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Innovation, Absorptive Capacity and Growth Heterogeneity: Development Paths in Latin America 1970–2010

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Abstract

The paper carries out an analysis of long-run development paths in Latin America in the period 1970-2010. We focus on three main dimensions – openness, industrial structure and innovation – and analyze how changes in these factors, and the specific combination of them adopted by each country, have affected its income per capita growth. We apply Johansen cointegration approach to time series data for 18 Latin American countries. The analysis leads to two main results. First, we show that Latin American countries have followed different growth trajectories depending on the combination of policies they have adopted to catch up. Secondly, we find a clear correspondence between policy strategies, on the one hand, and growth performance, on the other. Countries that have managed to combine imitation and innovation policy have experienced a higher rate of growth than those economies that have only made efforts to improve their imitation capability.

Keywords: innovation; absorptive capacity; economic growth; heterogeneity; development paths; long-run causality; Latin America

JEL codes: O1, O3, O4

1. Introduction

Between the mid-1970s and the late 1980s, most countries in Latin America experienced a sharp rupture with the previous era of State-led industrialization, and the introduction of a new economic model according to which free market mechanisms represent the major force driving economic development (Stalling and Peres, 2000; Bulmer-Thomas et al., 2006; Bertola and Ocampo, 2010). Latin American economies, though, have responded differently to the opportunities and challenges of globalization, adopting different policy strategies and following distinct growth trajectories. Some of the countries in the region have more actively embraced the new market-oriented model, whereas others have opted for a more cautious mixed approach, building on the path of the import-substitution era (ECLAC, 2010 and 2012; Cimoli and Porcile, 2011; Hausmann, 2011; Ocampo and Ros, 2011).

How can the development paths followed by Latin American countries during the last decades be explained in the light of the literature on innovation and economic growth? Schumpeterian research has extensively investigated the role of innovation and international knowledge diffusion for the process of economic growth and development. The literature has so far greatly emphasized the cross-country comparative dimension of this process. One strand of research has carried out cross-country econometric studies of empirical data (e.g. Fagerberg and Verspagen, 2002; Castellacci, 2008). Another line of research has presented Schumpeterian models of innovation and growth, and studied the steady state properties of these theoretical frameworks (Howitt and Mayer-Foulkes, 2005; Acemoglu et al., 2006).

While providing an in-depth analysis of the main factors shaping the catching up process of developing economies, Schumpeterian research on innovation and economic growth does however open up new questions, which are particularly relevant in the light of the Latin American experience summarized above. The first question refers to cross-country *heterogeneity*. Existing research provides a stylized uni-dimensional view of the catch up process, according to which developing countries either catch up or fall behind (depending on their initial conditions and structural characteristics). However, economic history and political economy analyses suggest that economic development is a complex process, and that countries can adopt distinct policy strategies and follow markedly different growth trajectories over time. This is a crucial aspect that deserves further research in order to shed new light on the long-run development paths of Latin American economies.

The second open question relates to the *time series* dimension. The Schumpeterian literature has so far largely focused on the cross-country comparative dimension of the growth process. By contrast, the time series patterns of the growth process have often been neglected (Castellacci and Natera, 2013). The Latin American experience indicates that countries undergo important economic transformations in the long-run, and that individual economies differ in the specific policy strategy they adopt when faced with the same changing economic and institutional environment. Therefore, time series analysis is crucial in order to shed further light on the different policy strategies and growth trajectories followed by developing economies.

Motivated by these two research issues, our study intends to provide an investigation of Latin America's growth experience with a focus on heterogeneity patterns and the related time series properties. First, we present a simple theoretical model of growth and catching up, based upon, and extending further, Verpagen's (1991) seminal model. The model focuses on three main dimensions – openness, industrial structure and innovation – and analyzes how changes in these factors affect the growth of income per capita of developing economies along their transitional dynamics. We then investigate the empirical evidence of this model by carrying out a time series analysis of 18 Latin American countries in the period 1970-2010. We make use of Johansen cointegration approach, which makes it possible to disentangle short-run and long-run causality effects, and it is then well-suited to estimate the effects of policy changes in terms of openness, industrial structure and innovation on the rate of income per capita growth.

This analysis leads to two main results. First, we show that Latin American countries have followed different growth trajectories depending on the combination of policies they have adopted to catch up (openness, industrial transformation and/or innovation policy). Secondly, we find a clear correspondence between policy strategies, on the one hand, and growth performance, on the other. Countries that have managed to combine imitation policy and innovation policy have experienced a higher rate of growth than those economies that have only made efforts to improve their imitation capability.

The paper is organized as follows. Section 2 describes the background and introduces the relevant literature; section 3 presents the theoretical model; section 4 outlines the time series data and indicators; section 5 explains the econometric method; section 6 presents the results; section 7 summarizes the main results and implications of the work.

2. Background

2.1 Economic growth and development in Latin America

In Latin America, the period spanning from approximately 1930 up to 1980 is commonly defined as the era of "State-led industrialization" (or "import substitution industrialization"; see Stalling and Peres, 2000; Bulmer-Thomas et al., 2006; Bertola and Ocampo, 2010). Many countries in the region experienced a shift from primary export-led growth towards domestic industrialization, and a growing role of the State in economic development. Economic performance in this period was in general positive, and various Latin American countries managed to catch up and reduce the technology and income gap *vis-a-vis* other regions in the world (Cimoli and Porcile, 2011).

The subsequent years, however, marked a much more turbulent era, characterized by important policy changes and a more heterogeneous growth dynamics. During the 1980s and 1990s, – a period often referred to as "the era of market reform" – most Latin American economies experienced three major changes as compared to the previous phase of long-run growth. First, there were substantial changes in macroeconomic policies (financial stabilization, fiscal restructuring) in order to manage crisis and financial instability. Secondly, Latin American countries increased the openness of the economy through trade liberalization (lower tariffs and trade agreements) and increased FDI. Thirdly, the new doctrine of market-led economic development rapidly became the mainstream view, and the State started to have a much less active role to foster industrial development and economic growth (at least until 2000s, when some countries, such as Argentina, Brazil, Ecuador, Venezuela and Bolivia, initiated a reversal of these reforms and a return to higher levels of State intervention in the economy).[1]

The new economic model did not easily lead to the expected economic outcomes. Economic growth performance was not as good as in the previous era, and some Latin American countries were unable to continue the convergence process they had undertaken in previous decades (Cimoli and Porcile, 2011). At the same time, this was an era of great heterogeneity, in which national economies responded differently to the opportunities and challenges of globalization, adopting different policy strategies and following distinct growth trajectories (ECLAC, 2010 and 2012; Ocampo and Ros, 2011). Some of the economies in the region actively embraced the new market-oriented model (e.g. Argentina, Chile and Colombia), whereas others opted for a more cautious mixed model, which built

[1] For a comprehensive account of these economic growth phases in the recent Latin American history, see Stalling and Peres (2000).

on the path of the import-substitution approach (e.g. Brazil, Mexico, Perú and Venezuela; see Bulmer-Thomas et al., 2006).

Three major dimensions are relevant to investigate the long-run drivers of economic growth in Latin America during the last four decades. The first is the increased openness of the economies in the region. International trade has increased substantially, although according to some recent meta-analysis (see Lora, 2011) the effects of trade policy on the growth of GDP per capita and productivity have so far been modest and transitory. Inwards FDI has also increased substantially, becoming a central, though highly debated, dimension of Latin America's development (Ferraz et al., 2011).[2] Inward FDI are potentially an important channel of international knowledge diffusion and catching up. However, their impact on economic growth depends largely on the sectors on which they focus, and the spillover effects that they may induce throughout the whole economy through the set of vertical linkages in the host economy.

Industrial structure and sectoral specialization patterns represent a second major dimension to explain heterogeneous policy strategies and growth trajectories in Latin America. In general terms, the ability of a national system to shift resources from traditional and low-productivity sectors (e.g. agriculture, public services) towards more advanced and dynamic industries (such as manufacturing and business services) is an important driver of aggregate growth, as it may support the country's capability to imitate and implement foreign advanced technologies (Fagerberg, 2000; Castellacci, 2010). However, in recent decades structural change has been slower in Latin America than in other developing countries and some of the economies in the region have actually increased their production and employment shares in lower productivity sectors (Cimoli and Porcile, 2011). This is also reflected in the export specialization patterns of Latin American economies, which is often focused on a narrow product range (except the cases of Brazil and Mexico) and on weakly dynamic industries (Hausmann, 2011).

