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## Abstract<sup>1</sup>

This paper combines development accounting exercises with economic theory to assess the importance of total factor productivity and the accumulation of factors of production as engines of growth in Latin America. Using the new, drastically revised Penn World Table (PWT) and Barro-Lee datasets, the paper shows that lower and non-convergent income relative to successful development benchmarks are explained by subpar productivity gains rather than slower factor accumulation. The empirical analysis of the interplay between productivity and accumulation in the process of development suggests that one explanation for this pattern is that investment in Latin America is not as productivity-enhancing as in less distorted economies.

**JEL classifications:** O11, O47

**Keywords:** Economic growth, Total factor productivity, Development, Productive development policies

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## **1. Introduction**

In contrast with other regions such as advanced countries or East Asia, Latin America and the Caribbean (LAC) has been growing slow in the last decades. While lack of investment is often suggested as the main reason behind this outcome, Daude and Fernández-Arias (2010) find that lagging total factor productivity plays a key role. In particular, they find that: i) slower growth in LAC is due to slower productivity growth; ii) LAC productivity is not catching up with the frontier, in contrast to theory and evidence elsewhere; and iii) LAC's productivity is about half its potential.

In this context, the contribution of this paper is threefold. First, the paper updates the calculations made in Daude and Fernández-Arias (2010) using the drastically revised Penn World Tables dataset and refines their methodology. By and large, the main conclusions concerning the weaknesses of productivity in LAC are confirmed and found robust. Five additional years of data also reveal that the productivity catch-up starting around 2002 has stalled. Second, the paper tests this methodology exploring whether some of the negative productivity findings in LAC may be due to measurement errors in human capital, especially in regards to the productive yield of schooling (or, in general, education “quality”). The answer is no: it is found that a possible bias in estimated human capital accumulation would actually reinforce the productivity shortfall in the region.

Having confirmed that lagging productivity is a distinctive characteristic of the region, the paper then looks at why this is so. The third contribution of the paper is the analysis of the productivity impact of physical capital accumulation. The paper finds that the pattern of factor accumulation in the LAC region is less productivity enhancing and is a key proximate cause of its characteristically weak productivity. The policy implication is that more investment is not the solution to the productivity problem and successful policies need to focus more specifically on productivity.

## **2. Productivity in a Comparative Development Framework: An Update**

The new Penn World Tables 8.0 has been drastically revised relative to the version used by the original Daude and Fernández-Arias (2010) work and includes additional years that may be informative about the shifting trends towards productivity convergence that these authors found at the end of their sample.

Following Daude and Fernández-Arias (2010), in this paper productivity is measured as total factor productivity (TFP).<sup>2</sup> TFP is estimated by looking at 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  $H=hL$ . Therefore, TFP measures the effectiveness with which accumulated factors of production, or capital, are used to produce output. This relationship between output, productivity and factor accumulation can be mapped using a standard Cobb-Douglas production function:

$$Y = AK^a H^{1-a} = AK^a (hL)^{1-a} \quad (1)$$

where  $a$  is output elasticity to (physical) capital. Taking advantage of the new information reported in PWT 8.0, the production function parameter  $a$  is set equal to 0.43, which is the 1960 average of the estimated elasticities.<sup>3,4</sup> Changes in this parameter over time are therefore captured as changes in productivity.

We construct the relevant series for output, physical capital and human capital ( $Y$ ,  $K$ , and  $H$ , respectively) since 1960 based on available statistics and following methods described in the Statistical Appendix.<sup>5</sup> It is worth noticing that this paper refines the methodology used in Daude and Fernández-Arias (2010) and PWT 8.0 concerning the human capital index  $h$ , which is estimated using a variation of the approach of Bils and Klenow (2000). (The methods used to estimate human capital are discussed in more detail in the next section.) Raw annual data are

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<sup>2</sup> Other alternatives are discussed in Daude and Fernández-Arias (2010), who that, in contrast with TFP, these measures can be affected by the evolution of capital accumulation and labor force trends.

<sup>3</sup> In Daude and Fernández-Arias (2010) this parameter was set at 1/3, a standard value in the literature (see Klenow and Rodríguez-Clare, 2005), which in this paper is used as a robustness check. For more information on the variables used in these calculations, see the Statistical Appendix.

<sup>4</sup> Although controversial, Gollin (2002) suggests that this uniformity assumption across countries and time is a reasonable assumption as a first cut.

<sup>5</sup> Roughly speaking, we rely on Penn World Tables 8.0 for data on output, physical capital and raw labor. Restricting the sample to countries with a population of at least 1 million as of 1960, we arrive at a sample of 74 countries (Table 1) from 1960 to 2010.

filtered to obtain smooth series that reflect their trends, thus reflecting only structural features of productivity. Using these series, we can compute our measure of TFP as follows:

$$A = \frac{Y}{K^a (hL)^{1-a}} \quad (2)$$

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 can be 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:

$$y = \frac{Y}{N} = A \left( \frac{K}{L} \right)^a h^{1-a} \frac{L}{N} = Ak^a h^{1-a} f \quad (3)$$

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:

$$A_{LAC} = \left( \prod_{i=1}^n A_i \right)^{\frac{1}{n}} \quad (4)$$

Similarly, we consider the simple (logarithmic) average of income per capita ( $y$ ), and the corresponding factor of production intensities ( $k$ ,  $h$  and  $f$ ).<sup>6</sup> 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 1 shows productivity in LAC for both the typical country and the region as a whole.<sup>7</sup> (More generally, we build various country groupings following similar methods for the analysis of a number of variables.) In particular,

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<sup>6</sup> 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.

<sup>7</sup> 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.

productivity in the region has been decreasing steadily since around 1975, with a small rebound since 2002 that subsequently stalled. It is useful to keep in mind that there is substantial diversity in productivity levels across countries in the LAC region that is masked by regional indicators. Figure 2 shows our estimation of current productivity levels in each country relative to the typical country in Latin America (as of 2010).<sup>8</sup>

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 3), with a correlation coefficient of 0.95 for 2010. In statistical terms, 90 percent of the cross-country income variation in the world today would disappear if TFP were the same across countries in the world. The diversity within the region, as expected, is also highly correlated with income per capita (with a correlation coefficient of 0.80; see Figure 3). 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.

### *2.1 Stylized Facts of Productivity*

Development accounting utilizes equation (5) to compare the components behind income per capita between an economy of interest and a benchmark economy taken as a development yardstick, denoted by “\*”, or level gaps:

$$\bar{y} = \frac{y}{y^*} = \frac{A}{A^*} \left( \frac{k}{k^*} \right)^a \left( \frac{h}{h^*} \right)^{1-a} \frac{f}{f^*} = \bar{A} \bar{k}^a \bar{h}^{1-a} \bar{f} \quad (5)$$

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:

$$\log(\bar{y}) = \log(\bar{A}) + a \log(\bar{k}) + (1-a) \log(\bar{h}) + \log(\bar{f}) \quad (6)$$

In order to highlight LAC’s weaknesses and anomalies, these gaps are computed against the rest of the world (ROW) and selected groups of countries, such as the East Asian Tigers

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<sup>8</sup> Country TFP estimations may be subject to measurement errors of the underlying economic variables which would tend to cancel out in regional TFP estimations, for example that of the typical country, which we regard as substantially more reliable.



(EA), currently Developed Countries (DEV), and “Twin” countries (TWIN, countries whose income was initially, by 1960, comparable to that of LAC countries).<sup>9,10</sup> Unless otherwise noted, comparisons are made between the typical countries of each one of the regions. Following convention, we take the US economy as the technological frontier against which “absolute” gaps in productivity are estimated.

Relying on equation (6), Daude and Fernández-Arias (2010) describe two stylized facts that are broadly confirmed in this update. First, LAC productivity is not catching up with the frontier, in contrast to East Asia. 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 4 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 Figure 4) 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 other groups of countries failing to catch up. For example, had productivity in the typical LAC country grown at the same pace as its counterpart in the rest of the world since 1960, by now its income per capita would be some 21 per cent higher.

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<sup>9</sup> The latter group of “twin” countries was constructed by selecting all countries in the sample whose 1960 income per capita fell in the inter-quartile range of Latin American countries (incomes within the second and third quartile).

<sup>10</sup> East Asian Tigers are Hong Kong, Korea, Malaysia, Singapore and Thailand; Developed Countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, United Kingdom and United States; Twin Countries are Fiji, Ghana, Greece, Hungary, Iran, Japan, Jordan, Malaysia, Portugal, Singapore, South Africa, Sri Lanka, Syria and Turkey; countries of Rest of the World include, apart from the ones above, Benin, Cameroon, Central African Republic, China, Egypt, India, Indonesia, Israel, Kenya, Lesotho, Malawi, Mali, Mozambique, Nepal, Niger, Pakistan, Philippines, Senegal, Sierra Leone, Togo, Tunisia, Uganda and Zambia.

The failure to catch up on productivity is widespread across LAC countries. Figure 5 shows all countries in the sample ranked by overall TFP catch-up (relative to the United States) in the period examined (1960-2010): there is a substantial concentration of Latin American countries in the bottom quartiles.

Secondly, Daude and Fernández-Arias (2010) show that 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 6). In particular, in 2010 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 (52 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 automatically double (to about a third 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 a substantially larger output. More generally, 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 is an artificial question because, as analyzed in Section 4, productivity and factor accumulation are interlinked and changes in productivity are bound to have indirect effects on factor accumulation. Nevertheless, the direct income effect of closing the productivity gap provides an indication of the relevance of that gap. In the case of the typical LAC country, income would multiply by a factor of 1.92.<sup>11</sup> Figure 7 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

The sizable room for improvement associated with productivity catch-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 without the burden of increased investment. The potential for improving productivity through catching up in the typical LAC country by around 92 percent is not available to the typical East Asian country (50 percent) or developed country (only 19 percent).

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<sup>11</sup> Using alternative accounting approaches (regarding the measure of physical capital and the inclusion of life expectancy and cognitive skills in human capital measurement), Caselli (2014, Table 1) finds that for 2005 the typical LAC country would have also increased its output per worker by a factor between 1.5 and 2.3 had it also closed its efficiency gap.

These data support a third stylized fact: the income gap with the United States is increasingly due to the productivity gap. Figure 8 shows the evolution over time of the development accounting exercise based on equation (6). From 1975 onwards, the contribution of TFP to the income gap has been increasing steadily, tripling its importance to reach a level of 37 percent. Physical capital accounts for a comparable portion of the income per capita gap (43 percent), with a stable contribution over time. In contrast, the contribution of human capital has declined substantially from around one fifth of the gap in 1960 to 13 percent in 2010. Similarly, while labor employment intensity explained an important share (over 20 percent) of the income gap during the early 1980s, today its contribution to the income per capita gap between the typical LAC country and the United States is about 8 percent. Productivity is increasingly important in explaining income gaps. Figure 9 shows this decomposition country-by-country in 2010.

## *2.2 Robustness of Stylized Facts*

The use of alternative methodologies confirms the robustness of the previous key stylized facts to technical assumptions. In particular, we consider the following four variations of the standard methodology employed:<sup>12</sup>

1. 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 (the assumed value in Daude and Fernández-Arias, 2010).
2. 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 Tables Version 8.0 (PWT 8.0).
3. A human capital index  $h$  based on Hall and Jones (1999) method, used by Feenstra et al. (2013) for PWT 8.0 and Daude and Fernández-Arias (2010).
4. The consideration of TFP as estimated by PWT 8.0 smoothed with a HP filter to allow for comparisons.

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<sup>12</sup> All the alternatives assume a Cobb-Douglas production function. Using non-parametric methods, Daude and Fernández-Arias (2010) show that this assumption is robust for this type of stylized facts.

The robustness of *Fact 1: 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 10). The remarkable lack of convergence persists under the alternative scenarios.

The alternative assumptions and methodologies also broadly confirm *Fact 2: Latin America's productivity is about half its potential*. The typical Latin American country and the frontier are estimated under the various alternatives (Figure 11).

Finally, the robustness of *Fact 3: The income gap is increasingly due to the productivity gap*, is established under the four alternatives by looking at the increasing share of the income gap of the typical Latin American country due to the productivity gap (Figure 12).

### 3. Education Yield and Productivity Gaps

Any distortion in the estimation of the productive capacity of the workforce (human capital) translates into distortions in the estimation of TFP, which is obtained as a residual. The methods used in the literature to estimate human capital, and followed in the previous section, are based on the years of school education received by the workforce. However, the unobserved yield of such schooling in terms of productive capabilities or education yield, a qualitative dimension, may vary widely across countries and introduce measurement errors contributing to the large productivity gaps previously estimated for LAC. In fact, there is widespread concern in LAC about the low quality of education, which could contribute to explaining the remarkably low productivity estimated with standard methods. Arguably, what appears as low total factor productivity could be effectively low human capital due to low education yield. In this section we review these methods and discuss the impact that unobserved education yields may have on TFP gaps. Based on this evidence, we discard this factor as an explanation for the above stylized facts: low TFP in LAC is real.<sup>13</sup>

#### 3.1 Estimating the Human Capital Index

In the traditional education-based approach, the construction of a human capital index,  $h$ , is based on Mincerian regressions of country samples such as in equation (7):

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<sup>13</sup> Other human capital measurement errors may relate to unmeasured pre-school readiness and job training, which according to the calibrated model in Manuelli and Seshadri (2014) are very important components of human capital, especially in underdeveloped countries.

$$\ln(w_j) = \eta_0 + \lambda s_j + \eta_1 EX + \eta_2 EX^2 + \varepsilon_j \quad (7)$$

where  $w$  is the wage rate,  $s$  represents years of schooling and  $EX$  measures years of experience (given by age). In this formulation, wages grow exponentially with years of education. The human capital index of individual  $j$  at time  $t$  with average years of schooling  $S_{it}$  is estimated as:<sup>14</sup>

$$h_{it} = e^{\phi(S_{it})}, \quad (8)$$

where  $\phi'(S) = \lambda$  represents the Mincerian return to an additional year of schooling. In this way,  $h$  aggregates labor skills in terms of the wages obtained by workers with different levels of education (relative to an unschooled worker). Then, the central question regarding the measure of human capital lies in the way of defining an aggregate function of cumulative returns,  $\phi(S)$ , such that  $\phi(0) = 0$  and  $\phi'(S)$  is the relevant Mincerian return for the country/year in question.

