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PHASES OF CONVERGENCE IN LATIN AMERICA: THE TECHNOLOGICAL DRIVERS

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Abstract: The paper analyses the convergence hypothesis in Latin America during 1960–2005. The evidence is not favourable to clear convergence or divergence trends and suggests the existence of transitory clubs of convergence. After 1990–1994, the lower income economies showed convergence to the richer countries but in a context of increasing dispersion of the per capita income. The development accounting and the decomposition of the total factor productivity indicate that those results are mainly explained by relative differences in technological capabilities. These are determined by structural and political factors. The efforts to integrate the economies were not enough to reduce the gap. Copyright © 2011 John Wiley & Sons, Ltd.

Keywords: convergence; aggregate productivity; technological capabilities; Latin America; development accounting; social infrastructure

1 INTRODUCTION

The long-run performance of the Latin American and the Caribbean countries, as well as their relative lags in comparison with the most advanced economies, is significant to evaluate the state of regional development. Nonetheless, in a context of increasing integration, the reduction in asymmetries—particularly in income—between those economies must be a critical focus of attention. Often, the smaller countries or less developed are not able enough to appropriate immediately the benefits of an integration process. Terra (2008) argued that this is a major problem because if the partners hope that integration does not contribute, or become an obstacle to their growth, the process loses the political support needed to consolidate it.

There is vast literature on economic convergence for a wide sample of countries, beginning with Baumol´s (1986) seminal paper and, after that, with the works of Barro

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and Sala-i-Martin (1992), Quah (1996a), Lee *et al*. (1997), De Long (1998) and Quah (1996b, 1997). On the other hand, there is a line of work that investigates the convergence within a region or into states of a country (Anríquez and Fuentes, 2001; Díaz and Meller, 2004) and Duncan and Fuentes (2006) for the Chilean regions, Cárdenas and Pontón (1995) for Colombian departments, Utrera and Koroch (1998) and Marina (1999) for Argentina, and Azzoni (1996) for Brazilian states. The evidence differs among countries. The studies show divergence for Brazil and convergence for Chile, whereas the evidence for Argentina is ambiguous. In the branch of research on convergence for countries that integrate an economic region, the evidence is heterogeneous. Cuaresma *et al*. (2008) found strong convergence for 15 countries of the European Union, whereas Madariaga *et al*. (2003) show convergence for the North American Free Trade Agreement (NAFTA) countries but not for the Mercado Común del Sur (MERCOSUR). Similarly, the results of Dobson and Ramlogan (2002) and Dabús and Zinni (2005) suggest that there is no convergence in Latin America. In short, there is no evidence of convergence in this region, but there are indications of divergence. This suggests as more plausible the convergence in blocks of developed economies so that the issue itself merits a deeper study.

Another collection of papers used the developing accounting methodology to show and explain an increasing gap between the Latin American countries and the most developed countries (Hopenhayn and Neumeyer, 2004; Fernández-Arias *et al*., 2005; González and Viego, 2010). This methodology 'uses cross-country data on output and inputs, at one point in time, to assess the relative contribution of differences in factor quantities, and differences in the efficiency with which those factors are used, to these vast differences in per-worker incomes' (Caselli, 2005, p. 681). In general, the decomposition of the relative per capita income and labour productivity shows the relevance of the technology gap to explain the delay in Latin America. However, the literature did not use this methodology to explain the delay of each economy compared with the others in the region. Latin America and the Caribbean are frequently considered as a block of countries with similar characteristics.

Hence, the goal of this paper is to analyse if, under the application of various methodologies, the hypothesis of non-convergence between the countries of the region is kept. Second, we investigate the explanatory factors of such dynamics by means of the development accounting methodology. This allows us to discern between possible channels through which the economies diverge or converge. Two methodological innovations are introduced here: first, we decompose the technological component of per capita gross domestic product (GDP), and second, we take the countries of the sample pair-wise in spite of taking a developed country as benchmark. In particular, our search focuses on the technological progress as the main factor to explain the per capita GDP dynamics in the region since the middle of the past century. Besides, we decompose the Solow´s residual to approximate the contribution of underlying sources to the multifactor productivity (technological capabilities, as well as technological and structural changes).

The results do not indicate a sustained long-run trend to convergence or divergence but transitory convergence clubs. The dynamics of the per capita relative income is explained by the relative behaviour of the total factor productivity (TFP) and, particularly, by the differences in technological capabilities. To shed light on what explains asymmetries in technological capabilities, following Hall and Jones (1999a, 1999b), we related them to some aspects of social infrastructure.

Our study is devoted to a set of similar emerging economies but with differences in per capita income levels and growth performance. Some of them have reached a relatively high

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income level, based mainly on their endowment of natural resources, whereas others have been in long-run stagnation. In turn, the evidence shows that they keep differences in their development level in time, which constitutes a key factor to explain differences in technological capabilities. In this sense, the institutional efforts of economic integration were not enough to reduce the gap. In fact, our evidence shows that neither foreign trade policies nor those measures devoted to improving institutional quality are significant to explain the dynamics of the economies in the region.

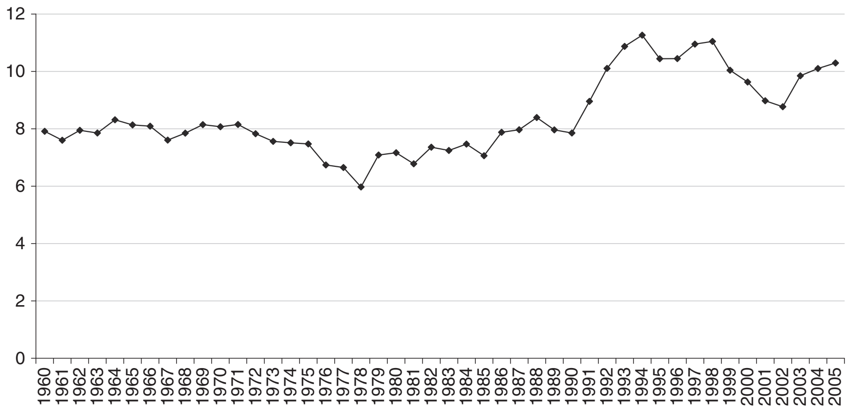
In the next section, we present empirical evidence. Section 3 introduces the baseline model of the development accounting methodology. The results obtained by applying this methodology are shown in section 4. In section 5, we analyse the explanatory factors of technological capabilities. Finally, the conclusions are presented in section 6.

