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Capacities, innovation and feedbacks in production networks in Argentina

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Capacities, innovation and feedbacks in production networks in Argentina

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This paper is based on an application of the complex systems approach to economics with the objective of exploring the micro- and meso-mechanisms of development. Under this approach, innovation can be seen as an emergent property that depends on micro interaction and on specificities of macro structure. This study emphasizes that the micro interactions can be described by the feedback mechanisms between the absorption and connectivity capacities of firms, and the macro structure by processes of creative destruction, knowledge appropriation and structural change. The paper presents empirical evidence on the feedback loops between absorption and connectivity capacities in production networks in Argentina and their impact on innovation results. This paper concludes that the restrictions on absorption capacity and mainly on connectivity capacity in several production networks in Argentina condition the development of positive feedbacks between the two capacities, and hence the scope of the innovation path.

Keywords: complexity; feedbacks; absorption and connectivity capacities; production networks; structural change

JEL Classification: E11; O30; O32

1. Introduction

The overall objective of this paper is to analyze the relationship between the absorption and connectivity capacities in industrial firms belonging to different production networks in Argentina and their impact on innovation results. The paper proposes the use of the complex systems approach applied to economics of innovation (Antonelli 2008; Foster 1993; Metcalfe, Foster, and Ramlogan 2006) in order to shed light on the micro- and meso-mechanisms of structural change. Taking complex systems as a framework allows us to understand the morphology and dynamics of economic systems characterized by (i) diversity and heterogeneity of skills and routines of agents, (ii) temporal irreversibility, as a result of a dynamic driven by a non-ergodic path dependence, (iii) disequilibrium interactions among agents and (iv) the presence of institutional rules, learning, discoveries and space of selection.

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Within this analytical framework, this paper aims to discuss the relation among the development of feedbacks between firms' absorption (Cohen and Levinthal 1989; Zahra and George 2002) and connectivity capacities (Norman 2002; Cullen 2000; Grandori and Soda 1995), their innovation results and the emergence of three processes: creative destruction (Schumpeter 1934, 1942; Metcalfe, Foster, and Ramlogan 2006; Metcalfe, Ramlogan, and Uyarra 2003), appropriation (Norman 2002; Erbes et al. 2006; Antonelli 1997, 2007) and structural change (Ocampo 2005; Ross 2005; Reinert 2007; Palma 2005; Cimoli et al. 2005), which could account for economic development (Cimoli, Porcile, and Rovira 2010).

The emergent order from micro interaction is one of the most highlighted properties of the complex systems (Arthur, Durlauf, and Lane 1997; Antonelli 2007; Rosser 1999; Lewin 1992, among others). This paper proposes that innovation and the mentioned processes emerge from interactions among components of the system. The interactions among firms allow for the development of feedback loops between absorption and connectivity capacities that enhance their learning path and impact over their innovation results. In this sense, processes of appropriation, creative destruction and structural change could also be seen as emergent properties of the system that account for the level of development of an economy. They are associated with innovation because innovation is a part of these processes and because their specificities act as restrictions or incentives to the development of capacities.

The second section introduces the theoretical framework. In this section, two main approaches of complex systems and economics of innovation are presented. It is also shown what the paper incorporates from each approach and how the complex system theory is useful in tackling issues related to evolutionism and development. The third section presents an analytical model that explains the self-reinforcing dynamics between absorption and connectivity capacities in firms and among these capacities and innovation results. We will argue that the presence and intensity of those feedbacks would impact over the improvement of processes of creative destruction, appropriation and structural change, and hence, on economic development. In the fourth section, the paper tests the feedback effects between: (i) absorption and connectivity firms' capacities and (ii) the relationship between these capacities and innovation results using a data base made up of 403 firms belonging to different production networks in Argentina. We utilize the instrumental variable method applied to ordered probit (Oprobit) models to account for simultaneity determination among firms' absorption and connectivity capacities and innovations results. Also, a graph methodology to assess feedback effects is presented. Given the analytical structure and the empirical results, the fifth section presents the conclusions.

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2. Theoretical framework based on an application of complex systems approach to productive networks

The approach of complex systems was introduced in economics over the last 20 years by different authors of evolutionary thought. Among the many contributions, two main perspectives can be identified: the first one is associated with the legacy of Marshallian and Schumpeterian thought, and the other one, linked to the Santa Fe Institute, is associated with the selection and adaptation mechanisms and computational modeling.

Within the first stream, it is possible to identify different authors such as Antonelli (2007), Metcalfe, Foster, and Ramlogan (2006), Silverberg, Dosi, and Orsenigo (1988), Dosi (1991), Dosi and Kaniovski (1994), Dosi and Nelson (1994), Foster (1993, 2005) and Witt (1997). The idea that brings together this patchwork of authors is that complex systems are able to be understood from (i) the Schumpeterian perspective whereby the evolution

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and economic dynamics of a capitalist system compose a process of qualitative change led by innovation with an open-end (Fagerberg 2003) and (ii) the Marshallian perspective, followed by Metcalfe and Antonelli, that provides a theoretical framework to understand the structural changing and self-organizing nature of capitalism. Authors linked to the Schumpeterian legacy (Silverberg, Dosi, and Orsenigo 1988; Dosi 1991; Dosi and Kaniovski 1994; Dosi and Nelson 1994) explain the evolution of the economy from variation, selection and retention mechanisms, which would account for the relationship among innovation and the processes of creative destruction, appropriation and structural change. On the other hand, Antonelli (2007, 2008) and Metcalfe, Foster, and Ramlogan (2006) explain the differential dynamic of production systems under the assumption of creative reactions of heterogeneous agents. Particularly, in Antonelli's perspective, intentional behaviors explain innovation and structural change as emergent properties that transform agents' routines in a non-linear path under disequilibrium conditions.

