Innovation for Development in Latin America: where we are regarding the critical mass of STI capabilities

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Abstract

A set of recently industrialized countries present an exemplary behavior regarding indicators related to their capabilities in science, technology and innovation (STI). In a way, this suggests that they have reached or are close to reaching the level of critical masses in their STI capabilities, which could explain the generation of endogenous processes that contribute to development processes. This document inserts itself within this discussion and its central purpose is to discuss how far Latin American countries are from reaching the critical masses that allow for the consolidation of national systems of innovation (NIS) and what the policy implications are. The analysis of STI critical masses is situated in the context of the structural characteristics of these countries.

Key words: critical masses, innovation systems, innovation indicators, innovation policy

INTRODUCTION[1]

There is a growing consensus about the centrality of scientific and technological advances in driving economic progress, and that increasing national investments in innovation are essential to ensure the countries' economic growth (Schumpeter, 1942; Solow, 1956; Abramovitz, 1956 and 1986). However, no agreement has been reached concerning the processes linking innovation and growth, even less so when development is introduced into the analysis. Today it is also quite clear that the structure of linkages at local, regional, national and international levels, and the construction of a national system of innovation (NIS) contribute to that success (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edquist, 1997; Kim, 1997; Niosi, 2000; Cimoli, 2000; Cassiolato, Lastres and Maciel, 2003).

[1] I would like to express my gratitude to Rodrigo Magaldi and Carlos Ramos for their support in the processing and analysis of the information.

From a structuralist and systems-evolutionary perspective (Schumpeter, 1934, 1939; Kuznets, 1971, 1973; and more recently Saviotti and Pyka, 2004) innovation affects economic growth and development if it triggers structural change (World Bank, 2008; Haussman and Klinger, 2007). This could be seen as the emergence of new sectors, markets, clusters, large multinational companies, and other forms of multi-agent structures (e.g networks, regional or sectoral innovation systems). An innovation and structural change-led economic development has to be placed in the context of the construction of NIS, as agents, functions and structures are important for the dynamics of change.

Based on coevolutionary approaches to STI and ideas coming from development economics (Gersenkron, 1962; Rosenstein Rodan, 1943; Myrdal, 1957), Dutrénit, Puchet and Teubal (2011) argue that in order to place innovation as a powerful process for the production of structural change, the NIS has to reach a threshold of STI capabilities before emergent behaviour appears to generate a structural change-led development. In other words, critical masses seem to be needed in order to generate self-sustaining endogenous processes.

The idea is that through processes of learning, capability building and coevolution across key technologies, institutions and agents of the NIS, it is possible for top-level organizations to emerge, such as new sectors/markets, which would trigger a structural change. This process is founded on the basis of advancing towards development with social equity. But the initial conditions do not refer exclusively to the STI capabilities; the countries' structural characteristics affect the possible trajectories.

The concept of critical mass has been introduced in different disciplines. It is usually used to determine when a certain level of accumulation of a capability or stock makes it possible to shoot a result that characterizes the process under study, and is maintained from there at a high rate of growth (Granovetter, 1978; Oliver, Marwell and Teixeira, 1985; Mahler and Rogers, 1999; Somasundaram, 2004; Booij and Helms, 2011; Azariadis and Drazen, 1990).[2]

Although the significance of reaching a critical mass of STI can be ambiguous, the STI capacities of those countries that have had a remarkable performance could be close to what

[2] Dutrénit and Puchet (2011) discuss the concept of critical masses and their application in the STI capabilities.

we would call critical masses of STI. In this way, the newly industrialized countries have an adequate behavior regarding the indicators related o their local capacities in science, technology, and innovation (STI) (e.g. Korea, Singapore, and more recently China), which in a way suggests that they have reached or are close to reaching the level of critical masses in their STI capacities. This could have allowed them to generate endogenous processes that contribute to the development processes. In some cases, it was the government who initiated these processes with an adequate design of STI policies and with a correct allocation of resources in order to generate adequate incentives (e.g. Israel).

The STI policy jointly with the industrial policy is called to play a key role in this process by fostering changes in the agents' behaviours to increase demand and supply of knowledge (and a balance between both), stimulating the emergence of strategic sectors and new areas of competitiveness, and promoting cooperation and balance between regions within the country. The coevolution of STI arenas emerges as a relevant process for building up such critical masses to accelerate a trajectory of innovation and structural change-led economic development. This requires a systemic/evolutionary approach to STI policy (Nelson, 1994; Murray, 2002; Breznitz, 2007; Sotarauta and Srinivas, 2006; Smits, Kuhlmann and Teubal, 2010; Dutrénit, Puchet and Teubal, 2011). Once critical masses are reached, self-sustaining endogenous processes may be generated.[3] However, a critical mass is a dynamic dimeNISon, which evolves over time, thus it can be thought of as a moving target (Somasundaram, 2004).

We do not know enough about what these critical masses of STI are, how they may be built and how they dynamically evolve, what is their relationship with co evolutionary processes of STI populations, and what the role of STI policies is in this process. This paper is inserted in this discussion and has as an objective the discussion of how far Latin American countries are of reaching the critical masses that would allow the consolidation of the NIS and what the implications are for the STI policy. The analysis of the critical masses of STI is located within the context of the structural characteristics of such countries.

[3] On the one hand, the coevolutionary processes may contribute to reach critical masses, on the other, when operating at the critical mass level, there may be conditions for new coevolutionary processes that may generate structural change-led economic development. Hence, coevolution may happen below a situation that triggers an endogenous dynamic process, but certainly contributes to that. The links between coevolution, endogenous dynamic processes, critical mass and development require further analysis.

After this introduction, section 2 explores the structural characteristics of the countries; section 3 analysis the NIS characteristics and their STI capabilities; section 4 compares the structural characteristics and the STI profiles; section 5 discusses the innovation policy regarding the existent analytical frameworks and suggests some areas of opportunity in the policy design according to the initial conditions; finally, section 6 concludes.

STRUCTURAL CHARACTERISTICS OF LATIN AMERICAN COUNTRIES: DIFFERENCES IN ECONOMIC PERFORMANCE AND SIMILARITIES IN LEVELS OF INEQUALITY

The profile of STI and the dynamics of its capacities are not independent from the structural characteristics of Latin American countries. Countries differ in their structural characteristics, such as the economic structure, the market size, the structure of their exports (commodities versus manufactures goods, technological contents, etc.) average age of the population, education level, poverty level, etc. Some of these characteristics are associated with the size of the country and the resource endowment, while others are related with the level of development. These characteristics may condition their STI capabilities, and in consequence, their STI policies. This section describes a set of structural features in these countries.