2 REGIONAL CONVERGENCE OR DIVERGENCE PATH?

In this section, we analyse the hypothesis of regional convergence by applying common statistical tools: the evolution of the maximum gap among the countries, the relationship between the initial and the final per capita GDP for each country (see source in Appendix), the relationship between initial income and growth rate for the period and the evolution of the dispersion of per capita income into the sample. Finally, we try to determine the existence of convergence clubs by means of the kernel density graphs.

At a first glance, we define a relative variable as the difference between the natural logarithm of per capita GDP of the countries with the maximum and minimum values for each year. This gap in per capita income increased from 7.9 to 10.6 times during the period 1960–2005 (see Figure 1). As a matter of fact, the evolution of this gap suggests a transitory catching-up at the end of 1970s, followed by a divergence path at the end of the period.

Figure 2 shows a positive relation between initial and final per capita values, which indicates that the 1960 GDP is a good predictor of 2005 GDP and an additional evidence against the hypothesis of convergence.



Source: Our own elaboration based on World Bank data.

Figure 1. Relative per capita GDP (natural logarithm of per capita GDP, US$ constant 2000).

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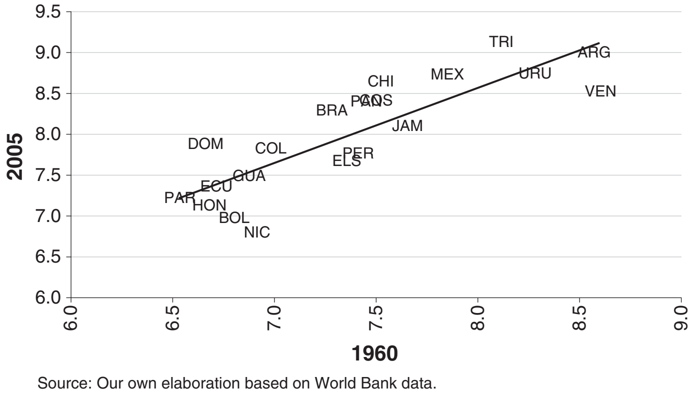

Figure 2. Per capita GDP: 1960 versus 2005 (natural logarithm of per capita GDP, US$ constant 2000).

On the other hand, Figure 3 shows the relation between the per capita income and the growth rate for the total period. The evidence is mixed. There are cases of high (low) initial levels with low (high) growth rates, whereas some countries present both low initial levels and growth rate, such as Bolivia, Nicaragua, Honduras and Paraguay, and others show high values in both cases, such as Chile, Mexico and Trinidad and Tobago. Thus, although this relation is not clear, again, there is no evidence of β-convergence.[1]

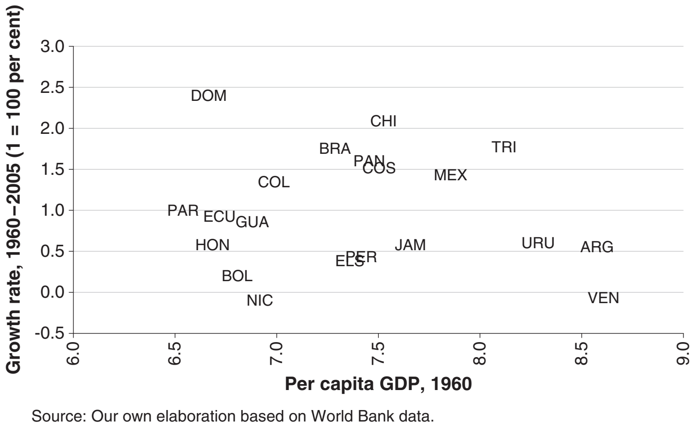

Figure 3. Growth rate versus initial per capita GDP (natural logarithm of per capita GDP, US$ constant 2000).

[1]Two main concepts of convergence appear in the classical literature. Following Barro and Sala-i-Martin (1995, pp. 382–387): Convergence applies if a poor economy tends to grow faster than rich ones so that the poor country tends to catch up with the rich one in terms of the level of per capita product. This property corresponds to our concept of β-convergence. The second concept concerns cross-sectional dispersion: '[A] group of economies are converging in the sense of σ if the dispersion of their real per capita GDP levels tends to decrease over time' (1020).

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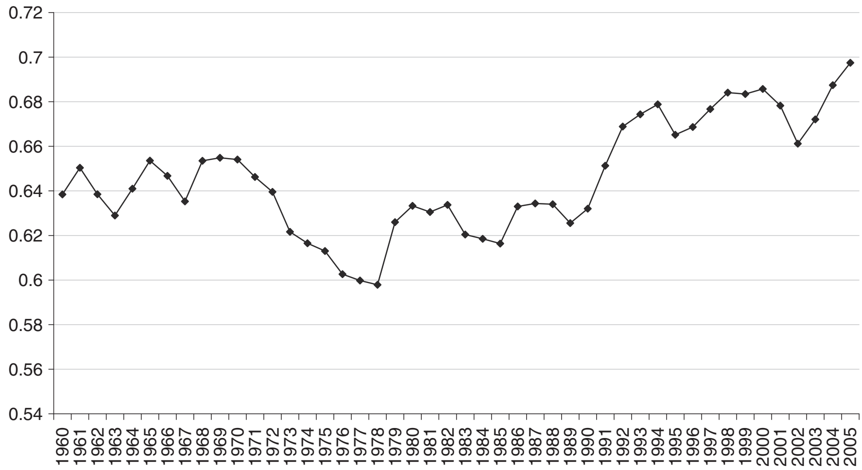

Source: Our own elaboration based on World Bank data.

Figure 4. Evolution of the dispersion of the per capita GDP (cross-section standard deviation of natural logarithm of per capita GDP, US$ constant 2000).

Figure 4 shows the evolution over time of the standard deviation of per capita GDPs. This measurement is a proxy of σ-convergence and indicates a decreasing divergence during the 1970s but a clear reversion and then higher divergence thereafter.

In short, a first empirical approach is favourable neither to convergence nor to a sustained trend of divergence in Latin America but a transitory process of convergence followed by global divergence from the end of the 1970s. In turn, the kernel density graph results, presented in Figures 5(a), 5(b) and 5(c), suggest evidence of clubs of convergence. As histograms, this is a non-parametric estimation of the random variable probabilistic function but, in this application, assumed a Gaussian kernel function for smoothing the sample.

The figures show the formation of a transitory club during the 1960–1974 period, which is reverted towards the end of the 1970s. The reversion can be explained by the Oil Crisis and the subsequent Debt Crisis, which pushed the region into a convergence process towards lower income equilibrium. However, the recovery was associated to a new club formation process, mainly during the beginning of the 1990s. Hence, some of the lower income economies were converging to the higher income equilibrium but into an environment of increasing dispersion of per capita income into the whole sample.