For instance, some Central American countries have strengthened their specialization in manufacturing industries, but focusing on assembling activities to serve export-platform FDI of foreign multinationals (e.g. car industry in Mexico, textile in Central America & Caribbean, ICT hardware in Costa Rica; see Ferraz et al., 2011). Sectors related to the exploitation of natural resources are also important in the region, and South American countries have attracted a substantial amount of resource-seeking FDI, mostly in energy and mining (Pineda and Rodriguez, 2011).

[2] The causal impact of FDI on economic growth is far from clear. Recent time series analyses shed new light on the complexity of this causal effect, e.g. on Chile (Chowdhury and Mavrotas, 2006; Herzer et al., 2008).

Although these industries are potentially important for economic development, productive activities in these branches must be accompanied by industrial policies and investments in infrastructures and technological capabilities (e.g. the oil industry in Venezuela and Mexico).

The third crucial dimension refers precisely to innovation and technological capability building, which is the key aspect that catching up countries should try to foster in order to make the jump to the innovation stage. During the period of State-led industrialization, industrial policies and active State interventions created favorable conditions for the development of domestic technological capabilities in Latin America. However, the new market-oriented paradigm undertaken since the 1980s marked a sharp rupture with the previous phase, so that public support to R&D and innovation policies weakened (at least until the 2000s, see Cimoli and Porcile, 2011). In the last decades, in fact, the innovation gap of Latin America *vis-a-vis* other regions of the world has increased (Castellacci and Archibugi, 2008; Castellacci, 2011). However, the innovation intensity and performance of national systems varies substantially across the region.

2.2 The literature on innovation and economic growth

How can the development paths followed by Latin American countries during the last decades be explained in the light of the literature on innovation and economic growth? Schumpeterian research has made major progress and extensively investigated the role of innovation and international knowledge diffusion for the process of catching up of developing economies (Fagerberg, 1994).

A large empirical literature has focused on the process of international knowledge diffusion and investigated the set of factors that affect the extent to which a national system is able to grow and catch up with the technological frontier by means of international learning and imitation activities. This approach was originally inspired by the work of economic historians such as Landes, Gerschenkron and Abramovitz, which, by focusing on historical case studies of the technological catch up process, pointed out that international knowledge diffusion is a complex and demanding process, and investigated the set of factors that are necessary for imitation-based technological development. This set of factors, in a nutshell, defines the *absorptive capacity*, or *imitation capability*, of a country (Abramovitz, 1986; 1994).

Empirical works in this tradition have typically followed a growth-regression econometric approach, and shown the large variety of factors, of both a techno-economic and socio-institutional nature, that affect convergence and divergence patterns in broad cross-country samples (e.g. Fagerberg and Verspagen, 2002; Fagerberg and Srholec, 2008; Castellacci, 2008 and 2011). Most of this empirical research, however, has so far focused on the cross-country comparative aspect ("why growth rates differ") and mostly neglected the time series dimension and the analysis of the dynamics of the technological catch up and economic growth process for individual countries (or specific regions) over time.

Theoretical models in the technology-gap (or distance-to-frontier) tradition have tried to formalize some of these ideas into stylized growth models, in which developing countries catch up with the frontier if they are endowed with a sufficient level of absorptive capacity and imitation capability, and fall behind otherwise. Absorptive capacity is in these models affected by countries' level of human capital, their openness to the international economy, as well as their industrial specialization patterns (Nelson and Phelps, 1966; Verspagen, 1991; Benhabib and Spiegel, 1994; Papageorgiou, 2002; Stokke, 2004).

A more recent class of theoretical models in the distance-to-frontier tradition puts greater emphasis on the innovative capabilities of catching up countries, and points out that the existence of threshold externalities may explain the cumulative nature of the process of technological accumulation and economic growth in the long-run. Specifically, threshold externalities models are based on the idea that the interactions between countries' R&D and innovation activities, on the one hand, and imitation activities, on the other, may generate different country clubs, and explain the transition of each national system from the imitation stage of development to the innovation stage (Howitt, 2000; Howitt and Mayer-Foulkes, 2005; Acemoglu et al., 2006).

A distinct growth modelling tradition is rooted in the rich strain of evolutionary economics models. This was initially inspired by Nelson and Winter's (1982) seminal evolutionary model, which described an economy composed of a population of heterogeneous firms, each of which, being characterized by bounded rationality and satisficing behaviour, follows routines and habits of thought rather than maximizing an intertemporal profit function. In evolutionary economics, microeconomic agents operate in an economic environment that is characterized by fundamental uncertainty and an out-of-equilibrium dynamics. In such a complex environment, it is typically not possible to solve the model analytically by means of steady-state conditions, and the model's properties are explored through computer simulations. Nelson and Winter's seminal model inspired a whole new strand of modelling research that investigated the interactions between firm-level heterogeneity, selection and competition mechanisms, and the creation of new variety through R&D and product differentiation activities (see e.g. Saviotti and Pyka, 2008; Ciarli et al., 2010).

Schumpeterian research on innovation and economic growth – while providing an in-depth analysis of the main factors shaping the catching up process of developing economies – does however open up new questions, which are particularly relevant in the light of the Latin American experience summarized above. The first question refers to cross-country *heterogeneity*. Economic history and political economy analyses suggest that economic development is a complex process, and that countries can adopt distinct policy strategies and follow markedly different growth trajectories over time. This is a crucial aspect that deserves further research in order to shed new light on the long-run development paths of Latin American economies. The second question relates to the *time series* dimension. The Latin American experience indicates that countries undergo important economic transformations in the long-run, and that individual economies differ in the specific policy strategy they adopt when faced with the same changing economic and institutional environment. Therefore, time series analysis – and specifically time series econometrics, and theoretical analyses of the transitional dynamics properties of growth models – is crucial in order to shed further light on the different policy strategies and growth trajectories followed by developing economies. Motivated by these two broad questions, our study intends to provide an investigation of Latin America's growth experience with a focus on heterogeneity patterns and the related time series properties.

3. Model

Our theoretical framework is based on Verspagen's (1991) seminal model of growth and catching up, and subsequent extensions of it by Papaegeorgiou (2002) and Stokke (2004). We extend these previous models and study their time series properties focusing on the effects of policy shocks on the growth rate of catching up countries along the transitional dynamics. The model studies the economic growth of two countries, a leader (L) and a follower (F) economy. The technology gap, or technological distance, between the two countries can be defined as:

$$G = \ln (K_L/K_F) \quad (1)$$

The knowledge stock of the leader country (K_L) is assumed to grow at a constant growth rate I_L:

$$\Delta K_L/K_L = I_L \quad (2)$$

This growth rate depends on the amount of resources that country L invests in R&D activities (RD_L) as well as the productivity of its research sector (β_L). Since the focus of the model is the process of growth and catching up of the follower country F, we assume for simplicity that both RD_L and β_L are constant and exogenous, reflecting the assumption that the leader country is growing at a constant speed along its steady state.

$$I_L = \beta_L \bullet RD_L \tag{3}$$

The knowledge stock of the follower country (K_F) depends on two factors: innovation activities (I_F) and international spillovers (S_F) that the country benefits from by imitating foreign advanced knowledge:

$$\Delta K_F / K_F = I_F + S_F \tag{4}$$

The innovation term depends again on the amount of resources that country F invests in R&D activities (RD_F) as well as the productivity of its research sector (β_F):

$$I_F = \beta_F \bullet RD_F \tag{5}$$

It is reasonable to assume that the follower country's R&D intensity and the productivity of its research sector are lower than those in the leader economy ($RD_F < RD_L$; $\beta_F < \beta_L$). This implies that $I_F < I_L$, i.e. the innovation rate in the follower country is lower than the one in the leader country.
The international spillovers term S_F represents imitation activities that catching up countries behind the technological frontier can undertake in order to adopt, import and implement foreign advanced technologies. We follow Verspagen's (1991) original formulation and assume a non-linear process of diffusion according to which international spillovers vary with the technological distance G between the leader and the follower country:

$$S_F = \varphi \, G \bullet \exp(-G/\delta) \tag{6}$$

The intuition behind this non-linear spillover function is well-known. The term φ G represents the *potential spillovers*, which depend positively on the size of the gap G as well as on the parameter φ. The latter ($0 < \varphi \leq 1$) measures the openness of the economy (e.g. in terms of international trade and FDI activities), indicating that the more open an economy is, the larger the scope for imitation activities through international knowledge flows.

However, imitation activities can only be successfully undertaken if the follower country has a sufficient level of *absorptive capacity* that enables to implement and adapt foreign advanced technologies into the domestic system of innovation (Abramovitz, 1986; Fagerberg, 1994). This absorptive capacity, or imitation capability, is noted by the parameter δ (with $\delta > 0$). The higher the parameter δ is, the greater the ability of country F to catch up through international spillovers.