In the calculation of  $h$ , the latest release of the Penn World Table by Feenstra, Inklaar and Timmer (2013)<sup>15</sup> is based on Hall and Jones (1999), who define  $\phi(S)$  as a piecewise-linear function:

$$\phi_a(S_{it}) = \begin{cases} 0.134 \times S_{it} & \text{if } S_{it} \leq 4 \\ (0.134 \times 4) + 0.101 \times (S_{it} - 4) & \text{if } 4 < S_{it} \leq 8 \\ (0.134 \times 4) + (0.101 \times 4) + 0.068 \times (S_{it} - 8) & \text{if } S_{it} > 8 \end{cases} \quad (9)$$

The numbers representing the Mincerian returns for each of the sections of this function come from Table 4 in Psacharopoulos (1994)<sup>16</sup> and correspond to the regional average Mincerian returns in the surveys conducted for that paper in Sub-Saharan Africa, the World and the OECD countries (13.4, 10.1 and 6.8 percent, respectively). Although there is no explicit justification for the use of these numbers or for the way Hall and Jones split the function (on a four-year basis), they do reflect the conventional wisdom that marginal returns decrease with average years of education. The highest return is assigned to the first years of education based on the returns to education in the region with the lowest schooling (Sub-Saharan Africa), while the lowest marginal return is assigned to the highest level of education based on the average return to education in the advanced countries, where the schooling level is the highest. The difference

<sup>14</sup> As usual, the data on average years of schooling come from the Barro-Lee database.

<sup>15</sup> This method is also utilized in, among others, Caselli (2005).

<sup>16</sup> See Psacharopoulos (1994: 1329).

between the average years of schooling in the OECD and Sub-Saharan Africa was 5 years. However, this ad hoc calibration is increasingly inconsistent; for instance, based on Psacharopoulos and Patrinos (2004), the structure of returns has changed substantially in more recent surveys and this schooling difference shrank to below 2 years.

In contrast to using aggregate data, Bils and Klenow (2000)<sup>17</sup> estimate series of country human capital in a fashion more consistent with private returns to education and the micro data evidence; in particular, they propose a log-linear form for the function  $\phi(S)$ :

$$\phi_b(S_{it}) = \frac{\theta_b}{1-\psi_b} S_{it}^{1-\psi_b} \quad (10)$$

in which  $\theta_b$  and  $\psi_b$  are parameters to be estimated and  $\lambda = \phi'(S) = \theta/S^\psi$  is the Mincerian return. With  $\psi_b > 0$ , returns are decreasing in average years of schooling. This is a way to reconcile constant returns at the country level (equation (7)) with cross-country decreasing returns to education.

Using data from Table A2 in Psacharopoulos (1994) for micro-based Mincerian returns and average years of schooling, they estimate the following equation by OLS:

$$\ln(\lambda_i) = \ln(\theta_b) - \psi_b \ln(s_i) + \varepsilon_i \quad (11)$$

This is the log-form of the Mincerian return ( $\lambda$ ), where  $s$  (in lower case) represents the average years of schooling in the sample. The estimates for  $\theta_b$  and  $\psi_b$  they obtained were 0.32 and 0.58, respectively, which are then used to estimate human capital with equation (10). In this formulation, the residual  $\varepsilon_i$  is interpreted as sampling error in each country survey with no information value concerning human capital.

In the previous section we adopted a variation of the Bils and Klenow method in the benchmark case. First we updated the base information. For this we used updated estimates of Mincerian returns and average years of schooling based on the data collected in Table A2 in Psacharopoulos and Patrinos (2004) completed through consultations with the primary sources. The resulting sample includes 56 countries. The updated estimation of equation (11) would yield significant and right-signed OLS coefficients:  $\hat{\theta}_c \approx 0.25, \hat{\psi}_c \approx 0.45$ .

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<sup>17</sup> Also recently used by the IMF (Cubeddu et al., 2014).

Additionally, we refined the method by considering not the sample average schooling ( $s_i$ ) but that of the entire workforce, consistent with an estimation of aggregate human capital. For this purpose, we used the average schooling years from Barro-Lee ( $S_{it}$ ) for the corresponding survey year, which allowed us to expand the sample to 67 countries. Our final estimates from equation (11) as utilized in our baseline were  $\hat{\theta}_d \approx 0.17, \hat{\psi}_d \approx 0.37$ .

Table 2 summarizes the relevant results for each of the estimation methods in this section. It is clear that under the Bils and Klenow model, the estimations differ substantially from those in Hall and Jones.<sup>18</sup> We now move to additional methods used to obtain region-specific estimations in order to see whether measurement errors in human capital may help explain the LAC productivity gap.

### 3.2 Education Yield and Productivity

Since only the quantity of education is accounted for in these methods, qualitative differences due to different education yields would end up reflected in TFP differences. In this context, education yield, meaning wage return for any given amount of years of education, does not necessarily refer to its academic quality but also to the appropriateness of the education process for the purpose of production in a given economy, that is to say, how it impinges on the working capacity of the labor force.

Education yield may differ significantly across countries, distorting country comparisons. As long as differences are uniform across all levels of education, the yield differential directly translate into productivity differentials. Suppose that the returns to education depend on quality-adjusted years of education defined as  $\phi(q \times S)$ . If the function is homogenous the parameter  $q$  factors out, such as in the Bils and Klenow function in (10) where  $\phi(q \times S) = q^{1-\psi} \phi(S)$ , which implies that  $h$  can be written as  $h = e^{\phi(qS)} = e^{q^{1-\psi}} e^{\phi(S)}$ . In that case, the difference in quality translates into a difference in log TFP equal to  $q^{(1-a)(1-\psi)}$ .

Previous studies have resorted to introducing explicit proxies of education yield such as PISA scores into calibrated Mincer equations in order to arrive at an adjustment factor to derive

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<sup>18</sup> As in most of the specifications  $\psi$  is statistically different from zero, so that the relationship between cumulative returns and schooling is concave. Also, the autonomous Mincerian returns (the parameter  $\theta$ ) are bigger than Hall and Jones (1999) have proposed, even for the least developed countries.

effective years of education, finding that this refinement does not change the big picture of the stylized facts on productivity.<sup>19</sup> By contrast, this paper uses the information in the estimation errors ( $\varepsilon_i$ ) from equation (11) to obtain country indicators of education yield, which would reflect all quality-relevant characteristics including academic attainment. In Bils and Klenow, this residual is assumed to be measurement error, with no information on wage returns to education. In the current opposite formulation, countries with larger than expected Mincerian returns are assumed to have structurally higher returns (quality effect) rather than being lucky, so that country-specific intercepts in Equation (11) would conform to the Mincerian return:  $\hat{\theta}_{d,i} = \hat{\theta} \times e^{\varepsilon_i}$ . Then, for country  $i$ :

$$\phi_{d2}(S_{it}) = \frac{\theta_d e^{\varepsilon_i}}{1 - \psi_d} S_{it}^{1 - \psi_d} \quad (12)$$

The question is: how does Latin America compare with other regions in regard to education yield under this statistical assumption? For countries with lower yield this new measure implies a downward adjustment to their human capital estimation and, consequently, an upward adjustment to their TFP. If the TFP adjustment factor is large, then this could be an indication that the productivity shortfalls uncovered in the stylized facts are partly due to low education yield, a qualitative factor.

Figure 13 shows the human capital and TFP adjustment factors for the typical country in various regions based on sample of 54 countries in our TFP database sample for which there is Mincerian information.<sup>20</sup> The typical country in Latin America has higher-than-average education yield and, therefore, a TFP adjustment factor smaller than one. In other words, TFP would be even lower after adjustment. The TFP gaps relative to other regions would generally worsen too. The gaps with respect to the East Asian Tigers would be largely unchanged because this group of countries would undergo a similar upward adjustment to its human capital.

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<sup>19</sup> Caselli (2014) utilizes the multivariate Mincer equation estimated in Vogl (2014) for his baseline and finds insignificant differences because the effect of PISA gaps appears negligible. Only aggressive calibration based on upwardly biased partial wage estimations produces some difference, also found in Daude (2013). Models with imperfect skilled labor substitution as in Caselli and Coleman (2006) offer an interesting angle for studying productivity gaps without assuming skill-neutral progress but confirm the result that differences in education yields is not the source of productivity gaps.

<sup>20</sup> This only reduces the sample of countries in the region we called “Africa and Developing Asia,” mostly because some African and Middle East economies are not included in the original sample due to lack of information. There is no statistically significant difference between the estimated parameters.



However, the productivity gaps with respect to Advanced Economies would open even further.<sup>21</sup> On the basis of this indicator, there is no evidence that low productivity in the region derives from the low yield of education.<sup>22</sup>

As a further test, in what follows we generalize this approach by using the entire data on Mincerian returns from Table A4 in Psacharopoulos and Patrinos (2004), including multiple observations for some countries (not only the last survey), to build an unbalanced panel of 185 observations for the 67 countries. This larger panel involves more data points from older surveys from where to obtain country-specific information but may introduce some noise if the model parameters are not stable over time.

Using this larger panel, we estimated the following equation using the Random Effects (RE) and Fixed Effects (FE) methodologies generalizing Equation (11):

$$\ln(\lambda_{it}) = \ln(\theta_e) + v_i - \psi_e \ln(S_{it}) + \varepsilon_{it} \quad (13)$$

Our new point estimates are:  $\hat{\theta}_e^{RE} \approx \underline{0.21}$ ,  $\hat{\psi}_e^{RE} \approx \underline{0.50}$ ;  $\hat{\theta}_e^{FE} \approx \underline{0.17}$ ,  $\hat{\psi}_e^{FE} \approx \underline{0.38}$ .

The Random Effects model has the attractiveness of making less extreme assumptions about the information content of residuals, recovering some country-specific quality information from them but without attempting to impute every unexplained return differential to it in the form of country dummies, which does not appear realistic because of presumably substantial sampling error in country surveys. Under the restrictive assumption that country quality effects are uncorrelated to their education quantum, the Random Effects model would be consistent and more efficient. Given that the Hausman test does not reject such hypothesis at the 5 percent significance level, we chose to use the Random Effects model as a baseline. The estimations from the Random Effects model are also quite robust to the inclusion of additional regressors (time trend  $t$ , capital-labor ratio  $k$ , GDP per capita  $y$ ) in the panel regressions in contrast to the ones obtained from the Fixed Effects specification (see Table 3).

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<sup>21</sup> Within the group of Advanced Countries, the United States is an exception: this method would lead to a very significant upward adjustment to its human capital and a correspondingly large downward adjustment to its TFP of almost 30 percent, which would push it well inside the productivity frontier. In this method, the United States is an outlier and it would not make sense to use it as a benchmark; it may be an indication that this adjustment is too extreme.

<sup>22</sup> This is not to say that the quality of school education in Latin America is good or above average. Quality of education expressed in student performance measures such as the scores on PISA examinations or Hanushek and Woessmann (2012) are partial expressions of the education yield because they only relate to students' academic experience rather than their job skills and their ability to compete for better jobs as measured by wage returns. Furthermore, these measures exclude drop-outs who did not get to the education level being tested, and therefore they are not representative of the workforce.

Again, we turn to the sample of 54 countries to recalculate the corresponding  $h$  series to obtain a new baseline using the average education yields, which is generally higher than the previous baseline (by a factor of 1.22 in the case of the typical LAC country in 2010). In order to obtain country-specific education yields, we use the Random Effects estimates and consider  $\hat{\theta}_i = \hat{\theta} \times e^{v_i}$  to obtain adjusted human capital series:

$$\phi_{e2}(S_{it}) = \frac{\theta_e e^{v_i}}{1 - \psi_e} S_{it}^{1 - \psi_e} \quad (14)$$

This alternative method confirms that in LAC the education yield is above average and its consideration does not contribute to explaining low measured TFP.

Finally, we checked the assumption that the slope  $\psi$  is constant across regions by estimating the regional parameters with a Random Effects model in which years of schooling is interacted with regional dummies corresponding to the four regions depicted in Figure 13. There is statistical evidence that regions differ in the slope parameter.<sup>23</sup> Therefore, we incorporate this additional source of variation in a third method to capture country-specific education yields:

$$\phi_{f2}(S_{it}) = \frac{\theta_f e^{v_i}}{1 - \psi_{f,r}} S_{it}^{1 - \psi_{f,r}}, \text{ if } i \in \text{region } r \quad (15)$$

The resulting series of human capital are compared to those of a baseline using the mean parameters (Figure 13, panel c). Additionally, we compared the human capital estimates in the case of regional intercepts and slopes for the Mincerian returns (panel d).<sup>24</sup>

As shown in Figure 13, there is no reason to believe that considering alternative measures of human capital to include country- or regional-specific education yields would help to explain the lower value of TFP in Latin America and the Caribbean. In fact, applying more refined measures of human capital would result in even wider gaps in relative TFP for the region. With this note, for the analysis in the following sections we return to our original measure of human capital and TFP in Section 2.

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<sup>23</sup> For example, the difference between the parameter for LAC and that for Advanced Economies is about 0.14 in favor of the latter (i.e., Mincerian returns are more flexible to the average years of schooling in the developed world than in LAC). A Wald test rejected the null hypothesis that all psi coefficients were equal at 1 percent.