These results are compatible with the evidence presented previously. In fact, Figures 5 (b) and 5(c) indicate an increasing gap of the relative income between poorer and richer countries. The differences among economies observed in the growth versus initial per capita product can be associated with the oscillating behaviour shown in Figure 5, whereas the fact that the clubs are not consolidated would indicate that such oscillations can be explained by shocks that became widespread in the region.

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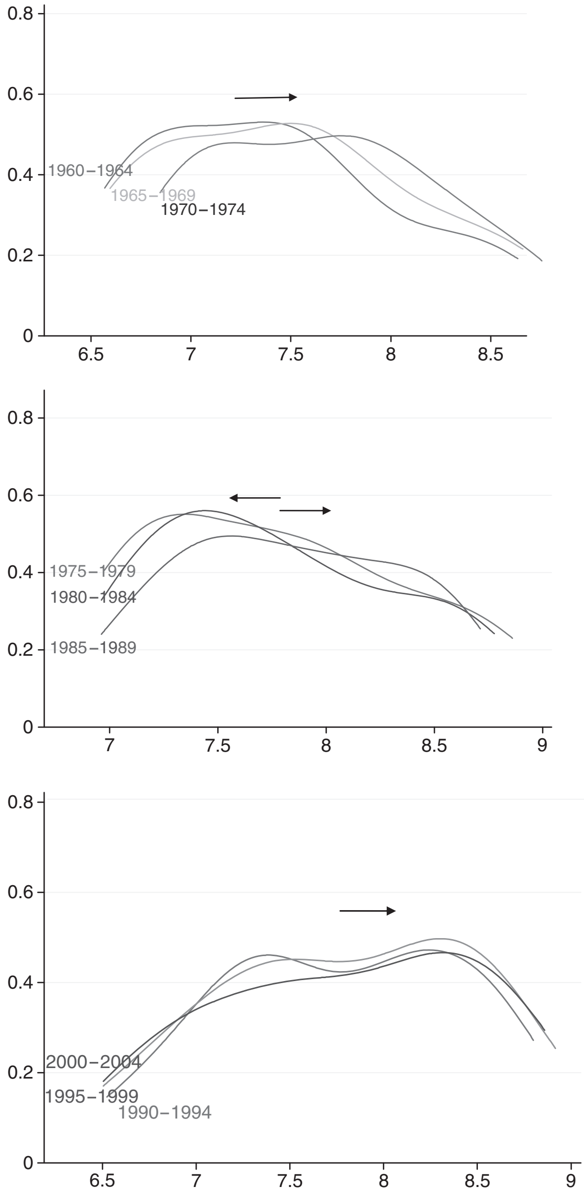

Figure 5. Kernel density graphs of per capita GDP (natural logarithm of per capita GDP, US$ constant 2000).

3 DEVELOPMENT ACCOUNTING: AN APPROXIMATION TO REGIONAL INCOME ASYMMETRIES

This section presents a baseline model of development accounting. As usual, this considers a Cobb-Douglas function that contains three productive factors and a multifactor

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productivity or TFP variable, which represents the residual of the production function. We assume that all the economies of the sample can be explained by the same model. Hence, the residual contains all the possible structural differences.

The product Y is represented in the following expression[2]:

$$Y_i = K_i^{\alpha} H_i^{\beta} (A_i L_i)^{1-\alpha-\beta} \tag{1}$$

where i indicates the country, whereas α and β are the shares of physical and human capital, K and H, in the product, respectively, with $(\alpha+\beta<1)$. The human capital stock is the product of the human capital average level, h, and the workers, L ($H_i = h_i \times L_i$). In turn, Arepresents the multifactor productivity.

To determine if differences in income are due to production factors or multifactor productivity, we obtain an expression that relates them with the per capita income. Denoting P_i as the population of the country i, Equation (2) contains per capita income and its components:

$$\frac{Y_i}{P_i} = \frac{L_i}{P_i} \left(\frac{K_i}{Y_i}\right)^{\frac{\alpha}{1-\alpha-\beta}} \left(\frac{H_i}{Y_i}\right)^{\frac{\beta}{1-\alpha-\beta}} Ai \tag{2}$$

where L/P is the labour participation rate and captures the effect of labour on per capita income. K/Y and H/Y indicate the intensity of physical and human capital in the product, and A is the multifactor productivity, which depends on two factors. The first is called 'technological capabilities' and represents a complex set of human abilities, technological knowledge and organizational structure, which are required to operate the technology efficiently and to reach a process of technological change (Lall, 1992). The second factor captures the jumps in the production possibility frontier, that is, changes in technology as a result of learning processes provoked by endogenous factors or incorporated from the rest of the world (by means of imports of goods or technology, foreign investment, immigration, etc.). These changes need to be relevant so that they can strongly modify the 'real costs of production' (Haberger, 1998).

From Equation (2), we carry out a typical exercise of development accounting. This consists in taking the ratio between per capita incomes of two economies and repeating the procedure with its respective components:

$$\begin{aligned}
&\varphi_{ij}^{Y/P} \equiv \frac{Y_i}{P_i} \Big/ \frac{Y_j}{P_j} = \varphi_{ij}^{L/P} \varphi_{ij}^{K/Y} \varphi_{ij}^{H/Y} \varphi_{ij}^{A};\\
&\varphi_{ij}^{L/P} \equiv \left(\frac{L_i}{P_i} \Big/ \frac{L_j}{P_j}\right); \quad \varphi_{ij}^{K/Y} \equiv \left(\frac{K_i}{Y_i} \Big/ \frac{K_j}{Y_j}\right)^{\frac{\alpha}{1-\alpha-\beta}};\\
&\varphi_{ij}^{H/Y} \equiv \left(\frac{H_i}{Y_i} \Big/ \frac{H_j}{Y_j}\right)^{\frac{\beta}{1-\alpha-\beta}}; \quad \varphi_{ij}^{A} \equiv \left(A_i / A_j\right) = \frac{\varphi_{ij}^{Y/P}}{\varphi_{ij}^{L/P} \varphi_{ij}^{K/Y} \varphi_{ij}^{H/Y}}
\end{aligned} \tag{3}$$

where i and j represent both economies, and φ_{ij}^{*} is the ratio of the component * of per capita income. More different values from the unity indicate higher differences of those components. Thus, these ratios show which factors are relevant to explain convergence

[2]Equation (1) can be reached from a three sectors model, one of them produces final goods and the others are composed by j firms that produce physical and human capital, respectively. A benchmark in this approach is the Romer´s model. In turn, this expression of the production function is used by Mankiw *et al.* (1992), and query Klenow and Rodríguez-Clare (1997).

