Industrial and technological policy: Contributions from evolutionary perspectives to policy design in developing countries.

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1. Introduction

In recent years there has been renewed and growing consensus about the crucial role of industrial and technological policy in economic development. As a consequence, this type of policy recommendation has been gaining space in the public agenda of major governments. However strong theoretical differences persist, both in the theoretical and applied field, concerning *why* and *how* the government must intervene in the economy. The orthodox stream, which guides a sizeable proportion of government intervention in Latin America, proposes that intervention is only justified by the presence of market failures, which leads to underinvestment in R&D expenditures with respect to the Pareto efficiency level (Arrow and Debreu, 1954). In contrast to this view, a heterodox position combining several theoretical approaches—such as neo-Schumpeterian[2] evolutionism and the new ideas of post-Keynesianism and neo-structuralism—can be identified. From this heterodox position, the objective of industrial and technological policy is to introduce changes into the production structure in order to achieve a process of structural change. The idea of structural change refers to a process of qualitative and quantitative transformation in the productive structure that induces the generation of related and non-related variety[3] (Saviotti and Pyka, 2011). This process leads to a positive feedback loop, increasing returns, and emerging properties. These emerging properties -such as creative destruction, cumulative causation, and innovation- helps to reduce the productive gap with advanced economies. In this sense, public intervention constitutes a micro meso macro process which requires that a process of creative destruction and cumulative causation be initiated, leading to the emergence of new sectors and improvement in capacities and interactions between agents.

This group of heterodox authors does not constitute a cohesive and homogeneous corpus. There is significant heterogeneity between their theoretical approaches which both enriches and complicates the theoretical debate around industrial and technological policy. A common characteristic is that they do not agree with the "failure" denomination for the coordination problem or the poor development of agents' capacities (Bleda and del Rio, 2013)[4]. In this paper, we identify three different approaches. Firstly, we consider evolutionist literature

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[2] This literature includes a broad number of contributions from authors that highlight the importance of i) habits and routines, ii) national, sectoral, and regional innovation systems, iii) the cumulative causation process and the role of demand, iv) the self-organization/self-transformation processes, and v) feedback and increasing returns (Robert and Yoguel, 2014)

[3] While related variety refers to incremental changes in the structure of pre-existing sectors, non-related variety refers to the generation of sectors absent in the production structure.

[4] Bleda and del Rio stress that Smith (2000) calls them *imperfections*, Llerena and Matt (2005) use the idea of *dysfunction,* Bergek et al (2010) allude to *debilities,* and finally Cheminade and Edquist (2009) make reference to *systemic problems*.

centered on population thinking models (Metcalfe 1994 and 2002; Dopfer, Foster, and Potts, 2004, among others) which is focused on the mechanism of variation, selection, and retention in the competition process[5]. Hence, innovation is manifested as an increase in system variety, which the market selection process reduces by limiting the firm's market share or pushing the firm out of the market (Metcalfe 2010, Knudsen, 2004)[6]. From this perspective, policy design must be centered on i) improving firms' capacities for increasing system variety so as to renew the market-selection process, and ii) enhancing the institutions that regulate the market-selection process. The second perspective that we have identified is the literature centered on the concept of national innovation systems (Lundvall, 1992; Freeman, 1987; Nelson, 1992; and Edquist, 1997), sectorial innovation systems (Malerba, 2002), and local innovation systems (Boschma and Martin, 2011; Antonelli, 2011). Although the authors in this group differ considerably from one another, they share the idea of innovation as the systemic result of both the successful interrelation between agents and organizations in the system and the effective functioning of the institutions that govern them. The elements that block the virtuous functioning of the system and lead to a low innovative performance are therefore targets for policy makers and point to the need for industrial and technological policies focused on enhancing agents' capacities and the interactions between them. Thirdly, we examine literature made up of contributions from evolutionary authors interested in the role of demand and the cumulative causation process (Dosi, 2014; Saviotti and Pyka, 2002; Antonelli, 2011). These contributions are complemented and extended by other contributions that come from neo-structuralist and post-Keynesian frameworks (Cimoli, Dosi, and Stiglitz, 2009; Cimoli and Porcile, 2011, 2013) and authors from both of these theoretical traditions (Lee, 2013; Dosi, 2014). This third perspective—which focuses on the divergence between economies—considers that reducing the gap would require policies that aim to promote the generation of non-related variety within the production structure (Saviotti andand Pika, 2002). That is, the promotion of new sectors characterized by the centrality of positive feedbacks, increasing returns, and network-economies. The absence of these sectors explains a significant proportion of the productive gap with developed nations.