Most previous models of growth and international knowledge diffusion typically assume absorptive capacity to be an exogenous country-specific factor, which depends on the level of human capital of an economy (Nelson and Phelps, 1066; Verspagen, 1991; Papaegeorgiou, 2002; Benhabib and Spiegel, 2005). We depart from these previous formalizations, and assume that the absorptive capacity does not depend on the level of human capital as such, but rather on the sectors of activity in which a country's human capital is employed. Specifically, suppose there are two sectors in the economy: a traditional sector T (e.g. agriculture) and a technologically progressive sector P (e.g. manufacturing and services). Hence, we point out that:

$$\delta = \lambda \bullet HK_p \tag{7}$$

i.e. the absorptive capacity δ of country F is a linear function of the share of human capital employed in the progressive sector of the economy (HK_p), where the parameter λ represents for instance the infrastructures and physical capital that it is necessary to support imitation activities. This formulation points out an important link between human capital and the industrial structure (or specialization pattern) of an economy, and the relevance of this for the catch up and development process. We argue that it is not the level of human capital as such that shapes absorptive capacity, but rather the shares of human capital that are employed in different sectors. For any given level of education and human capital, countries with a higher share of workers employed in technologically progressive industries will in general have stronger absorptive capacity than economies in which labor resources are employed in traditional sectors (Saviotti and Pyka, 2008). This idea is particularly relevant when applied to the Latin American context, in which cross-country differences in human capital levels are not substantial, whereas differences in terms of industrial structure and specialization patterns among countries in the region are considerable.[3]

In order to study the dynamic properties of this model, we take the time derivative of equation 1:

$$dG/dt = d(K_L/K_F)/dt = \Delta K_L/K_L - \Delta K_F/K_F \quad (8)$$

Using equations 2 to 6, the dynamics of the technology gap in equation 8 can be expressed as:

$$dG/dt = (\beta_L \bullet RD_L - \beta_F \bullet RD_F) - \varphi\, G \bullet \exp(-G/\delta) \quad (9)$$

This differential equation is solved by imposing the condition:

$$dG/dt = 0 \quad => \quad \beta_L \bullet RD_L - \beta_F \bullet RD_F = \varphi\, G \bullet \exp(-G/\delta) \quad (10)$$

Figure 1 depicts the dynamics of the technology gap and the equilibrium points (resembling figure 1 in Verspagen, 1991). The left-hand side of equation 10 represents the difference ($I_L - I_F$), i.e. the difference between the rate of innovation in the leader and the follower country. Figure 1 denotes this as ΔI, which, as noted above, is a positive constant. The right-hand side of the equation does instead represent the non-linear process of knowledge imitation, which is affected by the size of the gap, the openness of the economy, and its absorptive capacity (i.e. the country's industrial specialization pattern in our formulation). If [$\Delta I < (\varphi \bullet \delta)/e$] (i.e. if the horizontal line measuring the innovation advantage of the leader country is not higher than the maximum of the spillover term), there exist two equilibrium points, A_1 and A_2. The equilibrium point A_1 is stable whereas A_2 is unstable. The reason for this is that when the RHS of equation 10 is greater (lower) than the LHS, the gap tends to decrease (increase). Therefore, countries whose absorptive capacity is too low, lying on the right of point A_2, will not be able to catch up and diverge, whereas national economies above this threshold level will be able to exploit international knowledge spillovers and converge towards the equilibrium point A_1.

[3] As noted below, it is also important to point out that when we analyze the time series properties of these two variables for the case of Latin America (on which our econometric analysis will focus), human capital and industrial structure are cointegrated time series, meaning that the variables move together and follow a similar average growth trend during the investigated time span. This empirical fact represents a further reason to use industrial structure as a variable measuring absorptive capacity, instead of human capital as done in much of the growth empirics literature so far.

< Figure 1 here >

Let us now extend this simple framework to carry out some comparative analysis on the effects of policy shocks on the dynamics of growth and catching up of the follower country. Figure 2 presents this comparative exercise by showing equation 10 for different values of the absorptive capacity parameter δ and/or openness parameter φ (curves A and B) and for differential innovation terms ΔI (horizontal lines ΔI_A and ΔI_C). Focusing only on the stable equilibrium points, the figure outlines four different scenarios.

- The point A is the same stable equilibrium outlined in figure 1 above, and it represents our benchmark scenario in the absence of policy shocks.

- The point B is the equilibrium corresponding to a policy shock that increases the absorptive capacity parameter δ and/or the openness parameter φ, shifting the spillover curve upwards.

- The equilibrium C_A corresponds to a situation in which country F undertakes an innovation policy (e.g. increasing its innovation intensity RD_F, or the productivity of its research sector β_F), which shifts the horizontal line downwards from ΔI_A to ΔI_C.

- The point C_B is the equilibrium corresponding to a combination of the previous cases, i.e. in which country F simultaneously increases its imitation capabilities (through an improved absorptive capacity and/or openness policy) and its innovation ability.

Comparing the level of the technology gap G among these four policy scenarios, it is easy to see that: $G_{CB} < G_{CA} < G_B < G_A$, meaning that the more active the imitation and innovation policies undertaken by a follower country are, the smaller will be the distance between the country and the technological frontier at the end of the catch up process (although the gap will always be positive as long as we assume that $\Delta I > 0$).

Differently from previous related exercises, our main interest is not to analyze the steady state solutions of the model, but rather to focus on the properties of the *transitional dynamics* that catching up countries follow along their development process, and how this is affected by the different policy shocks outlined above. To do this, we study the effects of changes in our policy parameters on the transitional dynamics term dG/dt. The partial derivatives of dG/dt with respect to φ, δ and RD_F outline three main properties.

$$\partial(\Delta K_F/K_F)/\ \partial\varphi = G \bullet \exp\ (-G/\delta) > 0 \quad (11)$$

The first is that an increase in φ (openness policy) leads to an increase in the rate of growth of country F along the transitional dynamics.

$$\partial(\Delta K_F/K_F)/\ \partial\delta = [\varphi\ G^2 \exp\ (-G/\delta)]\ /\ \delta^2 \quad (12)$$

The second is that an increase in δ (shifting resources from traditional to technologically progressive sectors) leads to an increase in the rate of growth of country F along the transitional dynamics.

$$\partial(\Delta K_F/K_F)/\ \partial RD_F = \beta_F > 0 \quad (13)$$

The third property is that an increase in RD_F (through innovation policy) leads to an increase in the rate of growth of country F along the transitional dynamics.

< Figure 2 here >

In short, a policy shock increasing φ, δ or RD_F (openness, structural change or innovation policy) has a positive effect on the growth rate of a catching up economy along the transitional dynamics. These links between policy variables and rates of economic growth during the catch up phase represent the key aspect that our empirical analysis will focus on in a time series context. In turn, these model's properties can be summarized by the following two propositions, which we will test in the empirical part of the paper.

First, we point out that catching up is a complex process, which could be achieved through different policy strategies and following different growth trajectories. The modeling literature has so far focused on a uni-dimensional process, according to which developing economies either catch up or fall behind. To refine and extend this standard approach, we emphasize the existence of different roads and policy strategies to catch up, which is an obvious, though neglected, aspect of the growth and catch up process. Even in a relatively homogenous context as the Latin American region, countries have followed substantially different growth paths, as it will be shown in the empirical part of the paper.

Proposition 1: *Countries follow different growth trajectories depending on the combination of policies they adopt to catch up (openness, structural change and/or innovation policy).*

Table 1 outlines all possible combinations that can be generated by changing the policy parameters of our model. Imitation and innovation policies can be combined in different ways, and each combination determines a specific growth trajectory along the transitional dynamics that characterizes the development path of the economy. Specifically, table 1 points out eight distinct policy strategies, which lead to different growth trajectories.