<sup>24</sup> The reader may want to take the results of this last panel with caution. Wald tests for both the regional intercepts and slopes proved that they are not significantly different from each other. Then, statistically, this alternative would be equivalent to a model with uniform parameters.

#### **4. Beyond Accounting: Productivity-Driven Factor Accumulation**

In an accounting sense, a gap in income per capita can be attributed to a gap in productivity ( $A$ ), physical capital intensity ( $k$ ), human capital intensity ( $h$ ), or labor employment intensity ( $f$ ) (equation (6)). For example, as shown in Figure 6, a development accounting exercise benchmarking the typical Latin American country with the United States would indicate that if the productivity gap is closed then relative income would roughly double (TFP in the typical LAC country would increase by  $A^*/A = 1.92$  times or roughly double, and so would income). Furthermore, as shown in Figure 9 and discussed above, an accounting decomposition of the contributions of each underlying gap to the current income gap with the United States on the basis of equation (6) would indicate that the productivity gap accounts for about 37 percent and accumulated factors for the rest, or 63 percent, as of 2010.

While the income boost produced by closing the productivity gap in this simple accounting calculation is sizable, it would apparently leave most of the observed income gap in place. This metric would suggest that productivity is an important but not predominant consideration behind income gaps, but then why is it that income is so closely associated with productivity across countries (as shown in Figure 3) or that their evolution over time is parallel? An appreciation of the relevance of productivity performance for the overall economic development process requires the exploration of the interplay between productivity and factor accumulation: the indirect effects of productivity gaps on the incentives to accumulate production factors may account for a substantial portion of the observed development gaps. In fact, the traditional tools previously utilized underestimate the importance that closing the productivity gap would have on welfare.

In what follows, using the updated estimations and a more general optimization framework, we confirm the finding in Daude and Fernández-Arias (2010) that:

***Claim 1: The income per capita gap with respect to the United States would mostly disappear if the productivity gap were closed.***

The previous exercises on the contribution of the productivity gaps to income gaps assume that  $k$  and  $h$  are exogenous to TFP levels. First, we consider the case where human capital continues to be considered exogenous, but physical capital is endogenous. In market economies, private investment in physical capital is such that the marginal return to investing

equals the cost of capital as perceived by individual investors, under the financing conditions accessible to them. The private return appropriated by an individual investor may very well be a fraction of the social return to investing, for example, if the firm's returns are taxed away. In particular, let us assume that the representative firm solves the following static maximization problem:

$$\begin{aligned} \max_k (1-\tau)Ak^a h^{1-a} - p_k(r+\delta)k \\ \text{where } A = A(k) = A_0 k^\beta \end{aligned} \quad (16)$$

where  $p_k$ ,  $r$  and  $\delta$  are the relative price of capital goods, the real interest rate and the depreciation rate, respectively. We assume a "tax" rate  $\tau$  to capture all elements that reduce the private appropriability of output proceeds.

The traditional neoclassical optimization condition assumes that  $A$  is exogenous. Since this paper also explores the impact of investment on productivity (in the following section), it is important to allow for the possibility that private investors internalize some of this potential effect. Consequently, we generalize the standard formulation by assuming that productivity depends on capital intensity and allowing the investor to capture productivity returns with an elasticity  $\beta$ . The first order condition is then given by:

$$\begin{aligned} (1-\tau)A(k)ak^{a-1}h^{1-a} + (1-\tau)k^a h^{1-a} A'(k) = p_k(r+\delta), \\ \text{or} \\ (1-\tau)(a+\beta)Ak^{a-1}h^{1-a} = p_k(r+\delta) \end{aligned} \quad (17)$$

The second term on the left-hand side of the equation (17) shows that the investor is also willing to invest to increase productivity (as long as  $\beta > 0$ ).

Solving for profit maximizing  $k$  it becomes clear that, irrespective of prices and the magnitude of the diversion of returns to physical capital accumulation summarized in  $\tau$ , an increase in TFP would boost private returns relative to the status quo and lead to a higher stock of accumulated physical capital.<sup>25</sup> Closing the TFP gap would alter incentives, boosting physical capital investment relative to the status quo, an indirect effect of closing the productivity gap that ought to be attributed to it:

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<sup>25</sup> This process would, of course, take time; here we are abstracting from transitional issues.

$$k = (a + \beta)^{\frac{1}{1-a}} A^{\frac{1}{1-a}} \left[ \frac{p_k(r + \delta)}{1 - \tau} \right]^{-\frac{1}{1-a}} h \quad (18)$$

Dividing the right-hand side of equation (10) by output per worker yields:

$$(a + \beta) \frac{Y}{K} = \frac{p_k(r + \delta)}{(1 - \tau)} \quad (19)$$

Thus, we have that the equilibrium capital-output ratio  $\kappa$  is given by:

$$\kappa = \frac{K}{Y} = \frac{(1 - t)(a + \beta)}{p_k(r + \delta)} \quad (20)$$

This shows that the equilibrium capital-output ratio does not depend on the level of productivity. It depends only on the interest rate, the degree of private appropriability of returns and the price of capital goods. Therefore, distortions to these price-like conditions will be reflected in the capital-output ratio: “price” impediments to physical capital investment leading to a wedge between net marginal returns (net of cost of capital) across countries correspond to lower capital-output ratios. Interestingly, the capital-output ratio also depends on the productivity elasticity  $\beta$ . If productivity is exogenous to private investment ( $\beta=0$ ), then the traditional neoclassical case obtains.

Plugging the endogenously determined  $k$  (equation (18)) into equation (5) and solving for output per capita, we can write the production function in per capita terms in “intensive form” as labeled by Klenow and Rodríguez-Clare (2005), which remains valid with generality irrespective of the parameter  $\beta$ :

$$y = A^{\frac{1}{1-a}} \kappa^{\frac{a}{1-a}} h f \quad (21)$$

Dividing equation (21) by the benchmark  $y^*$ , following the notation introduced in equation (5), and taking logs we can decompose the GDP per capita gap as:

$$\log\left(\frac{y}{y^*}\right) = \log(\bar{y}) = \frac{1}{1-a} \log(\bar{A}) + \frac{a}{1-a} \log(\bar{\kappa}) + \log(\bar{h}) + \log(\bar{f}) \quad (22)$$

Thus, the overall contribution of the TFP gap to the income gap in equation (22) results from the one-to-one direct effect in equation (6) plus an additional indirect effect:

$$\frac{1}{1-a} \log(\bar{A}) = \log(\bar{A}) + \frac{a}{1-a} \log(\bar{A}) \quad (23)$$

How large is the overall effect of closing the TFP gap, inclusive of indirect effects on factor accumulation? Considering the stimulus to physical investment brought by higher productivity, the overall TFP contribution for the typical LAC country (as of 2010) would amount to 65 percent of the income gap, of which 37 percent is the direct effect mentioned above and 28 percent is the additional indirect effect via induced physical capital accumulation.

In this model of physical capital intensity endogenously reacting to changes in productivity and exogenously given education expressed in equation (22), the remaining 35 percent to make up the entire income gap is divided into the contribution of impediments to physical investment, which as explained are reflected in the capital-output ratio  $\kappa$  (5 percent), human capital intensity or education  $h$  (22 percent), and labor employment intensity  $f$  (8 percent); see Figures 14 and 15. There is, of course, some variation across countries, but the conclusion holds broadly.

If investment in human capital (education)—which, as shown, is dominant among the remaining factor-related gaps—is also recognized as an endogenous variable that would likely react to an increase in productivity, the case for a predominant contribution of the productivity gap would be even stronger. In our context, its consideration would add an additional indirect effect of closing the productivity gap.<sup>26</sup> One effort to calibrate such response can be found in Daude and Fernández-Arias (2010) based on the model by Cordoba and Ripoll (2008). More recently, Manuelli and Seshadri (2014) developed and calibrated an optimization model in which the response of human capital to productivity shocks is very strong. In the way they put it, relatively minor productivity gaps can explain the large income differences we observe. Of course, this more complete decomposition where human capital also reacts to productivity changes crucially depends on how elastic education demand is to increased productivity.

## 5. Productivity-Enhancing Investment?

The key development policy question, then, is how to close the productivity gap. As mentioned, the aggregate productivity gap reflects a variety of shortcomings in the workings of the overall

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<sup>26</sup> Both indirect effects would actually reinforce each other because of the complementarity between physical and human capital in the production function.

economy and should not be narrowly interpreted as a technological gap. However, in answering this question it is important to recognize that factor accumulation, in both physical and human capital, could be important in facilitating the objective of reducing the productivity gap. For example, physical capital investment may embody new technologies to help in catching up with the frontier. A more skilled labor force may facilitate innovation and the adoption of more advanced technologies. This amounts to studying the effects of capital accumulation on productivity, a direction of causation opposite to the one we just explored to trace the effects of closing the productivity gap. Can we expect faster factor accumulation to be the key to productivity convergence? The following analysis shows that this does not seem to be the case in the LAC region:

***Claim 2: The productivity-enhancing effect of physical capital accumulation in LAC is very low and substantially lower than in successful regions.***

We assume that there is a constant elasticity of productivity to capital intensity,  $k$ , represented by  $\gamma$ :

$$A_{it} = B_{it}k_{it}^{\gamma}, \quad (24)$$

where  $B_{it}$  is the autonomous level of productivity. We will show that  $\gamma$  is low in LAC.

Inspecting the joint evolution of productivity and physical capital intensity in various regions (Figure 16) gives a first indication that the association between investment and TFP growth in the region is weaker than in advanced countries or the East Asian Tigers. To quantify this correlation, we run a simple log-linear regression of TFP on physical capital per worker based on equation (24) in a panel framework, where autonomous productivity is captured by country dummies:

$$\begin{aligned} \log A_{it} &= b + \gamma \log k_{it} + \varepsilon_{it}, \\ \log B_{it} &= b + \varepsilon_{it} \end{aligned} \quad (25)$$

where the coefficient  $\gamma$  measures the productivity-enhancing elasticity and is allowed to vary across regions.<sup>27</sup> The estimation results shown in Table 4 confirm the hypothesis that the LAC

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<sup>27</sup> This specification is consistent with the model in Durán, Licandro and Puch (2006) in which the effects of capital accumulation on TFP growth come from the technical progress incorporated in equipment investment.

elasticity coefficient is significantly lower than that of East Asian Tigers and Advanced Economies.

While these associations are suggestive, they are naïve because they ignore the endogeneity of capital accumulation analyzed in the previous section. In order to establish the claim that capital investment in LAC has a low productivity-enhancing effect, we first assume that the neoclassical optimization condition expressed in equation (18) holds. We then substitute the profit-maximizing capital-labor ratio into the naïve equation (24) to obtain the following estimating equation:

$$\log A_{it} = z_0 + z_1 \left[ \log \left( \frac{K}{Y} \right)_{it} + (1-a) \log h_{it} \right] + \varepsilon_{it} \quad (26)$$

$$z_0 = \frac{b(1-a)}{1-a-\gamma}, \quad z_1 = \frac{\gamma}{1-a-\gamma}$$

Table 5 shows the estimated parameters of this equation in a panel framework. As expected, the recovered estimations for the productivity-enhancing elasticity  $\gamma$  are lower than in the naïve estimation. The main point is that in LAC the elasticity is significantly lower than in successful regions. These elasticity gaps are substantial. On the basis of these point estimates, if LAC had the productivity elasticity of less distorted economies such as that of advanced countries, its productivity would be about 50 percent higher, or even more in the specification with time dummies. There is no evidence that higher investment would lead to productivity convergence.

Alternatively, we control for capital accumulation endogeneity without assuming the exact fulfillment of the neoclassical optimization condition by positing a more flexible equation (18) in which the parameters associated with the explanatory variables are free. In order to avoid the possible endogeneity of  $K/Y$  in this scenario, we utilize the (exogenous) relative price of capital stock,  $p_K$ .<sup>28</sup> Correspondingly, we consider the following system of equations:

$$\begin{cases} \log A_{it} = b + \gamma \log k_{it} + \varepsilon_{it} \\ \log k_{it} = c + \pi \log A_{it} + \mu \log h_{it} + \omega \log p_{K,it} + \eta_{it} \end{cases} \quad (27)$$

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<sup>28</sup> This relative price in real terms was built based on data from Penn World Table 8.0. We also considered the relative price of capital formation with substantially similar results.



We estimated the system applying the SUR method to the corresponding system of reduced-form equations:

$$\begin{cases} \log A_{it} = z_0 + z_1 \log p_{K,it} + z_2 \log h_{it} + \varepsilon_{it}' \\ \log k_{it} = m_0 + m_1 \log p_{K,it} + m_2 \log h_{it} + \eta_{it}' \end{cases} \quad (28)$$

$$z_1 = \frac{\gamma\omega}{1-\gamma\pi}, \quad m_1 = \frac{\omega}{1-\gamma\pi}, \quad z_2 = \frac{\gamma\mu}{1-\gamma\pi}, \quad m_2 = \frac{\mu}{1-\gamma\pi}$$

Note that the productivity elasticity parameter of interest,  $\gamma$ , is overidentified, and can be obtained from both the ratios between  $z_1$  and  $m_1$  and  $z_2$  and  $m_2$ . We estimate  $\gamma$  efficiently considering the minimum variance consistent linear combination of  $\gamma_1 = z_1/m_1$  and  $\gamma_2 = z_2/m_2$  for each region. Results from the panel estimations (Table 6) confirm that the effect of capital accumulation on productivity in LAC is low and lower than in less distorted economies, on the same order as under the neoclassical optimization assumption.