In this context, the main objective of this paper is to discuss the prescriptions for industrial and technological policy that can be derived from this broad group of heterodox authors, while taking into account the specificities of developing countries stressed by Arocena and Sutz (2000, 2002, andand 2003), Dutrenit, Rodriguez, and Vera-Cruz (2006), and Cassiolato and Lastres (2009), among others. In this sense, we propose that the target policy should not be limited to enhancing capacities and interactions between agents but should also create the necessary conditions for the emergence of new activities that are currently absent from the production structure, or are too weak. These new sectors are characterized by showing

[5] Although these authors use terms like selection, retention, and variety, it does not mean that the contents of these are the same used as those used by biology.

[6] This dynamic can be separated into two components: selection and innovation effect (Andersen, 2004; Schubert, 2007). Evolutionary change is governed by the coevolution of these two effects.

simultaneously i) increasing returns, ii) Keynesian and Schumpeterian efficiency[7], iii) strong linkages with the science and technology system, iv) strong integration into more technologically developed global value chains, and v) demand for qualified human resources. This exercise in thinking about policy from the perspective of developing countries prompts a set of questions:

i) Which adaptations should be made to the broad evolutionary research program focused on public ICT policy (Schubert, 2009, 2012)?

ii) How far are the set of policies that emerge from these heterodox perspectives useful for economies characterized by productivity gaps and technological lock-ins?

iii) What complementarities and differences in industrial and technological policy prescriptions emerge from these three evolutionary perspectives and how far are they applicable to developing countries?

The rest of the paper is organized as follows. In the second section the main characteristics of each evolutionary perspective outlined above are stylized. Additionally, the dimensions that are relevant to industrial and technological policy are identified. In the third section some normative and positive prescriptions derived from each perspective are discussed. In the fourth sections we present an extension of these recommendations from the position of developing countries. Finally, in the fifth section, we present some conclusions that are focused on a policy design that brings together the three evolutionary perspectives discussed.

2. From population thinking models to neo-Structuralist and post-Keynesian postures: the key drivers of the productive dynamic.

The population thinking framework

The main characteristic of the evolutionary population approach is the central role of the competition and creative destruction processes in explaining technological change. As a consequence, this analytical framework proposes that the selection process and the generation of variety are key dimensions of economic development. Within this approach, innovations lead to the generation of variety in the system, which in turn lead to selection process which modify the population characteristics[8]. Since market selection reduces the variety of firms—both by reducing their market share or by forcing them to leave the market—the system requires the innovation process to continually generate variety in order to prevent this evolutionary process from coming to a standstill (Metcalfe, 1994 and 2002; Dopfer, 2001, 2005; Foster, 2005; Dopfer, Foster, and Potts, 2004; Potts, 2000: Witt, 1997; Cantner, 2007; among others).

[7] Keynesian efficiency works in sectors characterized by high income-elasticity of demand, and Schumpeterian efficiency alludes to those sectors innovative activities play a major role in the competence process.

[8] For example, surpassing a minimum capacities threshold (commercial, technological, productive, and organizational) to become part of the process of population competence. These thresholds are characteristics of idiosyncratic populations that increase in relation to the competition process dynamic adopted.

From this perspective, the fruit of evolutionary competition is manifested by changes in the firms' participation in the population (i.e., market share), or firms' entry into or exit from the market (Bartelsman and Doms, 2000; Haltiwanger, 2000). In this framework, one of the more important contributions regarding population models is that of scholars who focus their analysis on the process of self-organization and self-transformation, and also analyze the coordination mechanics used in the generation and transmission of knowledge. This group of scholars analyses the competition process by focusing on both microeconomic dimensions and firms' interactions at meso and macro levels (Dopfer, 2001 andand 2005). This population competition is characterized by i) firms' heterogeneity as a key driver of the selection process, ii) linkages between firms and institutions in the competition process, iii) the presence of hierarchies[9] and modularization, iv) being a competition process that is always in disequilibrium—the idea of restless capitalism put forward by Metcalfe and previously by Hayek—which generates the emergence of self-organization and structure (Robert and Yoguel, 2013).

From this perspective, technological change is understood as the result of two forces that evolve together and are mutually dependent (Andersen, 2004 andand 2007; Cantner, 2007). The first is the process of market selection, which explains why firms with different values in their population characteristics (i.e., productivity, unit labour cost, among others) show different growth rates (i.e., market share). As a consequence of this selection process, the mean for the selection characteristics being analysed changes over time. If the selection process works correctly, those firms characterized by a relative fit that is below the population mean are expelled from the market or suffer a progressive reduction in their market share. Both results generate a positive effect on the mean for the population characteristics[10]. In this line, Metcalfe (2010) stands out for his efforts at modelling this dynamic by employing the replicator dynamic mechanism[11], which proposes that a firm's market share evolve over time according to the distance between the firms' productivity level and the mean level for the population[12].