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or divergence paths. Frequently, these are computed in average terms for a certain period, and the persistence of the same value for several periods allows us to verify long-run trends. In turn, once the more important components are identified, we can determine which factors explain the behaviour of such components.

On the other hand, relative multifactor productivity is an indicator of the technological performance between two economies, as follows:

$$\mathrm{A}_{it} \equiv \mathrm{X}_{it}\,\mathrm{E}_i\,\mathrm{T}_t \tag{4}$$

where *it* represents an economy *i* in the period *t* so that X_{it} shows specific effects in *i* and *t*, and it refers to technological capabilities. E_i captures the effects that are specific in *i* and invariant in *t* (e.g. the effect of the productive structure on multifactor productivity). In turn, T_t is related to the effects that are invariant in *i* and specific to *t* (e.g. a widespread technological shock). Given a technological shock, this component captures the average effect on the economies, whereas X_{it} captures the differences between them.

Therefore, from Equations (2) and (4), we can estimateX_{it}, E_i andT_t, as follows:

$$\hat{\mathrm{X}}_{it} = \frac{\hat{\mathrm{A}}_{it}}{\hat{\mathrm{E}}_i\hat{\mathrm{T}}_t} \tag{5}$$

$$\hat{\mathrm{E}}_{i\psi} = \frac{\left(\overline{Y/P}\right)_{i\psi}}{\left(\overline{K/Y}\right)_{i\psi}^{\frac{\alpha}{1-\alpha-\beta}}\left(\overline{H/Y}\right)_{i\psi}^{\frac{\beta}{1-\alpha-\beta}}\left(\overline{L/P}\right)_{i\psi}} \tag{6}$$

$$\hat{\mathrm{T}}_{t} = \frac{\left(\overline{Y/P}\right)_{t}}{\left(\overline{K/Y}\right)_{t}^{\frac{\alpha}{1-\alpha-\beta}}\left(\overline{H/Y}\right)_{t}^{\frac{\beta}{1-\alpha-\beta}}\left(\overline{L/P}\right)_{t}} \tag{7}$$

Then,

$$\varphi^{\mathrm{X}}_{i,j,t} \equiv \frac{\hat{\mathrm{X}}_{it}}{\hat{\mathrm{X}}_{jt}}; \quad \varphi^{\mathrm{E}}_{i,j,t} \equiv \frac{\hat{\mathrm{E}}_{i}}{\hat{\mathrm{E}}_{j}} \tag{8}$$

where ψ represents a sub-period, $\wedge$ refers to the estimated values of the variables and $\overline{}$ is the average value. The behaviour of the ratio $\varphi^{\mathrm{X}}_{i,j,t}$expresses the relative evolution of the technological capabilities between *i* and *j* economies. Similarly, the behaviour of the ratio $\varphi^{\mathrm{E}}_{i,j,t}$reflects the relative performance of the domestic process in technological production. Finally, $\varphi^{\mathrm{T}}_{i,j,t}$ is equal to the unity for all time *t*.

4 DEVELOPMENT ACCOUNTING: ESTIMATION METHOD AND EMPIRICAL RESULTS

The estimations of coefficients φ are carried out in two steps. In the first place, the parameters of Equation (2) are calibrated. Second, the relative components are estimated from Equations (3), (5) and (8). Then, three calibrations are realised. The first is the main case, whereas the others are introduced to determine sensibility of the results to the parameters. Table 1 shows the values for the parameters used in each calibration, as well as the literature where these values are used for similar ends.

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The panel of data corresponds to the 1960–2005 period and contains the information of 20 American economies: 10 of South America, 7 of North and Central America and 3 of the Caribbean. Following the World Bank classification, 12 economies are of low medium income and 8 of high medium income. Table 2 presents the descriptive statistics of the relevant variables for the first and the last year of the sample.

The ratios φ were estimated pair-wise so that the exercise includes 190 *ij* individuals. Figures 6, 7 and 8 show the evolution of the average relative per capita income and φ, for each calibration.

The results show that physical capital is important to explain the relative economic performance in the region, with changing intensity at different values of parameters. On the contrary, labour force and human capital are not relevant; in fact, their ratios have been around the unity in all cases. Nevertheless, the multifactor productivity seems to have been the key variable to determine the path of relative per capita GDP. The evolution of φ^A oscillates until the 1970s but presents a clear process of technological divergence from the Oil Crisis and particularly from the beginning of the 1980s. In short, these results suggest that the formation of transitory clubs verified during the periods 1960–1974 and 1990–1994 were mainly driven by physical capital and multifactor productivity intensities. In turn, they indicate a fluctuating evolution of per capita GDP in Latin American economies, which have been between a low and a high equilibrium. The convergence process around the low equilibrium was clearly associated to physical capital intensity because it pushed down the relative income, although multifactor productivity had an opposite behaviour. However, since the middle of the 1970s, the multifactor productivity is the main explanatory factor of relative per capita

Table 1. Parameters used in the calibration

Cases	α	β	Sources
Main	0.31	0.28	Mankiw *et al*. (1992), Klenow and Rodríguez-Clare (1997), McGrattan and Schmitz (1999), Hopenhayn and Neumeyer (2004)
Alternative 1	0.31	0.04	(1-α- β) from Bernanke and Gurkaynak (2001): average share of wage in income for economies of both samples = 0.648; α is taken from Mankiw *et al*. (1992) and β by difference.
Alternative 2	1/3	1/3	Mankiw *et al*. (1992), McGrattan and Schmitz (1999)

Table 2. Descriptive statistics*. Latin America and the Caribbean (20 economies**)

Variable	1960				2005			
	Avg.	St. Dev.	Min	Max	Avg.	St. Dev.	Min	Max
Y/P	1981.0	1435.1	685.7	5425.4	3704.8	2413.0	893.4	9195.0
L/P	0.3	0.0	0.2	0.4	0.4	0.0	0.3	0.4
K/Y	1.3	0.3	0.9	2.4	1.8	0.4	0.9	2.6
H/Y	0.6	0.2	0.3	1.0	1.2	0.3	0.8	1.8
Y (000000)	21 987	36 088	1263.3	108 322	114 175	209 868	4600.3	739 613

Source: Our own elaboration based on sources reported in the Appendix.
*Average value, standard deviation, minimum and maximum.
**Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay and Venezuela.