Following Dutrénit, Puchet and Teubal (2011), the analysis of structural characteristics of these countries is based on their evolution through 3 periods, which are relevant in terms of Mexico and other emerging and developing countries: 1990 (previous to the Washington Consensus), 2000 (post Washington Consensus) and 2008 (current period). In this analysis a set of indicators is used that show the percentages and the levels of different economic and social aspects of Latin American countries. The three-year comparison shows the evolution of the profile. A set of indicators is included:

- Relative size of the economies (GDP PPP)
- Basis for developing the capabilities of the systems: health, education and income through the Human Development Index (HDI), diffusion of information technologies (Internet), % of urban population (Urban POP)

- Achievement of economies: GDP per capita (GDP/cap), equality (1/Gini[4]), export capacity of manufacturing sector (X Manufactura, %); export capacity of high technology goods (High-Tech X, %)

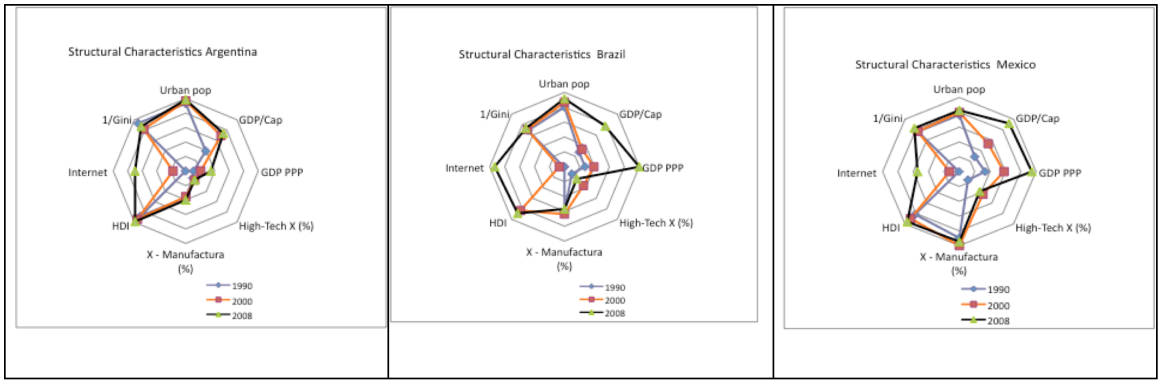
The analysis is based on structural graphics, which are related to the country that has a higher value in the period under review (1990, 2000 and 2008), which mostly refer to 2008. The reference countries for each indicator are:

▪ GDP PPP: Brazil ▪ GDP/cap: Venezuela ▪ Urban POP: Venezuela ▪ HDI: Chile	▪ Internet: Uruguay ▪ 1/Gini: Venezuela ▪ X Manufactura (%): Mexico ▪ High-Tech X (%): Costa Rica

Figure 1 shows the structural characteristics of a set of countries in Latin America and the Caribbean, for which the information is available. The countries were grouped by their relative performance in three groups:

- Group A, structural characteristics: Big countries with more balanced structural conditions
- Group B, structural characteristics: Mid-size countries with a satisfactory performance in living conditions
- Group C, structural characteristics: Countries with a less satisfactory performance

Figure 1.a Group A, structural. Big countries with more balanced structural conditions

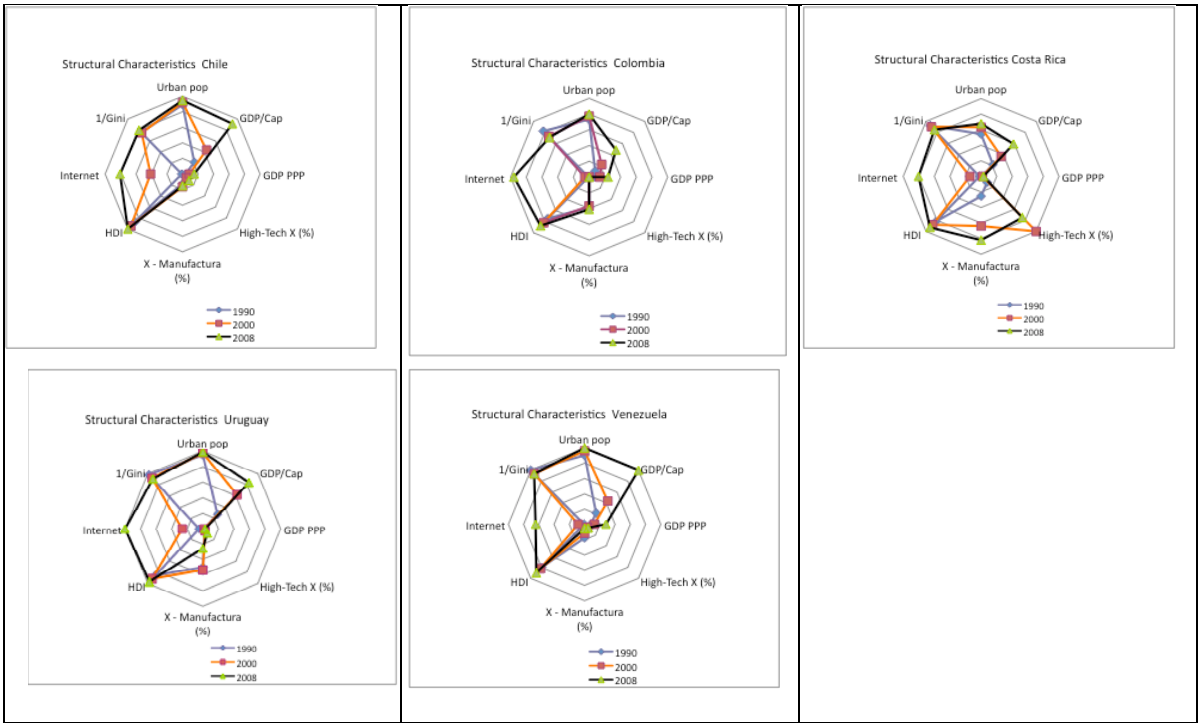


[4] We decided to use the inverse of the GINI coefficient to reflect a positive condition regarding inequality, due to the fact that the highest GINI levels reflect bigger levels of inequality.

While all the countries have made progress throughout the analyzed period between 1990 and 2008 in the social and economic dimensions, different results are observed. The structural profile of the big countries (Group A, structural characteristics) is more balanced:

- It includes the three biggest economies in the region
- High levels of relative welfare (high GDP per capita)
- Better living conditions, as evidenced by their high levels in the HDI and the percentage of Internet users. This performance is associated with them having mostly urban populations. But in the cases of Mexico and Brazil, the two countries with the best relative performance, there persists a strong inequality (the inverse of the GINI is relatively low).
- The export profile shows a significant weight of manufactures on total exports, especially in Mexico and Brazil, with a strong export specialization in high-tech products. (In particular, there is an important weight on manufacture exports in the case of Mexico, with an increase in those with a high-tech content; and a relatively smaller weight, although a significant one, on those exports in the case of Brazil, although with a decrease of high-tech exports).