However, replicator dynamics solely address the selection process, while the generation of new diversity (innovation) is neglected. This is the reasoning behind the name "equilibrium selection theory" (Samuelson, 1997). Replicator dynamics provide an incomplete representation of evolution. As Metcalfe stresses, it entails a bias towards the technology that currently performs best. This tendency implies the suppression of evolutionary change,

[9] This hierarchy is explained by the fact that differences are maintained at a higher aggregation level.

[10] It is worth pointing out that the population's mean productivity can also increase in a context characterized by poor dynamism among the more virtuous firms (those with a productivity level well above the population mean). That is, exiting the market or a loss in market share is the only mechanism through which the selection process operates.

[11] There are other models that explain the selection dynamic, such as the Best Response, Brown-von Neuman-Nash, imitation, mutator, and adaptative dynamics (see Safarzynska and van den Bergh, 2010). However, their application to explain technological change has been more limited.

[12] Formally, the equation proposed is $\Delta s_i = \sum s_i - \bar{s}$ where s_i is the firm's market share, s_i its productivity level, and $\bar{s}$ the mean productivity. Hence firms with the greatest growth are those with a productivity level above the population mean, which in turn is continuously changing as a consequence of market selection.

making it necessary for novelty to emerge if renewed variety is to be introduced into the system. The process which brings about the generation of variety is referred to by many authors as the innovation process, which also entails imitation, learning, and the random process. As a consequence, market selection and the generation of variety co-evolve within each population, which explains evolutionary change.

Considering the contributions listed above, the dimension that emerges as relevant to policy design is the competition process. That is, the influence that market selection exerts on the generation of variety. Therefore, the formulation of industrial and technological policy would have a wider field of action, with policy instruments acting on: a) firms' capacities, b) firms' selection characteristics, and c) the regulation of the market (seen as a social construction).

The innovation system perspective

Authors from the second evolutionary approach have centred their analyses on the concept of innovation system at the national (Freeman, 1987; Lundvall, 1992; Nelson, 1992), regional (Asheim and Isaksen, 1997; Cooke et al., 1998; Boschma and Frenken, 2006), and sectorial levels (Breschi and Malerba, 2000; Malerba, 2002). This perspective is a theoretical advance on previous frameworks associated with the linear innovation model, which assigns the supply of science and technology a central role in the generation of innovation. In contrast, from the perspective of non-linear innovation systems, basic research and applied science, production, and design co-evolve with positive feedback process.

Despite the marked differences between these perspectives, scholars belonging to these streams share the idea that these innovation systems are made up of firms and institutions that interact, giving rise to systemic capability-building processes which also feed the firms' pre-existing capacities. Therefore, innovation is the systemic result that emerges as a consequence of successful interaction between the agents that make up the system and the correct functioning of the institutions that regulate them. Cassiolatto and Lastres (2009) stress that "…emphasis has been given to its interactive character and to the importance of incremental and radical, technical and organizational innovations and their different and simultaneous sources. A corollary of this argument, is the specific and localised character of innovation and knowledge…". In this sense, this perspective highlights the importance of the role of institutions in providing answers to firms' technological, organizational, and commercial necessities. The innovative performance of the system depends on both the presence of positive feedbacks in the interactions between the agents and the institutions which regulate them (Bleda and del Rio, 2013; Cassiolatto and Lastres, 2009).

An innovation system can be conceived of as an analytical tool which reveals the non-linear and systemic processes of knowledge creation. This tool helps to capture a broad gradient of systems, ranging from the virtual absence of an innovation system—as a consequence of the scarcity of interactions and capacities among the actors and institutions—to the opposite extreme, characterized by the virtuous functioning of the system, which drives capability building and dynamic competitive advantages, which in turn lead to the emergence of innovation process (Edquist and Homem, 1999). As a consequence, the structural

characteristics of an innovation system could become a restriction to the future development of organizations or elements that promote their growth. In addition, the presence of linkages that stimulate the development of learning processes was conditioned by the level of endogenous capacities of the organizations that make up the system. In this context, to be able to appropriate the knowledge generated within the system, a critical mass of firms with a minimum capability threshold is needed. At the same time, this minimum threshold varies according to institutional development and the functioning of the interrelationship that regulates agent behaviour.