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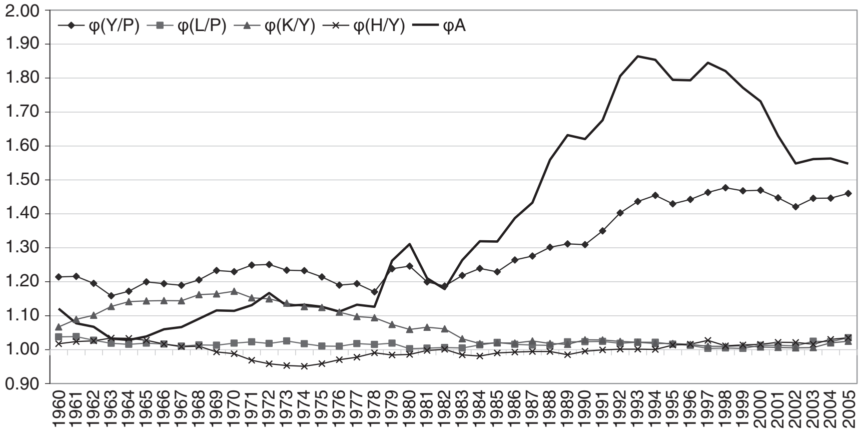
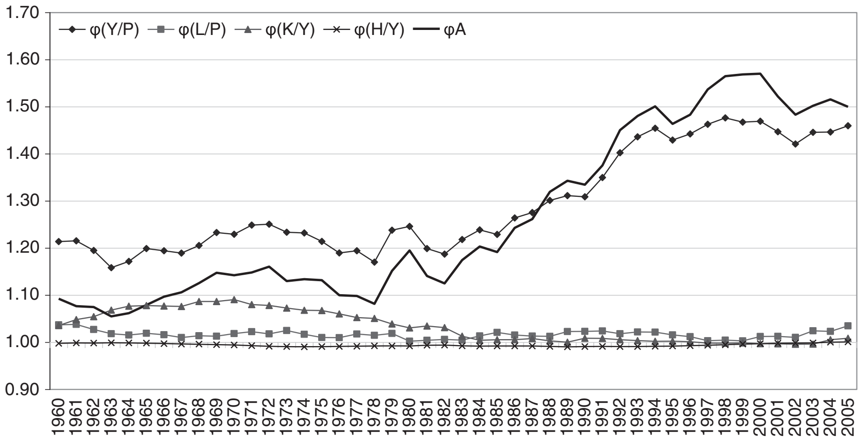


Source: Our own elaboration.

Figure 6. Average φ values. Main calibration (0.31; 0.28).



Source: Our own elaboration.

Figure 7. Average φ values. Alternative 1 (0.31; 0.04).

GDP, both in periods of convergence and divergence. In turn, the divergence process of per capita income seems to have come to a halt in the 1990s because of an abrupt convergence in such productivity.

Figure 9 shows the paths of averages in *i* of the multifactor productivity and its components. The average level of φ^E suggests structural differences among the economies, particularly in their possibilities to absorb and generate technology. Besides, the evolution of φ^X indicates stability in X differences until the beginning of the 1970s, after which they increased to reach their maximum in the 1990s. At the end of that decade, the evidence indicates the beginning of a process of convergence in technological capabilities, which explains the reduction of both φ^A and the relative per capita income.

In sum, technological capabilities show a process of divergence between the decades 1970 and 1990 and convergence during the last years of the sample. To understand the

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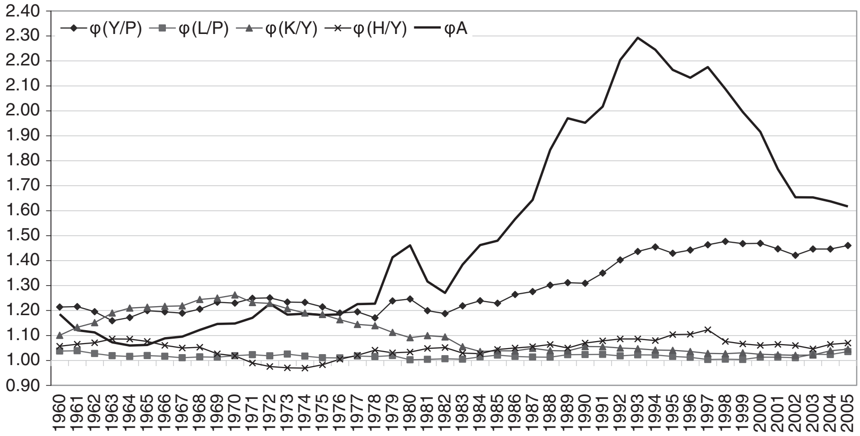
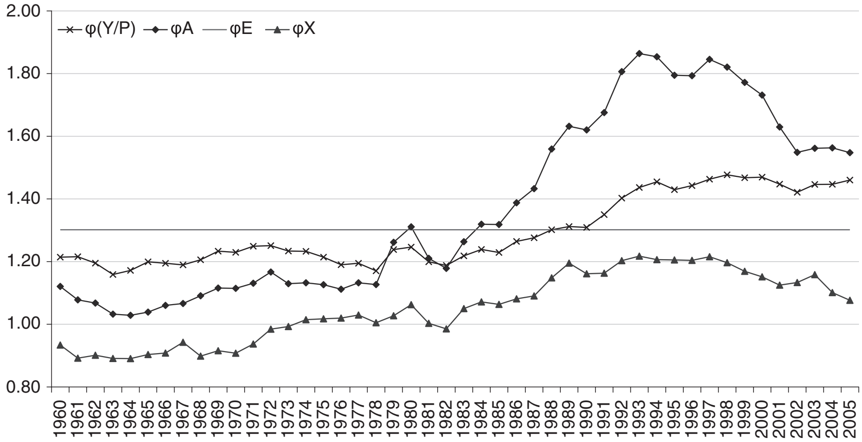


Source: Our own elaboration

Figure 8. Average φ values. Alternative 2 (1/3; 1/3).



Source: Our own elaboration

Figure 9. Average φ values of per capita GDP, A and its components. Main calibration.

deep determinants of these processes in the Latin American and Caribbean economies, in the next section, we study the determinants of φ^X.

5 DETERMINANTS OF TECHNOLOGICAL CAPABILITIES

The explanatory factors of relative economic performance are not captured directly by the typical exercise of development accounting. Rodrik (2003), Acemoglu (2007) and Hsieh and Klenow (2010) emphasised the role of geography, integration to international markets, quality of institutions and public policy. Acemoglu (2007) argued that cultural

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differences determine differences in individual preferences and beliefs, which in turn leads to diverse institutional arrangements. Geographic features, such as climate and natural resources, are rescued by Rodrik and Acemoglu as a key factor of institutional framework. These authors state that geography influences social behaviours, physical possibilities and economic integration.