Figure 1b. Group B, structural characteristics: Mid-sized countries with a satisfactory performance in living conditions

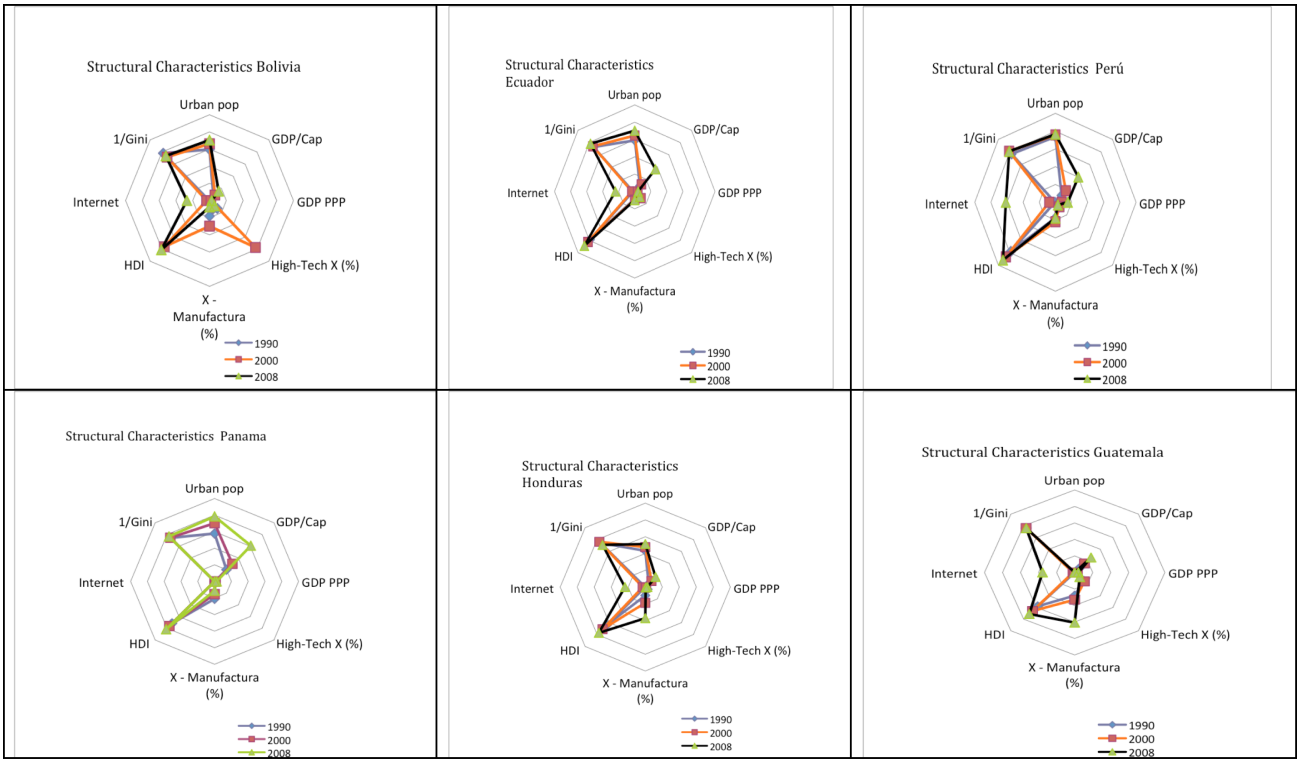


The profile of mid-sized countries with a satisfactory performance on living conditions (Group B, structural characteristics) has the following characteristics:

- Smaller economies
- High levels of welfare (High GDP per capita)
- These economies stand out for having high living conditions (Internet, HDI), which are also associated to a high percentage of urban populations. These countries present different characteristics of income distribution. Costa Rica, Uruguay and Venezuela present more equality in income distribution (the inverse of the GINI is high) than the big countries; in Colombia and Chile high inequality persists.
- The export profile shows a low participation of manufacture in the total exports as well as high-tech exports, except in the case of Costa Rica.

In contrast, there is a large group of countries that still present an unsatisfactory performance in almost all dimensions (Group C, structural characteristics):

Figure 1c. Group C, structural characteristics: Countries with a less satisfactory performance



- Their economies are significantly smaller
- The present low levels of welfare (GDP per capita), and worse living conditions linked to a rural population
- These countries present a strong inequality, but not superior to that of Colombia, Chile, Mexico and Brazil.
- The export profile shows a low participation of manufactures in the total exports as well as of high-tech exports in the total of manufactures. There are some exceptions, like Guatemala.

In conclusion, there are different structural profiles that reveal different levels of development. Latin America is not a homogenous, but rather a heterogeneous set of countries. A common element is the high inequality, as is analyzed in CEPAL (2010), or the export profile, with a high presence of manufactures in some countries, which corresponds to the strategy of insertion into global chains.

CHARACTERISTICS OF INNOVATION IN LATIN AMERICA: THE NIS AND THE FIRMS

The focus on NIS allows us to approach the innovation capabilities as well as the science and technology capabilities. From the NIS perspective, an analysis of the critical masses in STI must include indicators of inputs and outputs of this system. This section characterizes the NIS of Latin American countries and approaches a measurement of the critical masses of STI capabilities.

Emerging National Systems of Innovation with reduced and unarticulated national STI capabilities

The Latin American NIS are small, according to the size of their main agents, and have been the result of a process of aggregation of different institutions as well as public and private organizations that operate, to this day, in a poorly articulated manner. This is due to a number of factors, on the one hand, historically, the assessment of the activities related to STI has been poor and the technical change based on local and systematic STI efforts has rarely been identified as an important factor to improve the performance of the Latin American economies. On the other hand, the financial resources dedicated both by the public and private sectors to STI have been scarce, in fact, it seems that the most productive activities in the Latin American markets (at the industrial or service levels) have no relation to innovation efforts, that is, the signs of short-term relative gains appear to be disassociated from innovation (Cimoli 2000; Cassiolato, Lastres and Maciel, 2003; López, 2007; Dutrénit et al, 2010).

The STI agency (CONACYT/CONICYT, etc.) were created mostly during the 1970s, with a supply-side focus. They play a central role in the region's NIS, coordinating the design and implementation of the national STI policies and acting as mediators between the government and the scientists and between the government and firms (Braun, 1993; Guston, 1996; van der Meulen, 2003). In general, the institutional framework around the STI activities has radically changed in most countries during the 2000s, following the international patterns. The private sector maintains a very undeveloped culture of innovation, created from these supply-focused approaches. While there are some success stories, the market protections and the macroeconomic instability did not generate an appropriate incentive structure in order to

generate a more dynamic technological behavior (Katz, 1986, 2000; Vera-Cruz, 2006; Arza, 2007).

In general, the Latin American NIS can be characterized by the following traits:

- Scarce financial resources and allocation problems, small government financial effort (low Government Expenditure on Research and Development- GERD)
- A small scientific community with level of excellence in some scientific fields in the biggest countries, centered on curiosity-driven research, and with few incentives to develop research oriented towards national problems, but with experience in solving some specific problems related to health, environment and food.
- Public sector is the main source of funding
- High geographical and institutional concentration of STI capacities
- Firms make little effort in R&D and other innovation activities (small BERD) as reveled by the results in the national innovation surveys and international comparisons, nevertheless, many of their innovation activities seem to be unaccounted for in the current methodologies for measuring innovation
- There are limited links between agents
- There persists a combination of institutions that come from the model of import-based industrialization and other institutions created recently under a different logic
- There is a strong distortion in the incentive structure

In recent years there are various achievements that can be described, such as the emergence of new actors and their impact on the NIS reconfiguration, the increase in the quantity of R&D funded by the business sector and its successful performance in specific areas, and the increase in research productivity, among other factors.