Based on these scholars' contributions, the dimension that appears to be relevant to policy design is the idea of a systemic process of knowledge creation. Considering these prescriptions, there emerges a field of action for public instruments that focus on enhancing the linkages between the agents in the system and promote capability building. In particular, scholars subscribing to the concept of the sectoral innovation system focus on the specificity that policies must have, and allude to the existence of technological regimes characterized by the accumulativeness, appropiability, opportunity, and basic knowledge associated with the predominant profile of the production structure (Malerba and Orsenigo, 1999). Scholars focusing on the national innovation system emphasize the relationship between firms, universities, and S&T institutions. Finally, those authors closest to the idea of local innovation systems focus on the learning process that emerges at regional level.

The system divergence perspective

The third evolutionary stream examined in this paper focuses on the idea of divergence between production systems (Dosi, 2000; Marengo andand Dosi, 2005; Dosi, Levinthal and Marengo, 2003; Saviotti, 2011; Saviotti and Pyka, 2004; Antonelli, 2013). The system dynamic is governed by the co-evolution of the creative destruction process and the dynamic of demand. In this context, a positive feedback emerges between microfoundations and meso- and macroeconomic determinants. Saviotti (2001) stressed that the continuous growth of productivity and demand saturation in the sectors which determine production specialization are responsible for bottlenecks in future development. This can be compensated for by developing new sectors through the creation of non-related variety. From this perspective, demand plays a fundamental role in economic development because it co-evolves with the generation of variety and gives rise to the cumulative causation process. In this sense, demand is not considered as given, and requires a process of user-producer interaction and the development of users' capacities (learning by using and learning by doing).

In line with Dosi (2014) and Winter and Dosi (2002), the microfoundations for this perspective are: i) the presence of limited rationality, which is manifested in different degrees of limitations in accessing information, technology, the characteristics of the environment in which firms compete, and in clearly identifying their preferences, ii) the presence of different degrees of heterogeneity in the learning process, firms' capacities, and their representation of the world, iii) the existence of endogenous opportunities for innovation that are manifested in the generation of related and non-related variety (Saviotti and Pyka 2004; Saviotti, 2001), iv)

the presence of interactions between heterogeneous-and out-of-equilibrium organizations that function as information exchange, coordination, and selection mechanisms.

In this epistemological framework, the micro dynamic is centered on problem finding and solving. This process depends on the evolutionary construction of a system of routines and sub-routines (Nelson and Winter, 1982) and on organizational memory. In turn, as a consequence of the characteristics of the microfoundations and the intentional interactions that out-of-equilibrium organizations undertake, the system dynamic presents different regularities at different aggregation levels. From the complexity perspective, these regularities constitute emergent properties which in turn co-evolve and influence the meso-macro dynamic.

Complementing this evolutionary epistemological vision, Saviotti and Pyka (2013) consider that the economic development process is directly linked to two aspects: the growth derived from innovative processes in existent sectors (related variety), on the one hand, and both quantitative and qualitative transformation in the production structure generated by the emergence of new sectors (non-related variety)[13], on the other hand. At the same time, they propose that there is no rivalry between the growth driven by related and non-related variety. The latter requires a significant increase in system creativity and the exploitation of innovation efforts, preferably non-incorporated radical ones. In contrast, both varieties are complementary and necessary for economic evolution. This sort of co-evolution and feedback is similar to the one set out above between micro, meso, and macro dimensions. That is, the presence of feedbacks between these dimensions is needed for the system to function properly. From this perspective, the economic development process consists of the creation of new entities (new goods and services, activities, institutions, organizations, etc.) and the introduction of quantitative and qualitative changes that in turn imply deep transformations in the production structure, thus helping the catch-up process. As a consequence, the increase in variety—especially non-related variety—is necessary for long-term economic development. Returning to the idea of divergence, two different ways in which this phenomenon is manifested can be identified. According to Saviotti and Pyka, divergence arises from the different speeds at which non-related variety is generated on the national, regional, or world level. From Dosi's perspective, divergence is explained by the different speeds at which a system creates variety.

Within this theoretical perspective, the phenomenon of divergence is a trigger for industrial and technological policy design. This implies focusing on the following areas: i) developing

[13] In this framework the system' variety is measure as the change in the number of agents, activities and objects required to describe an economic system. The agents are institutions, organizations, individuals and the activities constitute all that is developed by the organizations and institutions. In turn, the objects are goods and services produced by the economic system. The variety is used as the degree of differentiation of the economic system to different aggregation levels, starting by an isolated product and finishing with all the economy. The increasing efficiency of pre-existent activities is manifested in time as a part of circular flow as well as new activities created by innovation are the determinants of long term growth.

new sectors triggered by the generation of non-related variety, and ii) introducing incremental improvements in existent sectors with related variety.