To consider the effects of different policy strategies on the growth rate of catching up economies, let us suppose that country F undertakes an effort to simultaneously increase both its imitation capability (openness and industrial transformation policies) and innovation ability (i.e. increasing both φ, δ and RD_F), i.e. like the last configuration outlined at the bottom of table 1. The corresponding effect on the growth rate during the transitional dynamics phase would be:

$$[\partial(\Delta K_F/K_F)/\,\partial\varphi] + [\partial(\Delta K_F/K_F)/\,\partial\delta] + [\partial(\Delta K_F/K_F)/\,\partial RD_F] = \Psi \qquad (14)$$

with:

$$\begin{cases} \Psi > \partial(\Delta K_F/K_F)/\,\partial\varphi \\ \Psi > \partial(\Delta K_F/K_F)/\,\partial\delta \\ \Psi > \partial(\Delta K_F/K_F)/\,\partial RD_F \end{cases}$$

Proposition 2: *The combination of imitation policy (openness and industrial structure) and innovation policy leads to a higher rate of growth along the transitional dynamics than either imitation or innovation policy alone.*[4]

[4] Before testing the empirical relevance of this model, it is important to acknowledge one important limitation of it, namely its focus on supply-side mechanisms and the abstraction from demand-side factors. The growth of aggregate demand, and in particular through its export component, may potentially be an important factor that interacts with the technology gap and the supply-side dynamics (e.g. through Kaldor-Verdoorn mechanisms). In the Latin American context, for instance, the commodity boom since 2004 (related to rising demand and prices, as well as Chinese demand for natural resources) spurred exports and economic growth for the later years of our investigation period. In our

< Table 1 here >

4. Data

Our empirical analysis focuses on 18 Latin American economies (listed in Appendix 1). We use time series data (annual observations) for each country for the whole period 1970 to 2010. As noted above, the use of time series data is a neglected aspect in the field of innovation and growth, and does therefore represent an important avenue for new research. However, the drawback of the time series approach is of course that time series data for a sufficiently long period of time are only available for some variables. Many other indicators of potential interest are only available for shorter periods of time (e.g. since the 1980s or 1990s), and cannot therefore be analyzed within a time series econometric setting. This is also the limitation and trade-off that we face in our study. The variables that we consider are available for the whole period 1970-2010, and this 40-year span is indeed the minimum period length that we can consider in order to have sufficient degrees of freedom and get sensible econometric results. By contrast, several other indicators that are often considered in cross-country studies of innovation and growth are only available for a shorter period of time, and this prevents us from using them in our time series study. The variables that we use are listed as follows.

GDP per capita: GDP per capita, purchase power parity, derived from growth rates of overall consumption, government consumption and investment, at 2005 constant prices (source: Penn World Table 7.0; Heston et al., 2011).[5] This is the dependent variable in our estimations. We use this variable as a measure of labor productivity, and use it to calculate the growth rate of Latin American countries over the period 1970-2010 (i.e. a proxy for the variable $\Delta K_F/K_F$ of the model in section 3).

Inward FDI: Inward flow of foreign direct investments as a percentage of GDP (source: United Nations Conference on Trade and Development, 2012). We use this variable as a measure of the openness of the economy. This corresponds to the parameter φ of the theoretical model, which determines the potential spillovers that a follower country can exploit if it has a sufficient level of

econometric tests, these demand side effects will simply be controlled for through country-specific dummies for some of the years; however, these mechanisms are important and should be included in future work to refine this type of model.

[5] Population data is from the World Bank Data Centre (World Bank, 2012a)

absorptive capacity. The reason we have chosen FDI as a measure of the potential spillovers is twofold. First, from a conceptual point of view, inwards flows of FDI represent a potentially important channel through which domestic companies can learn and adopt foreign advanced technologies and organizational practices from MNEs. As pointed out in the literature, the potential gains from FDI are not automatically realized, but require the domestic economy to have a sufficient level of absorptive capacity and imitation capability. Second, in the specific case of Latin America, FDI have traditionally played a relevant role, e.g. due to the proximity of the North American region. During the last four decades, FDI have grown considerably in most Latin American economies, and now account up to 10% of GDP for some of the smaller open economies in the region. By contrast, FDI in other fast catching up economies in East Asia (e.g. Korea and previously Japan) has been much less relevant (accounting now around 1% of GDP only). Given the great relevance and size of FDI in Latin America vis-à-vis other catching up economies in the world, it is thus reasonable to use this as an indicator of these countries' spillover potential.[6]

Industrial structure: In order to consider the substantial diversity in industrial structure and specialization patterns across countries in Latin America, we use three different indicators:

- **Services:** value added of the Service sector as percentage of GDP (World Bank, 2012b).
- **Manufacturing**: value added of industrial sectors as percentage of GDP (World Bank, 2012c).
- **Natural Resources**: rents coming from oil, natural gas, coal mineral and forest as percentage of GDP (World Bank, 2012d).

As previously explained in section 3, in our theoretical framework the industrial structure dimension represents the factor that shapes the absorptive capacity, or imitation capability, of a country (parameter δ, see equation 7 above). Our idea is that countries with a higher share of resources employed in technologically progressive industries – such as services, manufacturing and resource-based sectors – will in general have stronger absorptive capacity than economies in which labor

[6] In addition to the FDI indicator, we could have also used a variable measuring the openness of the economy through export and import activities (indicators that are available in time series for the period 1970-2010). We have verified in our time series dataset that these three variables are panel cointegrated, i.e. they move together and follow a similar average growth trend during the last four decades. This means that the results that we have obtained with the FDI variable (presented in the next section) do arguably resemble closely those that we would have obtained by using the exports or imports variables as indicators of potential spillovers.

resources are employed in traditional sectors such as agriculture. Within the Latin American context, the ability of countries to upgrade their industrial structure and shift resources from traditional to progressive and more dynamic industries is a crucial factor to explain their imitation capabilities.

As discussed in section 3, a variable that is often considered as a proxy for absorptive capacity in growth empirics is human capital. Some of the standard indicators of human capital, such as literacy rates and enrollment ratios are available for most Latin American countries for the whole period under investigation, so we could in principle have used human capital, rather than industrial structure, as a measure of absorptive capacity. However, we have chosen to focus on the industrial structure dimension since this is a crucial aspect that is at the centre of policy debates in Latin America. During the period 1970-2010, Latin American countries have adopted different strategies regarding their specialization patterns and industrial policies. Hence, by focusing on this dimension, we intend to catch this important source of variety in development strategies across the region. Further, from an empirical point of view, it is also important to point out that when we analyze the time series properties of these variables for the whole panel of Latin American economies, human capital and the industrial structure indicators turn out to be cointegrated time series, meaning that these variables move together and follow a similar average growth trend in the long-run. All in all, both conceptually and empirically, it is therefore reasonable to measure absorptive capacity by using indicators of countries' industrial structure (rather than human capital as it is commonly done in the literature).

Innovation: Number of patents registered at the USPTO per million people (U.S. Patent and Trademark Office, 2011). This is used as a measure of the variable I_F of our model (see equation 5). It is important to acknowledge the possible limitations of patents as indicator of innovation, particularly in the context of developing economies. At the same time, however, this is indeed the best indicator that is available for a time series study like the one we are presenting in this paper. Other commonly used indicators of innovation, and particularly R&D investments, are available for a much shorter period of time for most Latin American countries, and we are therefore forced to disregard them due to the restrictions imposed by our time series analysis in terms of degrees of freedom and minimum number of observations that are needed to run the cointegration analysis (see next section). By using patents, our results on the innovation dimension of the model should therefore be interpreted with some caution, and compared with the results of other previous studies that, focusing on a shorter time period, were able to use a broader set of innovation indicators.

In addition to this basic set of variables, all estimations also include a control variable measuring the institutional quality of each country, defined as such: "Civil Liberties, people's basic freedoms without interference from the state" (source: Freedom House, 2012).

5. Methods

The econometric analysis investigates the time series properties of the model presented in section 3, in order to estimate the effects of changes in imitation and innovation policies, on the one hand, and the growth rate of Latin American economies in the period 1970-2010, on the other. We make use of time series *cointegration analysis*, in the system approach developed by Johansen, and apply it to each of the 18 Latin American countries individually.

The time series cointegration approach analyses the relationships between non-stationary time series by looking both at their long-run equilibrium relationship as well as the process of short-run adjustment (Engle and Granger, 1987). More precisely, if two or more variables are integrated of the same order (e.g. they are both I(1) series), there might exist a linear combination of them whose residuals are stationary – in other words the two series are not stationary but one (or more) linear combination of them is.[7] If this is the case, the variables are said to be *cointegrated*. The Johansen cointegration method we use has one major characteristic that makes it suitable for analyzing the time series properties of the model described in section 3. Based on a Vector Error Correction (VEC) econometric specification, the approach makes it possible to distinguish between long-run and short-run structure, and hence to identify the long-run causal effect of each explanatory variable (policy parameter) on a country's growth rate along its development path. This is the crucial task that our analysis seeks to achieve.