Using these estimates, it is possible to have a view on what could have happened if LAC had invested with the same productivity efficiency East Asia did during the last five decades. Panel a of Figure 17 shows that, in absolute terms, LAC's TFP could have been 37 percent higher in 2011 than it was in 1960 (instead of 11 percent lower) had the region accumulated capital in a better way. The region would have narrowed its productivity gap with the United States and, since LAC started with a much lower productivity gap with the United States, the region could have been able to surpass the productivity attainment of East Asia (panel b). Finally, given that our model accounted for the double causality in the relationship between capital accumulation and productivity, it is also possible to estimate the effect on the capital-labor ratios of a higher productivity elasticity in LAC (panel d). The observed data show that the relative capital-labor ratio remained virtually constant over the last five decades. Had LAC achieved higher productivity through investment, by 2011 it could have had a capital-labor ratio more than twice what it was in 1960.<sup>29</sup>

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<sup>29</sup> Notice that the estimated productivity efficiency gap between LAC and East Asia in this formulation (i.e. the difference between the estimated  $\gamma$ ) is higher than in the naïve and the neoclassical model. Under the assumptions of these models, LAC's counterfactual would be qualitatively similar but more modest.

## 6. Conclusions and Policy Implications

Low total factor productivity rather than a shortfall in available factors of production is the key to understanding Latin America's low income relative to developed economies. Insufficient productivity growth rather than subpar factor accumulation (including low education quality) explains its stagnation relative to other developing countries that are catching up.

The following stylized facts summarize the findings of our development accounting exercise:

1. *LAC's productivity is not catching up with the frontier, in contrast to East Asia.*
2. *LAC's productivity is about half its potential.*
3. *The income gap with the United States is increasingly due to the productivity gap.*

Higher productivity would entail not only a more efficient use of accumulated capital stocks, both physical and human, but also faster accumulation of these production factors in reaction to the increased returns prompted by the productivity boost. In a conservative estimation in which the stimulus to human capital accumulation is disregarded, closing the productivity gap with the frontier would close most of the income gap with Developed Countries (about two-thirds). Therefore, it is clear that the key to the economic development problem in the region is how to close the productivity gap.

The traditional impediments to investment due to market distortions such as high borrowing costs, high taxation or uncertain expropriation risks have declined and their removal would amount to a small income gain, circumscribed to a margin of just 5 percent. Similarly, advances in education and labor force participation have also narrowed the work force gaps and offer no silver bullet. Unless these conditions of factor accumulation have a substantial impact on productivity, by themselves they are bound to be of marginal importance in closing the income gap.

The main development policy challenge in the region involves diagnosing the causes of poor productivity and acting on its roots. The analysis shows that policies easing physical capital accumulation cannot be expected to be effective in improving productivity. While this may be an important consideration in more advanced or less distorted economies, the empirical analysis suggests that capital accumulation in Latin America has a low productivity-enhancing effect.

Low productivity is not the result of low physical investment and there is no evidence to suggest that investment promotion across the board would help to narrow the productivity gap. The aggregate productivity problem will require specific productivity policies of facilitating the reallocation of productive resources to higher productivity activities and productive development policies with an eye on the productivity gains that new investments may bring to the economy beyond those captured by private investors. Fortunately, while increasing the stock of accumulated factors requires costly investments, boosting productivity more directly may “simply” require willingness to reform policies and institutions.

## Statistical Appendix<sup>30</sup>

Gross output ( $Y$ ) is computed as PPP adjusted real GDP from the *Penn World Table* version 8.0 (PWT). In the latest release, two versions of GDP have been published. The first one is expenditure-based and coincides with the one in previous versions of the PWT. The second one 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 ( $emp$ ).<sup>31</sup> It is often argued that hours worked are 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 sum 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:

$$h = e^{\phi(S_H)}, \quad (\text{A.1})$$

where the function  $\phi(S)$  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  $\theta$  and  $\psi$  from the data in Psacharopoulos and Patrinos (2004) and using the corresponding average schooling years (population older than 15 years) in Barro and Lee (2013) database. The data in Barro-Lee extends to 2010.

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<sup>30</sup> A more detailed version of this Appendix can be found as a methodological document accompanying the database by Fernández-Arias (2014).

<sup>31</sup> Blyde and Fernández-Arias (2006) show that the used of employed labor instead of labor force to measure factor input makes little difference in LAC.

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

For the estimation of system (28) we used the relative price of capital which we built as the ratio between the real price of capital stock,  $pl\_k$ , and the real price of output-based GDP,  $pl\_gdp$  from PWT 8.0. We also considered the relative price of capital formation (based on  $pl\_i$ ) with essentially the same results.

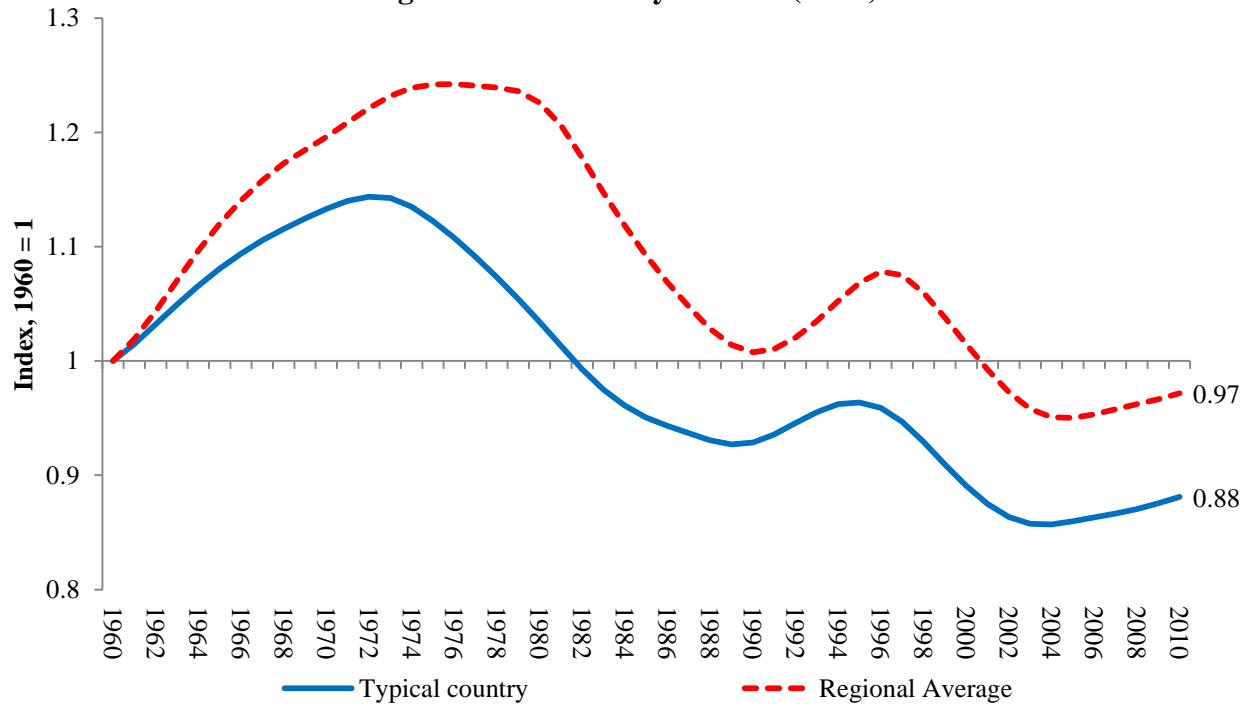
Finally, in order to obtain the structural series, we considered the logarithms of the series of output, physical capital, skill level and labor headcount ( $Y$ ,  $K$ ,  $h$  and  $L$ , respectively), filtered them with a Hodrick-Prescott filter with smoothing parameter  $\lambda=7$ , and then inverted the logarithmic transformation. Using these filtered series, we computed our measures of productivity. To avoid end-point problems in the filtering process we used WEO projections for 2012-2013. In order to obtain structural per capita measures, we also filtered the series of population.

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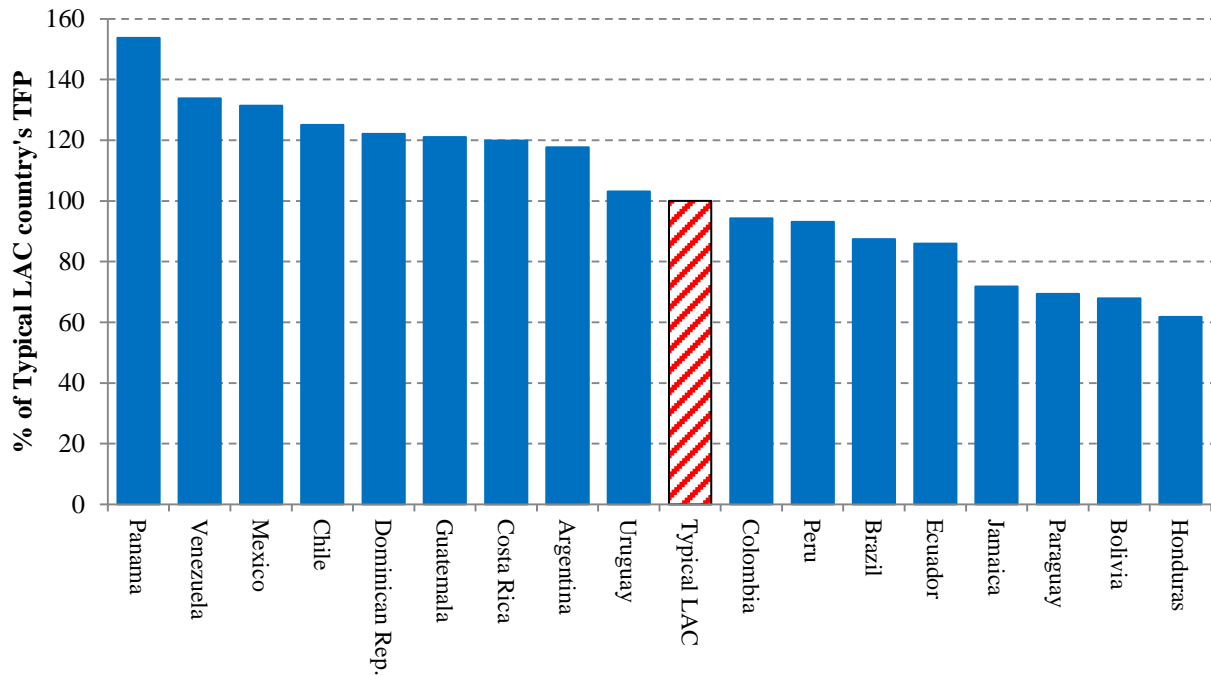
**Figure 1. Productivity Indexes (LAC)**



Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

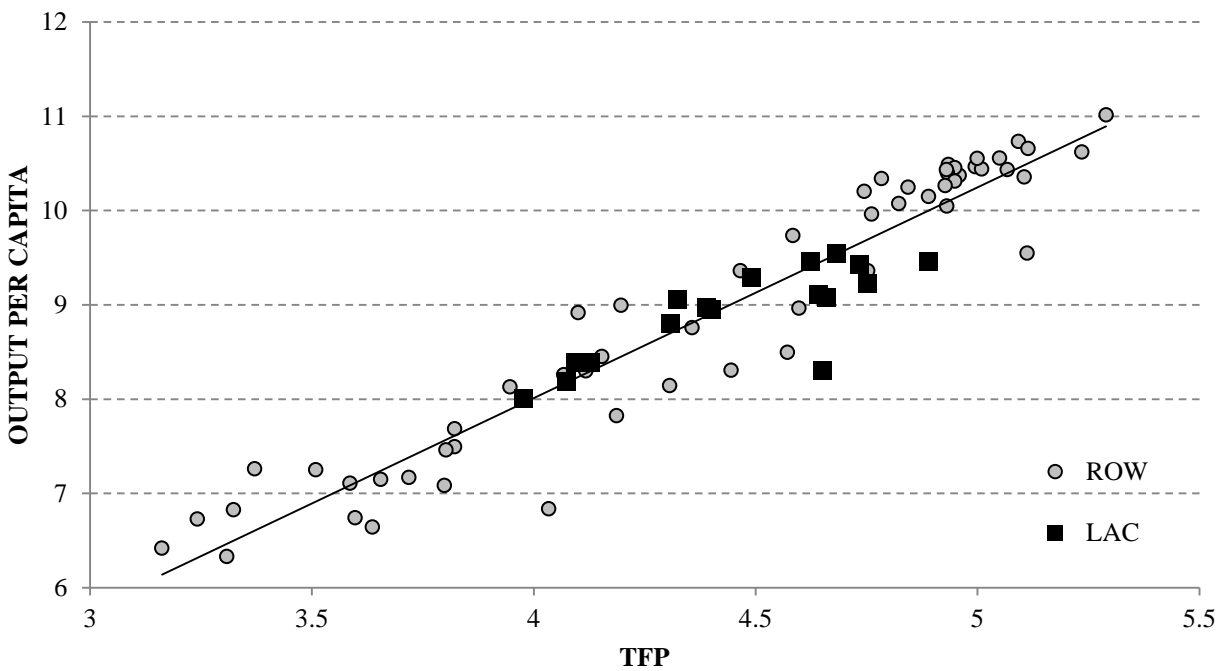


**Figure 2. Productivity Diversity within LAC, 2010**



Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

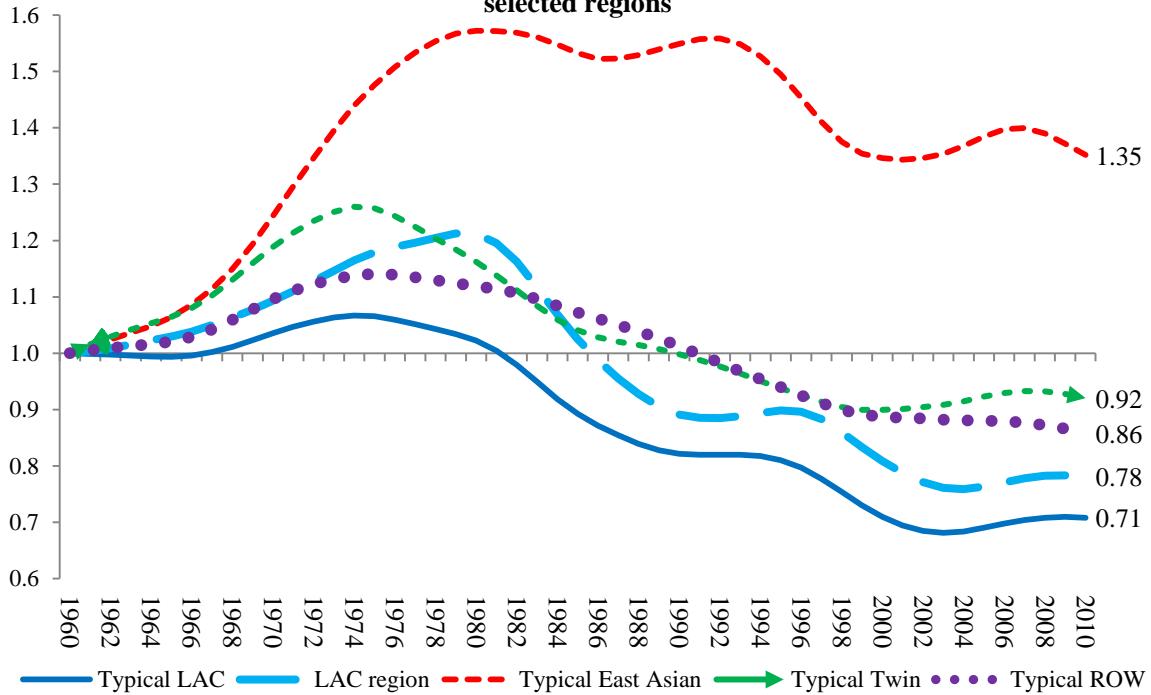
**Figure 3. Output Per Capita and Productivity across Countries (2010)**



Note: Income per capita and TFP measured in logarithmic scale.

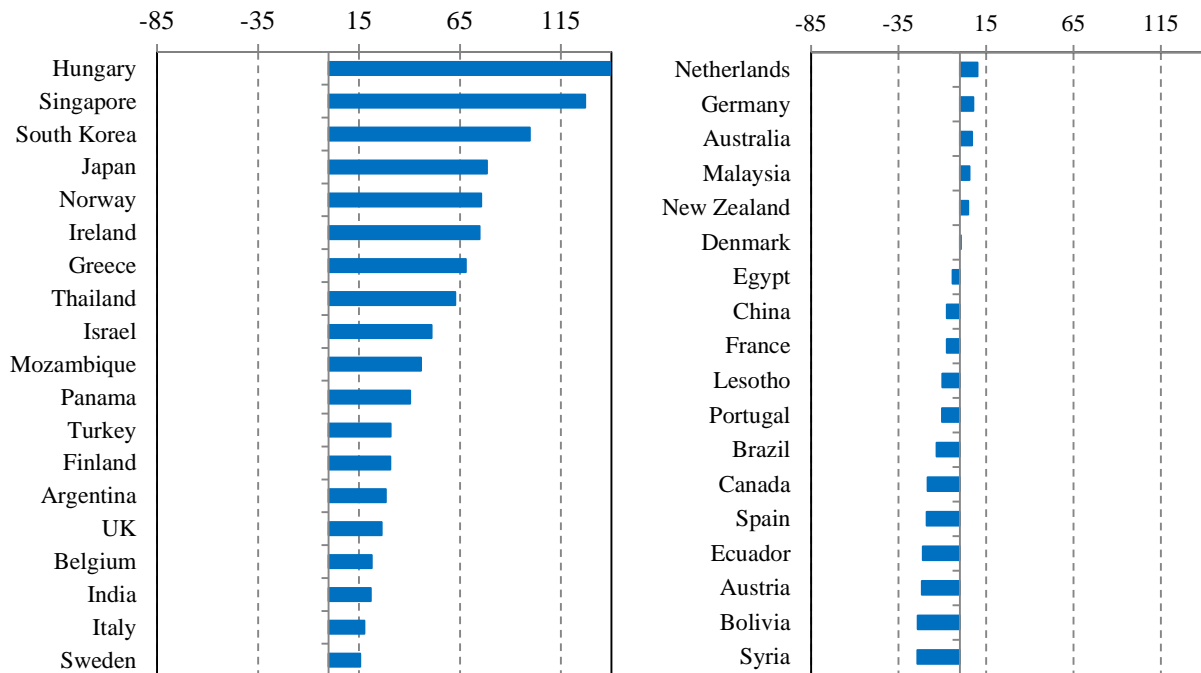
Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

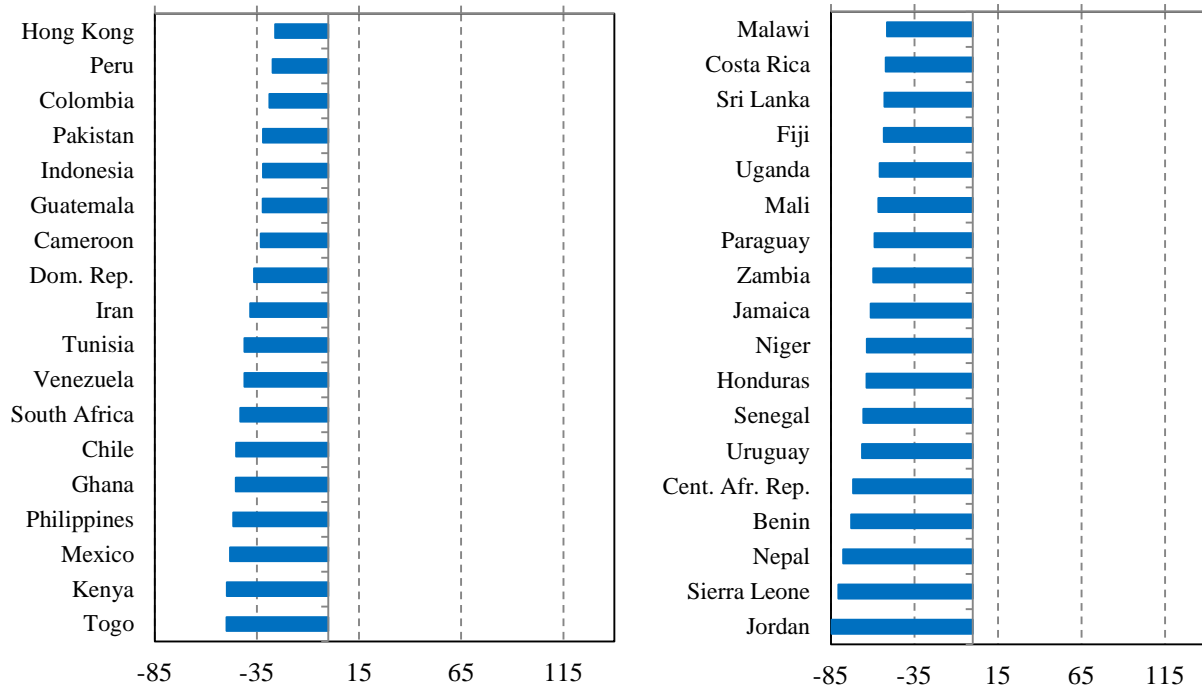
**Figure 4. Productivity Catch-up**  
 (Productivity Index relative to the United States, 1960=1) - Contrast with selected regions



Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

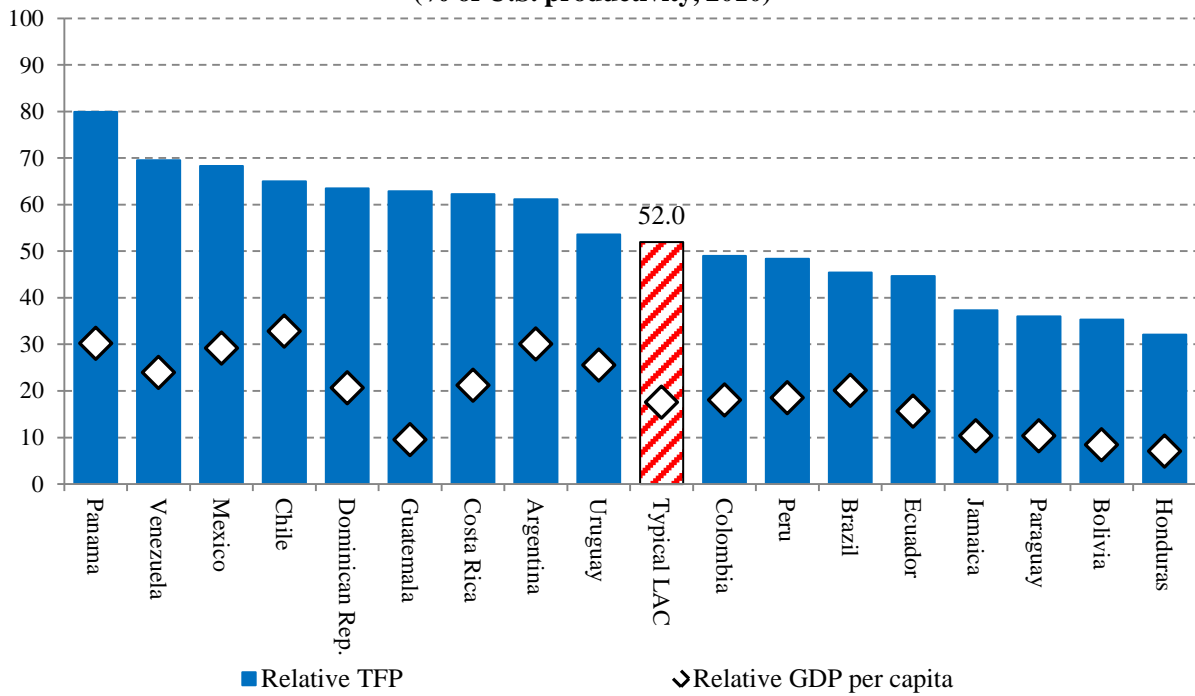
**Figure 5. TFP Cumulative Growth Relative to the United States 1960 - 2010 (%)**





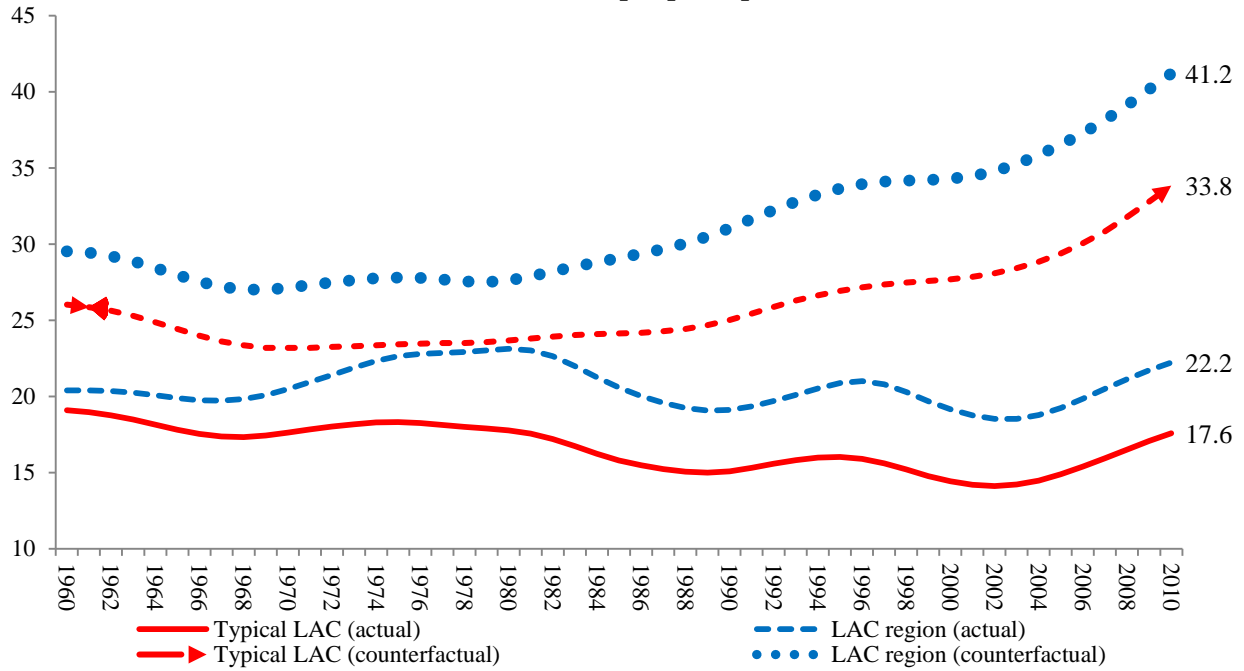
Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

