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Development profiles and accumulation of technological capabilities in Latin America

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ABSTRACT

The study of technological capability accumulation processes (TCA) for developing countries is long-standing. The studies tend to adopt a narrow perspective to science, technology and innovation and their policies, which do not seem to be sufficient to understand TCA in countries that face the middle-income trap. This adds to the limited metrics we have to measure TCA. This paper argues that it is necessary to frame the TCA processes at national levels, including the techno-economic and the socio-political spheres (TES and SPS). It is argued that countries' evolutionary trajectory combines these spheres differently and results in different development profiles. This is expected to have an impact on their TCA. The objective is to identify and analyse development profiles of Latin American countries (in terms of TES and SPS), and discuss it relationship with the characteristics of TCA at the firm level. This research departures from descriptive statistics based on Innovation Surveys for the TCA analysis at the firm and country level, and combines different steps and tools to asses country development profiles: (i) a long-term analysis (1980–2010) to verify the existence of cointegration between TES and SPS; and (ii) the identification and estimation of long run paths that determine three different country profiles. Finally, we outline some policy recommendations.

1. Introduction[1]

The study of the processes of technological capability accumulation (TCA) for developing countries is long-standing. Since the early 1980s, there has flourished an extensive literature recognizing the importance of the TCA for technological and economic development (Katz, 1986; Kim, 1997; Lall, 1987, 1992). Several studies have allowed a better understanding of the nature of technological capabilities (TC) and the process of TCA. Initially, the papers focused on proposing ways to approach the study of domestic TC and define the concept (Enos and Park, 1988; Kim, 1992, 1997; Lall, 1993; Westphal et al., 1985). From there, TC was defined as the ability to make an effective use of technological knowledge for production, investment and innovation (Katz, 1987; Maxwell, 1987; Teitel, 1987; Westphal et al., 1985).

Subsequently, an immense arsenal of works based on case study methodology provided evidence of these processes at the firm level (Dutrénit, 2000, 2004, 2007; Figueiredo, 2001, 2003, 2010; Hobday et al., 2004; Vera-Cruz, 2006among others), drawing largely on the analytical framework constructed by Lall (1992) and Bell and Pavitt (1995).[2] Different bodies of literature have converged on the argument that there is a relationship between the TC of firms and their innovative performance. This firm-level work has also explored the role of technological learning for TC building (Bell, 1984; Katz, 1976, 1986). More recently other studies have explored with quantitative methodologies the levels of TC at country level (Archibugi et al., 2009; Archibugi and Coco, 2005; Fagerberg and Verspagen, 2002, 2007), the nature of technology upgrading and dimensions such as Intensity, Breadth and Knowledge (Radosevic and Yoruk, 2017), and the processes of catching up in Asia, using largely R&D and patent data trajectories in Asian countries (Lee, 2013; Wong and Goh, 2015).

At the micro level, a strong interest was developed to study the processes of TCA of firms, mainly industrial ones, and build taxonomies that classify the capabilities accumulated in different stages (Bell and Pavitt, 1995; Lall, 1992). These taxonomies reflect that the TCA

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[1] We acknowledge the support of Miguel Angel Roldán, Jenai de la Cruz, Rodrigo Magaldi and Joaquín Sánchez for the systematisation of information and statistical analysis.

[2] A Special Issue of the Journal edited by Hobday (2007) compile a selection of works on this issue.

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processes are gradual, from a stage in which firms have only minimal levels of knowledge (necessary for the operation) to the stage where they have advanced innovative capabilities (which include capabilities for conducting R&D). These taxonomies have been used to understand the processes of accumulation of firms in various countries and industries (Bell and Figueiredo, 2012; Dutrénit, 2000, 2004; Figueiredo, 2001, 2003; Torres, 2004, 2006; Vera-Cruz, 2004).

More recently, there has been a special interest in understanding the factors that promote TCA until catching up, new levels of productivity and improvements in living conditions. However, despite the existence of a large literature on this subject, there is still no consensus on the real possibilities that these countries may have for achieving those objectives, and which would be "good STI policy designs", since several of the proposals made have failed to recommend successful policies. The existence of a group of countries that does not overcome the middle-income trap suggests that we need new metrics to understand the determinants of TCA (Radosevic and Yoruk, 2017). However, we should probably use a different lens, and look at other spheres that transcend the indicators associated with inputs and outputs of domestic science, technology and innovation (STI) capabilities. These studies that adopt a narrow perspective to STI do not seem to be sufficient to understand the problem of the TCA at the firm and national levels, particularly for those countries that are in the middle-income trap.

The use of a broader approach is rooted in other authors. Freeman (2011) argued about the connection between social policy and inequality with technology and growth. According to Katz (1986, 1987), Katz and Astorga (2013), Arza (2013) and Rasiah (2013), macro and micro levels are intertwined and firms respond to changes in the macroeconomic context with changes in their economic and technological behaviour.[3] In this line, Katz (1987:16–17) claims that the rate and nature of technical change, as well as the type of innovations and productivity advances that a given firm can undertake at a certain point in time, strongly depend upon: (i) strictly microeconomic forces emerging from the specific history of the firm; (ii) market variables related to the competitive environment in which the firm operates; (iii) macroeconomic forces characterising the framework conditions; and (iv) the evolution of the knowledge frontier at the international level. In other words, the macroeconomic conditions affect the microeconomic processes of TCA.

In this line, at the height of globalization, Freeman (1995) argued that, despite all its homogenizing tendencies, innovation systems would generate conditions for accumulating TC according to conditions that transcended STI activities. Some recent works have also adopted a broader approach, a multilevel analysis, which means a multifaceted description and measurement of the various factors that contribute to shape the domestic TC (or the innovative capability or absorptive capacity). They include variables of the economic and social spheres (Castelacci and Natera, 2013, 2016; Cimoli and Porcile, 2011; Fagerberg and Srholec, 2008). These papers focus on the analysis of national TC; however, they neither explore the TCA at the firm level nor the relationship between economic and social indicators with TCA at firm level.

This paper argues that it is necessary to frame the TCA processes at firm and national levels in a broader context, which we called the techno-economic sphere (TES) and the socio-political sphere (SPS). TES includes STI and economic dimensions, while SPS comprises social and political dimensions. It is argued that the evolutionary trajectory of countries combines these spheres differently and results in different development profiles. This is expected to have an impact on TCA processes at the firm, sector and country level. An implicit argument is that research, innovation, productivity and economic growth lead to improvements in education, health and democracy, as well as lower inequality.

[3] Vera-Cruz and Torres-Vargas (2013) describe Katz's argument in detail.

This paper draws on evidence on TCA coming from four Latin American countries and focus on countries' development profiles. It has two interconnected objectives: (i) to identify and analyse the development profiles of Latin American countries that relate to the techno-economic (TES) and socio-political (SPS) spheres, and (ii) to discuss the relationship between these profiles with the characteristics of TCA at the firm level. Based on these ideas, this paper explores some STI policy recommendations to strengthen TCA processes that take into account the co-evolution, on the one hand, of TES and SPS, on the other, of the TCA process.

We recognise that there are methodological difficulties to address such complex analyses at firm and country level. There is a lack of long-term indicators associated with STI, which would allow us to better characterize one of the components of the TES (STI performance), as well as some more appropriate indicators to measure the performance of economies (TES), and the socio-political sphere of the countries (SPS). This lack of information makes it difficult to analyse how TES and SPS interact with TCA, and impact on their evolution. In addition, as asserted by Radosevic and Yoruk (2016), we still know little about the appropriate metrics for understanding the determinants of the TCA of the business sector. The lack of reliable indicators on firm-level TCA in the long term is even more serious.

Hence, measuring TES, SPS and TC of the business sector involves making several analytical and methodological decisions. On the one hand, it is necessary to reflect on what kind of long-term indicators are necessary to achieve a better contextualization of the TCA, and to rethink how to measure that process, and, on the other, advance in new analytical frameworks to explain the TCA at firm-level and at the country-level with existing information.

This research focuses on the first challenge. It combines different steps and tools to analyse the countries' development profiles that affect TCA of firms and countries, considering such profiles according to the evolution of their TES and SPS over time. The period considered for this long-term analysis is 1980–2010. We verify the existence of cointegration between indicators of the TES and SPS spheres and identify and estimate long run paths to determine country profiles (Hendry and Juselius, 2000; Johansen, 1991, 1995).

The content of this paper is as follows; Section 2 briefly describes the general context of the Latin Americans' National System of Innovation (NSI). Section 3 describes some features of TCA in the region. Section 4 reviews literature related to socio-economic and socio-political dimensions and the TCA, and proposes a conceptual model to characterize, through macro-aggregate indicators, the co-evolution of TES and SPS with the TCA. Section 5 describes the research designs. Section 6 identify countries' profiles based on the long-term evolution of TES and SPS. Section 7 discusses countries' profiles and their relationship with the TCA, and their implications for STI policy. Finally Section 8 concludes.