3. Positive and normative policy prescriptions derived from evolutionary perspectives.

In the previous section we stressed the normative character that policy design has in the light of the innovation systems approach[14]. In contrast, the kinds of intervention stemming from both the population-competition approach and the divergence approach are both positive and normative.

From the population models perspective, the dynamic of change is driven by creative destruction processes which increase the variety within organizations in the competition process. This variety is later reduced when the selection process comes into play. Therefore, taking a positive vision of the population competition process as a starting point, this process goes through the phases of variety, selection, and retention. The majority of researchers and policy makers associated with these ideas agree with the notion that markets have selection failures. This means that the organizations that reach the highest levels of selection characteristics are not necessarily selected. These kinds of market failures require policy interventions that aim to improve market institutions (Metcalfe and Foster, 2007; Doppfer and Potts, 2004). As these authors stress, market institutions are a social construction requiring competition policies, norms, rules, regulations and standards. These dimensions define the established mechanisms by which selection operates within a specific market (Metcalfe, 2010). These selection attributes are dynamic because the development process within a population can bring about an increase in the selection characteristics, which are determined by the capacity levels firms reach along their evolutionary path. Therefore, given that competition policy is a key factor, policy instruments have to be centered on both market selection mechanisms and the institutions that lead to individual and specific types of selection. This requires analyzing how markets work, which can be understood as an emergent property of the heterogeneous behaviors of buyers and sellers, who are always in disequilibrium and are conditioned by the institutions that regulate the way they compete in the market (Kirman 2010; Sapio, Kirman and Dosi, 2011).

Other elements that emerge from this approach are based on the prescriptions raised by Knight (1921). These issues refer to the importance of identifying firms that require a policy centred on handicap because they that do not meet the standards required by the market. From this perspective, policy design should also include tools to improve the capacities of firms that do not meet the selection criteria. As a consequence of policies improving selection mechanisms and firms' capacities, this stream would expect firms to perform better than the dynamics that would exist without intervention. This intervention, which derives from the positive aspect of the theory, would increase the intensity of the creative destruction and

[14] This issue can be explained by the fact that the innovation systems approach does not refer to an ideal benchmark. However, saying that the innovation systems approach does not constitute such a benchmark does not mean that it is impossible to identify what is good or bad for the innovative dynamic.

innovation processes. Hence they must create or enhance the market institutions needed for the selection process to take place.[15]

The normative aspects of intervention using this approach include the need to influence the market selection factor levels that organizations achieve (Schubert, 2012). This refers to a set of factors relating to firms' capacities and their relationship with market selection factors. The evolution of these factors decreases the effect of the selection process on firms exiting the population under consideration. However, these normative aspects of policy are of little consequence when it comes to key issues like selecting areas of specialization and the weight these sectors should have in the specialization pattern. From this understanding of population competition, the specialization profile of a given system in a set of populations is an emergent property of the system, i.e. a dependent variable which this approach does not set out to intervene in.

From the evolutionary perspective of the third group, the positive vision is rooted in the idea of divergence between economic systems (Antonelli, 2011), the presence of cumulative causation phenomena (Dosi, 2014), and the emergence of related and unrelated variety in the production structure (Saviotti and Pyka, 2004). In turn, the normative aspects of policy design are more associated with capacity building, especially in middle-income countries.

This neo-Schumpeterian evolutionary stream is enriched by authors adhering to neo-structuralist thinking and post-Keynesian theory. These authors stress the key role of effective demand and the co-evolution of this with the process of creative destruction and the generation of related and non-related variety. In this line, recent papers from Cimoli, Dosi, and Stiglitz (2009) and Dosi (2014) propose a set of ideas that complement the macro dimensions of the phenomenon of divergence[16]. According to these authors, in the context of globalization, developing economies tend to diverge with respect to developed nations. In particular, they argue that the growing productivity gap can be explained by i) the low absorption capacities for the technology and the designs generated in developed countries and ii) the constraint on building innovative activities that results from limited capacities and linkages. Moreover, in the absence of explicit policies to improve the capacities and connectivity of firms located in developing countries, the process of globalization further increases divergence through mechanisms of self-reinforced lock-in in the activities characterizing their specialization pattern. From this perspective, industrial and technology policy is conceptualized as a comprehensive set of interventions—a process of institutional reengineering—including all micro, meso, and macro dimensions and the co-evolution between supply and demand that affect the competitiveness of firms, sectors, and countries. Hence, they are a central ingredient of any development process leading to dynamic processes that generate innovation and giving rise to positive feedback and thus to dynamic increasing returns (Arthur 1994). In this sense, the post-Keynesian and neo-structuralist authors argue

[15] This means acting through the selection processes from the perspective of firms' exit and entry and considering the changes in firms' market-share