**Figure 6. Relative Productivity in LAC Countries**  
(% of U.S. productivity, 2010)



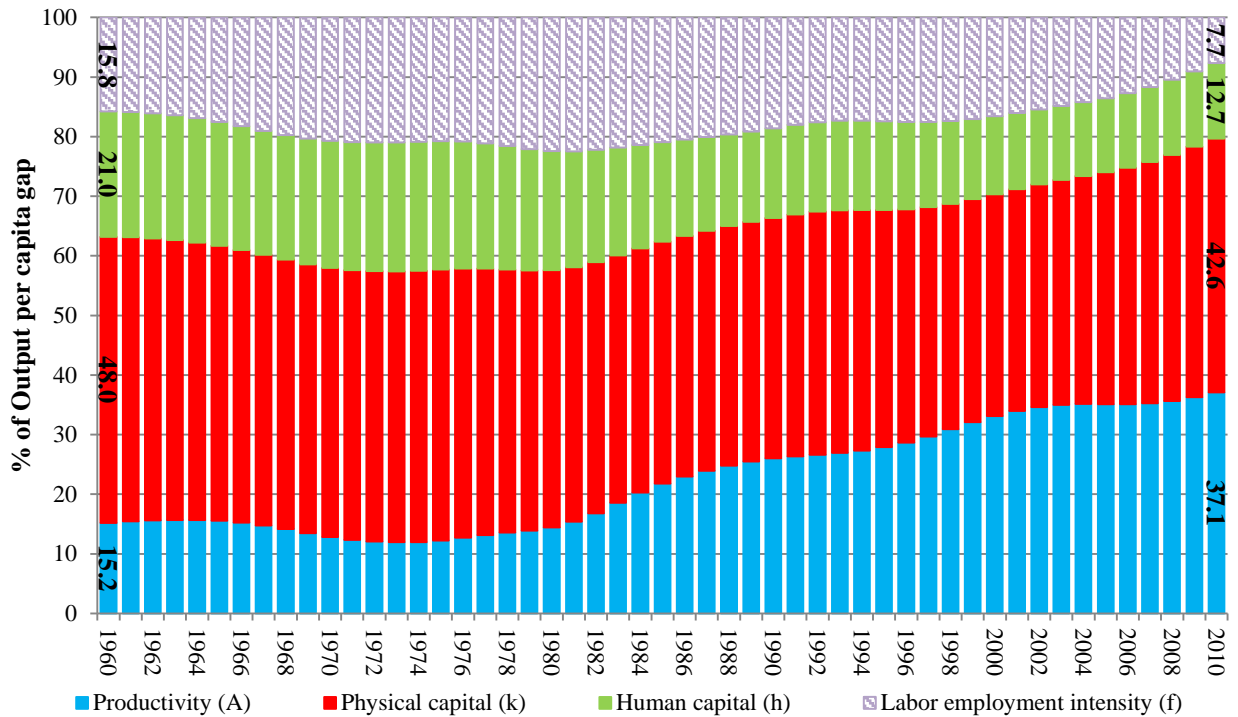
Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

**Figure 7. Direct Income Effect of Closing the Productivity Gap  
(% of U.S. output per capita)**



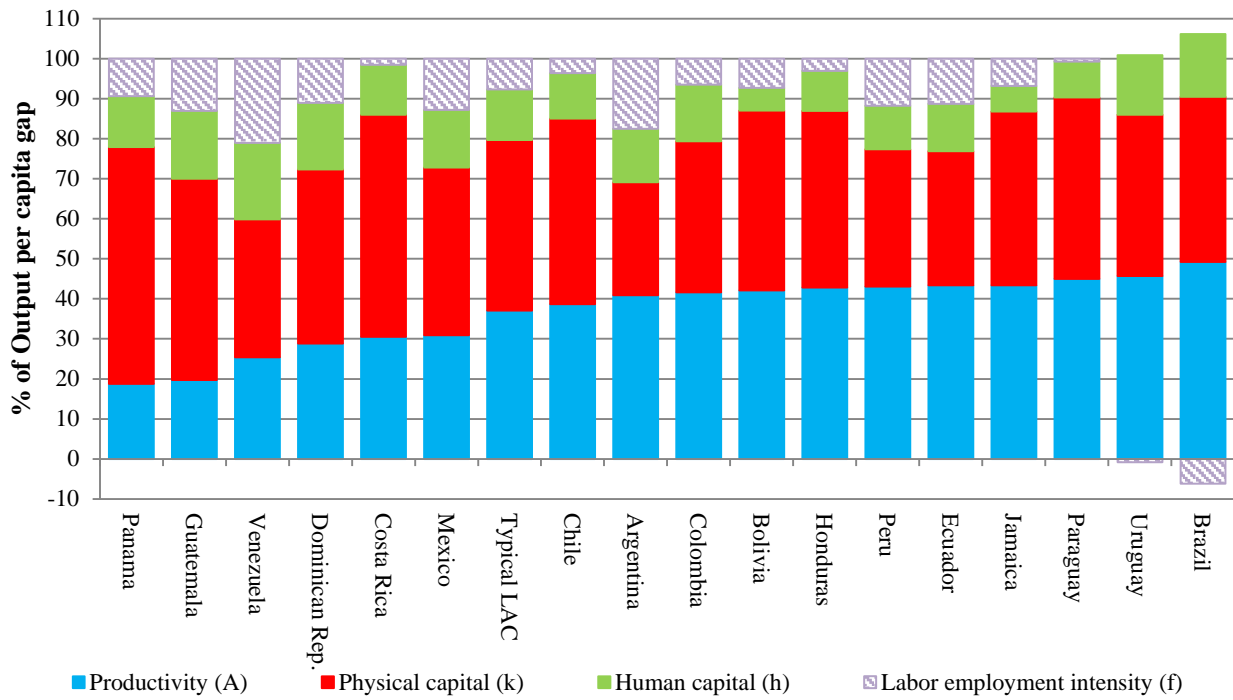
Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

**Figure 8. Contribution to Closing the Output Per Capita Gap  
(Typical LAC country versus United States)**



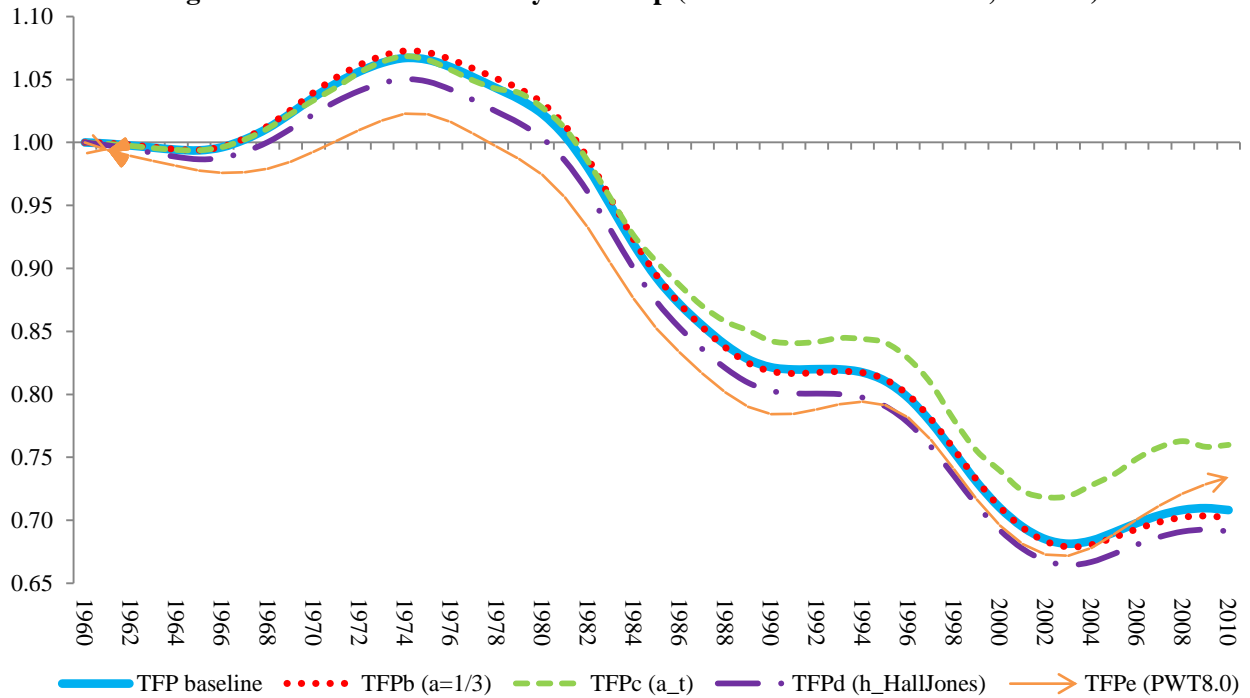
Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

**Figure 9. Contributions to Closing the Output Per Capita Gap versus U.S. in 2010**



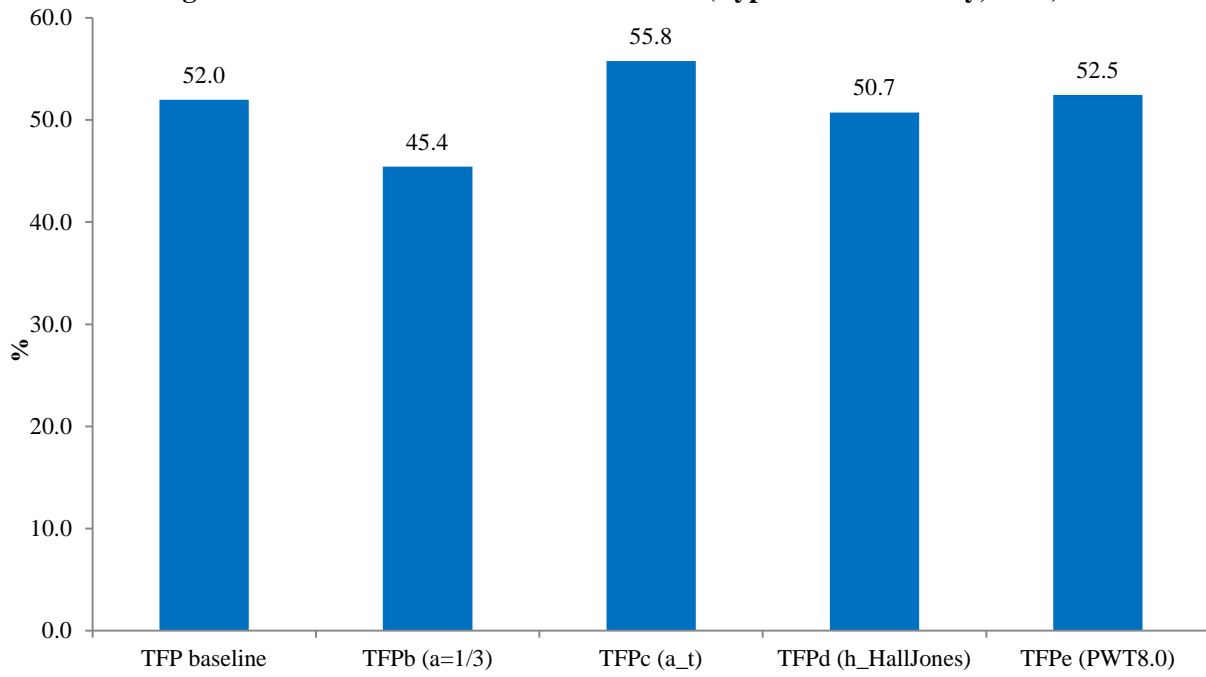
Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

**Figure 10. Lack of Productivity Catch-up (index relative to the U.S., 1960=1)**



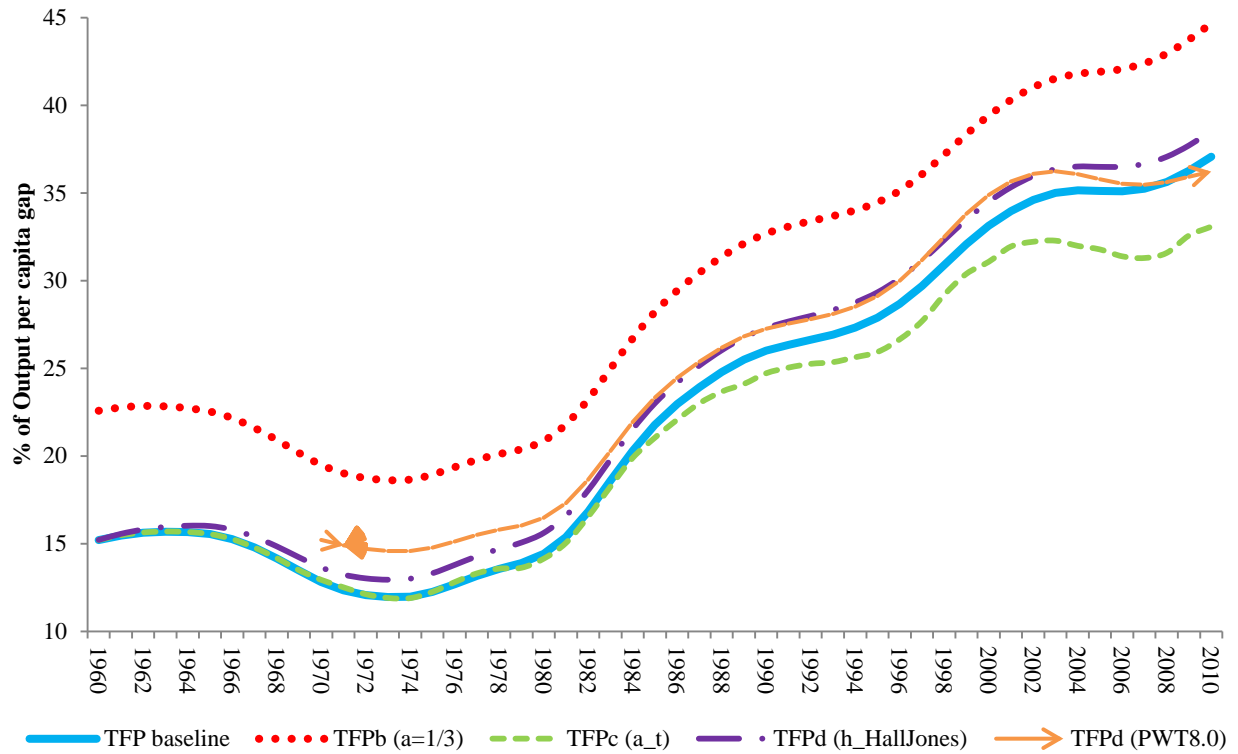
Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

