Barro and Lee (2016)

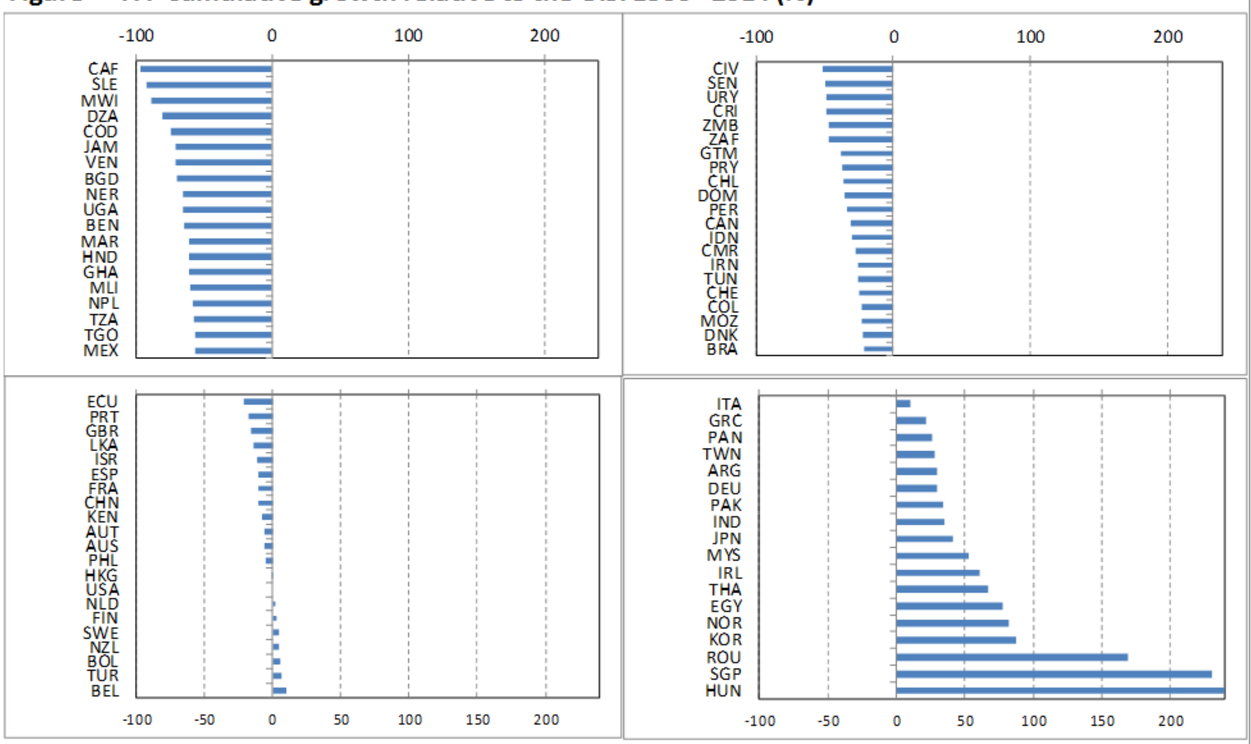
Figure 6: Productivity Catch-up

(Productivity Index relative to US, 1960=1) - Contrast with selected regions



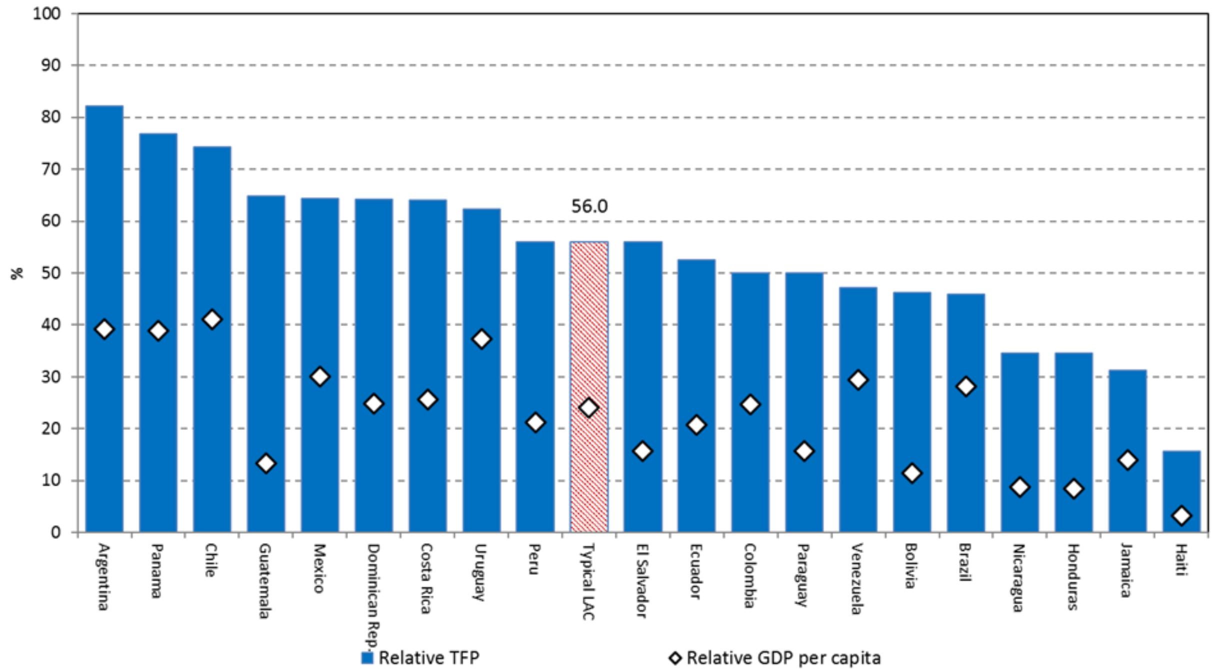