[16] Despite these claims about the need to examine the micro process of competition more closely, some of these authors remain at a relatively aggregate level of analysis.

that the generation of learning opportunities are not independent of the sectorial specialization patterns or the dynamics of demand. This distinction make these authors closer to those of the evolutionary divergence stream (Saviotti and Pyka, 2004; Dosi , Pavitt and Soete 19904; Dosi, 2014 , Lee, 2013 , Lee and Kim, 2009; Lee and Mathews, 2010) , and to authors like Prebisch (1963) and Hirshman (1958), linked to old Latin American structuralism and Keynesian thought (Kaldor, 1972; Rodrik, 1997 , 2008). Moreover, these authors move away from the idea that intervention has to solve market failures. Conversely, market failures are an integral and necessary aspect of the dynamics of knowledge generation, and do not constitute distortions that need to be eliminated by through policy design (Bleda and Rio, 2013; Cimoli and Rovira, 2008).

Taking capacities as key to explaining the divergence process between countries, Lee (2013) stresses that the limited technological capacities of developing countries constitute a blockage in their path that restricts structural change and catch-up. The problem does not lie in either the market failures[17] proposed by the neoclassical approach—which are key to generation and dissemination of knowledge—or in the systemic failures of coordination proposed by the population competition stream (Metcalfe, 2005). According to Lee, limited capacity for R&D and creating design and branding opportunities in high-tech sectors are the main difficulties faced by developing countries, especially when compared to the successful experiences of Korea and Taiwan. Hence, the trend is towards the acquisition of incorporated R&D in capital goods (in general imported) or the acquisition of production facilities via licences or patents, and the specialization in global value chains at the assembly stage characterized by their low technological content. In contrast to the neoclassical idea of "market failure", Lee proposes the concept of "failure capacity"[18] as a justification for the need to promote state intervention in the economy.

Finally, from the perspective of innovation systems, a normative view of intervention is clear. Edquist (1997) argues that as the notion of optimality is absent from this approach, comparing the existing innovation system with its ideal configuration is an impossible exercise. In addition, as Edquist and Hommem (1999) and also Lundvall (1992) stress, the development of user-producer interaction and improvement in the capacities of end users constitute key areas of policy design. Although public policy recommendations take on different characteristics depending on local, sectorial, and national innovation systems, a set of elements common to all can be identified. From this perspective, policy design is centered on acting upon the elements that block the functioning of the system and prevent a virtuous system dynamic. As such, intervention is key to improving capacities and connections, which in turn lead to co-evolution and positive feedback. In this context, both universities and centers of science and technology play an important role in identifying and resolving firms' production, commercial, organizational, and technological needs. Therefore, building capacities in firms and institutions

[17] The concept of market failures assumes that countries lagging behind in the development race already know how to do R&D and have the capacities to do it; the only problem is that they carry out R&D with values below the ideal Pareto level.

and interactions between actors are both key. In turn, for this systemic process to evolve, a minimum capabilities' threshold are required within organizations.

Despite these coincidences, the underlying differences between the different approaches are explained by the specificity of each kind of innovation system. While sectoral and local systems show prescriptions focused on micro meso dimensions, the industrial and technological policies arising from the national innovation system approach focus mainly on the meso macro dimensions and especially on the role of institutions.

4. The perspective of developing countries and policy design.

In order to extend the policy prescriptions examined in the previous section to developing countries, certain considerations must be made. In particular, in the case of Latin America, the literature has emphasized both the difficulties that lie behind the ability to innovate (Arocena and Sutz , 2003) and the various deficiencies in the design and implementation of STI policy that have resulted in barriers to inducing changes in agents' behavior (Dutrenit, Rodriguez, and Vera-Cruz, 2006). Expanding these propositions, Sutz and Arocena (2000) state that reduced public spending on R&D, the lack of a critical mass of innovative firms, excessive informal focus on internal R&D, and the limited capacities of universities and public R&D laboratories make it difficult for firms to complement those missing capacities they are missing. From this analytical perspective, knowledge asymmetries are more important than technological ones. In this sense there is a learning divide between the north and the south. This divide highlights the need for a new way of thinking in order to discuss the problems of development and policy design.

Meanwhile, from similar theoretical points of view, Cassiolato and Lastres (2009) argue that policy recommendations have to be highly context dependent, and constraints should depart from the specific restrictions. Agreeing with the position of Myrdal (1958)—contexts and institutions matter, and positive and negative feedbacks bring about cumulative causation—and also with Hirshman (1958) about the importance of interdependence between activities, they argue that "…policy recommendation has to be based on the assumption than the process of development is influenced by and reflects the particular environment of each country, rather than the recommendation based on the reality of advanced countries" (p. 4). In turn, from their neo-Schumpeterian position they also consider that economic development is a systemic phenomenon "generated not only by inter-firm relations but most significantly by a complex inter-institutional network of relations that condition the emergence of positive and negative feedbacks in the productive structure".