Different profiles of STI in Latin American countries: capabilities and results

According to the focus of this document on the measuring of critical masses of STI to explain the generation on self-sustaining processes, we need to explore the indicators of relative as well as absolute levels of expenditures and outputs of STI. Along this line, both the efforts on R&D as a percentage of GDP and the absolute amount of expenditure on R&D are important.

As in the case of the structural characteristics, the analysis of the STI profile of these countries is based on their evolution through three periods: 1990, 2000 and 2008. Eight indicators for STI capacities, including indicators for percentages and amount of relevant dimensions of STI, ST and Innovation, were selected to illustrate the evolution of the profiles over the period:

Science

- Scientific articles per one hundred thousand people (Articles/100,000 Hab)
- Country's percentage in the production of scientific articles in the world (% world share Articles)
- Number of students that obtained a PHD (Total PHDs granted)
- Researchers per thousand of the Economically Active Population (Researchers/1,000 EAP)

Innovation

- Gross Domestic Expenditure on R&D as percentage of the GDP (GERD/GDP)
- Business Expenditure on R&D as percentage of the GERD (BERD %)
- Percentage of researchers working in the private sector (% researchers in firms)

For the case of STI indicators, the differences between the countries are of a magnitude that makes the comparison difficult. There are countries that make such a small effort or that have such small values that any comparison is difficult. For example, while the total number of granted PHD in 2008 was 10,611 in Brazil, in Trinidad and Tobago it was 19. These differences are also observed in indicators that measure the effort regarding the GDP, while Brazil spends 1.09% of its GDP on STI, Panama spends 0.21%. Other countries do not systematize the information on STI and publish figures only for some of the indicators. For this reason, we could only compare countries that provided complete information on STI; these were compared within two groups of countries, in order for the magnitudes to be meaningful when compared:

- Group A, STI: Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, Uruguay and Venezuela.
- Group B, STI: Bolivia, Ecuador, Perú, Guatemala, Panamá, Honduras and Trinidad and Tobago.

The reference countries for each indicator in each group are the following:

Articles/100,000 Hab: Group A: Chile Group B: Trinidad and Tobago % world share Articles: Group A: Brazil Group B: no data Total PHDs granted: Group A: Brazil Group B: Ecuador Researchers/1,000 EAP: Group A: Argentina Group B: Trinidad and Tobago	GERD/GDP: Group A: Venezuela Group B: Panamá BERD %: Group A: Uruguay Group B: Panama % researchers in firms: Group A: Chile Group B: Ecuador

Figures 2a and 2b illustrate the STI profile of a set of Latin American countries, for which information was available. There are difficulties to access to information particularly for the small countries. In general we observe:

- An increase in the values of the variables throughout time, between 1990 and 2008, clearly in Group A and in some countries in Group B
- A high value of BERD in the countries that make the greatest effort, which reveals that part of the effort is being made through the participation of the private sector in the GERD
- An imbalance between the indicators of the capabilities of science and innovation

Figure 2a. Group A, STI: Countries that make a great effort in STI

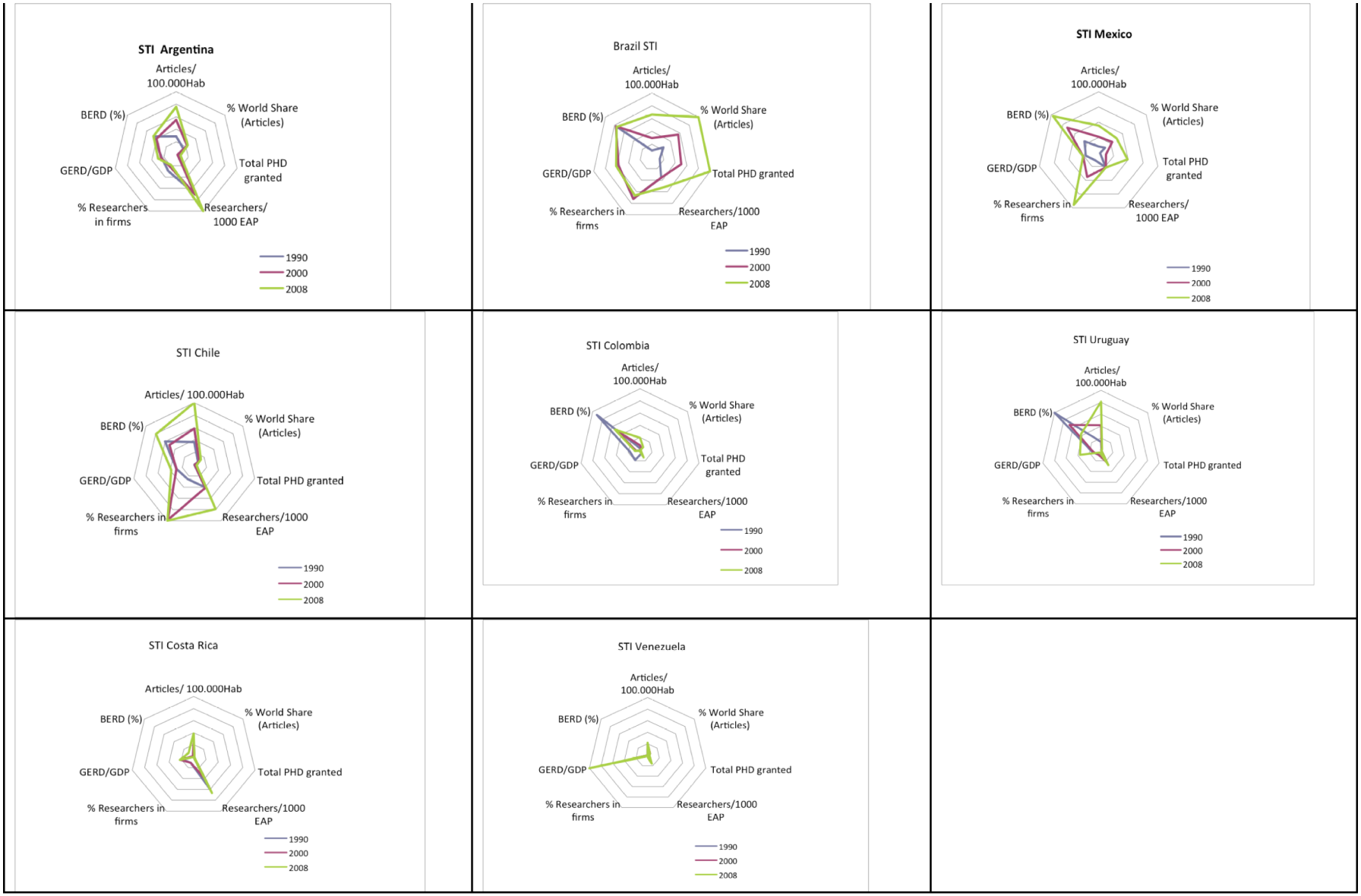
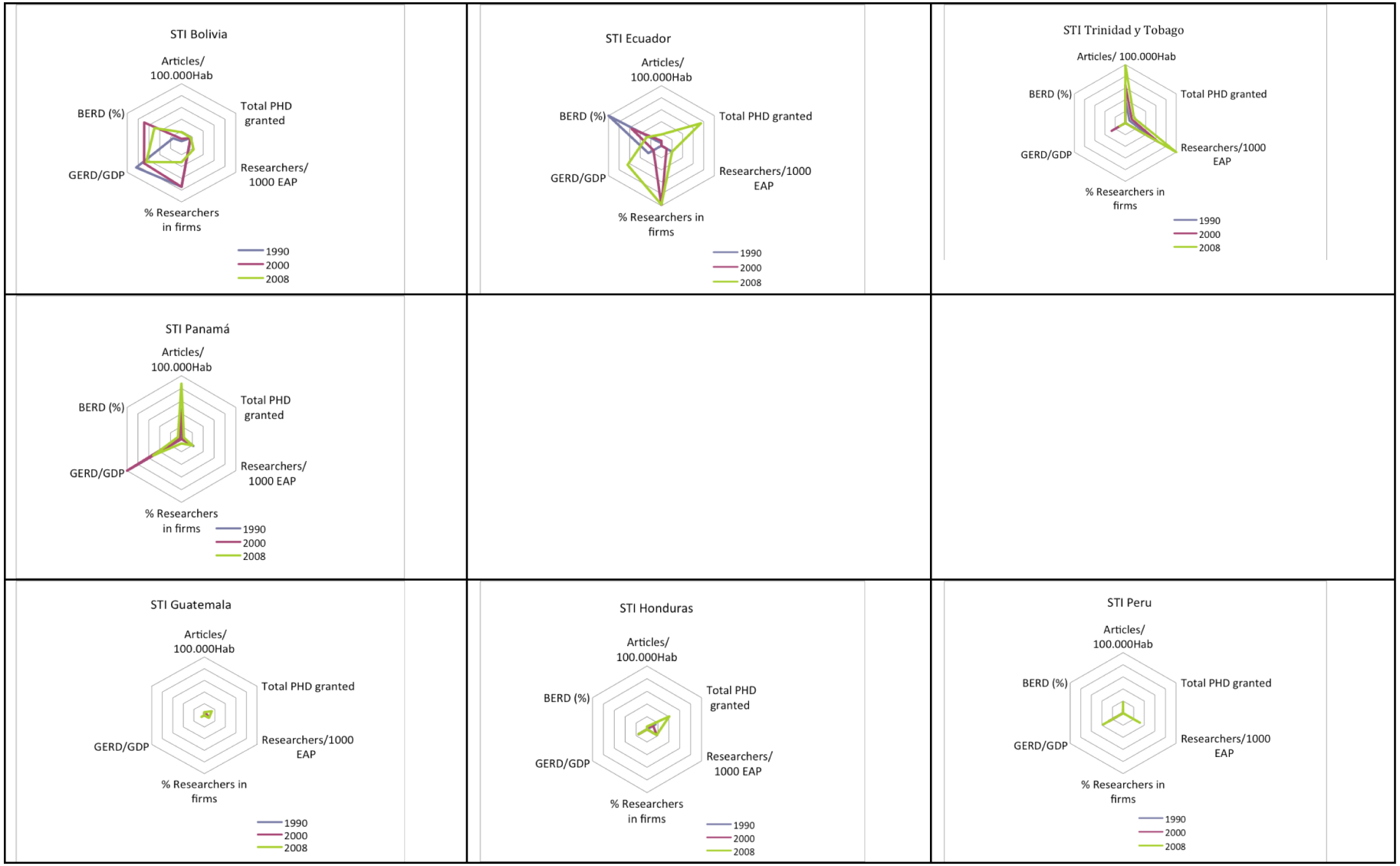