Source: Authors' Calculations based on Penn World Table 9.0 and Barro and Lee (2016)

Figure 7: TFP cumulative growth relative to the U.S. 1960 - 2014 (%)



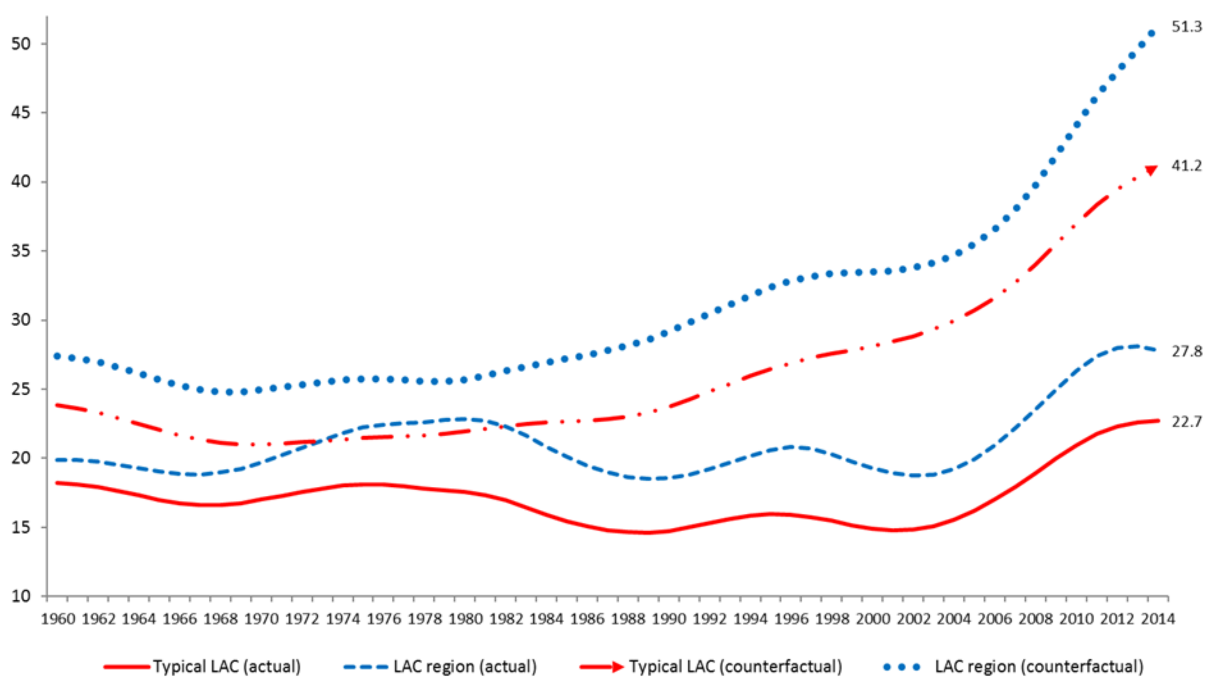
Source: Authors' Calculations based on Penn World Table 9.0 and Barro and Lee (2016)