**Figure 11. TFP Relative to the United States (Typical LAC country, 2010)**



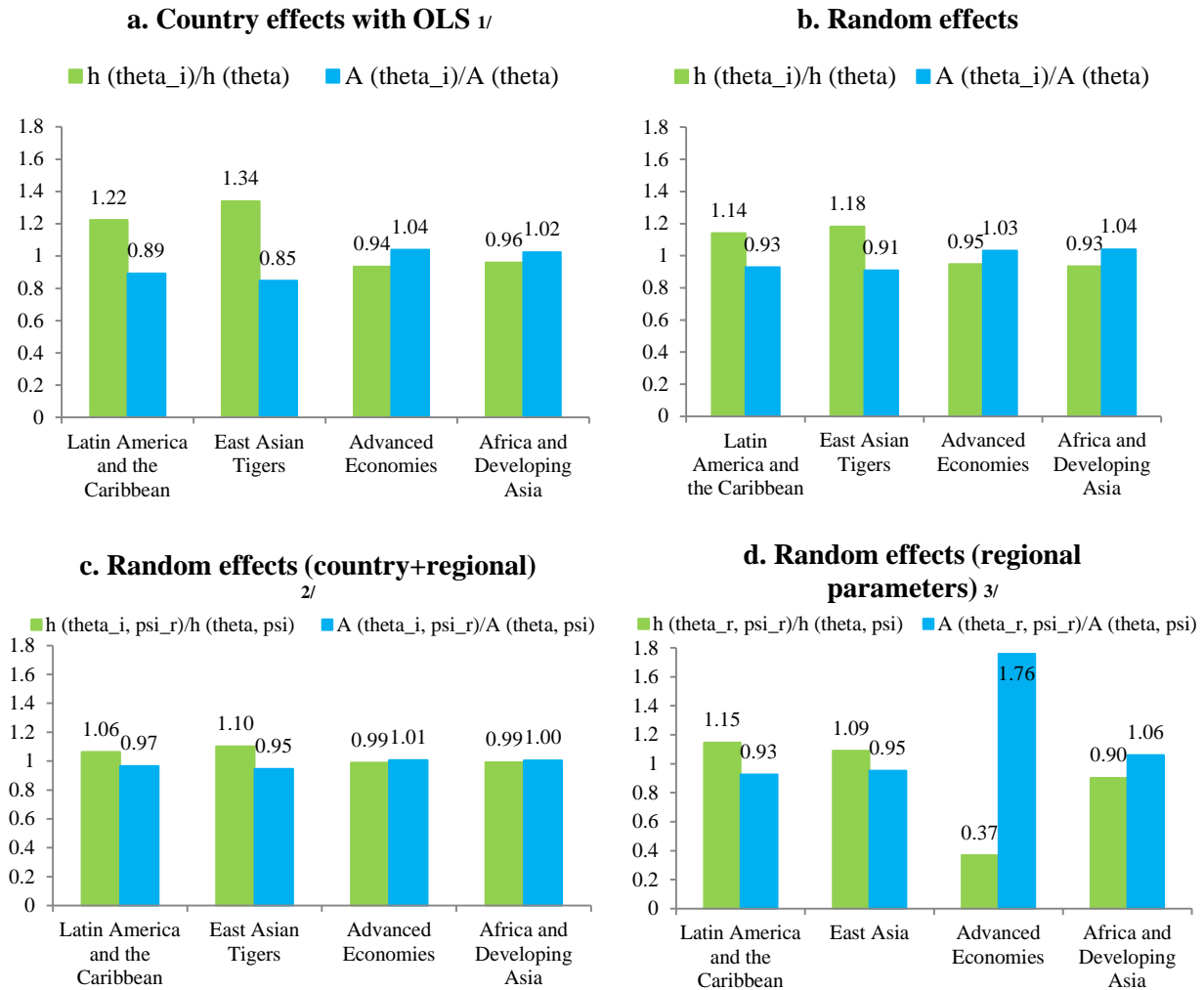
Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

**Figure 12. TFP Contribution to Closing the Output Per Capita Gap  
(Typical LAC country versus U.S.)**



Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

**Figure 13. Factors of Adjustment in Human Capital and TFP with Country-Specific Education Yields (2010)**



Source: Authors' calculations based on Fernández-Arias (2014) and Psacharopoulos and Patrinos (2004).

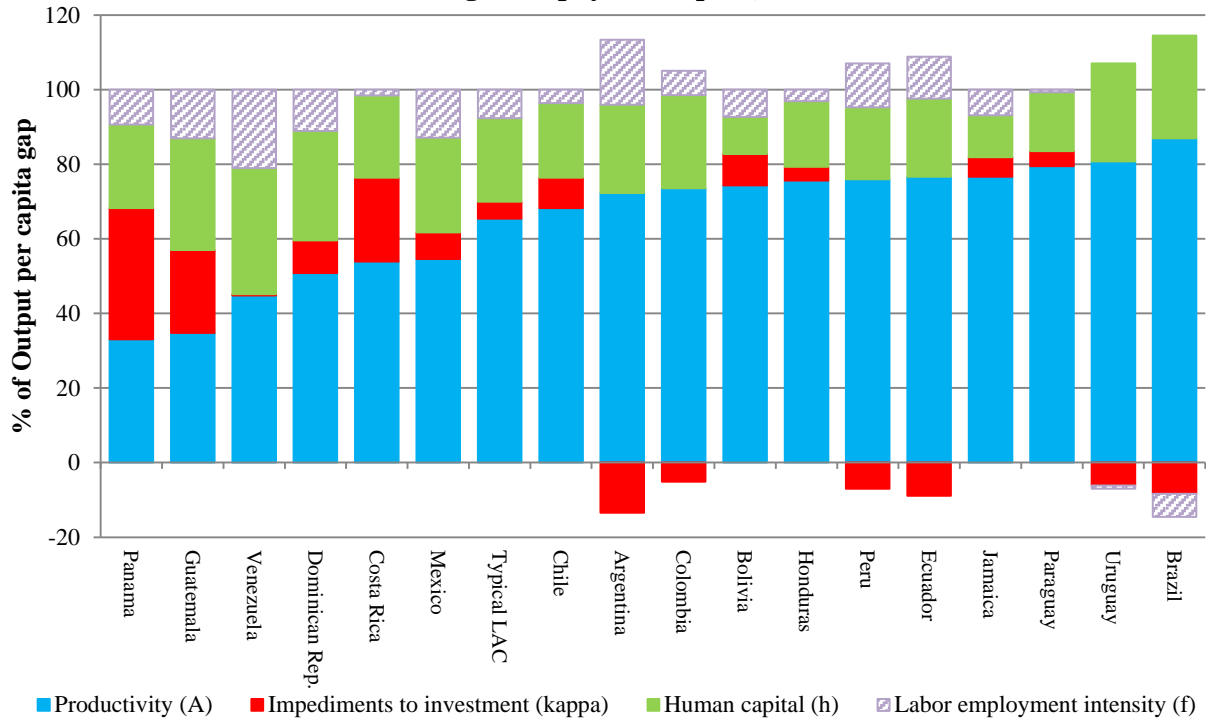
1/ For panels a) and b) we only apply country-specific intercepts ( $\theta$ ) to the mincerian returns. The slope ( $\psi$ ) is common to all countries in the sample.

2/ In the Mincerian return equation, the intercept is country-specific while the slope is region-specific.

3/ Both parameters in the Mincerian return are region-specific.

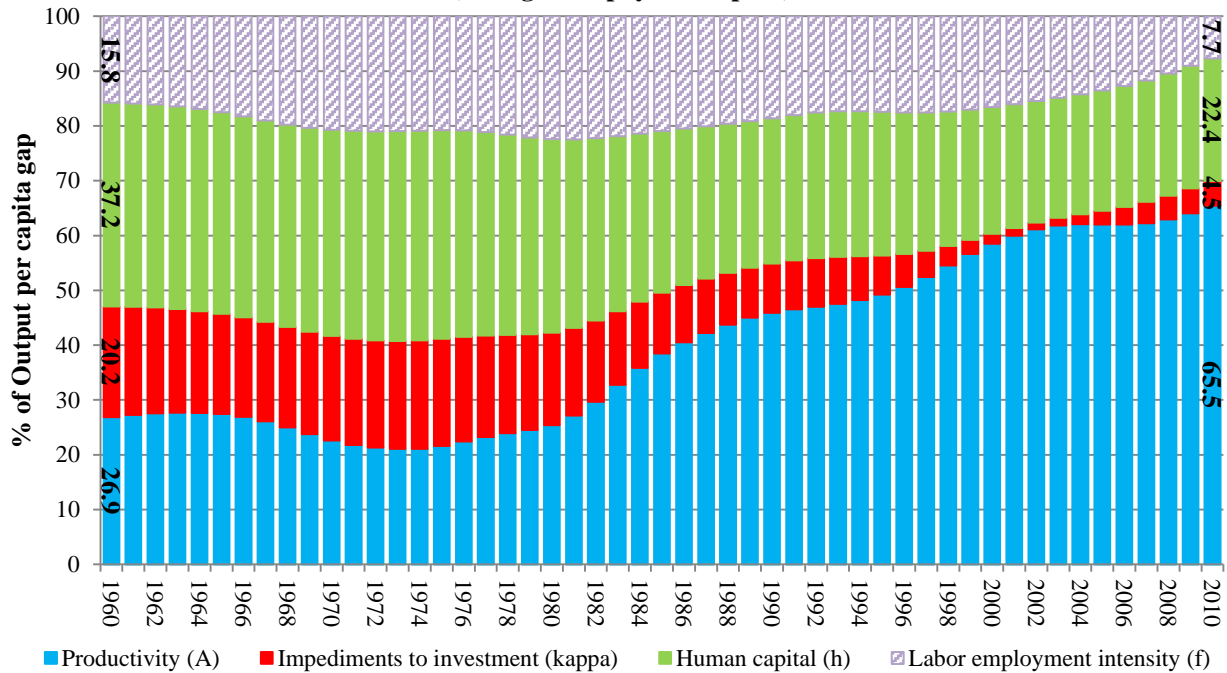


**Figure 14. Overall Contribution to Closing the output per capita gap vs. U.S.  
(Endogenous physical capital, 2010)**



Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

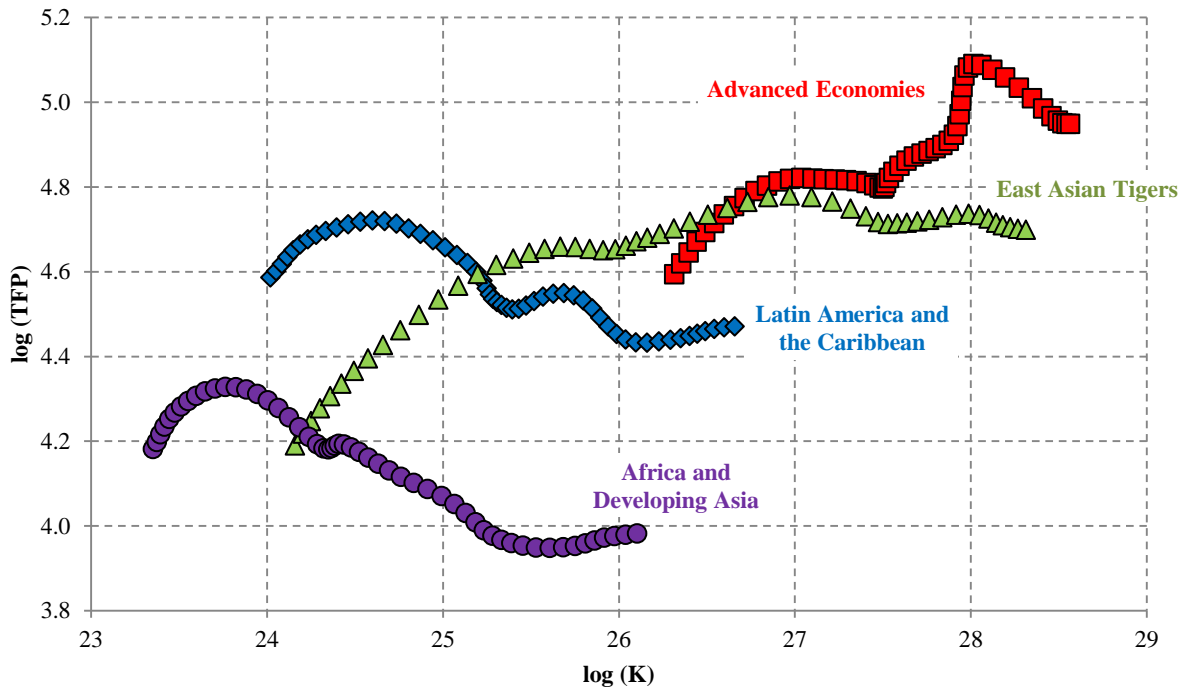
**Figure 15. Contributions to Output Per Capita Gap, LAC Typical Country vs. U.S.  
(Endogenous physical capital)**