Figure 2b. Group B, STI: Countries that do not make such a great effort in STI



But there are various profiles that reveal different maturity in the NIS:

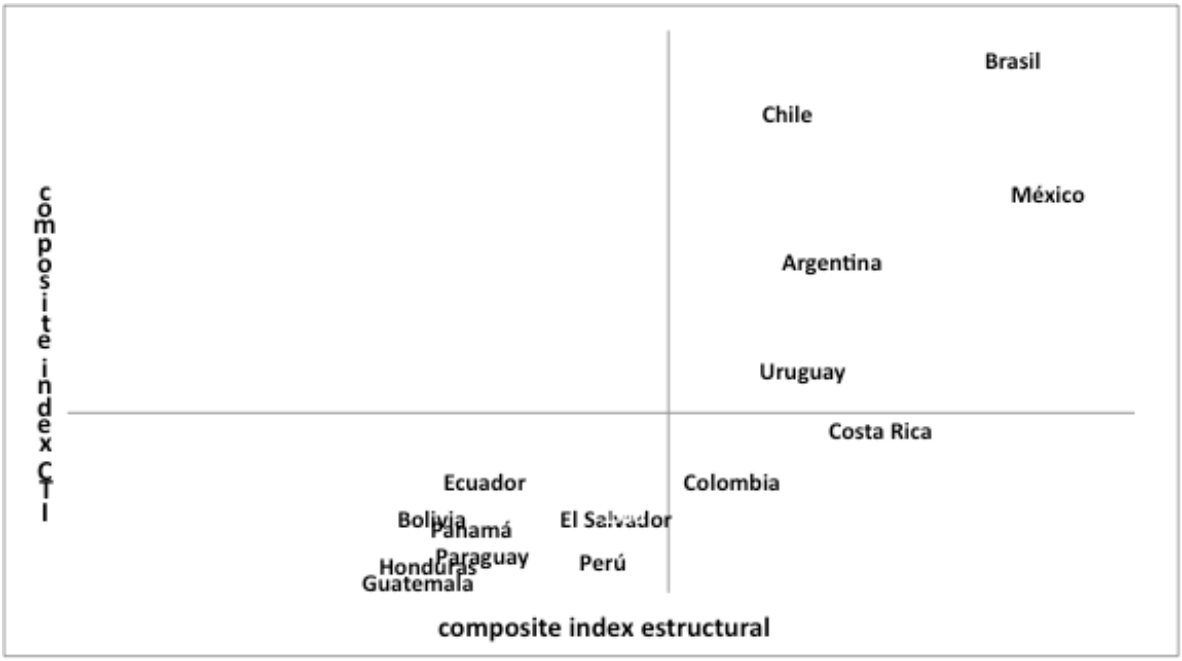
- A1 Profile. High values for the STI variables and a more balanced profile among every indicator (e.g. Brazil, Mexico, Chile and Argentina), but with a bias towards science (e.g. Brazil: WorldShare and PHD; Argentina: researchers) or towards innovation (e.g. Mexico: BERD % and % of researchers working in firms; Chile: researchers working in firms).
- A2 Profile. Average values in a process of change towards a different profile, or smaller relative values (e.g. Uruguay, Colombia).
- B Profile. Low values of STI variables, not comparable to the A Group, and strong distortions of some indicators, with no clear articulation and with no sustained tendency towards growth. Trinidad and Tobago is the only country that has more balance of capabilities, with very low levels of effort.