The method proceeds in three steps. First, it investigates the presence of unit roots in the variables. This can be done through two different tests: the Augmented Dickey Fuller (ADF) test and the Phillips and Perron (PP) test . Secondly, it studies the existence of cointegration relationships among the variables of interest. For doing that, we specify a VEC model comprising K variables:

[7] It is also possible to find cointegration between I(1) and I(0) series. Some authors argue that the restriction of having only I(1) variables within the estimation is unnecessary: as long as there exists a stable combination of the variables, cointegration techniques can be used. On this point, see Juselius (2006) and Loayza and Ranciere (2005)

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \nu + \eta t + \varepsilon_t \quad (15)$$

where Y_t is the vector that contains the *K* variables of the model, Π is the matrix that contains the Error Correction Term (ECT), Γ_i are the matrices related to the transitory effects (part of the short-term structure), *p* is the lag order, ν and ηt are the deterministic components, and ε_t are independently and identically distributed (i.i.d.) errors with mean zero and a finite variance σ^2. Engle and Granger (1987) show that if variables are cointegrated, the Π matrix in equation 15 should have a reduced rank *r*, such that $K > r > 0$. Johansen (1991; 1995) cointegration rank test seeks to determine those *r* cointegrating relationships by adopting Trace Test and Maximun Likelihood specifications. Under the null of finding an additional cointegrating relation, it uses a recursive test starting with $r = 0$ until the first rejection is encountered.

The third and crucial step is the estimation and identification of the model. The ECT term comprises all the information about the long run structure of the system. The Π matrix can be expressed as:

$$\Pi = \alpha\beta' \quad (16)$$

where β is a matrix with the cointegrating relations – representing the long-run equilibrium relationships – whereas α represents the set of long-run Granger causality effects, measuring how variables react to deviations from the long-run equilibrium path (Granger, 1969). Specifically, Johansen approach allows us to determine two distinct types of causality. On the one hand, we can analyze *short-run causality* by using the Γ_i matrices to investigate how variables react to short term external shocks (i.e. the effect of one variable change on another variable change). On the other hand, for our study it is more interesting to investigate *long-run causality* patterns, namely how variables react to deviations from the long-run equilibrium β. Hence, we will focus on the estimation results for the α matrix, which represents the way variables react when an exogenous shock (e.g. a policy change) tends to move the system out of its long-run equilibrium path.

To illustrate this further, consider the system of equations represented in (15) and focus on the equation that expresses the growth rate of a country (ΔK_t) as a function of the three main policy variables outlined in our theoretical model: openness (φ), absorptive capacity (δ) and innovation (I_F). This can be expressed as:

$$\Delta K_t = \alpha_1(K_{t-1} - \theta_1 \varphi_{t-1}) + \alpha_2(K_{t-1} - \theta_2 \delta_{t-1}) + \alpha_3(K_{t-1} - \theta_3 I_{t-1}) + \sum_j(X\Delta\varphi_{t-j}) + \sum_j(W\Delta\delta_{t-j}) + \sum_j(Z\Delta I_{t-j}) + + \nu + \eta t + \varepsilon_t \quad (17)$$

where the vector $[\theta_1; \theta_2; \theta_3]$ represents the long-run cointegration (equilibrium) relationships, and the vector $[\alpha_1; \alpha_2; \alpha_3]$ provides a measure of the extent to which the growth rate of the economy responds to a (level) change in openness, industrial structure or innovation activity (e.g. due to a policy change). As explained in section 3, our theoretical model postulates a positive relationship between each of these variables, on the one hand, and the rate of growth of a catching up country along its transitional dynamics process. By looking at the sign and significance of the three coefficients α_1, α_2, and α_3, we are therefore able to identify the specific policy strategy and growth trajectory followed by each Latin American economy over the period 1970-2010.[8] Specifically, a *positive* value for the estimated coefficient α_1 (or α_2, or α_3) for country *i* would indicate that a 1% change in the openness of that country (or in its industrial structure, or innovation activity) has a permanent α_1% influence on the rate of growth of its GDP per capita over this four-decade period of its transitional dynamics. By contrast, a *negative* value of the coefficient α_1 (or α_2, or α_3) would imply that changes in the country's openness (industrial structure or innovation activity) have had an equilibrium correcting effect, but no permanent impact on the growth rate of the economy along its transition path.

There are two more methodological aspects that it is worth to point out. During the last forty years, Latin American economies have undergone important economic and political transformations, and many of them have sometimes experienced episodes of crises and stability. These structural breaks have important effects on the aggregate time series dynamics, and must therefore be considered in the econometric analysis. The inclusion of *permanent* time dummies, for long-lasting external shocks, and *temporary* time dummies, for shocks with a shorter effect, allows us to control for the presence of these exogenous events in the empirical exercise. Besides the time dummies, the deterministic

[8] Significance of these coefficients can be assessed by applying a Wald Test with a Chi-Squared statistic distribution. Reliability of the models could be evaluated by observing stationary cointegrating relations, testing that the roots of the companion matrix is smaller than one and that errors are uncorrelated and normally distributed.

component of the model could also incorporate time series data: we have added an indicator measuring the institutional quality of each country as exogenous control variable in the model.[9]
Based on this econometric methodology, we have specified three models (one for each of the three indicators of industrial structure) for each Latin American country. In total, we have evaluated and compared 54 different models specifications and selected those that exhibit the clearest patterns.

6. Results

As outlined in the previous section, our empirical methodology follows three steps: the first two are preliminary phases that are necessary in order to check that it is appropriate to use a cointegration approach for the time series data of Latin American economies, whereas the third step is the estimation of the long-run determinants of economic growth in the region, which is the core phase of our research.
First, it is necessary to verify the presence of unit roots in all of the empirical models. We applied ADF and PP tests (including constants and trends in the regressions) and found that *I(1)* processes are present in the time series of Latin American economies in the period 1970-2010. Tables 2 and 3 report the results of these unit root tests. Next we checked for cointegration by applying the Johansen rank test. We considered the existence of structural breaks in the data by adding year dummies (see Appendix 2 for the full list of time dummies we used). On average, we have identified five permanent shocks for each economy: this indicates the substantial instability that has characterized the region over this four-decade period (Bulmer-Thomas et al., 2006; Ocampo and Ros, 2011). Table 4 shows the results of rank tests. We find a value $r > 0$ in all of the models, so there is no evidence to reject cointegration.[10] These tests also allow us to choose the rank of each model, an important decision that determines the number of parameters that will describe our VEC models.

< Tables 2, 3 and 4 here >

[9] The decision of inserting this institutional variable as an *exogenous* factor is based on a previous study (Castellacci and Natera, 2013), in which we noticed that institutional variables move at a different pace than techno-economic variables, so that in a time series context it is appropriate to assume that the former affect the latter but not *vice versa*.

[10] Only the results for some selected models are reported in table 4. Note also that we have used different deterministic components for each model and each country, depending on the nature of the time series data for each national economy.

The third and crucial step in the analysis is the estimation of the VEC model, which relates the dynamics of GDP per capita, on the one hand, and our explanatory variables measuring openness, industrial structure and innovation, on the other. In order to have comparable models across countries, we have imposed restrictions on the β vector, in which GDP per capita is the main reference (dependent variable) and the behavior of the other variables adapts accordingly.[11] Once the β vector has been identified, we are able to proceed with the analysis of the α matrix, that contains our parameters of interest measuring the effect of changes in absorptive capacity and innovation on the growth rate of GDP per capita (see equation 17 in the previous section).

Table 5 shows the results of the VEC estimations for some selected models, reporting the α_i coefficients for each country along with their significance levels (between brackets). As explained in the previous section, we focus our attention on estimated coefficients that turn out to be *positive* (see the coefficients reported in bold in table 5). Specifically, a positive value for the estimated coefficient α_1 (or α_2, or α_3) for country *i* would indicate that an increase in the openness of that country (or in its industrial structure, or innovation activity) has led to a permanent α_1% increase in the rate of growth of its GDP per capita over this four-decade period. On the other hand, a *negative* value of the estimated coefficient α_1 (or α_2, or α_3) would simply imply that changes in the country's openness (industrial structure or innovation activity) have not led to a higher growth rate of the economy along its transition path, and we will therefore disregard them in our discussion of the results. In short, table 5 reports time series evidence that it is useful to identify the specific policy strategy and growth trajectory followed by each Latin American economy over the period 1970-2010.

< Table 5 here >

An overview of the results confirms our general hypothesis that the three major dimensions investigated in this analysis have had different impacts on Latin American countries. Openness (FDI) has increased substantially throughout the whole region, but according to our time series evidence

[11] The specification of a cointegration model entails an iterative process. The identification of the long-run and short-run structure could imply changes in the whole model. Further, reliability tests could also imply that some of the models should be re-specified or even disregarded. In our analysis, in particular, we could not set stable models for Bolivia (Industrial Production and Natural Resources), Costa Rica (Natural Resources), Ecuador (Services and Natural Resources), Guatemala (Services and Natural Resources), Mexico (Services) and Peru (Natural Resources). Furthermore, we have had to exclude Paraguay and Uruguay from the country sample because of reliability issues in the estimation of these models.

inwards FDI have led to a permanent increase in the GDP per capita growth rate only in five of the countries in the sample (Brazil, Costa Rica, Ecuador, Nicaragua, Peru).