2. The evolution of the STI policies

Latin American NSI have been the result of a process of aggregation of different institutions, as well as public and private organizations that still operate in an uncoordinated way. This is due to several factors. On the one hand, historically, the assessment of STI-related activities has been poor and technical change based on local and systematic STI efforts has rarely been identified as an important factor in improving the performance of the Latin American economy. On the other hand, it seems that the activities of greater productivity in the Latin American market (at the industrial or service level) are not related to the efforts in innovation, that is to say, signs of short-term relative gains appear to be dissociated from innovation (Cassiolato et al., 2003; Cimoli, 2000; Dutrénit et al., 2010; Dutrénit and Sutz, 2014; López, 2007; Viotti, 2002).

The STI agencies (CONACYT/CONICYT, etc.) were created mostly in the 1970s, with a supply approach. They still play a central role in the

NSI of the region, coordinating the design and implementation of national STI policies. In general, the institutional framework for STI activities has changed radically during the 2000s in most countries, following international standards. The systemic approach began to be adopted, but it was interviewed with the still predominant supply approach. The private sector maintains an underdeveloped culture of innovation, created from these approaches (Crespi and Dutrénit, 2014). While there are success stories, the protection of markets and macroeconomic instability did not generate an appropriate incentive structure to generate more dynamic technological behaviour (Arza, 2007; Katz, 1986, 2000; Vera-Cruz, 2006).

In general, the following features characterize the Latin American NSI (Dutrénit, 2012):

- Scarce financial resources with allocation problems.
- A small scientific community, with levels of excellence in some scientific fields in large countries, focused on research guided by curiosity, and with little incentive to conduct research oriented to national problems.
- Public sector as the main source of funding.
- High geographical and institutional concentration of capacities.
- Companies make a small effort in R&D; however, much of its innovative activity does not appear to be captured by current methodologies for measuring innovation.
- Limited links between agents.
- A combination of institutions that originate from the import-based industrialization model persists with other newly created institutions under a different logic.
- A strong distortion in the incentive structure.

As Viotti (2002) argues, the Latin American NSI can be better described as a National Learning Systems, instead of one based on innovation. In recent years, a number of achievements can be described, such as the emergence of new actors and their impact on the reconfiguration of NSI, the increase in the amount of R&D financed by the business sector, successful performance in specific areas, and increased productivity of research, among other factors (Crespi and Dutrénit, 2014). However, some NSI traits undermine the processes of capacity building: problems of demand (e.g. weak demand that is associated with a small market, problems of inequality, among others), supply weaknesses (e.g. lack of high-level human resources, or even engineers), shortage of private sector investment, scarcity of private and public venture capital, complexity of the economic structure, effects of the rupture of the productive chains with the opening, among others.

While there has been a STI policy model for the region, largely following recommendations of international organisms, the countries have followed different dynamics in their design and implementation and have shown different degrees of independence with respect to these recommendations (Benavente and Bitrán, 2012; Cimoli et al., 2009; Dutrénit, 2012; Lemarchand, 2010; Porta and Lugones, 2011).

Overall, this has resulted in different performances in terms of STI. For example, in relation to the target of the increase of Gross Expenditure on Research and Development (GERD) as a percentage of Gross Domestic Product (GDP) to 1%, countries have adopted these recommendations in various ways. On one extreme, Brazil has included STI as an important factor in its national development strategy, which has translated into a larger investment in R&D and an increase of GERD/GDP until it reached 1.2% in 2012 (Cassiolato et al., 2014). This investment has been accompanied by a combination of programs that have stimulated both basic research as well as a support for innovation in all types of firms. Recent political changes are having impacts on this behaviour. On the contrary, Mexico has not assigned that role to STI, and as a result, the GERD as a percentage of GDP has not surpassed 0.5%, beyond having a pretty modern design of STI policies (Corona et al., 2014). In the case of Argentina, new programs were introduced to stimulate innovation, however, the financial effort has been still limited (Suárez et al., 2014).

Even though, there have been a lot of experimentation, the designed programs largely represent adaptations of successful programs in other regions, which were designed for different initial conditions, with a more balanced composition of different actors. The specificities of the economic and social structural characteristics, governance system and politics have not been properly taken into account.

3. Some features of the TCA

Within these NSI, and moving to micro level, what can be said about TCA at firm-level in Latin America? How this micro behaviour connects with aggregate economic data. This section focuses on these issues.

3.1. Stages of TCA at the firm level

As Radosevic and Yoruk (2016) recognise, we do not have the appropriate metrics to measure TCA, however, innovation surveys provide information to broadly characterize the TCA at firm level.[4] We focus on innovation activities at firm level from Brazil, Chile, Mexico and Uruguay,[5] which are suitable for international comparison.[6] Table 1 reports firms' innovation activities for these countries. Data refers to the percentage of firms that have carried out a set of innovation activities, without considering the amount of the investment in these innovation activities. In all cases, we have included all firms surveyed in the period of analysis (including innovative and non-innovative firms).

A quick view at Table 1 shows some features:

- As expected, firms develop a variety of innovation activities, which go beyond R&D activities.
- Activities related to Investment in machinery and equipment, and Training are more widespread than R&D activities.
- Investment in machinery and equipment remains as the main innovation activity for Chile, and very important but not the most for

Table 1
Innovation activities for the four selected countries.

Innovation activities	Uruguay	Brasil	Chile	Mexico
Investment in machinery and equipment	33.0%	30%	26.7%	10.9%
Training	26.0%	24%	10.5%	18.2%
Acquisition of external knowledge	47.6%	6%	6.5%	14.6%
Other preparations for product innovation	6.6%	14%	8.5%	16.9%
R&D activities	14.7%	7%	11.0%	9.3%
Internal R&D activities	13.8%	6%	9.7%	5.3%
External R&D activities	3.8%	2%	4.3%	5.6%

Source: Own elaboration based on the innovation surveys. Included innovation surveys are: (i) Uruguay - Encuesta de actividades de innovación en la industria manufacturera y servicios seleccionados (EAI), n = 3706 firms, 2006–2009; (ii) Brazil, Pesquisa de Inovação (PINTEC), n = 235,561 firms, 2008–2011; (iii) Chile - Encuesta de innovación y de gasto y de personal de I + D en el sector privado, n = 8096 firms, 2006–2009; (iv) Mexico - Encuesta Sobre Investigación y Desarrollo Tecnológico (ESIDET), n = 12,560 firms, 2006–2009.

[4] It has to be recognised that using innovation surveys in Latin America is quite challenging, since most of the instruments heavily differs from country to country (Guillard and Salazar, 2017). There are many considerations that should be done in order to make reasonable comparisons: the definition of the firms that are surveyed varies, the methodologies are not consistent or designed to support international comparability, and questionnaires fail to provide a sound logical structure that could actually capture the complexity of the innovation process.

[5] These countries represent > 60% of the Latin American GDP during the last two decades.

[6] By the time that this investigation is taking place, we are also developing a methodological analysis of the available innovation surveys in Latin America. Unfortunately, the results from that project are only partially available now.

Uruguay. This is actually not so different from what can be found elsewhere in the world (see Bogliacino et al., 2012).

- Brazil also heavily invests in machinery and training, having a low percentage of firms investing in R&D activities. Nevertheless, it is remarkable that most of the Brazilian firms that undertake R&D activities do it internally.
- In the case of Mexico, the Survey includes 2009, a year of a profound crisis, which can contribute to explain the lower investment observed.
- In Mexico and Chile, firms combine R&D activities based on internal and external sources; however, acquisition of external knowledge is a less relevant activity for the majority of firms. Training also resulted an important activity for firms.
- Uruguay has a more homogenous innovative behaviour: it has an important percentage of firms developing in-house R&D, acquisition of external knowledge, and training activities. This case, a small country, shows other interesting information: there are a high percentage of firms that undergo the activity of acquisition of external knowledge, which may be combined with some internal R&D activities.

These features of the innovation activities carried out by firms are certainly connected with their stage of TCA. Based on the taxonomy of Bell and Pavitt (1995), referred in Section 1, we estimated the stage of TCA of firms for each country. The estimation is based on the following steps: (i) to identify the innovation activities developed by firms in the innovation surveys, which are listed in Table 1, (ii) to identify whether a firm perform each of the innovation activities, and (iii) according to the mix of innovation activities carried out by firms, to classify them into four stages of TCA:

- Routine production TC: firms that only have capabilities to use and operate existing technologies; they do not invest in any innovation activity.
- Basic innovative TC: firms only invest in one type of innovation activities.
- Intermediate innovative TC: firms that are moving towards greater level of capability accumulation; they invest in several types of innovation activities. However, these firms do not perform R&D activities.
- Advanced innovative TC: firms at this stage are the most technologically advanced in the country; they perform R&D activities, and many other innovation activities.

Table 2 contains the results of this exercise: the distribution of firms of the four selected countries according to the TCA stages.

Table 2 shows the heterogeneity of firms' stages of TCA inside each country and between countries. Some features emerge in the composition of stages of firms' TCA.