In short, this set of variables determines the ‘social infrastructure’ defined by Hall and Jones (1999a, 1999b) as the set of laws, institutions and public policies that provide the setting for economic decisions. If such infrastructure favours policies that divert resources to unproductive activities, it reduces the physical and human capital accumulation and the technological transfer of abilities. Hence, different social infrastructure can account for differences in relative per capita income.

In the next section, we test the relevance of this argument to explain the relative performance in Latin American and Caribbean economies. Instead of considering the relative per capita income, we focus on its principal component: the ratio between technological capabilities.

5.1 Data and Estimation Method

We carry out a set of panel regressions for a panel of 190 individuals and 26 years in the full sample. Following the already mentioned literature, three sources of differences in technological capabilities are identified: (i) structural differences in the developing process of these capabilities; (ii) geographical differences that determine dissimilar degrees of economic integration; and (iii) differences in quality of political and economic institutions. All the variables are normalised ratios so that 0 represents equality, and they can take only positive values. Thus, higher values imply higher differences between two economies. The estimation methodology and the sources of the variables are presented in the Appendix.

In general, more developed economies should be in better conditions to incorporate technological innovations. To capture this effect, variables associated to the level of development are included in the estimations. In both cases, the expected sign is positive: [a] the relative income level (Scala2) is given by the GDP ratio, and it is taken as the principal variable of this subset. In turn, there could be mutual dependence between this and the explained variable so that we include our ratio φ^E as control variable. [b] The ratio φ^E, by definition, is conceptually the best variable to capture structural differences. Nonetheless, this does not present time variability, and then this was included only in pool data regressions.

On the other hand, to consider the effects on the geographical differences, we used three variables usually included in the gravity models of bilateral trade: [c] the geodetic distance (in km) between economies; [d] a dichotomous variable, Border, with value 1 if the economies are adjacent, and 0 otherwise; [e] a categorical variable, Area, with 4 options: 0 if the economies belong to the same geographic area, 1 if the combinations are South America-Central America or Central-North or North-Caribbean, 2 if the combination is South-North or Central-Caribbean and 3 for South-Caribbean.

In most cases, we expect greater different technological capabilities for more distant economies. In these cases, there should be less flow of products and factors, as well as higher cultural differences, which affect the transfer of knowledge and institutional design.

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Thus, [c] and [e] should be positive and [d] negative. Again, these variables do not have time variability so that they were not included in panel data but in pool regressions.

Finally, the differences in public policies and quality of economic and political institutions were approximated by the following variables:

[f] A dichotomy variable, Partner, which takes value 1 when the economies share political or economic agreements and then promote a more favourable environment to trade as well as to acquire technological capabilities, and 0 otherwise. Thus, its sign should be negative: when such agreement is applied, there should be lesser differences between economies.
[g] Openness, which is a rate that captures differences in trade policies. The raw variable used in the calculus indicates the excess of trade in relation to the expected values for a similar economy (see the Appendix for additional explanation). In turn, if the economy is closer to the world, it implies that it must obtain higher productivity levels to compete for exports in foreign markets, and at the same time, it can reach technological advances. Then, more differences in openness imply more differences in technological capabilities so that the expected sign is positive.
[h] Government, a ratio that denotes differences in the role of the State on economic activity. The raw variable is the ratio between public expenditure and GDP. The expected sign is negative because the incentives to innovation should be lesser in economies with higher state participation. Thus, higher differences in that variable among economies should imply lower differences in technological capabilities.
[i] Inflation, as it is defined here, captures differences in economic stability. Instability should diminish knowledge accumulation and also technological capabilities so that the expected sign of this relative variable is negative in terms of technological capability differences.
[j] Conflict, as it is defined here, measures differences in political stability, and similar to inflation, its sign should be negative.
[k] Regime refers to political organization differences. The raw variable presents four categories: civil government, civil militar, militar and others (e.g. foreign dependence). The environment for technological capabilities development is more favourable (adverse) in the first (last) category. Therefore, the expected sign is negative[3]
[l] Polity3 is a measure of the differences in political institutions quality. The raw variable, Polity2, takes value 10 for more democratic organizations, and –10 for more autocratic organizations. This was transformed so that it is always positive. Then, the expected sign is positive: stronger democracy should show better incentives to accumulation of technological capabilities.
[m] Pluralism and [n] Democracy are similar to Polity3. The first is an indicator of political plurality, and the other refers to electoral competence and participation. Thus, the expected sign is positive for both variables.

Variables [k] to [n] are substitute because they capture similar aspects: the quality of government institutions.

[3]For example, if country A is governed by a more democratic regime (Reg value equal to 1) than country B (Reg value equal to 3), then it is expected that country A would be more technologically capable than country B. A positive change in country B's political regime is a lesser value in its Reg and, in relative terms, an *increase* in Regime—the ratio between Reg variable of A and B. This change in country B would imply an improvement in its technological capabilities, so a *reduction* in the value of the ratio between the previously technologically more capable country A and its follower, country B. That is a process of technological convergence.

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5.2 Empirical Results

Assuming the existence of country and temporal unobserved characteristics that can explain the differences in technological capabilities, the estimation was carried out by applying two-way fixed effects (TWEs). We also took in consideration the presence of autocorrelation, serial correlation and heteroscedasticity, so the estimations were made using the panel-corrected standard-errors method (PCSE). The use of this method allowed us to correct the above-mentioned problems and had robust results. We also employed alternative methods of estimations to test the sensibility of the selected method.

Table 3 shows the first series of estimations, which take the complete model and consider alternatively the variables of government institutions' quality. It is important to mention that the country and temporal dummies result significant. This result confirms what we had supposed about the existence of country and temporal unobserved characteristics that can explain the differences in technological capabilities (two way effects).

Scala2 and Partner are always significant and with the expected sign. Thus, a lesser difference in the degree of development and a greater consensus to generate political or economic agreements seem to produce a more favourable environment to converge technologically. Surprisingly, Inflation, Government and Openness remain non-significant in all cases. This indicates that the differences in economic instability, openness and the weight of the public sector in the GDP do not contribute significantly to explain productivity differences among countries. Despite the fact that these variables could be statistically relevant to explain the innovation process or acquisition of technology of an economy, they lose significance when the countries are taken pair-wise. The intuition is that the effect of each variable along the period has been the same for all countries or at least for the majority of them. These results are robust to changes in the proxy variables of institutional quality.

Finally, Regime is slightly significant (*p* value equal to 7 per cent) and presents the expected sign so that a greater difference in Regime would imply lower differences in technological capabilities.[4] On the other hand, Democracy and Polity3 are not significant (*p* value greater than 10 per cent). These results imply that the differences in the quality of government institutions did not have statistically significant effects during the periods of the sample, but it does not indicate that a more advanced democracy cannot ensure better incentives to accumulation of technological capabilities. These results are supported by the fact that, with a few exceptions, the Latin American and Caribbean countries are young democracies and shared periods of strong autocratic government, several *coup d'éstat* and social conflicts during the 45 years of the sample.