Figure 8: Relative productivity in LAC countries
(% of US productivity, 2014)



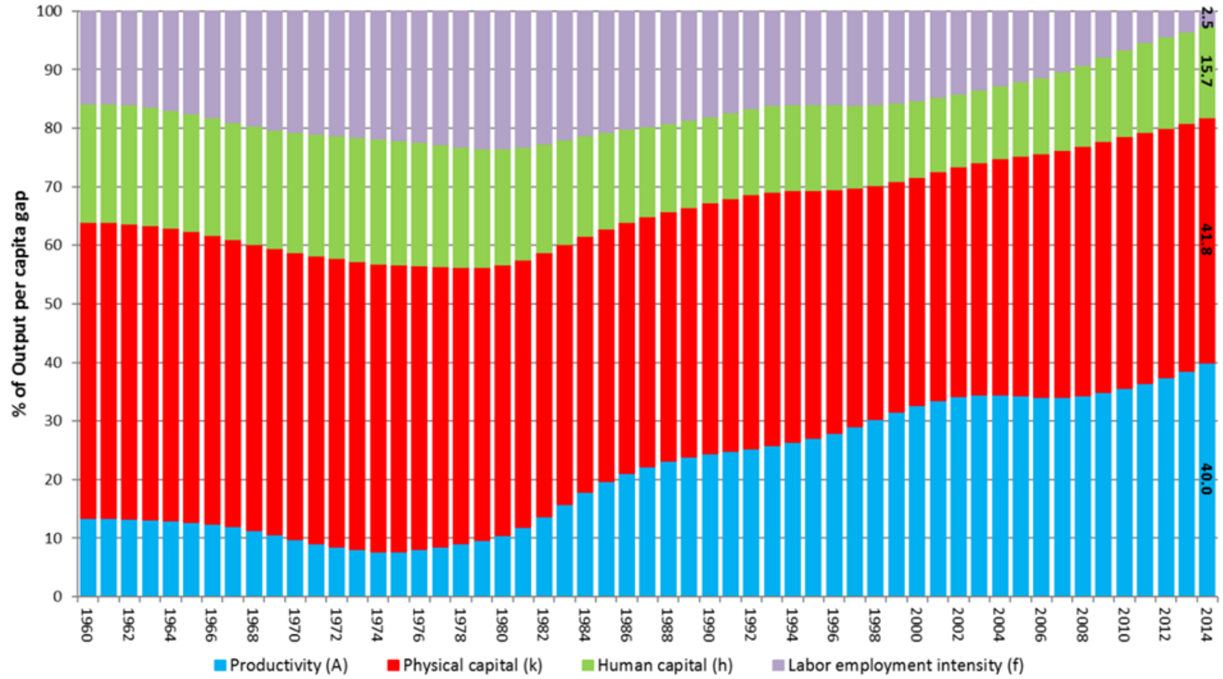
Source: Authors' Calculations based on Penn World Table 9.0 and Barro and Lee (2014)

Figure 9: Direct Income Effect of closing the productivity gap
(% of US output per capita)