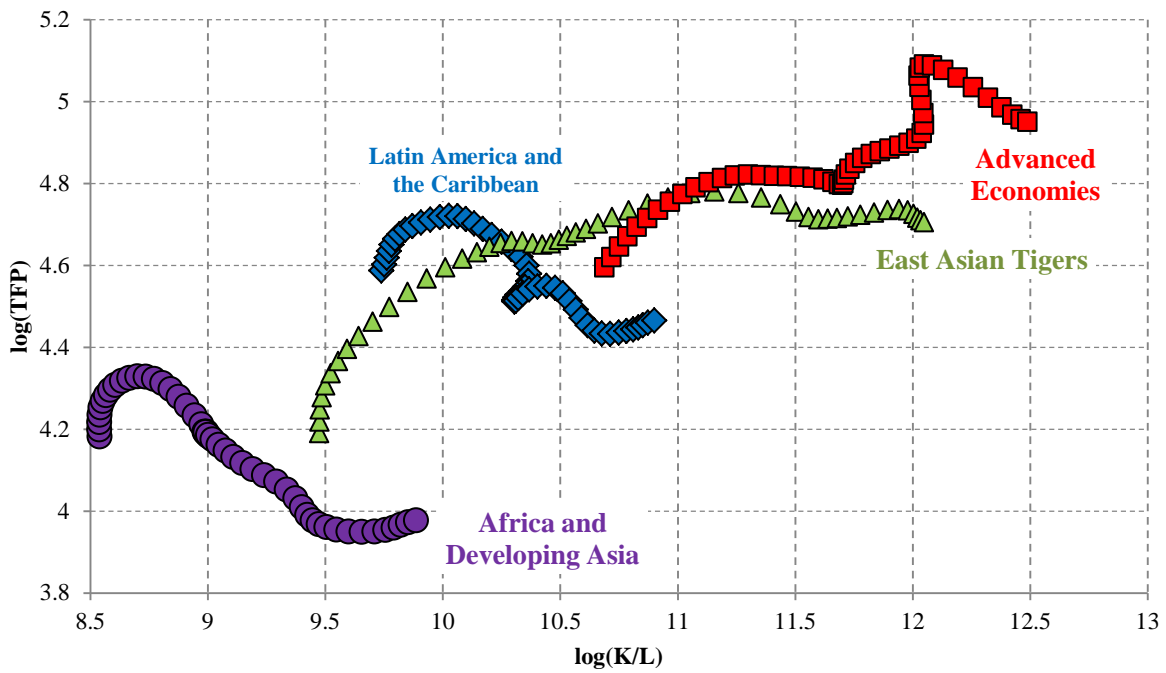
Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

**Figure 16. Total Factor Productivity and Capital Accumulation, 1960-2011**

**a. TFP vs. Capital Stock**

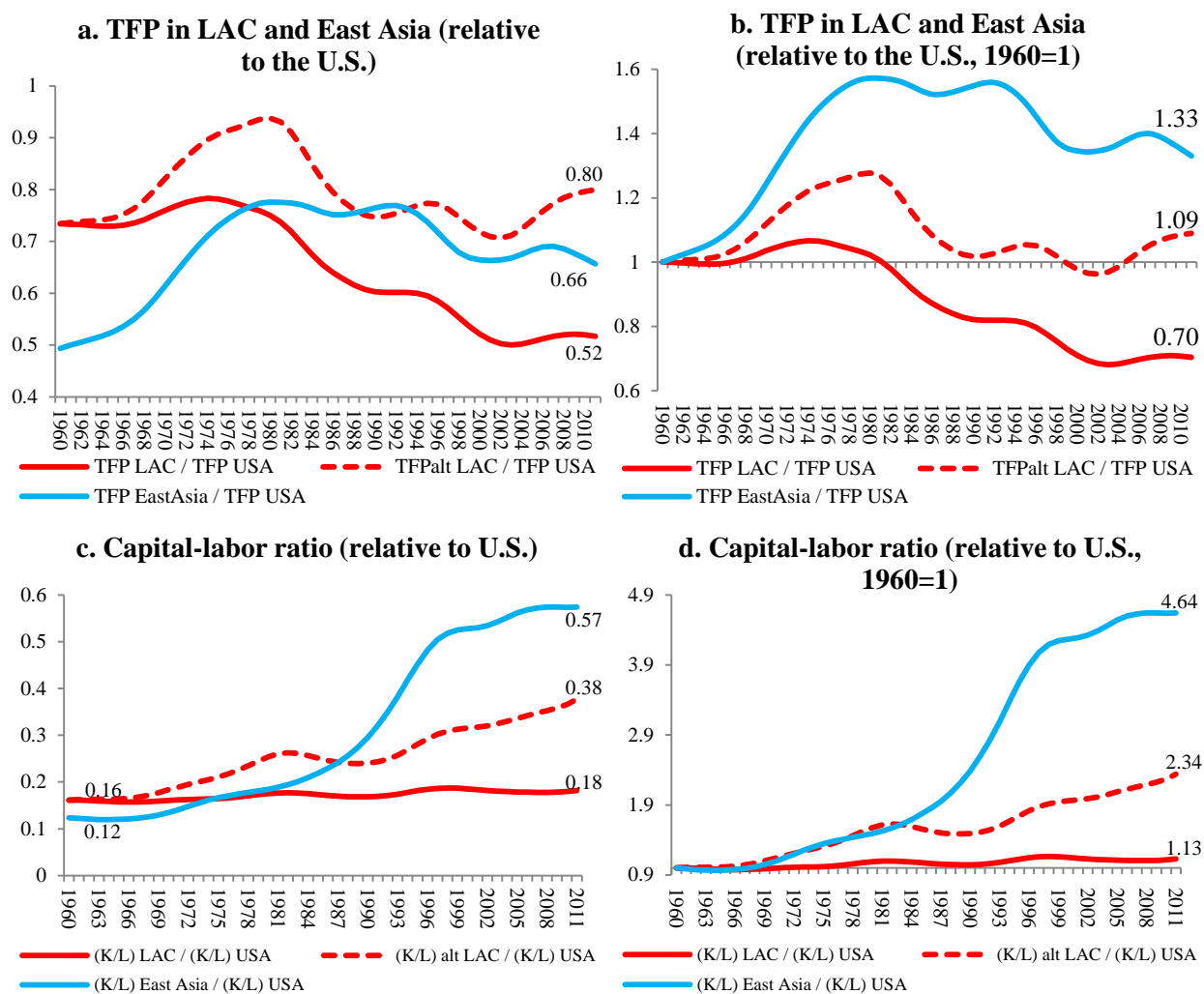


**b. TFP vs. Capital-Labor Ratios**



Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

**Figure 17. Counterfactual Evolution of Total Factor Productivity and Capital-Labor Ratios for Latin America and the Caribbean Using East Asian Efficiency of Capital Accumulation**



Source: Authors' calculations based on Feenstra, Inklaar and Timmer (2013) and Barro and Lee (2013).

**Table 1. Sample**

Argentina	Honduras	Pakistan
Australia	Hong Kong	Panama
Austria	Hungary	Paraguay
Belgium	India	Peru
Benin	Indonesia	Philippines
Bolivia	Iran	Portugal
Brazil	Ireland	Senegal
Cameroon	Israel	Sierra Leone
Canada	Italy	Singapore
Central African Republic	Jamaica	Spain
Chile	Japan	South Africa
China	Jordan	Sri Lanka
Colombia	Kenya	Sweden
Costa Rica	Korea, Republic of	Syria
Denmark	Lesotho	Thailand
Dominican Republic	Malawi	Togo
Ecuador	Malaysia	Tunisia
Egypt	Mali	Turkey
Fiji	Mexico	Uganda
Finland	Mozambique	United Kingdom
France	Nepal	United States
Germany	Netherlands	Uruguay
Ghana	New Zealand	Venezuela, RB
Greece	Niger	Zambia
Guatemala	Norway	

**Table 2. Different Methods of Estimating Parameters  
Involved in Human Capital Measurement**

Specification	$\psi$	$\theta$	R-sq	Observations	Countries
a. Hall-Jones (H-J)	0.00	0.134 if $S \leq 4$ 0.101 if $4 < S \leq 8$ 0.068 if $S > 8$	n.a.	n.a.	n.a.
b. OLS: Bils-Klenow (B-K) using original sample	0.58 [0.168]***	0.32 calculated from $\psi$	0.2076	56	56
c. OLS: B-K updated using sample schooling years	0.45 [0.115]***	0.25 calculated from $\psi$ as in B-K	0.1781	56	56
d. OLS: B-K updated using Barro-Lee schooling years - whole sample	0.37 [0.101]***	0.17 [0.034]***	0.1754	67	67
d. OLS: B-K updated using Barro-Lee schooling years - selected sample	0.35 [0.111]***	0.17 [0.035]***	0.1358	54	54
e. Panel RE: B-K updated using Barro-Lee schooling years - whole sample	0.50 [0.085]***	0.21 [0.035]***	0.2116	185	67
e. Panel RE: B-K updated using Barro-Lee schooling years - selected sample	0.47 [0.097]***	0.21 [0.038]***	0.2013	161	54
e. Panel RE: B-K updated using Barro-Lee schooling years - selected sample - regional $\psi$	0.40 [0.088]***	0.18 [0.029]***	0.2992	161	54
e. Panel FE: B-K updated using Barro-Lee schooling years	0.38 [0.219]*	0.17 [0.073]**	0.2116	185	67

**Table 3. Estimations of  $\psi$  and  $\theta$ : Robustness Analysis**

Specification	$\psi$	$\theta$	$\beta \{t, k, y\}$	R-sq	Observations	Countries
Panel RE + GDP per capita	0.47 [0.121]***	0.22 [0.076]***	-0.01 [0.051]	0.2119	179	65
Panel RE + K/L	0.48 [0.123]***	0.19 [0.066]***	0.01 [0.043]	0.1966	178	64
Panel RE + time trend	0.46 [0.092]***	0.22 [0.036]***	0.00 [0.003]	0.2177	185	67
Panel FE + GDP per capita	0.27 [0.295]	0.22 [0.260]	-0.05 [0.169]	0.2065	179	65
Panel FE + K/L	0.26 [0.270]	0.25 [0.308]	-0.06 [0.679]	0.1837	178	64
Panel FE + time trend	-0.25 [0.421]	0.07 [0.047]	-0.01 [0.007]*	0.0523	185	67

**Table 4. Estimation Results from the Naïve Model**

Regions	Parameters	Dependent Variable: $\log\_A$				
		(1)	(2)	(3)	(4)	
Latin America and the Caribbean (17)	$\gamma (\log\_k)$			-0.09 [0.075]	0.09 [0.074]	
East Asian Tigers (5)				0.16 [0.040]***	0.27 [0.044]***	
Advanced Economies (21)				0.19 [0.037]***	0.35 [0.057]***	
Africa and Developing Asia (31)				-0.11 [0.062]*	0.00 [0.068]	
Average (74)			0.01 [0.038]	0.12 [0.056]**	0.00 [0.033]	0.14 [0.049]***
		<i>Constant</i>	4.36 [0.389]***	3.28 [0.539]***	4.38 [0.319]***	2.98 [0.459]***
	Country Fixed Effects - Intercept	Yes	Yes	Yes	Yes	
	Regional interaction dummies	No	No	Yes	Yes	
	Year dummies	No	Yes	No	Yes	
	Observations	3848	3848	3848	3848	
	R-squared	0.4699	0.5397	0.2713	0.3579	

*Note:* Fixed Effects (within) estimators with clustered robust standard errors. Both  $A$  and  $k$  are filtered series using the Hodrick-Prescott technique. (\*), (\*\*), (\*\*\*) indicate statistical significance at the 10%, 5% and 1% levels, respectively.

**Table 5. Estimation Results: Allowing for Endogeneity in the Capital Accumulation (Neoclassical assumptions)**

Regions	Parameters	Dependent Variable: $\log_A$	
		(1)	(2)
Latin America and the Caribbean	$\gamma$	-0.27 [0.084]***	-0.69 [0.254]***
East Asian Tigers		0.09 [0.035]***	0.00 [0.053]
Advanced Economies		0.05 [0.029]	-0.11 [0.067]*
Africa and Developing Asia		-0.33 [0.076]***	-0.58 [0.143]***
Average		-0.13 [0.028]***	-0.35 [0.088]***
		<i>Constant</i>	4.67 [0.043]***
	Country Fixed Effects - Intercept	Yes	Yes
	Regional interaction dummies	Yes	Yes
	Year dummies	No	Yes
	Observations	3848	3848
	R-squared	0.2886	0.1414

*Note:* Fixed Effects (within) estimators with clustered robust standard errors. All series are filtered using the Hodrick-Prescott technique. Standard errors for non-linear combinations of parameters are obtained using the delta method described in Oehlert (1992). (\*), (\*\*), (\*\*\*) indicate statistical significance at the 10%, 5% and 1% levels, respectively.

**Table 6. SUR Estimations: Endogeneity of Capital Accumulation  
with More Flexible Assumptions**

Regions	Parameters	Dependent Variables: $\log_A$ , $\log_k$		Dependent Variables: $\log_A$ , $\log_k$	
		(1)		(2)	
Latin America and the Caribbean	$\gamma$	-0.23		-0.24	
		[0.019]***		[0.041]***	
East Asian Tigers		0.21		0.14	
		[0.013]***		[0.024]***	
Advanced Economies		0.19		-0.01	
		[0.009]***		[0.034]	
Africa and Developing Asia		-0.30		-0.30	
		[0.011]***		[0.018]***	
Average		-0.17		-0.40	
		[0.011]***		[0.031]***	
	Country Fixed Effects - Intercept	Yes		Yes	
	Regional interaction dummies	Yes		Yes	
	Year dummies	No		Yes	
	Observations	3837	3837	3837	3837
	R-squared	0.8995	0.9588	0.9091	0.9639

*Note:* SUR estimators with country fixed effects. All series involved are filtered using the Hodrick-Prescott technique. Standard errors for non-linear combinations of estimated parameters are obtained through the delta method. (\*), (\*\*), (\*\*\*) indicate statistical significance at the 10%, 5% and 1% levels, respectively.