Lastly, Conflict is significant with negative sign only when Democracy is included. The interpretation of this result should be that stronger social conflicts are enough to harm the technological capabilities, that is, when such conflicts have significant effects on economic and policy decisions, and a part of the process of divergence is explained by the existence of these conflicts. However, this result is not robust and depends on the definition of the quality-of-government variable. If we relax the limit for statistical significance and accept that Democracy is relevant (*p* value under 15 per cent), its unexpected negative sign and the positive sign of Conflict seem to indicate that there were statistically more cases of technological convergence when one of the countries had an autocratic government with popular support. However, this mixed effect is not strong enough, as we have seen in

[4]See previous footnote for a clarification of the arguments about the expected sign.

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Figure 9 because the average φ^Xshows the process of convergence during the consolidation of the democracy in the region, that is, 1990–2005.

Table 4 presents the results of the regressions with clearly significant variables. We use four alternative models to test, as we mentioned, the sensibility to the estimation method: (i) by pool ordinary least squares, OLS, (ii) by fixed effects, FE, (iii) by TWEs; (iv) by random effects, RE; and (v) by TWE with PCSE.

Except for the last model, there is coincidence with respect to significance and signs of the explanatory variables. The TWE-PCSE column shows that Scala2 lost significance, but the *p* value takes a statistically acceptable value. The constant term lost significance and the usual tests raised their values notably. Thus, the selected variables—Scala2, Partner and Regime—are strong determinants of the differences in technological capabilities, and this result is robust across methodology. The interpretation of these results is rather intuitive. As aforementioned, the lesser the differences in the level of development and the greater the difference in political regime (more democracy implies more technological

Table 3. Explanation of the differences in technological capabilities

	Model 1	Model 2	Model 3	Model 4
Scala2	1.924241 (0.007)	1.917712 (0.009)	1.915448 (0.007)	2.683144 (0.000)
Partner	-0.0447303 (0.002)	-0.0461963 (0.004)	-0.0453887 (0.001)	-0.0467217 (0.000)
Openness	5.37e-06 (0.959)	9.25e-06 (0.929)	6.31e-06 (0.952)	4.49e-06 (0.883)
Government	-0.0823377 (0.187)	-0.0830307 (0.186)	-0.0788726 (0.205)	-0.0500908 (0.158)
Inflation	0.0000214 (0.565)	0.0000169 (0.737)	0.0000184 (0.618)	0.0000218 (0.527)
Conflict	-0.0000419 (0.720)	-0.0000536 (0.660)	-0.0000419 (0.717)	-0.0001737 (0.000)
Regime	-0.015874 (0.067)			
Polity3		-0.000017 (0.985)		
Pluralism			-0.0023172 (0.141)	
Democracy				-0.0006149 (0.136)
Constant	-0.0527454 (0.679)	-0.0472792 (0.718)	0.00014 (0.999)	-0.1730223 (0.0287058)
Observations	7357	7376	7357	6806
R^2	0.3157	0.3108	0.3151	0.3465
Wald	146418.48	145526.74	129122.69	1.47e+10

p values between parentheses.

Table 4. Explanation of the differences in technological capabilities (part II)

	Pool	EF	TWE	EA	TWE-PCSE
Scala2	0.408648	0.8915019	0.8844751	0.5716248	0.8844751
	(0.000)	(0.000)	(0.000)	(0.000)	(0.161)
Partner	-0.0161764	-0.0198331	-0.041499	-0.0197683	-0.041499
	(0.017)	(0.002)	(0.000)	(0.002)	(0.001)
Regime	-0.0320443	-0.0282779	-0.016966	-0.028618	-0.016966
	(0.000)	(0.000)	(0.000)	(0.000)	(0.012)
Constant	0.2862467	0.2534225	0.1958796	0.276895	0.1043842
	(0.000)	(0.000)	(0.000)	(0.000)	(0.327)
Observations	8267	8267	8267	8267	8267
Adjusted R2	0.0145	0.0125	0.0395	0.0139	0.3082
Wald	40.62	23.81	9.48	74.62	8.90e+06

p values between parentheses.

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Table 5. Explanation of the differences in technological capabilities (part III)

	1	2	3	4
φ^E	0.0269106 (0.000)			
Scala2		0.3094159 (0.000)	0.4093255 (0.000)	0.4054104 (0.000)
Partner	-0.0184961 (0.145)			
Regime	-0.0334642 (0.000)	-0.0331685 (0.000)	-0.0306728 (0.000)	-0.0303313 (0.000)
Distance		0.000013 (0.000)		
Border			-0.0166858 (0.000)	
Area				0.011152 (0.005)
Constant	0.2825022 (0.000)	0.2399167 (0.000)	0.275537 (0.000)	0.2607126 (0.000)
Observations	8267	8267	8267	8267
Adjusted R^2	0.0214	0.0229	0.0144	0.0159
Wald	36.45	55.48	48.68	45.07

All regressions are pool OLS-PCSE.
p values between parentheses.

capabilities), jointly with the existence of political and economic agreements, seem to favour an environment of convergence in technological development.

The robustness of results across the selected variables was tested using, in the first place, the substitution of Scala2 for the variable related to structural differences, φ^E. In the second place, we substituted Partner for the three alternative geographical variables. All new variables are time invariant so that we estimated by means of pool OLS. Table 5 shows the results. Again, all the variables are significant and with the expected sign. Therefore, economic or political partnership and greater differences in government regime were consistently the factors of rapprochement, whereas these economies were hampered by the persistence of structural differences and the long distances between some of them.

6 CONCLUSIONS

The evidence presented in this paper does not verify clear convergence or divergence trends among Latin American countries for the last 4 decades, but a slight convergence process until the middle of the 1970s, and global divergence afterwards. Transitory convergence clubs were formed during the periods 1960–1974 and 1990–1994. Finally, the lower income countries, on the average, became closer to the more developed economies in an environment of increasing per capita income dispersion.

The development accounting approach allows us to explain such results. This indicates that differences in technological capabilities can explain the dynamics of relative per capita GDP. In turn, differences in development level and in the achievement of political and economic agreements are a key factor to explain such divergence capabilities and, therefore, its dynamics. Our intuition is that the economies with a higher level of development and political consensus have been better able to reach technological advances in the last decades.

A second interesting result is that the efforts to integrate the economies were not enough. From 1975, all countries were formally associated in political and trade agreements, but a divergence process took place afterwards, which is explained mainly by technological factors. Nonetheless, the significance and sign of this variable process indicate larger divergence in technological capabilities without the integration process. Differences in the role of the State, openness and economic stability were not significant.