Changes in the industrial structure have had a positive impact on economic growth in eight Latin American economies, with the strongest estimated impacts in Mexico and Cuba. This general result does however contain three distinct patterns. Some of these countries have experienced a process of structural change towards the manufacturing sectors (e.g. Brazil, Colombia); others have increased their production shares in natural resource-based activities (Argentina, Guatemala, Mexico); and only one economy, El Salvador, has sustained its growth rate by shifting labor resources to the service sectors (e.g. financial services).

Thirdly, the innovation variable does also turn out to be important in the VEC results. For seven out of 18 Latin American countries, changes in innovation performance (measured by patents) have had a positive effect on the rate of growth of GDP per capita. The strongest estimated impact is for the time series of Chile and the Dominican Republic. This is an interesting finding: despite the fact that industrial and technology policies have been quite low on the policy agenda of most Latin American countries during the period 1970-2010, the relatively low investments in innovative activities are positively related to the (sluggish) income per capita growth in the region. This confirms the potentially crucial role of technological capability building for catching up economies in Latin America, and suggests that public policy efforts to increase the innovation performance of business firms do matter for economic development, and should be strengthened substantially in the future.

Besides looking at the effects of these three dimensions separately, it is also important to consider their combination, i.e. the specific policy strategy or mix that each Latin American country has adopted, and how this has shaped its growth performance. Table 6 presents a summary of the VEC estimation results (taking into account all possible model specifications that we have run). Based on the VEC results that we have obtained from this exercise, it is evident that Latin American countries have followed different paths. Notice that table 6 can be directly compared to table 1 (section 3), which outlined the different policy strategies and growth trajectories that could be expected on the basis of our theoretical model.

For Bolivia we find that none of the three explanatory factors pointed out in the model has had a positive effect (i.e. a long-term impact) on the growth rate of the economy. Peru, Ecuador and Nicaragua show a positive effect from FDI activities. For other countries, structural changes and industrial transformations have been the main driving forces of economic development, specifically in services (El Salvador), manufacturing (Colombia) and natural resources (Argentina, Mexico, Guatemala and Honduras). The Venezuelan growth trajectory is based on a combination of inwards FDI and resource-based activities. All of the countries pointed out here, despite their different policy strategies, have on the whole had a stagnant dynamics in the period, with an average annual growth rate of GDP per capita lower than 2%.

In contrast, there are other countries that have had an above average performance within the region (growth rate above 2%). The specific characteristic of these economies, and the factor arguably explaining their slightly more dynamic trajectory, is innovation. Specifically, for Chile and Panama, we find that innovation is one of the main factors that have led to a permanent increase in the growth rate of GDP per capita. Both Chile and Panama had a relatively low level of patents per capita at the beginning of the period, but both countries experienced a more dynamic performance than other countries in the region between 1970 and 2010. In Chile, these technological improvements can partly be explained by R&D and capital investments related to its export-oriented natural resource sector, whereas in Panama a great majority of the new patents produced in the period are related to the activity of foreign MNEs from the US and other advanced countries.

Results for Dominican Republic, Cuba and Trinidad and Tobago, the Caribbean economies in our sample, show a trajectory based on a combination of innovation and industrial transformation. Interestingly, no Latin American country shows evidence of combining inward FDI and innovation. Finally, there are two countries that exhibit a strategy that combines together all three growth factors (inward FDI, industrial transformation and innovation): Brazil and Costa Rica are, according to our VEC estimation results, the two economies with such a mixed strategy. On average for the entire time span considered here, both Brazil and Costa Rica have experienced a positive growth performance *vis-à-vis* several other countries in the region (average growth rate above 2%), although their economic performance is arguably more questionable when compared to the fast catching up economies in East Asia.

On the whole, this clustering exercise should be taken with caution. Due to some differences in the results across model specifications, it is not easy to find common patterns among these economies, which indeed feature different structural characteristics. However, the purpose here is not to point out a thorough taxonomy of Latin American economies based on their long-run growth patterns. Rather, our exercise provides evidence that corroborates the theoretical framework and main propositions that we previously pointed out in section 3, and shows the large variety of development paths across Latin America.

The general result highlighted by our empirical analysis is twofold. First, as argued by Proposition 1, the Latin American case clearly illustrates that developing countries follow different growth trajectories depending on the combination of policies they adopt to catch up (openness, industrial transformation and/or innovation policy). Secondly, there is a clear correspondence between policy strategies and growth performance. As postulated by Proposition 2, the combination of imitation policy (openness and industrial transformation) and innovation policy (as in groups 5 to 8) leads to a higher rate of growth along the transitional dynamics than imitation policy alone (as in groups 1 to 4).

< Table 6 here>

7. Conclusions

The paper has carried out an analysis of long-run development paths in Latin America in the period 1970-2010. We have shown that economies in the region have responded differently to the opportunities and challenges presented by the globalization era and the related new market-led economic model. Specifically, we have focused on three main dimensions – openness, industrial structure and innovation – and analyzed how changes in these factors, and the specific combination of them adopted by each country, have affected the growth of income per capita of Latin American economies.

The first part of the paper has presented a simple theoretical model of growth and catching up, based upon, and extending further, Verpagen's (1991) model. Our theoretical analysis has focused on the properties of the transitional dynamics of the model, in order to illustrate the extent to which policy changes that affect a country's imitation capability and its innovation ability may lead to a permanent increase in the growth rate of the catching up economy over its transitional dynamics path. The second part of the paper has investigated the empirical evidence of this model by carrying out a time series analysis of 18 Latin American countries. We have made use of Johansen cointegration approach, which makes it possible to disentangle short-run and long-run causality effects, and it is then well-suited to estimate the effects of policy changes in terms of openness, industrial structure and innovation on the rate of income per capita growth.

This analysis leads to two main results. First, we have shown that Latin American countries have followed different growth trajectories depending on the combination of policies they have adopted to catch up (openness, industrial transformation and/or innovation policy). Secondly, we have found a clear correspondence between policy strategies, on the one hand, and growth performance, on the other. Countries that have managed to combine imitation policy and innovation policy have experienced a higher rate of growth in the period 1970-2010 than those economies that have only made efforts to improve their imitation capability.

These results have two major implications. The first relates to the literature on innovation and economic growth. Schumpeterian research has extensively investigated the role of innovation and international knowledge diffusion for the process of economic growth and development. The literature has so far greatly emphasized the cross-country comparative dimension of this process, e.g. by carrying out cross-country econometric studies of empirical data, or by studying the steady state properties of growth models. Our paper has instead focused on the time series dimension, which has so far been substantially neglected in this field. We argue that this is a major avenue for future research on innovation and growth. On the one hand, theoretical analyses should focus much more on the transitional dynamics properties of growth models rather than their steady state outcomes: the steady state is a fiction while transitional dynamics is all that matters, since it describes the path effectively followed by countries during their development process. On the other hand, time series econometrics is useful to shed further light on the different policy strategies followed by developing economies, and how these affect their growth trajectories. It is an important methodological approach that can extend and complement standard methodologies based on cross-country and panel data analyses, and provide a more in-depth analysis of the heterogeneity issue.

The second implication refers to economic policy. The time span considered in this paper comprises a sharp rupture with the previous era of State-led industrialization, and the introduction of a new economic model according to which free market mechanisms represent the major force driving economic development. However, Latin American economies have responded differently to the opportunities and challenges of globalization, adopting different policy strategies and following distinct growth trajectories. Some of the countries in the region have more actively embraced the new market-oriented model, whereas others opted for a more cautious mixed model, which built on the path of the import-substitution approach. One of the findings of our paper is that those countries that have been able to shift to the new market-led model while at the same also maintaining an active role for the State in industrial and innovation policies have experienced a more rapid process of industrialization and currently face better prospects for further economic growth in the future. The take home message of the Schumpeterian development literature is that it is crucial to combine imitation and innovation policies in order to catch up with the frontier, and that public policies that support capability building and the exploitation of technological opportunities play a key role for developing economies.