HETEROGENEITY OF COUNTRIES IN TERMS OF STRUCTURE AND STI CAPABILITIES

This section integrates the results of the analysis of the countries' structural characteristics from section 2 and of the STI profile presented in section 3. Figure 3 relates the two dimensions for the countries that present this information; some countries were not included because the information available is for only one dimension (e.g. Trinidad and Tobago). The countries have been located in the plane according to their performance.

A composite index was built for the structural characteristics and for the STI profile. The countries are located in the figures based on these composite indexes. In the case of the STI, as two groups of countries were defined due to the difference sin the magnitudes, the composite index of countries from Group B was normalized according to the lower level of countries from Group A.

Figure 3. Comparing the structural and STI profile of Latin American countries



The countries with a better performance are those that are located in Group A of the structural characteristics and group A1 of the STI profile. Brazil presents the best balance between structural characteristics and its STI profile; Mexico follows with a lesser effort on STI; Chile stands out more on its STI profile, with a greater lag in the structural characteristics, and then Argentina in a medium position. At the other end are the countries with lags in both dimensions. Paraguay, Peru, Guatemala, Honduras and Bolivia have the worst relative performances in both dimensions. Uruguay, Costa Rica and Colombia are in an intermediate situation. There seems to be some relation between both dimensions, that is, the countries with better structural characteristics are those that make a greater effort in STI and have a better profile. Again, many Latin Americas emerge.

THE INNOVATION POLICY: INITIAL CONDITIONS AND EXISTING ANALYTICAL FRAMEWORKS

In this section we reflect on the rationality of the STI policies (policy mix) regarding initial conditions observed in Latin American countries, both regarding structural characteristics and the exiting STI profiles.

Regarding design, Latin American countries have followed recommendations by international organisms based on countries with more mature NIS or the experience of successful emerging economies (such as Korea, China, Singapore, or even Brazil).

Latin American countries have designed their STI policies according to the existent analytical framework at the international level. This analytical framework was elaborated from the initial conditions of developed countries and of some successful emergent countries. These countries are characterized by having a rather consolidated scientific base, a broad base of firms that perform R&D and in many cases by having what Guston (2000) has called a social contract of S&T with society.
Under these conditions, a priority of the innovation policy is to increase the effort in private R&D and to increase the mass of firms that perform significant innovations. These countries seem to have the critical masses or at least an important mass of STI capabilities, which explains the emphasis they place on the innovation policy and not in the S&T policy. The countries in Latin America have followed the recommendations of the OECD, IDB, etc. that have emerged from those countries with more mature NIS and critical masses or in the international experience of the more successful emerging economies, without having those initial conditions.

Spaces to improve the STI policies in the existent analytical framework

From different evaluations of the design and implementation of the STI policies (see OECD 2007 for Chile, López 2007 for Argentina, Dutrénit et al 2010 for Mexico, and Sennes and Britto Filho 2011 for Brazil) and the evolutionary and systematic focus of the STIC policy used in this paper, a set of spaces to improve policy-making emerge.

The policy mix used in the region includes more programs/resources to foster R&D than to foster other innovation activities (e.g. sectorial fund of innovation). It is necessary to broaden the support in order to include other innovation activities that foster firms to learn and move along the innovation process towards activity of higher innovativeness.

Even though it is broadly recognised that transversality may be a feature of innovation policy (Kuhlmann, 2001; Georghiou, 2001; Shinn, 2005; Cooke, 2011), difficulties to coordinate

between ministries and the STI agency are observed, which negatively affects the possibility of taking advantage of this characteristic. This limits the scope of the innovation policy and affects the innovative performance. The difficulties for this coordination are also related to the lack of a clear definition, a common language, and a standardized way of defining the items that integrate the STI budget at all levels.

The evidence suggests that a strategic level of innovation policy would contribute to a better efficiency to induce changes of the STI capabilities, which include a policy-learning dimension (Avnimelech, Rosielo and Teubal, 2010). Policy makers may internalize the need of continuously adjusting their actions to foster STI capabilities, as these capabilities evolve. This requires a long-term view of the policies, which includes the evolution of the programs as the sectors/agents evolve to attend new needs, the definition of priorities in key areas, and targeting new industries/sectors/clusters (Avnimelech and Teubal, 2008; Avnimelech, Rosielo and Teubal, 2010).

Some relevant aspects are:

- Articulation between the innovation policy and a national policy for development
- Resource allocation within different national demands
- Evolving towards a strategic level of innovation/STI policy, which would allow, among other things, an evolution of the instruments *pari pasu* to the evolution of the sectors to attend new needs. This demands policy learning, the introduction of horizontal policies to foster variation and experimentation of new programs and the design and implementation of new programs centered on new sectors
- Definition of strategic priorities in key areas, and a 'vision' of the country and its growth, while performing high-level coordination
- Transversality of the innovation policy and attention to different demands
- Broaden the focus of attention of the innovation policy, from promoting R&D and competitiveness, to other aspects of the innovation process (adaptation, copy, imitation, improvement), that include other economic and social areas
- Ensure the continuity of the programs in order to change the behavior of the agents
- Ensure that there are locks in order to avoid opportunistic behaviors

But the combination of STI policy instruments (policy mix) must consider that the initial allocations of STI capabilities analyzed in section 3 are weak and must be strengthened, at the same time that structural characteristics analyzed in section 2 are contemplated. This leads to meeting the different demands for STI, such as: strengthening the science and technology capabilities, stimulating innovation and competitiveness of the firms and the country, satisfying social needs and also considering environmental problems.

Without an additional mass of resources to generate a greater variety of researchers, firms, projects, sectors, among other populations, it is difficult/impossible to generate radical changes in the structural and STI profile that would lead to a change in the NIS's performance.

Thinking about the STI policy from the initial conditions of countries in Latin America

Looking at the STI policy in response to the structural characteristics analyzed in section 2, the STI profile analyzed in section 3, the combination of initial conditions in both dimensions, as well as the challenges for development in Latin America, new relevant issues emerge for policy design and another way of formulating the questions that are important for the region.

These questions move us outside the existing analytical framework at the international level and allow us to discuss some of the debatable issues in the region from another perspective.

1. Should Latin American countries focus on a STI policy or in a long-term growth strategy (development) with s STI component?
2. How much should STI policy follow the suggestions of international organizations or pay more attention to their initial conditions and local needs? How much should we concentrate on increasing R&D or in supporting the set of activities in the innovation process? In other words, how to define the innovation activities that must be supported?
3. How to create the critical masses of STI capabilities in order to have more balanced capabilities?
4. How to generate complementarities between modernizing processes guided by the domestic market and the ones guided by the international market?

5. How much science should we generate and in what areas? Should we place more emphasis in looking for excellence or in exploring new areas of specialization? Should new research be guided by curiosity or should it pay more attention to local/national problems?
6. What should be the emphasis of the support: selecting the winners to generate success stories or focusing on horizontal supports to increase variety and generate a critical mass of innovative firms?
7. The high levels of inequality lead to other questions: grow fist and then distribute? Or distribute to increase the domestic market and therefore grow?