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In sum, the persistence of asymmetries in the level of development has impeded the sustained convergence process through technological channels. This persistence can be explained from an institutional approach. In this sense, our findings suggest that political efforts should be geared towards the consolidation of democracy, with some degree of political consensus on long-term economic and social goals. This institutional framework would foster a favourable economic environment to the development of business, technology acquisition, etc. However, to consider only the domestic scene is not enough.

The integration projects during the period would not have generated incentives to the extent necessary for the incorporation of technology, and the knowledge spillover has not close the gap between the economies of the region. Despite the significant results obtained in terms of trade and investment, evidence suggests that they have not met one of the founding objectives posed by the agreements, namely, the consolidation of development of the economies involved. In this regard, the future focus should be directed towards common policies on science and technology with the aim of accelerating the reduction of asymmetries in technological capabilities.

Finally, our evidence suggests differences between the integration experiences of developed and emerging economies. Whereas in the first case, the literature shows a convergence process, like in the European Union, for the second, specifically the Latin American and the Caribbean economies, our evidence shows a complex situation of transience in the convergence process explained by significant differences in social infrastructure. This states an interesting subject in the agenda of future studies of convergence. In particular, a topic of a future agenda can be to carry out a comparative analysis among blocks of developed and developing countries, to find the explanatory factors of such differences between both integration processes.

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APPENDIX

Symbol	Specification	Calculus or transformation	Source
Y/P	Per capita product	= Y/P	Our own elaboration
Y	GDP, 2000 constant prices, US$		World Bank Development Indicator Online (WBDI Online)
P	Total population		World Bank Development Indicator 2007 (WBDI 2007)
L	Employment	= (1-U%/100) LF where LF is working age population, and U% is unemployment rate.	Employment data: (1) Marcel P. Timmer and Gaaitzen J. de Vries (2007), 'A Cross-Country Database for Sectoral Employment and Productivity in Asia and Latin America, 1950-2005', Groningen Growth and Development Centre Research Memorandum GD-98, Groningen: University of Groningen, August 2007. (2) The Conference Board, Total Economy Database, June 2009 (3) ILO, LABORSTA Labour Statistics Database. (4) ILO, ICMT, 5 edition. Unemployment rate: (i) CEPAL, (ii) ILO, LABORSTA Labour Statistics Database (iii) WBDI 2007 y (iv) WBDI Online
L/P	Labour participation rate	= L/P	Our own elaboration

(*Continues*)

(Continued)

Symbol	Specification	Calculus or transformation	Source
K/Y	Physical capital intensity	= K/GDP	Our own elaboration
K	Stock of physical capital	King and Levine's (1994) 'pre ferred' methodology. Initial K/Y estimated using: average inversion rate, average growth rates for completed period. Parameters value as the original (delta = 0.25 y depreciation rate = 0.07). We supposed that K/Y in time t-1 was exactly the K/Y of steady state.	Our own elaboration based on the following sources: (1) Gross fixed capital formation (constant 2000 US$)—WBDI Online. (2) Estadísticas e Indicadores Económicos [BADECON] of CEPAL, or PENN World Tables 6.2
H/Y	Human capital intensity	Mankiw *et al.*'s (1992) methodology: $\frac{H}{Y} = \frac{I_H/Y}{n+g_{st}+\delta}$ where numerator is the human capital inversion rate proxied by the ratio between the secondary enrolment population and population with working age.	Our own elaboration based on the following sources: Secondary enrolment: (1) Ferreres, O. Dos Siglos de Economía Argentina. (2) Della Paollera and Taylor, Statistic Appendix. (3) CEPAL. (4) Oxford Latin America Economic History Database. (5) UNESCO, Institute for Statistics. (6) UNESCO estimates [code 25540]. (7) Secondary education, pupils—WBDI 2007. (8) Secondary enrolment by level BANKS dataset 2005.
		The values of the parameters are the same as those used in the K/Y estimation process.	Population with working age: population between 15 and 64 years old, and total population, WBDI 2007.
Scala2	Relative development level	= abs(1-ratio(ln GDP))	Our own elaboration
Distance	Geodesic distance (Kms) between two economies		CEPII
Border	Dichotomy variable	1 if the economies are neighbours 0 if not	Our own elaboration
Area	Categorical variable	0 if the economies are in the same subcontinent 1 if the combination is South America-Central America, Central-North or North-Caribbean 2 if South-North or Central-Caribbean 3 if South-Caribbean	Our own elaboration
Partner	Dichotomy variable	1 if the economies share political or trade agreements	Our own elaboration based on INTAL database.

(*Continues*)

(Continued)

Symbol	Specification	Calculus or transformation	Source
		0 if not.	
Openness	Ratio	= abs(1-ratio(Residual)), where Residual = Residual of the following cross-section pool OLS regression: [(M + X)/GDP]t = a + b*[ln(P)]t + c* (KM2) + d*ln(Y/P)t + g*Oil_-dummy + g*Island_dummy + residual	Our own elaboration. Oil dummy from CEPII and WBDI 2007
Government	Ratio	= abs(1-ratio(ln GP)), GP = public expenditure on GDP	Our own elaboration based on: Government Share of CGDP, % in Current Prices, Alan Heston, Robert Summers and Bettina Aten, Penn World Table Version 6.2, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, September 2006.
Inflation	Ratio	= abs(1-ratio(Inf)), Inf = ln(1 + inflation rate/100)	Our own elaboration based on: Inflation, consumer prices (annual %) WBDI 2007
Conflict	Difference	= abs(CBi-CBj), CB = Conflict indicator	Our own elaboration based on: conflict indicator from Banks' Cross-National Time-Series Data Archive
Regime	Difference	= abs(Regi-Regj), Reg is the regime type: (1) Civil (2) Militar-Civil (3) Militar (4) Other	Our own elaboration based on: regime from Banks' Cross-National Time-Series Data Archive
Polity3	Difference	= abs(POLi-POLj) POL = Polity2 + 10	Our own elaboration based on: Polity2 of Polity IV Project Center for Global Policy School of Public Policy George Mason University
Pluralism	Difference	= abs(PLi-PLj) PL = pluralism indicator	Our own elaboration based on: pluralism indicator from Banks' Cross-National Time-Series Data Archive
Democracy	Difference	= abs(DEMOi-DEMOj), DEMO = indicator of quality of democracy	Our own elaboration based on: Democracy from Vanhanen (2002) Polyarchy Database

INTAL, Instituto para la Integración de América Latina y el Caribe

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