- As expected, in any country, firms have different levels of TCA and are located along the four stages of TCA.
- Most firms in the four countries have mostly built Routine production TC. However, it is significantly higher (> 60%) in the case of Brazil, Chile and Mexico; in contrast, firms at this stage roughly represent half of the sample in Uruguay.
- If we look at the Advanced innovative TC, we notice that Uruguay has the higher percentage of firms, followed by Chile, while Brazil and Mexico have the smaller percentage (under 10%) of firms in this group. However, if we consider Intermediary and Advanced innovative TC altogether, Brazil occupies the second position after Uruguay.

Table 2
Firms by stages of TCA.

Stages of TCA	Uruguay	Brazil	Chile	Mexico
Routine production TC	50.32%	61.50%	67.01%	68.80%
Basic innovative TC	9.69%	7.90%	12.56%	11.07%
Intermediary innovative TC	25.26%	23.60%	9.40%	10.87%
Advanced innovative TC	14.73%	7.00%	11.03%	9.26%
Total firms	100.00%	100.00%	100.00%	100.00%

Source: own elaboration based on the innovation surveys.

All in all, from this very simple exercise, we have the following picture: Uruguay is better positioned in terms of firms' TC, as it has a more balanced distribution of firms in different stages of TCA, followed by Brazil and, in a lower position we find Chile and Mexico.

3.2. From micro evidence to macro aggregates

A conventional approach would support the idea that having more innovative microeconomic behaviours will lead to getting higher levels of labour productivity. At the same time, this higher productivity will generate better welfare conditions because of a higher average of wages. Therefore, in terms of productivity, we would expect economies to be located according to proportions of firms in the group of Intermediary innovative and Advanced innovative TC, as reported in Table 2. In addition, countries productivity position should coincide with their average wages.

Table 3 lists the orders in which the countries are located with respect to the percentage of firms in the highest stages of TC in the periods of innovation surveys (Intermediary and Advances Innovative TC stages), and the evolution of labour productivity (LP) and average wages (AW) in period of time corresponding to these surveys.

The inconsistency between the country's position concerning to labor productivity and average wages suggests some distortions. For example, Brazil is first in labor productivity and third in average wages; Chile and Mexico are in an inverted order: third in labor productivity and second for average wages to the first country and second and first, respectively, to the second. At contrary, Uruguay is fourth in both labor productivity and average wages. These discrepancies and coincidences are the result of distributive struggles and institutional conditions that suggest the presence -and even the strengthening- of power groups, whose performance is not always in accordance with the evolution of productive efficiency.

It is suggestive the inverse order, of the four referred countries, in the percentage of firms that have built Intermediate and Advanced technological capabilities respect at the index of average wages, in each of them.

The evidence presented in Table 3 leads to questioning the conventional hypothesis about the relationship between TCA and the performance of economies in the generation and distribution of income. This makes it possible to formulate different hypotheses for the Latin American's countries, with respect to the somehow linear idea that the TCA has a direct influence and conditions both the improvement of productive efficiency and the expansion of social welfare.

First, the persistency of unequal productivity leads to the formation of strata of low and high productivity firms, which adds to countries' structural heterogeneity (Cimoli, 2005). This is a permanent feature that hinders firms from moving from the low productivity strata to those of high levels. The TC stages registered by the surveys (Tables 1 and 2) are probably persistent; so firms would tend to remain in the same stage instead of moving from Routine production to Advanced innovative TC.

Second, both at the level of economic decisions as well as the policies, institutional constraints affect the adaptive processes associated with the TCA (Freeman, 2011). This also affects the income distribution associated with technological change, particularly in sectors that participate in global value chains, which tend to observe regressive impacts on income distribution (Jaumotte et al., 2013).

The TES and SPS spheres, proposed in Section 4, combine and

Table 3
Stages of TCA, LP and AW in Brazil, Chile, Mexico y Uruguay.

	Intermediary and advances innovative TC stages			Labour productivity			Wage average		
Country	% of firms	Order	Period	Average Index of the period (2016 = 100)	Order	Period and trend	Average Index of the period (2016 = 100)	Order	Period and trend
Uruguay	40.0	1°	2006–09	80.61	4°	2003–12, + +	53.34	4°	2003–12, + +
Brazil	30.6	2°	2008–11	100.72	1°	2005–14, + +	62.31	3°	2005–14, + +
Chile	20.4	3°	2006–09	93.75	3°	2003–12, + −	71.01	2°	2003–12, + +
Mexico	20.1	4°	2006–09	96.91	2°	2003–12, + −	71.52	1°	2003–12, + +

Note: Ascending (+) or descending (−) trend by sub-periods.
Source: own elaboration based on Table 2, labor productivity: The Conference Board (2016); average wages: CEPAL (2017).

express these two hypotheses. The TCA, in Latin American countries, is conditioned by structural dualism, and there are idiosyncratic institutions. These characteristics suggest that the analysis of the determinants of TCA should include the TES and SPS dimensions.

4. Techno-economic and socio-political dimensions, and TCA

The works of Schumpeter (1942), Solow (1956) and Abramovitz (1956, 1986) illustrate that the increase of investment in STI is an essential factor for the economic growth of a nation. Later, Lundvall (1992), Nelson (1993) and Kim (1997) showed that the economic dynamism depends on the generation of scientific, technological and innovation capabilities, the structure of linkages among the agents as well as an appropriate regulatory framework; in other words, it depends of the construction of NSI. In Latin America these systems are small according to the size of their main agents, the structure of linkages is incipient and the financial resources dedicated by the public and private sectors to STI are scarce, as described in Section 2. Even though, there are differences between the countries regarding structural characteristics, STI efforts, profiles of TCA and the outputs of the system (Cassiolato et al., 2003; Cimoli, 2000; Dutrénit et al., 2010; Katz, 2001). The level of inequality and immaturity of the political system are also stylised features of the region. Hence, science and technology, economic, social and political dimensions seem to be relevant for the analysis of the TCA. We aggregate science and technology and economic dimensions in the TES, and social and political dimension in the SPS.

4.1. Techno-economic and socio-political dimensions, innovation systems and development

Technological and economic aspects are privileged in the analysis of NSI, at different scales and lengths. However, the history of these systems reveals that they are the result of exchanges taking place, on the one hand, on innovation resources markets and, on the other, through interactions between organizations located outside and within states, as political entities, at the national, sub-national or local levels (Freeman, 1993, 1995; Lundvall, 2007). This fact alone reveals that the techno-economic sphere is an aspect of the constitution of NSI, but not the only one.

It is common to think that the process of maturation and advances in the complexity and completeness of the NSI tends to turn them into techno-economic systems. That is, entities that privileges the transformation of knowledge resources of diverse nature into products, techniques, services and other results that are valuable strictly by economic criteria. However, the emergence of the responsible research and innovation (RRI) perspective (European Union, 2012) introduces some questions to this unilateral perspective of NSI. From an operational point of view, the RRI approach aims to be "… an iterative and transparent process of opening up research and innovation that seeks to improve the model of relationship between science and society".[7]

The consideration of the RRI components of 'politics' incorporates the dynamics of a SPS into the NSI (Eizagirre et al., 2017; Stilgoe et al., 2013; Von Schomberg, 2013). The enunciation of this and other aspects show that in the operation of the TES, as well as for the NSI to obtain efficient and desirable results, it is necessary to observe how other features of the NSI arise and are stabilized, which are of social and political nature. Government guidance is not enough for the operation of the NSI; high levels of governance of collaborative actors (Turke, 2008), as paramount, emerges to involve the NSI. In addition, this approach stresses the importance of the reduction of different types of inequality in the system. However, ~~t~~he RRI approach is referred to the most developed countries from the point of view of maturity and evolutionary completeness of their NSI. In this sense, it is arguable that the evolution of the NSI involves and requires the interaction of the TES and SPS.

From an evolutionary point of view, Dutrénit and Teubal (2011) characterized the stages of economies according to the role of NSI in their economic development of TCA by an appreciative model, which represents dissimilar experiences of Israel and Mexico. The stages through which the NSI goes are the following: (i) Stage I. Preconditions for virtuous science, technology and higher education (STE)-innovation (I) Coevolution, (ii) Stage II. STE-I Coevolution and Emergence of Specific Financial/Technical Infrastructures, and (iii) Stage III. Reconfigured STE-I Coevolution and Widespread Emergence.

The development of economies corresponds to these stages, where accumulativeness and threshold matter. In this line, Dutrénit, Puchet and Teubal (2011: 69) pointed out that "… times and forms of transit between stages depend on the accumulated capabilities for generating STE and Innovation in the previous stages". The transit between stages is conditioned by the possibilities of reaching the thresholds of critical masses to jump from one to another stage (Dutrénit and Puchet, 2011; Dutrénit and Teubal, 2011). In this argument, structural changes that guarantee in each stage the adequate linkages between dynamic economies to scale, and institutional changes that create norms and incentives play a key role.

In the same vein, referring to China catching up process, and specifically putting the eyes on the role of innovation policies to stimulate the evolution from low-income country to middle-income until catch up, Liu et al. (2017) points out that institutional and framework conditions for innovation are the most important shortcoming that have to be taken into account.