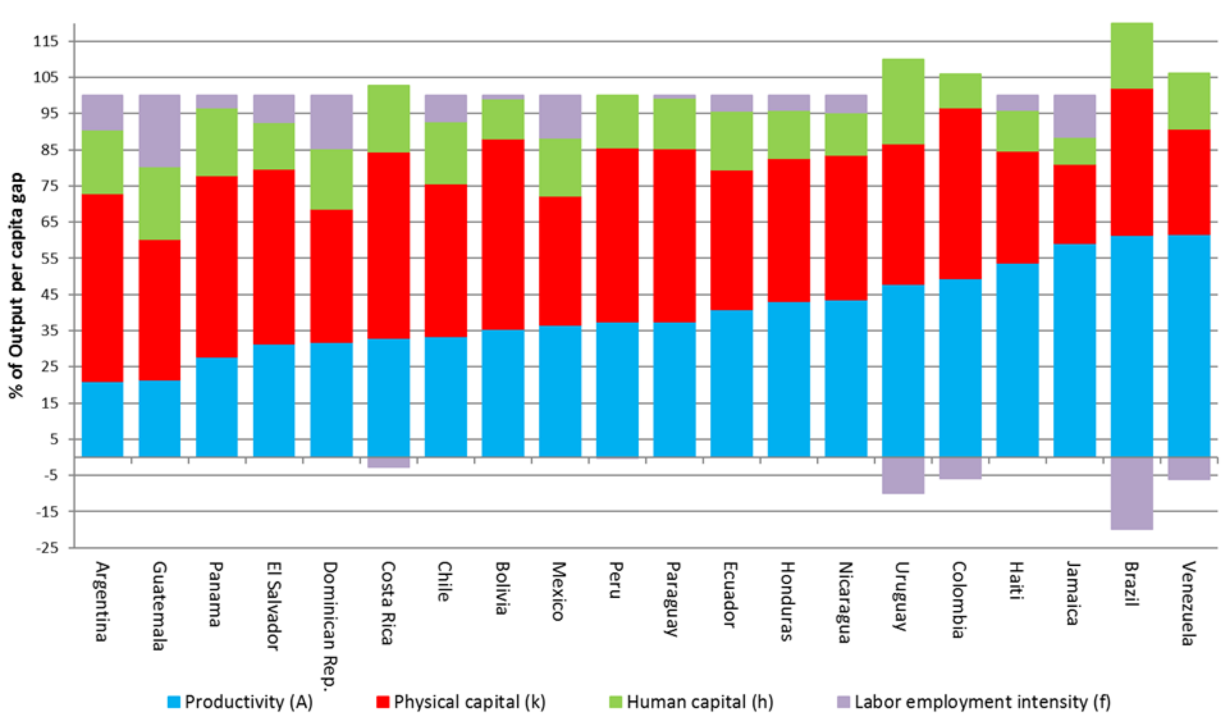
Source: Authors' Calculations based on Penn World Table 9.0 and Barro and Lee (2014)

Figure 10: Contribution to closing the output per capita gap
(Typical LAC country versus USA)



Source: Authors' Calculations based on Penn World Table 9.0 and Barro and Lee (2016)

Figure 11:Contributions to closing the output per capita gap versus U.S. in 2014



Source: Authors' Calculations based on Penn World Table 9.0 and Barro and Lee (2016)