Lets explore some of the issues, for instance, how to define the innovation that must be supported? The GERD focuses in the fostering of innovation activities based on R&D. The methodologies for measurement (Oslo & Frascati manuals) guide us towards that direction. At the same time, the international comparisons are based on indicators generated from these methodologies (GERD/GDP, BERD, etc.). The Latin American reality shows that there are few firms with R&D centers, there are undoubtedly more in big countries like Brazil and Mexico. In contrast, a lot of firms are starting to venture in innovation activities, but countries do not have a broad variety of innovating firms, and are therefore far from reaching critical masses. In this way, it seems necessary to also foster other innovation activities not based on R&D, such as copy, imitation, diffusion, transference and learning. This would contribute to stimulating the process that would lead to the building of R&D capabilities. Regarding these aspects, two topics of discussion arise:

- Are we focusing on radical innovations or do we foster a spectrum that goes from incremental to radical innovations?
- Do we foster innovation based on R&D or the one based on existing knowledge, from scientists and technicians to traditional ones?

Another topic of debate is related to which sectors must be supported. Latin American countries are characterized by having a market fragmented into two groups: modern and traditional. The modern sector consists of firms and is more oriented towards international markets that cater to affluent consumers. The traditional sector consists of communities, and is more oriented towards local markets, which are far from the international market. There is no doubt that we need to address both markets and that the innovation policy does not address

the traditional sector. How to articulate both sectors in order to reduce poverty, inequality, and social gaps?

FINAL COMMENTS

This paper analyzes the relationship between structural characteristics and STI profiles in Latin American countries, and discusses in what measure critical masses of STI have been built that lead to the consolidation of the NIS.

The evidence on structural characteristics and STI profiles suggests that there are many Latin Americas. Some countries have advanced more in both dimensions, while others show a significant relative lag. But even the most advanced countries in the region do not seem to have reached critical masses of STI in order to generate endogenous and self-sustained processes that would allow the NIS to contribute decisively to the economic and social development.

STI policy is called upon to accelerate the building up of this critical mass of STI capabilities, but this requires a systemic/evolutionary approach to STI policy, which looks at the system-the NIS, focuses on the generation and absorption of knowledge as nonlinear dynamic models, and on systemic failures. For this approach, learning, accumulated capabilities and time matter, institutions mediate between agents, and there is an increasing concern for the regional level and the governance of the NIS. (Metcalfe, 1995; Teubal, 2002; Woolthuis, Lankhuizen and Gilsing, 2005; Smits, Kuhlmann and Teubal, 2010)

Today there is a strong emphasis on innovation, but drawing on this systemic/evolutionary approach, and following Dutrénit, Puchet and Teubal (2011), this paper argues that the focus should be put on building critical masses of STI capabilities, adressing the structural characteristics of the countries. A unilateral focus on innovation is limited since science capabilities are also still below the critical masses, and these capabilities are also needed for knowledge generation, technology transfer and human resources formation.

One of the principles for building the critical masses of STI capabilities is to achieve a more efficient allocation of resources and bigger budgets for STI activities. This is necessary in

order to reach a broad variety of researchers, firms or projects, which will allow a better selection process and thus the conditions for an efficient retention process. An increased budget is also required to allocate additional resources to new demands; without the emergence of governance problems. But it also requires to think of STI policy in a fresh way, considering the initial conditions. As argued by Rodrik (2007) the same recipe does not work in different institutional buildings and policies paths. Surely, different groups of countries in Latin America require different policy approaches and different combinations of instruments.

Several questions remain pending to be answered, such as: in what measure is the analytical framework used for the design of STI policies, which was conceived on the basis of countries with different initial conditions, is useful to be applied in economies with different initial conditions, like Latin American countries? And, how can critical masses be measured? These questions require further research.

References

Abramovitz, M. (1956), "Resource and Output Trends in the United States since 1870", *American Economic Review*, Vol. 46 (2), pp.5-23.

Abramovitz, M. (1986) "Catching Up, Forging Ahead and Falling Behind", *Journal of Economic History*, Vol. 46, pp. 385-406.

Arza, V. (2007): "¿Cómo influye el contexto macroeconómico en el comportamiento de largo plazo de las empresas? Decisiones empresariales de inversión en I+D y en maquinaria en Argentina durante los años 1990s", *Desarrollo Económico,* Vol. 47 (187), pp. 459-484.

Avnimelech, G. And Teubal, M. (2008), Evolutionary targeting, *Journal of Evolutionary Economics*, 18(2), pp. 151-66

Avnimelech, G., Rosiello, A. and Teubal, M. (2010), Evolutionary interpretation of venture capiyal policy in Israel, Germany, UK and Scotland, *Science and Public Policy*, 37 (2), pp.101-12

Azariadis, C. and A. Drazen (1990), "Threshold Externalities in Economic Development", *THE Quarterly Journal of Economics*, Vol. 105 (2), pp. 501-526.

Bogliacino, F., G. Perani, M. Pianta and S. Supino (2009), "Innovation in Developing Countries. The Evidence from Innovation Surveys", paper prepared for the FIRB conference Research and Entrepreneurship in the Knowledge-based Economy, Milano: Universita L. Bocconi.

Booij, E. and R. Helms (2011), "Dissecting the Critical Mass of Online Communities towards a Unified Theoretical Model", *WP,* Department of Information and Computing Sciences, Faculty of Science, Utrecht University.

Braun (1993) "Who governs intermediary agencies? Principal–agent relations in research policy-making", *Journal of Public Policy*, 13(2), p.p. 135–162.

Breznitz, D. (2007), "Industrial R&D as a national policy: Horizontal Technology Policies and Industry-state coevolution in the growth of the Israeli software industry", *Research Policy*, 36, pp. 1465-1482

Cassiolato, J, H. Lastres and M. L. Maciel (eds.) (2003), Systems of Innovation and Development Evidence from Brazil, Cheltenham, UK: Edward Elgar.

Cepal (2010), La hora de la igualdad: brechas por cerrar, caminos por abrir, CEPAL: Santiago de Chile.

Cimoli, M. (ed) (2000), Developing Innovation Systems, Mexico in the Global Context, London: Pinter.

CONACyT, (2010), Estado General de la Ciencia y la Tecnología 2009, Mexico: CONACyT.

Cooke, P. (2011), "Transversality and regional innovation platforms", in Cooke, P, Asheim, B, Boschma, R, Martin, R, Schwartz, D. & Tödtling, F. (eds.) The Handbook of Regional Innovation & Growth, Cheltenham, Edward Elgar (forthcoming).

Dutrénit, G., Capdeville, M., Corona, J., Puchet, M., Santiago, F., & Vera-Cruz, A., (2010), El Sistema Nacional de Innovación Mexicano: Instituciones, Políticas, Desempeño y Desafíos. México, UAM-X/Textual S.A..

Dutrénit, G., M. Capdevielle, J. M. Corona, C. Hernández, C. Ramos, R. Rivera, A. Rocha, J.L. Sampedro, M. Sánchez and J. Díaz (2011), Estudio para determinar la inversión federal y estatal que se realiza en México en ciencia, tecnología e innovación, Technical report, UAM-X, Mexico, March.

Dutrénit, G., Puchet, M. and Teubal, M. (2011), "Building bridges between co-evolutionary approaches to science, technology and innovation and development economics: an interpretive model", *Innovation and Development,* Vol. 1 (1), pp. 1–24 (forthcoming).