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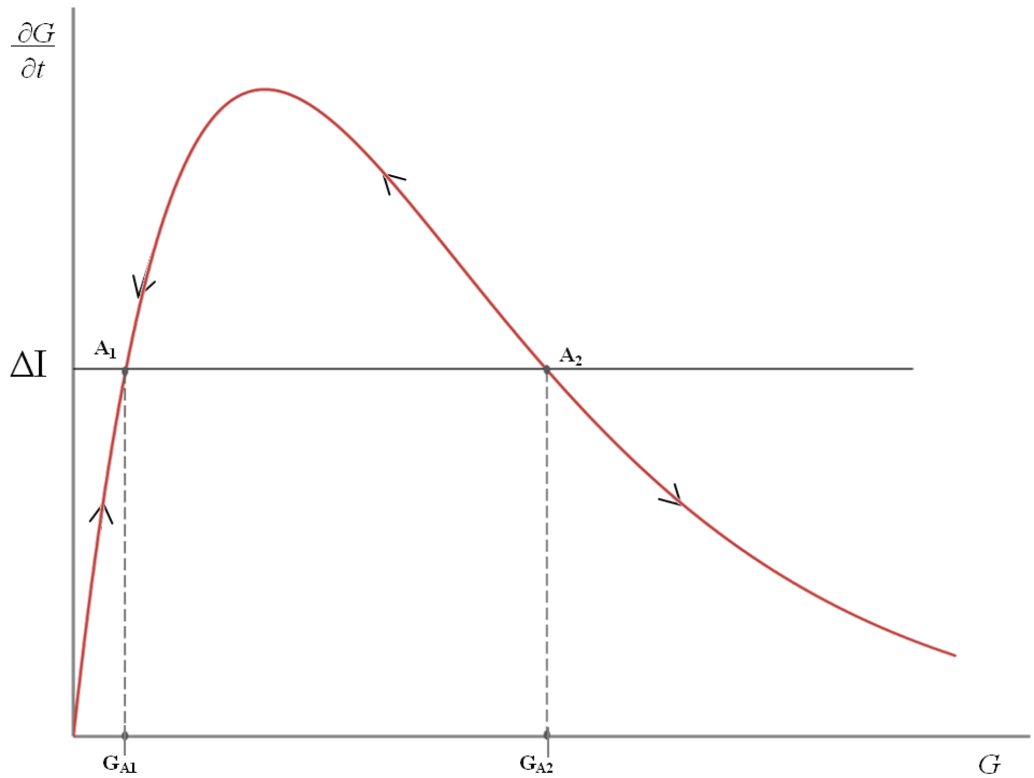
URL http://data.worldbank.org/indicator/NV.IND.TOTL.ZS/countries.

World Bank (2012d): "Total natural resources rents (% of GDP)",
URL http://data.worldbank.org/indicator/NY.GDP.TOTL.RT.ZS.

Figure 1: The dynamics of the knowledge gap



(source: Verspagen, 1991)

Figure 2: Effects of policy changes on the dynamics of the knowledge gap

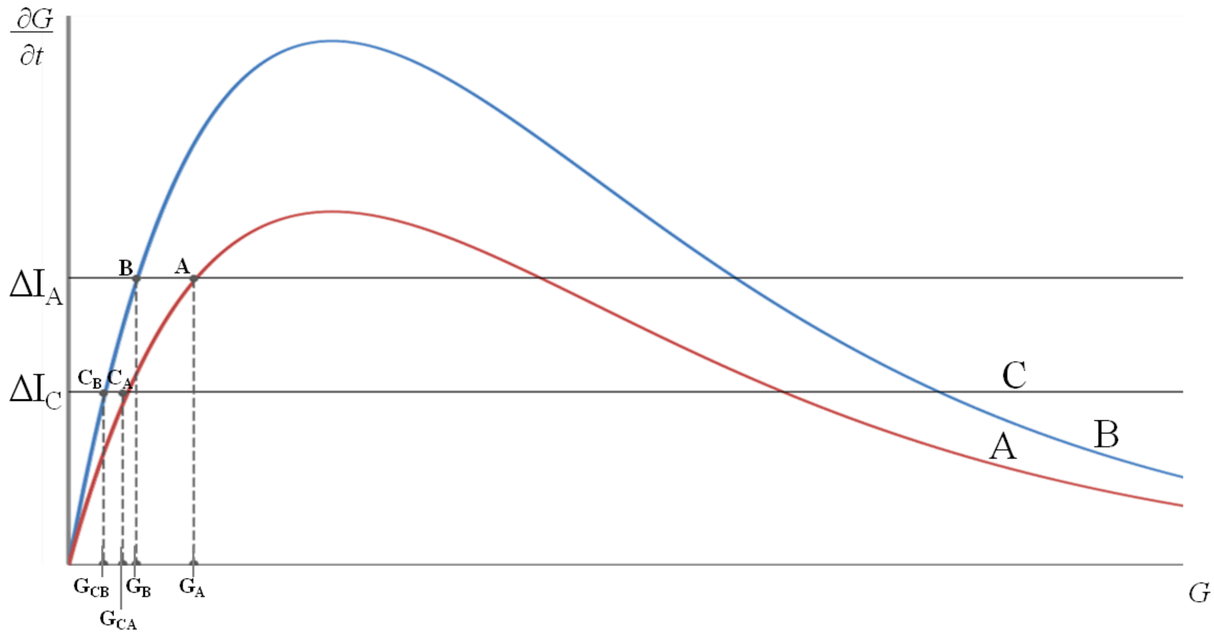


Table 1: Summary of model outcomes: Different policy strategies and growth trajectories

Policy strategy	Openness (φ↑)	Industrial structure (δ↑)	Innovation (RD_F↑)	Equilibrium point in figure 2	Growth rate on the transition path
No policy change along the transition path	No	No	No	A	Low
Openness policy	Yes	No	No	B	Medium
Industrial policy	No	Yes	No	B	Medium
Openness and industrial policy	Yes	Yes	No	B	Medium
Innovation policy	No	No	Yes	C_A	Medium
Innovation and openness policy	Yes	No	Yes	C_B	High
Innovation and industrial policy	No	Yes	Yes	C_B	High
Innovation, openness and industrial policy	Yes	Yes	Yes	C_B	High

Table 2: ADF Unit root tests

	Level Data				First Difference Data			
	GDP	**Innovation**	**Industrial Structure**	**Inward FDI**	**GDP**	**Innovation**	**Industrial Structure**	**Inward FDI**
Argentina	-0.59	-2.424	-3.824**	-4.397***	-3.382*	-4.575***	-2.059	-1.78
Bolivia	-1.672	-	-2.063	-2.273	-2.002	-2.345	-2.495	-3.46*
Brazil	-3.878**	-3.895**	-2.049	-1.934	-5.4***	-7.749***	-4.907***	-6.764***
Colombia	-3.166	-4.686***	-3.59**	-4.161**	-2.702	-	-6.392***	-6.943***
Costa Rica	-0.892	-5.552***	-3.839**	-2.933	-2.868	-9.346***	-5.921***	-5.484***
Cuba	-1.664	-3.911**	-2.218	-4.636***	-4.29***	-6.535***	-3.235*	-6.513***
Chile	-3.12	-4.697***	-4.148**	-4.225***	-5.874***	-7.722***	-5.186***	-6.847***
Dominican Republic	-1.449	-5.877***	-2.03	-3.755**	-3.622**	-7.085***	-5.092***	-4.027**
Ecuador	-2.894	-5.926***	-3.599**	-3.139	-4.979***	-7.769***	-5.425***	-8.198***
El Salvador	-2.198	-4.657***	-5.456***	-4.753***	-4.829***	-9.54***	-10.211***	-7.421***
Honduras	-2.647	-5.683***	-3.471*	-1.905	-4.964***	-9.759***	-5.159***	-4.936***
Guatemala	-2.279	-6.208***	-3.539**	-5.45***	-2.786	-6.33***	-6.307***	-6.96***
Mexico	-2.513	-2.101	-2.962	-2.909	-6.049***	-7.782***	-4.94***	-7.298***
Nicaragua	-1.605	-	-3.493*	-2.424	-2.994	-9.7***	-6.345***	-7.011***
Panama	-2.022	-6.115***	-2.791	-3.543**	-4.983***	-10.792***	-6.453***	-7.596***
Peru	-2.097	-6.241***	-2.412	-3.532**	-1.676	-	-5.725***	-7.346***
Trinidad and Tobago	-1.029	-2.993	-2.333	-2.711	-2.729	-3.915**	-9.182***	-6.882***
Venezuela	-0.213	-5.03***	-9.414***	-3.631**	-3.844**	-5.007***	-5.335***	-8.455***

ADF statistics are reported. Test includes constants and trends in the regression.
Significance levels for rejection of the null hypothesis of unit root presence at 1% ***, 5% **, 10% *.