Finally, it can be argued that the evolutionary approach to development places the SPS as a main component of NSI. Both the

[7] http://blog.caixaciencia.com/-/formacion-sobre-la-investigacion-y-la-innovacion-responsables-para-mas-de-cien-profesionales-de-la-comunidad-cientifica.

accumulation of the multiple capacities required by the co-evolution of the substantive activities of the NSI, and the constitution of institutions that make structural changes possible and, in turn, emerge from them, operate through the SPS.

4.2. A conceptual model to characterize the co-evolution of TES and SPS with the TCA

Drawn on the literature reviewed in the previous sections, this paper argues that it is necessary to frame the TCA processes at the firm and national levels in a broader context, which include the TES and SPS.

TES includes indicators of economic performance, such as GDP growth rate, labour productivity, manufacturing value added (% of GDP), among others, and indicators of STI inputs and outputs. SPS includes indicators of quality of living, such as life expectancy, Gini index of inequality, corruption perception index, among others. TCA corresponds to the micro behaviour; it refers to firms' processes of TCA.

This analysis that links, on the one hand, variables of performance of the economy with its conditioning factors and, on the other, microeconomic behaviours is based on the empirical studies of growth and development (Durlauf et al., 2005; Easterly, 2005; Solimano and Soto, 2005) and national competitiveness (Delgado et al., 2012). Both aspects include determinants of an economic and technological nature and, at the same time, of a social and political nature. The prevailing conception is that growth and competitiveness are processes resulting from the interactions of diverse factors. The explanations tend to consider that these factors are fed back and reinforce, and in other cases they have opposite effects.

The evolutionary trajectory of countries combines the TES and SPS differently and results in different development profiles. This is expected to have an impact on TCA processes at the firm, sector and country level. It is argued that social and political characteristics of the countries could condition the microeconomic processes of TCA. Fig. 1 illustrates the proposed conceptual framework.

5. Research designs

This research combines two steps and different statistical tools to analyse the TCA of firms and countries, considering the profile of the countries according to the evolution of TES and SPS over time. The period considered for this long-term analysis is 1980–2010.

1. To verify the existence of cointegration between indicators of the TES and SPS and to identify and estimate long run paths to determine country profiles.

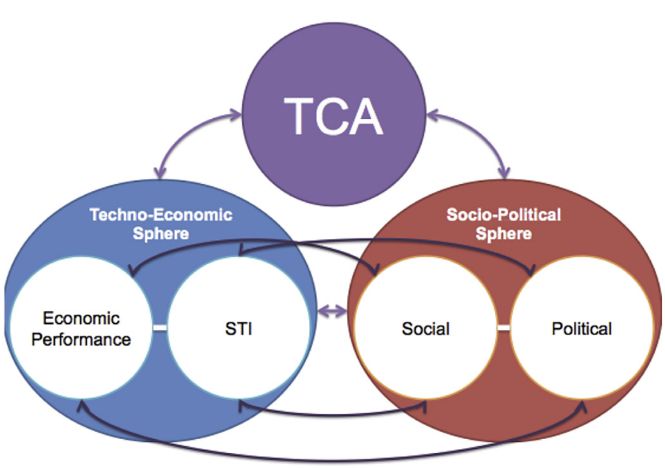

Fig. 1. Conceptual diagram: co-evolution of TCA with TES and SPS.
Source: Own elaboration.

For this exercise, 17 indicators are used to characterize the TES and SPS. Indicators were chosen for which a series of data are available from 1980 to 2010 for Latin American countries. We selected 12 countries for which we have a complete database for the long-term period: Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Mexico, Panama, Paraguay, Peru and Uruguay. According to the World Bank, most of the countries correspond to the upper middle-income countries. Within this, only Guatemala is classified as lower middle income, and Chile and Uruguay correspond to the high-income segment. This selection implies having 12 out of 18 Latin American countries. The sample satisfies three conditions: it includes countries of different sizes and relative position in the regional economy, it includes a set of countries that contribute to 85% of the GDP and > 82% population of the region, and it considers quality of the data that countries provide.

Indicator selection comes from a detailed analysis of the literature of innovation systems. Following Castellacci and Natera (2011) we have selected the most accepted available indicators used for international comparisons in the literature. They provide information in two direction that are worthy for our study: (i) they have surveyed the empirical analysis related to innovation systems, in order to find the most suitable proxies that could express countries evolution; and (ii) they make available a dataset with complete information (including observed and estimated data) that make the most out of the available data for time series and panel analyses.[8] Based on this, we selected a set of indicators and organized them in terms of our proposed conceptual model, namely the TES and the SPS.

TES indicators:

(i) Indicators of economic performance: GDP growth rate, Commercial Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Labour productivity (per person employed in 2010 US$), Agriculture value added (% of GDP), Manufacturing value added (% of GDP), Services value added (% of GDP).
(ii) Indicators of STI inputs and outputs: GERD as % GDP, GERD performed by Business Enterprises (% of total GERD), Royalty and license fees (as % current payments to rest of the world), Trademark applications (per capita), Scientific and technical journal articles (per capita), High-technology exports (% of manufactured exports).

SPS indicators:

(i) Indicators of quality of life: Life Expectancy, Mean years of schooling, Gini Index of Inequality.
(ii) Indicator on socio political environment: Corruption Perception Index.

Based on the evolution of these indicators two analysis are carried out:

- Static comparative analysis of the relative position of each Latin American country, in three periods (1985–1989, 1995–1999, 2005–2010), compared to the OECD average in the two spheres;
- Cointegration analysis of variables within TES and SPS, in order to find evidence supporting of variables being linked together in the long run. Cointegration allows for full endogenization and cross effects of variables within a system, incorporating information from the past to explain current states (Greene and Zhang, 1997). If cointegration is confirmed, it means that the vector contains a unit root and that included variables move together. Based on this, it is possible to distinguish different relationships: (a) the long-run relations, which are at the core of the system, and (b) the short-run

[8] Castellacci and Natera (2011) discuss the indicators to measure innovation systems at a national level.

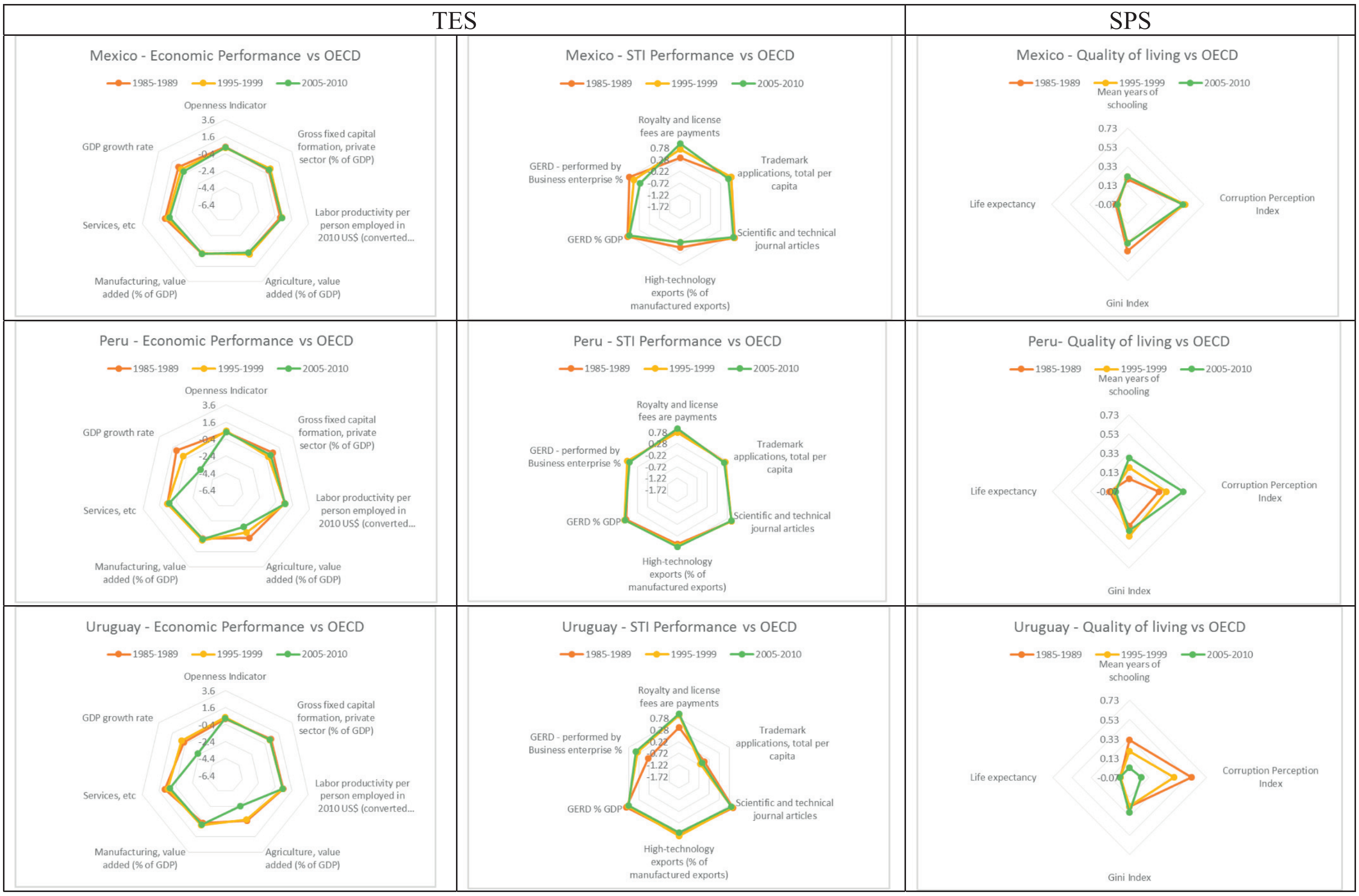

Fig. 2. Countries' performance in relation to the OCDE average: 1985–1989, 1995–1999, 2005–2010.
Source: Own elaboration.

structure, which represents how the system reacts to changes (Hendry and Juselius, 2000; Juselius, 2006).