Dutrénit, G. y Puchet, M. (2011), "Approaching the measurement of the critical mass of science, technology and innovation: how far off is Mexico?", trabajo presentado en el congreso Globelics, noviembre, Buenos Aires.

Foro Consultivo Científico y Tecnológico, (2006), Diagnóstico de la política científica, tecnológica y de fomente a la innovación en México (2000-2006). FCCyT, México.

Gerschenkron, A. (1962), Economic Backwardness in Historical Perspective. A Book of Essays, Harvard University Press, Cambridge.

Granovetter, M., (1978), "Threshold Models of Collective Behavior", *American Journal of Sociology* Vol. 83, pp 1420-1443

Guston, D.H. (1996), "Principal–agent theory and the structure of science policy", *Science and Public Policy*, Vol. 23 (4), pp. 229–240.

Guston, D.H. (2000), "Retiring the social contract for science", Issues in Science and Technology, Summer, Dallas: University of Texas.

Haussman, R. and Klinger, R. (2007), Structural Transformation in Chile, typescript, June

Kim, L. (1997), From Imitation to Innovation: The Dynamics of Korea's Technological Learning, Harvard Business School Press, Boston.

Katz, J. (ed.) (1986), Desarrollo y Crisis de la Capacidad Tecnológica Latinoamericana, Buenos Aires, BID-CEPAL-CIID-PNUD.

Katz, J. (2000), *Reformas Estructurales, Productividad y Conducta Tecnológica en América Latina*, FCE/Cepal: Santiago de Chile.

Kuhlmann, S. (2001), Future governance of innovation policy in Europe — three scenarios, *Research Policy,* Vol. 30 (6), pp. 953-976.

Kuznets, S. (1971), Economic Growth of Nations: Total Output and Production Structure, Harvard University Press, Cambridge, MA.

Kuznets, S. (1973), Modern Economic Growth: Findings and Reflections, *American Economic Review,* 63, pp. 247-258.

López, A., (2007), *Desarrollo Económico y Sistema Nacional de Innovación en la Argentina*, Buenos Aires: Consejo Profesional de Ciencias Económicas de la Ciudad Autónoma de Buenos Aires.

Lundvall, B.-A. (1992), National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning, London: Pinter.

Mahler, A., and Rogers, E.M., (1999), "The Diffusion of Interactive Communication Innovations and the Critical Mass: The Adoption of Telecommunications Services by German Banks", *Telecommunications Policy*, Vol. 23, pp 719-740.

Metcalfe, J.S., (1995). "Technology Systems and Technology Policy in an Evolutionary Framework", *Cambridge Journal of Economics*, vol. 19 (1), pp. 25-46, February.

Ministério da Ciência e Tecnologia (MCT), (2011), Indicadores Nacionais de Ciência e Tecnologia, available at: http://www.mct.gov.br/index.php/content/view/740.html

Ministry of education, science and technology (MEST), (2011), available at http://english.mest.go.kr/web/1716/site/contents/en/en_0218.jsp

MOST (2011), S&T programmes, available at http://www.most.gov.cn/eng/programmes1

Murray, F. (2002), "Innovation as coevolution of scientific and technological networks: exploring tissue engineering", *Research Policy*, 31, pp. 1389-1403

Myrdal, G. (1957), Economic Theory and Undeveloped Regions, Routledge and Kegan Paul, London.

Nelson, R. R. (ed.) (1993), National Innovation Systems: A Comparative Analysis, New York: Oxford University Press.

Nelson, R. (1994), "The Coevolution of Technology, Industrial Structure and Supporting Institutions", *Industrial and Corporate Change,* 3, pp. 47-63

Niosi, J. (2000), Canada's national system of innovation, Montreal: McGill-Queen's University Press.

OCDE (2007), OECD Reviews of Innovation Policy: Chile, OCDE: Paris.

OCDE, (2010b), Science, Technology and Industry Outlook, Paris: OCDE.

OCDE, (2010c), Main Science and Technology Indicators, Volume 2009, Issue 2, Paris: OCDE.

Oliver, P. E., Marwell, G., and R. Teixeira (1985), "A Theory of the Critical Mass. I. Interdependence, Group Heterogeneity, and the Production of Collective Action", *The American Journal of Sociology*, 91(3), pp. 522-556.

RICYT (2011), http://www.ricyt.org/index.php?option=com_content&view=article&id=149&Itemid=3, 5/4/2011.

Rodrik, D. (2007), One Economics, Many Recipes: Globalization, Institutions, and Economic Growth, Princeton University Press.

Rosenstein Rodan, P. (1943), "Problems of Industrialization of Eastern and South- Eastern Europe", *Economic Journal.*

Saviotti, P. and Pyka, A. (2004), "Economic Development by the Creation of New Sectors", *Journal of Evolutionary Economics* 14, pp. 1-35

Schumpeter, J. (1934), The Theory of Economic Development, Harvard Univ. Press. Cambridge. MA. (1st German edition: 1911).

Schumpeter, J. (1939), *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process,* McGraw Hill, New York.

Schumpeter, J. (1942), Capitalism, Socialism and Democracy, London: George Allen & Unwin.

Sennes, R. y A. Britto Filho (eds) (2011), Inovações Tecnológicas no Brasil: Desempenho, Políticas e Potencial, EDITORA UNESP: Sao Paolo.

Smits, R.E., S. Kuhlmann and M. Teubal (2010), "A System-Evolutionary Approach for Innovation Policy", in Smits, R.E., S. Kuhlmann and P. Shapira (eds), The Theory and Practice of Innovation Policy, Edward Elgar Publishing.

Solow, R. (1956), A Contribution to the Theory of Economic Growth, *The Quarterly Journal of Economics*, Vol. 70 (1), pp. 65-94.

Somasundaram, R. (2004), "Operationalizing Critical Mass As The Dependent Variable For Researching The Diffusion Of eMarketplaces –Its Implications, 17th Bled eCommerce Conference eGlobal, Bled, Slovenia, June 21–23.

Sotarauta, M. and Srinivas, S. (2006), "Coevolutionary policy processes: Understanding innovative economies and future resilience", *Futures*, 38, pp. 312-336

Teubal, M. (2002), "What is the Systems of Innovation (SI) Perspective to Innovation and Technology Policy (ITP) and how can we apply it to Developing and Industrialized Economies?", *Journal of Evolutionary Economics*, 12, pp. 233-257.

UNESCO, (2010), UNESCO Science Report 2010, Paris: UNESCO.

Van der Meulen, B. (2003), "New roles and strategies of a research council: intermediation of the principal-agent relationship", *Science and Public Policy*, Vol. 30 (5), pp. 323–336.

Vera-Cruz, A. O. (2006), "Firms' Culture and Technological Behaviour: the Case of Two Breweries in Mexico", *International Journal of Technology Management*, Vol. 36 (1/2/3), pp. 148-165.

Woolthuis, R., Lankhuizen, M., and Gilsing, V., (2005), "A system failure framework for innovation policy design", *Technovation* 25, pp. 609-619

World Bank, (2008), Commission on Growth and Development, WB, Washington DC.