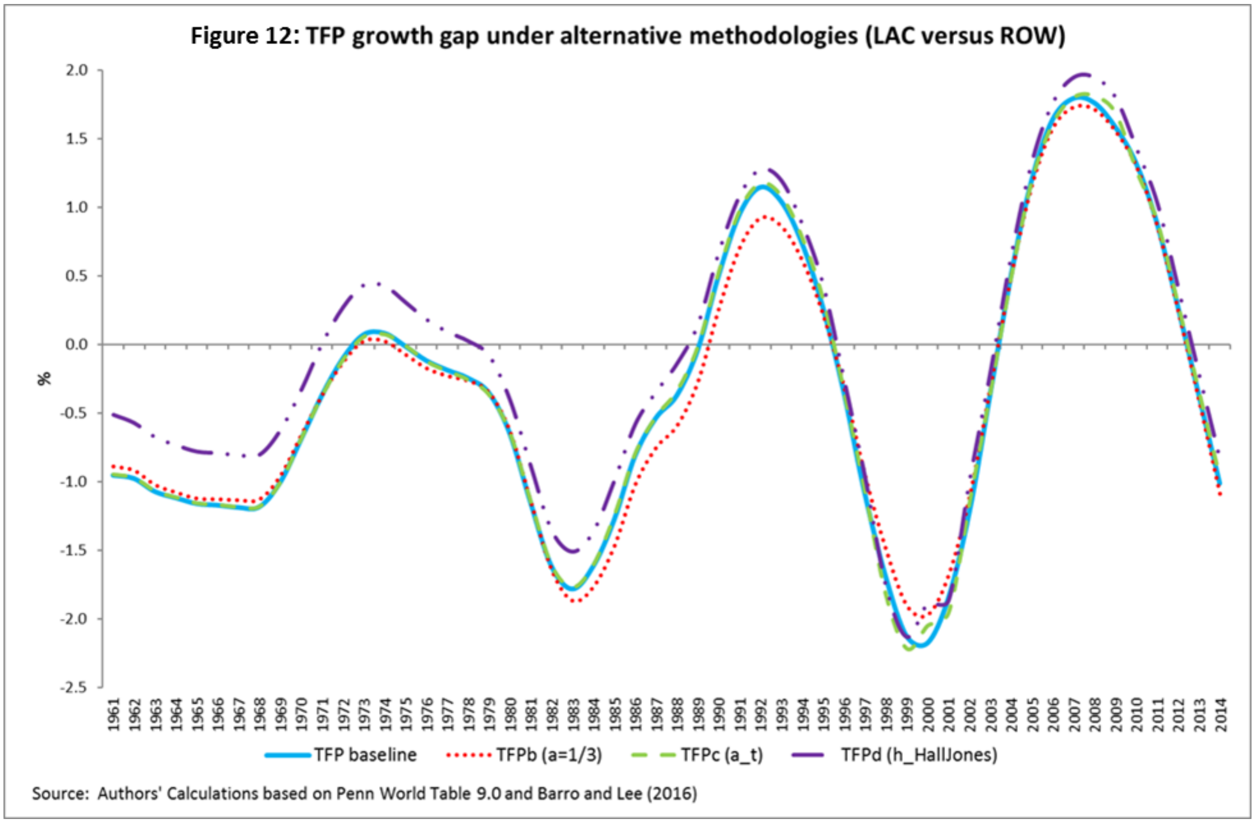


Figure 12: TFP growth gap under alternative methodologies (LAC versus ROW)
%
TFP baseline
TFPb (a=1/3)
TFPc (a_t)
TFPd (h_HallJones)