Table 3: PP Unit root tests

	Level Data				First Difference Data			
	GDP	Innovation	Industrial Structure	Inward FDI	GDP	Innovation	Industrial Structure	Inward FDI
Argentina	-0.754	-2.364	-3.745**	-4.411***	-1.951	-4.55***	-2.029	-1.851
Bolivia	-1.236	-	-2.31	-2.273	-2.186	-2.401	-2.633	-3.454*
Brazil	-3.679**	-3.861**	-2.051	-2.203	-5.372***	-7.885***	-4.812***	-12.063***
Colombia	-2.501	-4.617***	-1.861	-4.015**	-2.624	-	-6.409***	-6.903***
Costa Rica	-0.844	-5.565***	-3.604**	-2.881	-4.316***	-10.063***	-5.972***	-5.489***
Cuba	-1.643	-3.689**	-1.817	-7.918***	-4.303***	-16.836***	-6.442***	-9.94***
Chile	-2.289	-4.817***	-4.158**	-4.205**	-3.58**	-12.251***	-10.647***	-7.829***
Dominican Republic	-1.449	-5.902***	-3.477*	-3.727**	-3.676**	-17.428***	-5.031***	-18.072***
Ecuador	-2.863	-6.045***	-3.853**	-2.879	-4.991***	-22.533***	-5.497***	-15.391***
El Salvador	-1.421	-4.669***	-3.737**	-4.743***	-4.555***	-17.006***	-10.08***	-9.181***
Honduras	-2.698	-5.708***	-2.81	-2.884	-5.055***	-28.395***	-5.201***	-8.712***
Guatemala	-2.129	-6.272***	-3.518*	-5.428***	-2.773	-13.71***	-7.339***	-14.293***
Mexico	-2.513	-2.101	-2.962	-2.909	-6.048***	-13.672***	-5.695***	-7.796***
Nicaragua	-1.581	-	-2.239	-2.325	-2.447	-23.972***	-9.121***	-20.145***
Panama	-1.831	-6.167***	-1.746	-3.462*	-4.983***	-10.792***	-6.453***	-7.596***
Peru	-2.098	-5.571***	-2.411	-3.522*	-6.609***	-	-8.989***	-8.078***
Trinidad and Tobago	-0.469	-5.439***	-2.357	-2.771	-4.8***	-16.352***	-11.121***	-15.551***
Venezuela	-0.832	-5.07***	-7.431***	-2.624	-3.844**	-18.733***	-5.269***	-9.133***

PP statistics are reported. Test includes constants and trends in the regression.
Significance levels for rejection of the null hypothesis of unit root presence at 1% ***, 5% **, 10% *.

Table 4: Cointegration Rank tests

Country	Cointegration Rank	Eigenvalue	Statistic	Critical Value
Argentina	4	0.646515	40.55666*	44.4972
Bolivia	2	0.744867	53.27286*	56.70519
Brazil	4	0.578314	33.67626*	37.16359
Colombia	5	0.635025	39.30917*	43.41977
Costa Rica	4	0.608973	102.4784**	107.3466
Cuba	4	0.556854	31.7404*	38.33101
Chile	3	0.629525	114.6433**	117.7082
Dominican Republic	5	0.491200	26.35228*	38.33101
Ecuador	3	0.705373	47.65971**	49.58633
El Salvador	3	0.661082	42.19788**	43.41977
Honduras	4	0.472108	56.22696*	63.8761
Guatemala	4	0.613895	37.11423**	38.33101
Mexico	4	0.659618	42.02976*	50.59985
Nicaragua	3	0.591020	34.86947**	37.16359
Panama	5	0.542737	87.24515*	107.3466
Peru	3	0.654095	106.9985**	107.3466
Trinidad and Tobago	3	0.546955	78.79105**	79.34145
Venezuela	3	0.587682	100.0661*	117.7082

Significance levels for rejection of the null hypothesis of finding another cointegrating relation at 1% ***, 5% **, 10% *.

Table 5: Long-run Causality: VEC estimation results (selected models)

	Specification	Industrial structure	Inward FDI	Innovation
Argentina	Natural resources	**0.121665*** **	-0.210448***	-0.094763
		[7.982994]	[17.79498]	[1.781303]
Bolivia	Services	0.021519	-0.016766***	-
		[0.224313]	[8.894036]	-
Brazil	Manufacturing	**0.538939** **	**0.09898* **	**0.015187* **
		[5.532527]	[3.419471]	[3.224582]
Chile	Services	-3.889594***	-0.037285	**3.280536*** **
		[8.873596]	[1.034816]	[7.358538]
Colombia	Manufacturing	**0.235119*** **	-0.214947**	0.049839
		[15.9551]	[5.546374]	[1.06647]
Costa Rica	Services	**0.018769* **	**0.727968*** **	**0.065426** **
		[3.45078]	[17.04856]	[6.14068]
Cuba	Manufacturing	**0.9324** **	-0.013005	0.035388
		[5.703126]	[0.006341]	[1.259175]
Dominican Republic	Services	0.955652	-1.237764	**4.103316*** **
		[1.039793]	[0.510991]	[11.46506]
Ecuador	Natural resources	-1.533394***	**0.975586*** **	0.113227
		[17.41643]	[9.052073]	[1.096077]
El Salvador	Services	**0.020798*** **	-0.263562***	-0.13116*
		[8.987157]	[6.907432]	[2.749086]
Guatemala	Natural resources	**0.255708*** **	-0.013453**	-0.795252***
		[24.21908]	[5.131703]	[39.01117]
Honduras	Natural resources	0.035163	-0.147183*	-0.041747*
		[0.243395]	[3.18726]	[3.505973]
Mexico	Natural resources	**1.417296*** **	-0.004168	**0.092259* **
		[25.52489]	[0.010498]	[2.925049]
Nicaragua	Natural resources	-0.61709***	**1.291423*** **	-
		[10.01845]	[62.43663]	-
Panama	Natural resources	-0.414099**	-0.971683***	**0.077899** **
		[4.423823]	[11.30999]	[6.253894]
Peru	Manufacturing	-0.349571	**0.722861** **	-0.525339**
		[2.069322]	[5.595606]	[5.350308]
Trinidad and Tobago	Manufacturing	0.141095	0.0118	**0.054081*** **
		[2.126461]	[0.280168]	[16.68752]

Venezuela	Natural resources	**0.245535***	**0.296107*****	-0.405049**
		[3.41117]	[6.755397]	[5.587171]

Positive and significant coefficients in bold. Significance levels at 1% ***, 5% **, 10% *. Chi- Squared statistic in brackets.

Table 6: Summary of VEC estimation results:
Heterogeneity of policy strategies and growth trajectories in Latin America

Group	Development path	Countries	Growth rate (average annual)	
1	No effect of policy changes	Bolivia	< 2%	**Below average performers**
2	FDI-driven	Peru, Ecuador, Nicaragua	< 2%	
3A	Industrial transformation: Services	El Salvador	< 2%	
3B	Industrial transformation: Manufacturing	Colombia	< 2%	
3C	Industrial transformation: Natural resources	Argentina, Mexico, Guatemala, Honduras	< 2%	
4	FDI and industrial transformation	Venezuela	< 2%	
5	Innovation-driven	Chile, Panama	> 2%	**Above average performers**
6	Innovation- and FDI-driven	-	> 2%	
7	Innovation and industrial transformation	Dominican Republic, Cuba, Trinidad & Tobago	> 2%	
8	Innovation, FDI and industrial transformation	Brazil, Costa Rica	> 2%	

Appendix 1: List of countries

Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru, Trinidad and Tobago and Venezuela.

Appendix 2: Time dummies

Table A2.1: Time dummies included in the selected models

Country	Permanent dummies	Temporary dummies
Argentina	1980, 1985, 1990, 1999, 2002, 2005	-
Bolivia	1974, 1977, 1986, 1994, 1999, 2002, 2005	-
Brazil	1981, 1985, 1990, 1994, 1999	2003
Colombia	1974, 1977, 1980, 1985, 1990, 1994, 1999	1997
Costa Rica	1975, 1980, 1991, 1996, 2000, 2008	-
Cuba	1980, 1985, 1990, 1994, 2000	1996, 1999
Chile	1975, 1981, 1988, 1992, 1999	-
Dominican Republic	1975, 1980, 1987, 1991, 1999, 2003	-
Ecuador	1976, 1980, 1987, 1990, 1999, 2008	1971, 1974, 2000
El Salvador	1974, 1978, 1983, 1991, 2008	1995, 1998, 2007
Honduras	1974, 1979, 1990, 1999	1973, 2000, 2006
Guatemala	1980, 1985, 1988, 2000, 2008	1972, 1976, 1998, 2001
Mexico	1973, 1981, 1988, 1994, 2000, 2003, 2008	-
Nicaragua	1977, 1980, 1987, 1993, 2001	-
Panama	1976, 1982, 1986, 1991, 1996, 2002, 2006	1989
Peru	1974, 1979, 1985, 1992, 2001	1988, 1996, 2009
Trinidad and Tobago	1980, 1989, 1999, 2008	1975, 1997
Venezuela	1977, 1983, 1992, 1998, 2003	1974, 1989, 1990