In addition to these issues raised by the literature focusing on industrial and technology policy in Latin America, the following issues are also of concern: i) there is low critical mass of organizations with high capacity, connections, and productivity, ii) there are restrictions to designing the market institutions involved in the selection process, and iii) the specialization pattern generates Dutch disease macro phenomena that do not favour the emergence of new sectors leading to positive feedbacks, increasing returns, and structural change.

Thus, in a fiercely heterogeneous context, the capacities and connections of the components belonging to the region's production and innovation systems (firms and institutions) are weak, limiting the presence of a critical mass of firms with high productivity levels in those sectors that are not natural resource intensive.

In addition, market institutions are weak, and are often close to a pre-established conception of the market that does not require a social construction of norms, rules, and standards. Moreover, a significant proportion of the productivity gap is explained by the absence of high-productivity sectors. Therefore, efforts to generate processes of related variety should be greater. To complete this characterization of the production structure, it should also be noted that, except for activities where there are comparative advantages, the productivity of all other activities is also lower. As a consequence, major efforts have to be made to significantly increase related variety. In particular, lower productivity in some manufacturing sectors corresponds to a peripheral integration into global value chains, usually associated with assembly and the end consumption of the respective chains.

In turn, the advances associated with specialization in natural resource–intensive sectors has not generated local linkages upstream (e.g., machinery for the extractive sectors, precision machinery and biotechnology in natural resource–intensive sectors) and therefore are not able to narrow the productivity gap with developed countries, despite the strong growth in the region.

Finally, another limiting factor is the overemphasis on industrial and technological policy—when present—in issues related to financing. The design of such instruments are based on the idea that all stakeholders have the necessary requirements to carry out R&D and build linkages to improve their initial capacities. While policies based on the idea of market failure are not unique to developing countries, their consequences are particularly harmful in these economies because they only impact a small group of firms .

As Lee (2013) stresses, financing is a necessary but insufficient condition in middle-income economies because most firms have strong limitations when developing R&D. Therefore, in order to build capacities, it is necessary to design instruments that promote learning and create public-private institutions that lead to a critical mass of knowledge likely to be transferred to firms. The successful experience of Southeast Asian countries highlights the development of public-private R&D partnerships, and/or the transfer of R&D developed by public laboratories or technological institutions. These situations generate the basic conditions leading to learning processes. In sum, there are different types of barriers limiting the processes of micro-meso-macro co-evolution, the emergence of positive feedbacks, and increasing returns (Erbes, Robert, Yoguel, 2010).

These features that characterize developing countries require that policy design incorporates the need to generate changes in the specialization pattern, as a priority. As such, the tools developed should take into account the difficulties and restrictions to a co-evolution between related and unrelated variety in the production structure. That is, the challenges that need to be taken on to bridge the gap are so great that only generating related variety—that is, focusing

innovation efforts and support policies in existing sectors—is an insufficient condition for initiating the processes of structural change and development.

The proposed policies for developing countries are highlighted by authors that think of technological change by starting from the phenomenon of divergence. These issues arise mainly at the confluence of these authors' work with that of neo-structuralists and post-Keynesians, and, to a lesser extent, with those from the innovation system stream. Designing such policies requires the introduction of high-productivity sectors, and the promotion of related variety in existing sectors using instruments that increase connectivity and capacities in organizations (quality, design, new forms of work organization, training, incorporated and disembodied innovation efforts, etc.). Since economic growth is affected by timescale, the related variety needs to be developed in the short term and unrelated variety in the medium and long term The co-evolution of the two types of varieties and the emergence of unrelated variety will reduce the productivity gap . Thus, as the generation of related and unrelated variety is key to generating structural change and growth, providing the conditions for the creation of variety is a central issue in industrial and technological policy.

These comments are based on the idea that not any specialization profile can achieve high levels of productivity, reduce the gap between systems and generate processes of structural change. A corollary of this is that the specialization pattern, while still an emergent property of the system, is a trait that can interact intentionally with explicit policies that combine horizontal and vertical interventions aimed at promoting and improving skills and connectivity. Therefore, specialization is an emergent property of a complex system and in order to change it, its determinants must be acted on. In this line, identifying technology sectors characterized by short cycles, where the rate of obsolescence is very rapid, provides concrete opportunities for developing countries that are far from the technological frontier (Lee, 2013). In this respect, the development path is not about following countries that were successful at long-cycle technologies, although the proposal to avoid replicating successful experiences of developed economies requires even more intense public activism.