Source: Authors' Calculations based on Penn World Table 9.0 and Barro and Lee (2016)

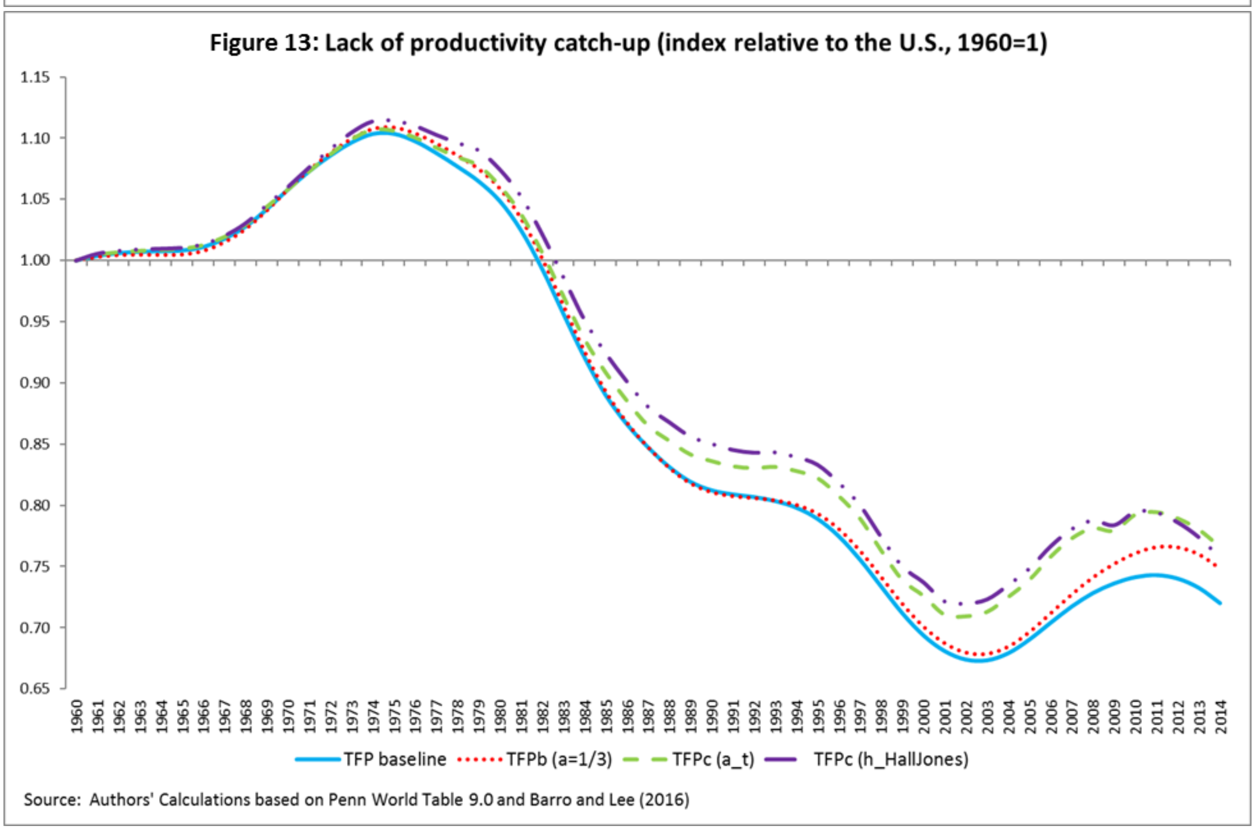
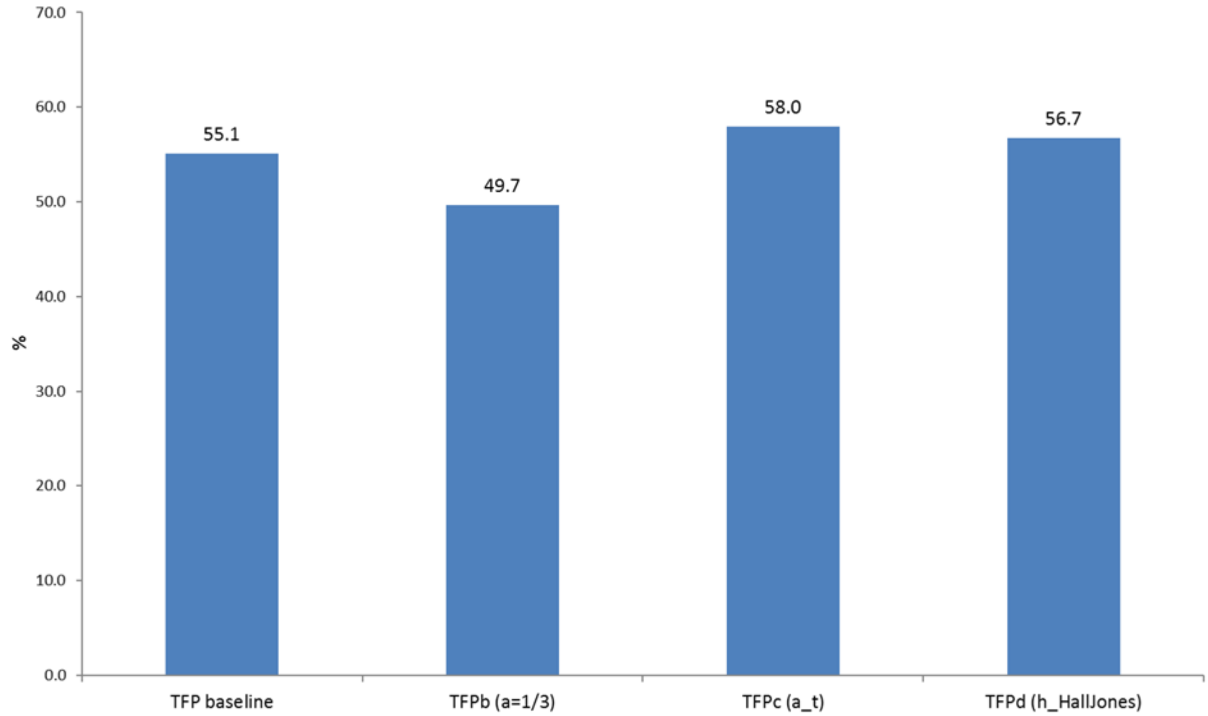