2. Based on Long-Run development profiles, to identify development profiles of the countries

Drawn on the long-term indicators constructed in step 1, the long-run paths of the countries were identified and estimated. From the methodological point of view this exercise consists of the following:

- Estimate a co-integrating equation (using per capita income as a signal of the level of development), relating TES-economic performance, TES-STI performance, and SPS indicators. Therefore, three equations per country were estimated (two for TES and one for the SPS). We will use real GDP per capita (in PPP) in order to estimate how each of this dimension affects development.
- Mark the independent variables of each cointegration equation that are significant and positive.
- Identify the development profiles of upper middle-income countries based on the independent variables of the long-run paths that are significant and positive.

The cointegration methodology has been selected because of its suitability for empirical analyses of the NSI and economic development. It offers the flexibility that the analysis of NSI need, it recognizes history as the main source of information and it evaluates the relationships as the result of mutual effects among different dimensions. Time series cointegration, in which a single country data is evaluated over a given period, is useful to incorporate the highest level of heterogeneity in the data. Hence, the individual evaluation makes it possible to identify specific events in each country; it is the closest version to using empirical analyses in a case study fashion (Hendry and Juselius, 2000).

Cointegration aims at describing the full space in which variables interact. In its system version (Johansen, 1991, 1995), we find many restrictions in terms of the degree of freedom we have, since the time spam is relatively short. In order to include a wider number of variables (that could represent the complexity of each dimension), we decided to restrict our analysis to the long-run stable part of the model, by using co-integrating equations. Therefore, we are not able to look at the causality structure or the way that the system reacts to different changes in variables levels. We will evaluate, nevertheless, the relationship between variables that constitute system's long-term development (see Annex 1).

We acknowledge the systemic nature of cointegration analysis, and try to find a way around to underestimating it when analysing only a part of it (and not using Johansen systemic's approach). In order to describe the space in a more detailed way, we tested all the possible models that can be specified using the combination of the different variables. More precisely, we tested 2^n-1 models per dimension (where n is the number of variables included in each dimension): 15 for Quality of Life (QL), 127 for Economic Performance (EP) and 63 for Science and Technology (ST). To each of them we programmed at least 6 different configurations of Dummy Variables to characterize different changes in the time structure (looking for a better stability of these models). Each country has, therefore, 90 (15 × 6) models of QL, 762 (127 × 6) of EP and 378 (63 × 6) of ST. All models were evaluated, but not all generated consistent results. However, from the coherent ones it was possible to see which was the most stable pattern for each variable and to select a model that is representative of that pattern. From the selection that comes from the total of 15,990 tested models, we present our results to characterize Latin American countries' profile. Those variables that were positive and significant in the long term for each axis - the

Techno-Economic (TES: EP and ST) and the Socio-Political (SPS: QL) – were counted.

6. Countries' profiles based on TES and SPS

6.1. Static comparative analysis for each country compared to the OECD average in the two spheres

A static comparative analysis of four years over a period of 30 years is carried out for each country compared to the OECD average in the two spheres: TES and SPS. This analysis is based on graphing the indicators of the two spheres with respect to a threshold that acts as a norm. The indicators are plotted on the rays passing through the centre and the vertices of the polygons corresponding to: TES-economic performance, TES-STI performance, and SPS. Using graphs of spiders, the evolution of the size of the gap with the OECD for 1980–1985, 1995–2000, and 2005–2010 is plotted. This exercise includes 12 countries. Fig. 2 illustrates the results for three different countries.

The main results of this simple comparative static exercise show that the Latin American countries have the following features:

- TES-Economic performance:
  - Volatility in GDP growth rates with alternating periods of ups and downs
  - Low gross fixed investment of companies
  - Different economic structures that emerge from the added value of agriculture, industry and services
  - Low labour productivity without significant improvement

- TES-STI performance:
  - Low scientific production
  - Low investment in STI
  - Persistent technological dependence
  - Different shares of high technology exports
- SPS – Quality of Life:
  - Bridging the gap in terms of life expectancy and schooling
  - High and irreducible levels of inequality
  - High levels of corruption

This exercise is the putting into operation of a toy model, which is based on the following argument: if in a country the scientific production of researchers increases, and companies invest in R&D, and increase the royalties paid and the number of trademarks, then we would expect that both labour productivity and high-tech exports should grow. This path should be in line with higher growth in capital formation and product. At the same time, following such a reasoning, we would also expect that research, innovation, productivity, accumulation and growth will always bring better health of the population, more education, less inequality and a decrease in the perception of corruption.

Concerning to the cointegration analysis, Table 4 summarizes the results, according to the models specified in full detail in the Annex 2. It shows evidence of cointegration in many different models' configurations. This is a result that gives robustness to our analysis, since cointegration does not seem to depend on the inclusion of a particular variable; it is rather a common feature of our empirical exercise.

6.2. Identification and estimation of the long-run paths of the countries

Based on the previous results, we estimated a cointegration equation (using per capita income as a signal of the level of development), relating TES-economic performance, TES-STI performance, and SPS indicators. In fact, we have estimated three equations per country (two for the TES and one for the SPS). We mark the independent variables of each cointegration equation that are significant and positive. They receive "1" in Table 5. This exercise made it possible to identify the development profiles of upper middle-income countries of Latin America.

Table 4
Summary of models' configuration selected to represent cointegration evidence*.

	TE		SP
Country	EP	ST	QL
Argentina	ArgEP1, ArgEP2	ArgST1	ArgQL1, ArgQL2
Brazil	BraEP1, BraEP2	BraST1	-
Chile	ChiEP1	ChiST1, ChiST2, ChiST3	-
Colombia	ColEP1, ColEP2, ColEP3	ColST1, ColST2	ColQL1
Costa Rica	CoREP1, CoREP2	CoRST1	CorQL1
Ecuador	EcuEP1, EcuEP2, EcuEP3	EcuST1, EcuST2	EcuQL1
Guatemala	GuaEP1, GuaEP2	GuaST1	GuaQL1
Mexico	MexEP1, MexEP2, MexEP3	MexST1, MexST2	-
Panama	PanEP1, PanEP2, PanEP3	PanST1, PanST2	PanQL1
Paraguay	ParEP1, ParEP2, ParEP3	ParST1, ParST2	ParQL1
Peru	PerEP1	PerST1	-
Uruguay	UruEP1, UruEP2	UruST1, UruST2, UruST14	UruQL1, UruQL2, UruQL3

Source: own elaboration.
Note: *Each codified model and its related results of cointegration tests are described in Tables A2-1, A2-2 and A2-3 in the Annex 2.

The exercise made it possible to identify three different profiles (see Fig. 3):

- Profile I. Biased towards the techno-economic, and lacking in socio-political development: Mexico, Brazil and Chile.
  Countries biased towards TES indicators where labour productivity has a positive impact on GDP per capita, and lack of a favourable presence of the SPS (little positive impact of these indicators on GDP per capita).
- Profile II. Biased towards the socio-political and lacking in techno-economic development: Guatemala, Ecuador, Paraguay and Peru.
  Countries biased towards a positive influence of the SPS, but still with low impact of these indicators on GDP per capita, and lacking a favourable presence of the TES.[9]
- Profile III. More balanced systems: Uruguay, Costa Rica, Argentina, Colombia and Panamá.
  Countries with more balanced systems between both spheres. They have the better impact of SPS on GDP per capita.

The results reveal one of the key problems of development in Latin American countries: the high levels of inequality. The indicator of income distribution - Gini Index - did not result positive and significant for any of the countries (0 for all the countries), hence the improvement of the GINI index in the region is not enough to generate a positive impact on the GDP per capita. In the same vein, the results of the Corruption Perception (0 for most of the countries) mean that the levels of corruptions are neither positive nor significant for the improvement of GDP per capita. Only Uruguay and Costa Rica present a positive and significant impact of this indicator, revealing a better performance of their democratic processes.

Trade liberalization has positively affected the TES of most of countries. After the Washington Consensus, the Latin American countries opened their borders and interviewed into the international

[9] It has to be noticed that even though the SPS indicators behave better than the TES indicators, the levels are low.