At the same time, from the perspective of innovation systems, a policy aiming to reduce the gap with developed countries should focus on improving not only skills but also the linkages with scientific and technological organizations to stimulate the flow of information and knowledge, and to contribute to increasing initial capacities. But the design of such policies needs to be complemented by a focus on population competition. It is necessary to know how firms change productivity and market share, and whether these changes are the consequence of policy designs aimed at improving market selection or generating variety. This requires putting forward handicap policies that help more backward firms reach minimum capacity levels, therefore acting on market selection; and also upgrading policies that support the development of the capacities of firms that are above the minimum threshold and stimulate innovation.

In this sense, and in the context of the vertical policies discussed above that arise from the other two approaches, the existence of relationships between the selection and innovation

processes in each population gives policy an experimental and adaptive nature that enables the continuous generation of changes and adjustments. In sum, this make it possible to generate learning processes in the design of the instrument in question. This experimental nature of policy also requires that successful historical events and their associated features be identified and generalized.

5. Conclusions

The objective of this paper was to discuss the policy prescriptions that derived from different evolutionary approaches, so as to contribute to the formulation and design of policy instruments in developing countries. In that vein, this paper puts forward a set of issues linked to methods of intervention. Intervention is a necessary condition for the development of capacities and connectivity, and therefore is central to the emergence of new sectors. It is therefore necessary to generate instruments that go far beyond solving market failures. This premise gives rise to the need to rethink methods of public intervention, prioritizing the framing of horizontal instruments within vertical programs.

In addition, it is important to reflect critically on the central role that financial instruments are assumed to have when the context is characterized by strong constraints to the capacities local actors have to develop to undertake innovative activities. In this regard, the success of Asian countries highlights the need to develop public-private partnerships for R&D in the areas of specialization chosen, to promote innovation transfer from government R&D laboratories, to generate an efficient technology consulting market from the actions of intermediate institutions, and benefit from the capacities of residents located abroad in leading sectors (brain gain) to identify vacant niches which could be developed. Finally, policy instruments should be evaluated based on the performance of firms in the market, and should therefore take on a more experimental character. This point highlights the need for databases and evaluation tools that are little used in developing countries.

This paper highlights the requirements of industrial and technological policy arising from the three evolutionary approaches presented, which focus on: i) population models, ii) innovation systems, and iii) the idea of divergence, as built upon by post-Keynesian and neo-structuralist contributions.

Although these approaches differ in the emphasis they place on specific aspects of the innovative dynamic, the dialogue between them that we have stressed in this paper can achieve complementarities that enhance policy design. For instance, by using the population approach it is possible to analyze how the competition process influences innovation while highlighting the co-evolution between the innovation dynamic and the market. This issue originates in Metcalfe and Ramlogan's (2006) criticisms of the innovation systems perspective for not incorporating competition processes into the analysis of evolutionary dynamics. However, due to these authors' overemphasis on the influence of market forces, the systemic and nonlinear relationships between firms and firms and institutions are not analyzed in depth. In this line, the innovation system approach provides a very suitable scheme from which to design policies, as it addresses the role of linkages in building capacities. Although there are notable differences

between the two approaches, these do not extend to the phenomenon of divergence and the mechanisms by which it is generated. In contrast, the third evolutionary approach articulates its policy recommendations by taking into account the productivity gap between middle- and high-income countries. They stress that the gap depends on the specialization pattern, the dynamics of demand, and the weight elites have in society (Cimoli and Rovira, 2008). This stream stresses a set of recommendations that highlight elements that are key to explaining the processes of divergence, mainly the importance of policies that modify the specialization pattern and generate related and unrelated variety

The combination of the three evolutionary streams is the path that industrial and technology policy should follow in developing economies, especially in this region if the aim is to generate processes of structural change. It would be key to incorporate a concern for divergence and the need for instruments that strengthen both the co-evolution of related and unrelated variety, and of the micro, meso, and macro dimensions, with the explicit inclusion of demand. These instruments would be enhanced yet more if population competition and innovation systems approaches were taken into consideration. This would require: i) considering which scheme of population competition the generation of variety emerges in, ii) developing firms' capacities, and iii) designing tools to improve the selection conditions These related and unrelated variety processes have a sectorial and regional general affiliation. Therefore, the contribution of the literature of local and sectorial innovation systems is important to understanding existing barriers to generating positive feedbacks and increasing returns. Finally, the national innovation system approach can add elements of policy that focus on both the institutions necessary for generating unrelated variety processes in the interactions between institutions and firms, and the need to identify the barriers that impede the process of building capacities