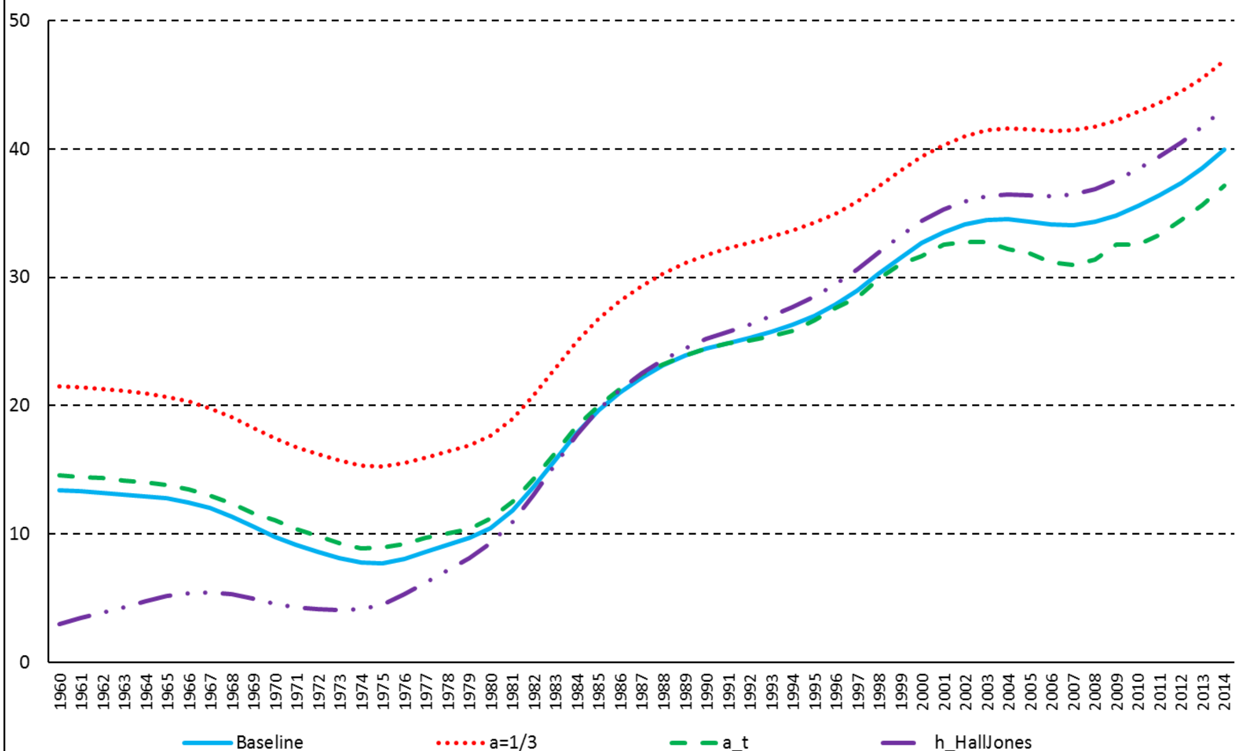
Figure 13: Lack of productivity catch-up (index relative to the U.S., 1960=1)
TFP baseline
TFPb (a=1/3)
TFPc (a_t)
TFPc (h_HallJones)
Source: Authors' Calculations based on Penn World Table 9.0 and Barro and Lee (2016)