Table 5
Cointegration equations: variables with significant and positive effects in the long term.

Group	Country	TES-economic performance and TES-STI domestic capabilities								
		GDP growth rate	Commercial Openness Indicator (X + M/GDP)	Gross Fixed Capital Formation by private sector (% of GDP)	Labour productivity (per person employed in 2010 US$)	Agriculture value added (% of GDP)	Manufacturing value added (% of GDP)	Services value added (% of GDP).	Research and development expenditure (GERD as % GDP)	GERD - performed by Business Enterprises (% of total GERD)
I	Brazil	1	1	1	1	0	0	1	1	0
	Chile	0	1	0	1	0	0	1	0	1
	Mexico	1	1	0	1	0	1	0	0	0
II	Ecuador	0	1	0	1	0	1	0	0	0
	Guatemala	1	1	0	0	0	0	1	0	1
	Paraguay	1	1	0	0	0	0	0	1	1
	Peru	0	1	0	1	0	0	0	0	1
III	Argentina	0	1	1	1	1	0	1	0	1
	Colombia	0	1	1	0	0	0	1	1	0
	Costa Rica	1	1	0	1	0	0	1	0	0
	Panama	1	0	1	1	0	0	1	0	0
	Uruguay	0	0	0	1	0	1	0	0	0

Group	TES-economic performance and TES-STI domestic capabilities				SPS				Total	
	Royalty and license fees (as % current payments to rest of world)	Trademark applications (per capita)	Scientific and technical journal articles (per capita)	High-technology exports (% of manufactured exports)	Life Expectancy	Mean years of schooling	Gini Index of Inequality	Corruption Perception Index	TES	SPS
I	1	0	1	0	0	0	0	0	8	0
	0	1	1	1	0	0	0	0	7	0
	1	1	0	1	0	0	0	0	7	0
II	0	0	1	0	0	1	0	0	4	1
	0	0	0	0	1	1	0	0	4	2
	0	0	0	1	1	0	0	0	5	1
	0	1	1	0	0	0	0	0	5	0
III	0	0	1	1	1	0	0	0	8	1
	0	1	1	0	1	0	0	0	6	1
	0	0	1	1	1	0	0	1	6	2
	0	1	1	0	1	0	0	0	6	1
	1	1	1	1	1	1	0	1	6	3

Source: Own elaboration.

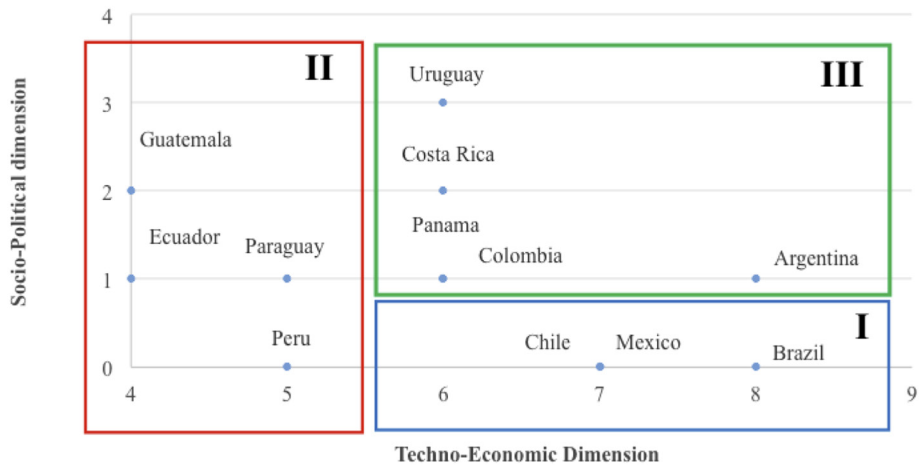

Fig. 3. Latin American countries development profiles.
Source: Own elaboration.

markets through increasing the presence of subsidiaries of multinational corporations, incorporation into the global value chains, and trade agreements and other export strategies. The impact of trade liberalization confirms the results by Dutrénit et al. (2014).

The profiles illustrated in Fig. 3 also suggest a reflection: there seems to be a trade-off between techno-economic performance and socio-political performance. It seems that the economies continue to extract resources, which they do not distribute and for that they use political mechanisms that privilege their extractors. This argument deserves more research.

7. Development profiles and TCA: some implications for STI policy

The results from countries development profiles could be analyzed in the light of the descriptive evidence we have from TCA of selected Latin American countries, described in Section 3. If we recall Table 2, we will notice that Brazil, Chile and Mexico, which were classified in profile I, with high TES but low SPS, report the highest percentage of firms at the lowest stage of TCA-Routine production TC. In other words, these firms only have capabilities to reproduce technologies and products already existent in the market. In fact, Brazil, Chile and Mexico have a particular composition of firms in terms of TCA, on one side a large percentage of firms that have only Routine production TC, and, on the other a small percentage of firms with Advanced innovate TC, based on R&D activities. This suggests the existence of a very heterogeneous manufacturing sector. In contrast, Uruguay, a country classified in profile III, has a more distributed manufacturing sector along different levels of TC.[10] In other words, countries with a more balanced SPS and TES, seems to have a more balanced distribution of firms along the four stages of TCA, while countries with a stronger TES and a weaker SPS tend to have a more heterogeneous manufacturing sector in terms of firms' TCA.

Hence, the evidence suggests that countries differ in terms of their development profiles, and particularly the balance between TES and SPS, and that might be a link between the country profile and the composition of firms according to stages of TCA. Therefore Latin American countries are heterogeneous concerning to these characteristics. This section reflects on the implications for STI policy.

If we elaborate in terms of policy implications, it looks that having a general analytical framework is not appropriated to deal with such heterogeneity. The design of STI policies may have to take into account the different initial conditions of the countries, in terms of TES, STS, and TCA. As Liu et al. (2017) argues for the case of China, a new innovation policy is required to move from the middle-income stage to catch up, and be able to overcome the trap. Three arguments emanate from the evidence.

First, three Development Profiles were identified. In the three profiles, countries confront a set of problems that undermine the processes of TCA, related to the NSI such as: problems of demand, supply problems, low private sector investment, shortage of private and public venture capital, rupture of domestic productive chains, among others, which are described in Section 2. The design of STI policy should take into account these particularities of the TES and SPS, their connexion and the specificities of the NSI' agents to be able to design efficient programs in economic, social and innovative terms.

Second, the evidence revealed a weak balance between the TES and SPS, and this has impact on TCA. While the ultimate goal of development is embodied in broad national economic and social objectives, the ultimate goal of STI policy in Latin America continues to be to build capacity in STI, especially innovation, and to promote productivity, competitiveness and economic growth. The weakness of the balance between TES and SPS suggests the need to pay more attention to other societal needs, such as poverty, food production, diabetes, renewable energy sources, water supply, among others. This requires more coordination between the STI authorities with other ministries, and putting into practice the transversality feature of STI policy. This should consider not only the goal of improvements in productivity and competitiveness, but also social welfare (Casas et al., 2014). This would contribute to making TES, SPS and TCA stronger.

Third, it is clear that instead of having a model of STI policy for Latin America, we need different types of STI policy strategies in accordance with the countries' development profiles (I, II, III) and TCA levels:

- For countries with Profile III, where a large percentage of firms have built Intermediate and Advanced innovative TC: the focus might be on increasing productivity and improving innovation performance to reach the technological frontier; and at the same time, to keep the balance with the SPS, policy also may include attention on the solution of national problems.
- For countries in Profile II, with a weak TCA dynamics and where the larger percentage of firms have only built Routine production TC: the focus should be to promote learning, imitation, adaptation, and a variety of innovation activities; and at the same time, to keep the balance with the SPS, policy may also include attention on the solution of national problems.
- For countries in Profile I, with high TES performance but a weak

[10] Argentina's Innovation Survey (ENDEI) has been generated using a questionnaire with a very different structure. We have not been able of including this data in this comparative and descriptive exercise because we are unable to assess the information in equal terms. Nevertheless, an exploratory analysis shows a similar trend that the one shown by Uruguay in the upper TCA stages: a high percentage of the innovative firms exhibit Intermediary or Advanced innovative TC.

SPS: the attention to national problems should be at the centre of the STI policy.

The challenge is how to keep productivity increase with the solution of national problems and an improvement of the SPS. This issue requires more research.

8. Final reflexions

The existence of a group of Latin American countries that does not overcome the middle-income trap suggests that we should look at other spheres that transcend the indicators associated with inputs and outputs of domestic STI capacities and capabilities, including those that focus on TCA. These indicators have been appropriated for developed countries, including those that have done the catch up already in some Asian countries. However, they result a narrow approach to TCA, which does not seem to be sufficient to understand the problem that firms face in countries that are still in the process of building TC. This paper shows that upper-middle income countries of Latin America still face problems to overcome the middle-income trap, and such problems surpass aspects related to TCA. Other dimensions of the TES, such as economic aspects, should be included into the analysis, as well as several social and political dimensions, included into the SPS.

Departing from a description of the TCA at the firm level in a set of Latin American countries, this paper had two interconnected objectives: i) to identify and analyse the development profiles of Latin American countries that relate to the techno-economic (TES) and socio-political (SPS) spheres, and (ii) to discuss the relationship between these profiles with the characteristics of TCA at the firm level.

Concerning to the development profiles of Latin American countries, the evidence reveals that countries differ in relation to having or not a balance between the TES and SPS. Three profiles of countries were identified: (i) Profile I: countries with strong TES but a week SPS (Brazil, Chile and Mexico), (ii) Profile II: countries with week TES and stronger SPS (Guatemala, Ecuador, Paraguay and Peru), and (iii) Profile III: countries with a more balanced TES and SPS, but with low levels of performance in both spheres (Uruguay, Costa Rica, Argentina, Colombia and Panamá).

The evidence of TCA of four countries suggests some links between development profiles, based on the balance between TES and SPS, and the composition of stages of firms' TCA. Hence, the STI policy oriented to strengthen TCA processes at the firm, and then country level, may have to take into account: (i) the stages of firms' TCA in the country, (ii) policy learning to adjust the instruments as the firms, sectors and country evolve, and (iii) the co-evolution, on the one hand, of TES and SPS, and, on the other hand, the TCA process.

Our knowledge about the factors that explain successful TCA, at the firm and country levels, is still limited. We need more research to disentangle the links between the TCA processes in their broader context, including the TES and STS. By means of articulating into the analysis of the TCA, the TES and SPS, this paper contributes to different streams of literature. This literature has made important contribution to the understanding of the TCA processes, but do not articulate their analysis with other spheres, such as the TES and SPS. A first stream has focused on the analysis of TCA, largely at firm level, and has distinguished between stages of TCA, but they tend to neglect the effect of the SPS on TCA (Bell and Pavitt, 1995; Dutrénit, 2000; Figueiredo, 2001, 2003, 2010; Radosevic and Yoruk, 2016). A second stream has centred its attention on the catching up processes, but they do not look at the links with TES and SPS (Lee, 2016; Liu et al., 2017; Radosevic and Yoruk, 2017; Rasiah, 2013). A third stream looks at the link between NSI and development, and refer to TCA processes; even though the SPS is included into the analysis, they do not distinguish stages of TCA and do not explore empirically the links between TCA and SPS (Castellacci and Natera, 2013, 2016; Katz, 1986; Katz and Astorga, 2013).

Finally, some words are needed about the available data. We do not have neither the data nor the metrics we need for this type of analysis of the stages and processes of TCA, and their coevolution with the TES and SPS. As pointed out by Radosevic and Yoruk (2016), it is necessary to build new indicators that reflect the micro behaviour of different stages of the TCA, which could allow us to use evidence to inform policy. The design of new indicators and the bases for the collection of new data is itself an area of urgent research.

Annex 1. Estimating cointegrating regressions for our long-run development profiles

If two or more variables are integrated of the same order (for example, both are I(1) series), there might be a linear combination of them that produces stationary residuals. This would imply that the two series are not stationary but that there exists at least one linear combination of them that it actually is.[11] If one finds evidence of such case, we say that variables are co-integrated. Therefore, the relationship between these non-stationary time series could be assessed through a co-integration approach, where their long-run equilibrium relationship and processes of short-run adjustment could be disentangled (Engle and Granger, 1987).

We could argue that Johansen co-integration method poses the most comprehensive approximation to the investigation of cointegration processes. Based on a Vector Error Correction (VEC) econometric specification, the approach helps to distinguish between long- and short-run structures. If we specify a VEC model comprising K variables:

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

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 co-integrated, the Π matrix in Eq. (1) should have a reduced rank r, such that $K > r > 0$. Johansen (1991, 1995) co-integration rank test seeks to determine those r co-integrating relationships by adopting Trace Test and Maximun Likelihood specifications. Under the null of finding an additional co-integrating relation, it uses a recursive test starting with $r = 0$ until the first rejection is encountered.

A crucial step is 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:

$$\Pi = \alpha\beta' \tag{2}$$

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, the in this

[11] It is also possible to find co-integration 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, co-integration techniques can be used - see Juselius (2006) and Loayza & Ranciere (2005).

paper we focus on the description of the long-run equilibrium β, since they represent the stable development path that countries have followed during the period of analysis.

If we would like to investigate our β vector using Johansen approach, we would face a data constrain that could impede the inclusion of a greater set of variables in the Y_t, since one caveat of this systemic method is the amount of data it requires for the estimation process. An alternative would be setting a cointegrating regression analysis, in which we could explore how a set of cointegrated variables γ_{it} are related to a reference variable ψ_t, where $Y_t = \{\psi_t, \gamma_{it}\}$. In this case, we should also consider deterministic trends, but only if those terms have a permanent effect (transitory effects do not belong to the β vector). In order to do so, we should apply a Fully Modified OLS (FMOLS) estimation method that takes into account the issues generated by the long run correlation between the cointegrating equation and stochastic regressors innovations (Phillips and Hansen, 1990). Therefore, FMOLS estimation method makes it possible the application of standard Wald tests using asymptotic Chi-square statistical inference.

In this paper, we run a group of cointegrating equations using GDP per capita (in PPP real terms) as our ψ_t, and defining different sets of γ_{it} according to the dimensions of the two spheres. More precisely we used the combinatory (2n-1 models per dimension, where n is the number of variables included in each dimension) of the following variables:

Table A1
List of included variables in the cointegrating regression analysis (1980–2010).

Sphere	Dimension	Variable	Source
Tecno-economic	Science, technology and innovation	Research and development expenditure (GERD as % GDP)	World Bank; OECD; UNESCO
		GERD - performed by Business Enterprises (% of total GERD)	UNESCO; OECD; RICYT
		Royalty and license fees (as % current payments to rest of the world)	World Bank; UNCTAD
		Trademark applications (per capita)	World Bank
		Scientific and technical journal articles (per capita)	World Bank
		High-technology exports (% of manufactured exports)	World Bank
	Economic performance	GDP growth rate	World Bank
		Commercial Openness Indicator (X + M / GDP)	World Bank
		Gross Fixed Capital Formation by private sector (% of GDP)	World Bank
		Labour productivity (per person employed in 2010 US$)	Total Economy Database - Groningen Growth and Development Centre
		Agriculture value added (% of GDP)	World Bank
		Manufacturing value added (% of GDP)	World Bank
		Services value added (% of GDP).	World Bank
Socio-political	Quality of living	Life Expectancy	World Bank
		Mean years of schooling	UNESCO
		Gini Index of Inequality	WIID; World Bank; OECD
		Corruption Perception Index	Transparency International

Source: own elaboration.

Out of this strategy, we analyzed 15,990 models, from which we selected the indicated models shown in Table 1 of this document as the most representative of the whole exercise. However, we still hold the results from all of the other models and could provide on demand if readers are interested in looking at the details of the empirical results.

Annex 2. – Results from TES and SPS cointegration tests

Table A2-1
Cointegration test – TES-economic performance dimension.

Country	EP model Code	Economic performance model specification	EP included dummies	EP Engle-Granger z-statistic
Argentina	ArgEP1	GDP growth rate Commercial, Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Labour productivity (per person employed in 2010 US$), Agriculture value added (% of GDP), Services value added (% of GDP).		−44.356***
	ArgEP2	GDP growth rate Commercial, Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Labour productivity (per person employed in 2010 US$), Agriculture value added (% of GDP), Services value added (% of GDP).	D1985, D1999, D2005	−55.583***