Figure 14: TFP relative to the U.S. (Typical LAC country, 2014)



Source: Authors' Calculations based on Penn World Table 9.0 and Barro and Lee (2016)

Figure 15: Productivity Contribution to Closing the GDP Per Capita Gap under alternative scenarios (TypLAC vs USA)



Source: Authors' Calculations based on Penn World Table 8.0 and Barro and Lee (2013)

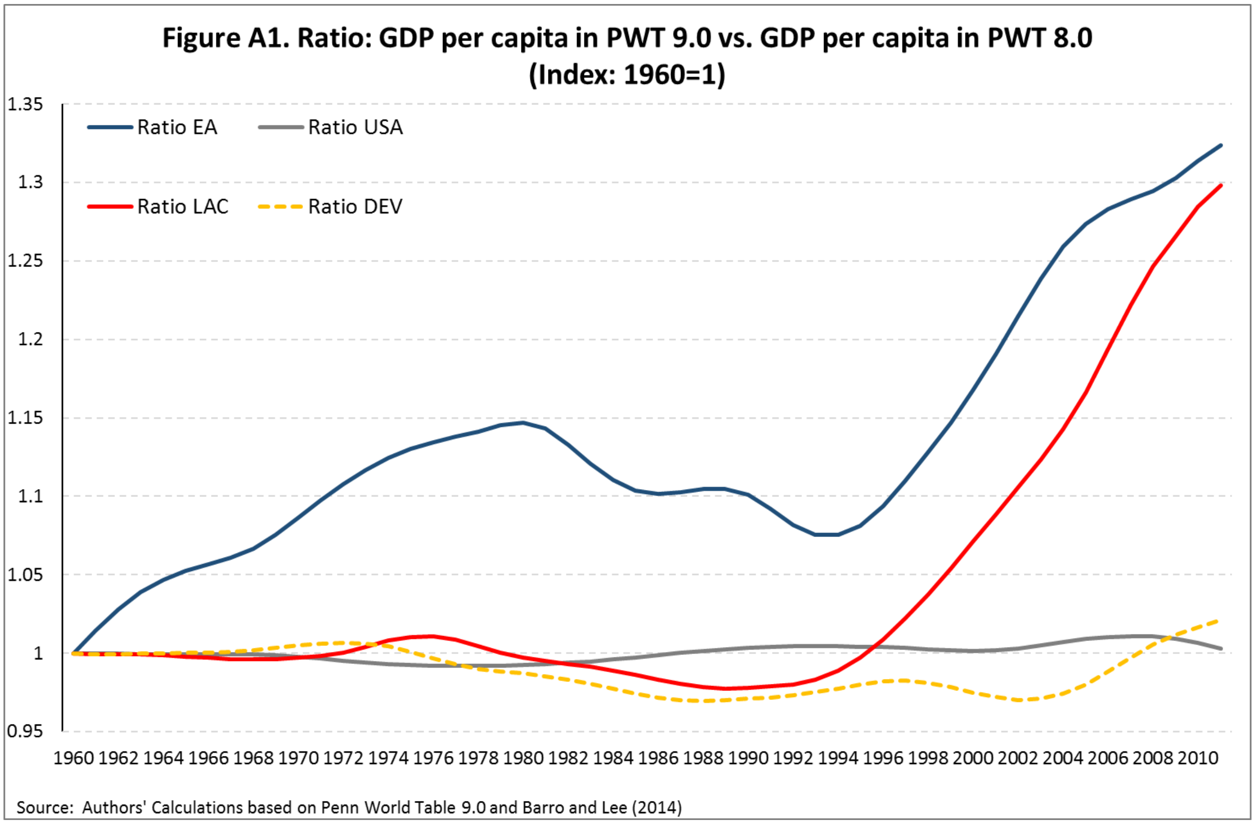


Figure A1. Ratio: GDP per capita in PWT 9.0 vs. GDP per capita in PWT 8.0
(Index: 1960=1)
Ratio EA
Ratio USA
Ratio LAC
Ratio DEV
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
0.95
1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010
Source: Authors' Calculations based on Penn World Table 9.0 and Barro and Lee (2014)

Table 1: Sample

Country	Country groups	Country	Country groups	Country	Country groups
Argentina	LAC	Ghana	EA	Tanzania	EA
Bolivia	LAC	Greece	EA, DEV	Uganda	EA
Brazil	LAC	Hong Kong	EA, ROW	USA	EA, DEV
Chile	LAC	Hungary	EA, DEV	South Africa	EA
Colombia	LAC	Indonesia	EA	Zambia	EA
Costa Rica	LAC	India	EA	Haiti *	LAC
Dominican Rep.	LAC	Ireland	EA, DEV	Nicaragua *	LAC
Ecuador	LAC	Iran	EA	El Salvador *	LAC
Guatemala	LAC	Israel	EA	Albania *	EA
Honduras	LAC	Italy	EA, DEV	Armenia *	EA
Jamaica	LAC	Japan	EA, DEV	Burundi *	EA
Mexico	LAC	Kenya	EA	Bulgaria *	EA
Panama	LAC	Republic of Korea	EA, DEV, ROW	Congo *	EA
Peru	LAC	Sri Lanka	EA	Czech Republic *	EA
Paraguay	LAC	Morocco	EA	Estonia *	EA
Uruguay	LAC	Mali	EA	Croatia *	EA
Venezuela	LAC	Mozambique	EA	Kazakhstan *	EA
Australia	EA, DEV	Malawi	EA	Kyrgyzstan *	EA
Austria	EA, DEV	Malaysia	EA, ROW	Cambodia *	EA
Belgium	EA, DEV	Niger	EA	Lithuania *	EA
Benin	EA	Netherlands	EA, DEV	Latvia *	EA
Bangladesh	EA	Norway	EA, DEV	Myanmar *	EA
Central African Republic	EA	Nepal	EA	Mongolia *	EA
Canada	EA, DEV	New Zealand	EA, DEV	Poland *	EA
Switzerland	EA, DEV	Pakistan	EA	Russian Federation *	EA
China	EA	Philippines	EA	Rwanda *	EA
Cote dIvoire	EA	Portugal	EA, DEV	Saudi Arabia *	EA
Cameroon	EA	Romania	EA	Sudan *	EA
D.R. Congo	EA	Senegal	EA	Slovakia *	EA
Germany	EA, DEV	Singapore	EA, ROW	Slovenia *	EA
Denmark	EA, DEV	Sierra Leone	EA	Tajikistan *	EA
Algeria	EA	Sweden	EA, DEV	Ukraine *	EA
Egypt	EA	Togo	EA	Viet Nam *	EA
Spain	EA, DEV	Thailand	EA, ROW	Yemen *	EA
Finland	EA, DEV	Tunisia	EA	Zimbabwe *	EA
France	EA, DEV	Turkey	EA		
United Kingdom	EA, DEV	Taiwan	EA		

An "*" indicates that TFP could not be constructed for 1960 due to lack of observations; this also indicates that these countries were excluded when generating regional averages.
LAC: Latin America. ROW: Rest of the World. DEV: Developed Country. EA: East Asia.