Brazil	BraEP1	GDP growth rate Commercial, Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Labour productivity (per person employed in 2010 US$), Agriculture value added (% of GDP), Services value added (% of GDP).	D1981, D1990, D1999	− 43.961**
	BraEP2	GDP growth rate Commercial, Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Labour productivity (per person employed in 2010 US$), Services value added (% of GDP).	D1981, D1990	− 37.48**
Chile	ChiEP1	GDP growth rate Commercial, Openness Indicator (X + M / GDP), Labour productivity (per person employed in 2010 US$), Services value added (% of GDP).	D1975, D1999	− 58.078***
Colombia	ColEP1	GDP growth rate Commercial, Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Services value added (% of GDP).		− 253.867***
	ColEP2	GDP growth rate, Services value added (% of GDP).		− 41.333***
	ColEP3	GDP growth rate, Gross Fixed Capital Formation by private sector (% of GDP), Services value added (% of GDP).	D1980	− 26.818*
Costa Rica	CoREP1	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Labour productivity (per person employed in 2010 US$), Agriculture value added (% of GDP), Services value added (% of GDP).	D1991, D2008	− 37.896*
	CoREP2	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Labour productivity (per person employed in 2010 US$), Agriculture value added (% of GDP), Manufacturing value added (% of GDP).	D1991, D2008	− 38.606*
Ecuador	EcuEP1	GDP growth rate, Gross Fixed Capital Formation by private sector (% of GDP), Labour productivity (per person employed in 2010 US$), Agriculture value added (% of GDP), Manufacturing value added (% of GDP).		− 36.235**
	EcuEP2	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Labour productivity (per person employed in 2010 US$), Agriculture value added (% of GDP), Manufacturing value added (% of GDP), Services value added (% of GDP).	D1980, D1990, D2008	− 50.194***
	EcuEP3	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Labour productivity (per person employed in 2010 US$), Agriculture value added (% of GDP), Manufacturing value added (% of GDP).	D1990	− 33.74*
Guatemala	GuaEP1	Commercial Openness Indicator (X + M / GDP), Manufacturing value added (% of GDP), Services value added (% of GDP).	D1980, D1988, D2008	− 33.262*
	GuaEP2	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Labour productivity (per person employed in 2010 US$), Agriculture value added (% of GDP), Manufacturing value added (% of GDP).	D1985, D2008	− 35.79*
Mexico	MexEP1	GDP growth rate, Gross Fixed Capital Formation by private sector (% of GDP), Labour productivity (per person employed in 2010 US$), Agriculture value added (% of GDP), Manufacturing value added (% of GDP).		− 29.541*
	MexEP2	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Labour productivity (per person employed in 2010 US$), Services value added (% of GDP).		− 37.359**
	MexEP3	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Labour productivity (per person employed in 2010 US$), Agriculture value added (% of GDP), Manufacturing value added (% of GDP), Services value added (% of GDP).	D1994	− 45.939***
Panama	PanEP1	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Labour productivity (per person employed in 2010 US$), Agriculture value added (% of GDP), Services value added (% of GDP).		− 39.496***
	PanEP2	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Manufacturing value added (% of GDP), Services value added (% of GDP).	D1986, D1996, D2006	− 65.842***
Paraguay	ParEP1	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Agriculture value added (% of GDP), Manufacturing value added (% of GDP), Services value added (% of GDP).		− 44.56***
	ParEP2	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Agriculture value added (% of GDP), Manufacturing value added (% of GDP), Services value added (% of GDP).	D1985, D2002	− 101.896***
	ParEP3	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Agriculture value added (% of GDP), Manufacturing value added (% of GDP), Services value added (% of GDP).	D1981, D1994	− 61.902***
Peru	PerEP1	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Labour productivity (per person employed in 2010 US$), Agriculture value added (% of GDP), Manufacturing value added (% of GDP).		− 35.953**

Uruguay	UruEP1	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Labour productivity (per person employed in 2010 US$), Manufacturing value added (% of GDP).	D1980, D1990, D2002	−35.63*
	UruEP2	GDP growth rate, Commercial Openness Indicator (X + M / GDP), Gross Fixed Capital Formation by private sector (% of GDP), Labour productivity (per person employed in 2010 US$), Manufacturing value added (% of GDP).	D1985, D1999, D2005	−41.227**

Significance levels: 1% ***, 5% **, 10% *.
Source: own elaboration.

Table A2-2
Cointegration test – TES-science and technology dimension.

Country	ST model Code	Science and technology model specification	ST included dummies	ST Engle-Granger z-statistic
Argentina	ArgST1	GERD - performed by Business Enterprises (% of total GERD), Trademark applications (per capita), Scientific and technical journal articles (per capita), High-technology exports (% of manufactured exports)	D1985, D1999, D2005	−66.946***
Brazil	BraST1	Research and development expenditure (GERD as % GDP), Royalty and license fees (as % current payments to rest of the world), Scientific and technical journal articles (per capita), High-technology exports (% of manufactured exports)	D1985, D1994	−39.414***
Chile	ChiST1	Royalty and license fees (as % current payments to rest of the world), Trademark applications (per capita), Scientific and technical journal articles (per capita), High-technology exports (% of manufactured exports)	D1988	−27.512*
	ChiST2	GERD - performed by Business Enterprises (% of total GERD), Trademark applications (per capita), Scientific and technical journal articles (per capita), High-technology exports (% of manufactured exports)		−25.333*
	ChiST3	Trademark applications (per capita), Scientific and technical journal articles (per capita), High-technology exports (% of manufactured exports)	D1992	−25.984*
Colombia	ColST1	Research and development expenditure (GERD as % GDP), GERD - performed by Business Enterprises (% of total GERD), Royalty and license fees (as % current payments to rest of the world), Trademark applications (per capita), Scientific and technical journal articles (per capita), High-technology exports (% of manufactured exports)		−96.97***
	ColST2	Research and development expenditure (GERD as % GDP), GERD - performed by Business Enterprises (% of total GERD), Royalty and license fees (as % current payments to rest of the world), Trademark applications (per capita), Scientific and technical journal articles (per capita), High-technology exports (% of manufactured exports)	D1994	−11.081**
Costa Rica	CoRST1	Research and development expenditure (GERD as % GDP), Scientific and technical journal articles (per capita), High-technology exports (% of manufactured exports)		−23.013*
Ecuador	EcuST1	GERD - performed by Business Enterprises (% of total GERD), Scientific and technical journal articles (per capita), High-technology exports (% of manufactured exports)		−39.509***
	EcuST2	Research and development expenditure (GERD as % GDP), Royalty and license fees (as % current payments to rest of the world), Trademark applications (per capita), Scientific and technical journal articles (per capita), High-technology exports (% of manufactured exports)	D1990	−12.072**
Guatemala	GuaST1	GERD - performed by Business Enterprises (% of total GERD), Trademark applications (per capita), High-technology exports (% of manufactured exports)	D1985, D2008	−69.449***
Mexico	MexST1	Research and development expenditure (GERD as % GDP), Royalty and license fees (as % current payments to rest of the world)		−19.543*
	MexST2	GERD - performed by Business Enterprises (% of total GERD), Trademark applications (per capita), High-technology exports (% of manufactured exports)	D2003	−25.84*
Panama	PanST1	Research and development expenditure (GERD as % GDP), GERD - performed by Business Enterprises (% of total GERD), Royalty and license fees (as % current payments to rest of the world), Trademark applications (per capita), Scientific and technical journal articles (per capita		−43.166***
	PanST2	GERD - performed by Business Enterprises (% of total GERD), Royalty and license fees (as % current payments to rest of the world), Trademark applications (per capita), Scientific and technical journal articles (per capita), High-technology exports (% of manufactured exports)	D1986, D2006	−46.89***

Paraguay	ParST1	Research and development expenditure (GERD as % GDP), GERD - performed by Business Enterprises (% of total GERD), Royalty and license fees (as % current payments to rest of the world), High-technology exports (% of manufactured exports)		−26.808*
	ParST2	GERD - performed by Business Enterprises (% of total GERD), Royalty and license fees (as % current payments to rest of the world), Trademark applications (per capita), Scientific and technical journal articles (per capita)	D1985, D2002	−45.522***
Peru	PerST1	Research and development expenditure (GERD as % GDP), GERD - performed by Business Enterprises (% of total GERD), Trademark applications (per capita), Scientific and technical journal articles (per capita)	D1985, D2001	−30.424**
Uruguay	UruST1	Research and development expenditure (GERD as % GDP), GERD - performed by Business Enterprises (% of total GERD), Royalty and license fees (as % current payments to rest of the world), Trademark applications (per capita), Scientific and technical journal articles (per capita), High-technology exports (% of manufactured exports)		−16.915**
	UruST2	Research and development expenditure (GERD as % GDP), GERD - performed by Business Enterprises (% of total GERD), Royalty and license fees (as % current payments to rest of the world), Trademark applications (per capita), Scientific and technical journal articles (per capita)	D1985, D2002	−33.791**
	UruST3	GERD - performed by Business Enterprises (% of total GERD), Royalty and license fees (as % current payments to rest of the world), Trademark applications (per capita), Scientific and technical journal articles (per capita)	D1985, D2002	−42.397***

Significance levels: 1% ***, 5% **, 10% *.
Source: own elaboration.

Table A2-3
Cointegration test – SPS-quality of life dimension.

Country	QL model	Quality of life model specification	QL included dummies	QL Engle-Granger z-statistic
Argentina	ArgQL1	Life Expectancy		−16.704*
	ArgQL2	Mean years of schooling Corruption Perception Index		−32.245***
Colombia	ColQL1	Life Expectancy		−37.09***
Costa Rica	CoRQL1	Life Expectancy Gini Index of Inequality Corruption Perception Index	D1991, D2008	−39.574***
Ecuador	EcuQL1	Mean years of schooling	D1990	−19.681*
Guatemala	GuaQL1	Life Expectancy Mean years of schooling Gini Index of Inequality Corruption Perception Index	D1985, D2008	−104.473***
Panama	PanQL1	Life Expectancy Mean years of schooling	D1986, D2006	−30.86**
Paraguay	ParQL1	Life Expectancy Mean years of schooling Corruption Perception Index	D1985, D2002	−27.518*
	ParQL2	Life Expectancy Mean years of schooling Corruption Perception Index	D1985, D2002	−27.518*
Uruguay	UruQL1	Corruption Perception Index		−26.046***
	UruQL2	Life Expectancy		−38.585***
	UruQL3	Mean years of schooling	D1985, D2002	−493.528***

Significance levels: 1% ***, 5% **, 10% *.
Source: own elaboration.

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