The second group represents the Santa Fe Institute perspective about the complexity applied to economics (Arthur, Lane, and Durlauf 1997; Lane and Maxfield 1997, among others). These authors have focused on the study of economy as an out-of-equilibrium evolving complex system. According to Arthur, Lane, and Durlauf (1997), this group analyzes these systems from three different approaches. The first one uses evolutionary games and computational and agent-based modeling (Arthur 1999; Tesfatsion 2003), which is interested in non-linearities in the form of positive feedbacks emerging from increasing returns. The second approach analyzes these systems from the perspective of adaptive complex systems using the biological metaphor following Holland (2004) among others and enriched by the interdisciplinary analysis of complex systems. In this regard, emphasis is placed on studying the ability of actors to learn and to develop rules of decision-making in the process of adaptation to the environment, rather than on studying the economic dynamics. Finally, the third one uses a historical approach from storytelling and verbal argumentations (David 1985; Lane and Maxfield 1997). In this case the highlighting is on the self-reinforcing mechanisms that may even work at an institutional level.

A common thread among all these authors is the idea that the complex system approach comprises an enhanced analytical framework compared with that provided by classical mechanics used by the neoclassical economic theory. In this regard, Metcalfe, Foster, and Ramlogan (2006) emphasize the idea that the complex systems approach can account for some key elements of economic systems, which conventional economic theory has sidelined by resorting to the notion of equilibrium. This approach differs from the arguments supported by the mainstream in economics in which equilibrium is considered a position of optimum order that requires the existence of perfect connections between system components, which imply the assumptions of perfect information (Foster 2005). Complex systems can generate order from decentralized and dispersed agents' interactions. Furthermore, since complex system dynamics are essentially open-ended, the idea of a global optimum is by itself useless. Therefore, the notion of a steady state should change with the concept of evolution (Durlauf 1997). 'Because new niches, new potentials, new possibilities, are continually created, the economy operates far from any optimum or global equilibrium. Improvements are always possible and indeed occur regularly' (Arthur, Durlauf, and Lane 1997, 10). Therefore the relevance of complex systems is that this approach can account for some traits of economic systems like temporal and structural irreversibility, uncertainty, path dependence and the presence of increasing returns, in which the non-linear dynamics and the positive feedbacks mainly occur (Arthur 1999).

Following Antonelli (2007), this paper considers the relevance of regarding innovation as an emergent property of a complex system. This property is a result of the creativity of the components of the system and their ability to change the architecture of connections, which are endogenous consequences of the localized interactions. This paper assumes that the absorption and connectivity capacities of firms are key factors in understanding both creativity and the architecture of connections among components of the system. The feedback mechanisms between these capacities aid in understanding the non-linear dynamics of learning and innovation. This paper proposes that a complex system can be conceived as a mechanism for generating order from the reinforcement of absorptive and connectivity capacities and between them and the innovation results. Finally, although the macro dimension has not been introduced in the econometric exercise proposed in the fourth section,[1] the view of complexity used in the paper is in agreement with the idea that the complex systems approach applied to economics allows an understanding of economic evolution, innovation and structural change as an ordered macro structure that emerges from dispersed and decentralized micro interaction.

This paper proposes an application of complexity approach to productive networks with the purpose of understanding the development of capacities and the innovation dynamics in a set of firms linked beyond commercial relations. The technological and institutional changes that occur in the last decades were associated with transformations in the way production and especially knowledge production is organized (Powell 1990; Antonelli 1999; Langlois 2003). The idea of productive networks assumes that the change and innovation are not only a result of internal learning but also of those generating in the architecture of links. In this sense, the productive networks play a key role in generating capacities and then in the development of processes of creative destruction, appropriation and structural change.

We assume that a firm is part of a productive network when it belongs to an architecture of links that involves non-exclusive commercial relations, lasting and of long run with suppliers and costumers, other firms, commercial chambers, consultants, universities and technological centers (Albornoz and Yoguel 2004; Bisang et al. 2005; Erbes et al. 2006; Yoguel 2007). In this sense, the key role in conceptualizing the production network is the existence of economic exchanges between the agents over time, linked to the generation, circulation and appropriation of knowledge. The production network is a different concept with regard to the sum of the attributes of firms and individual institutions that comprise and, therefore, lies in a meso-economic dimension. This feature stems from the feedbacks between absorptive capacity and connectivity of agents, which justifies applying the complexity approach.

Characteristics and boundaries of a production network are related to the components' absorptive and connectivity capacities that define the architecture of connections. In this sense, the idea of production networks involves a variety of situations ranging from the most virtuous to the weakest in terms of the capabilities of components, the connectivity and the presence of interfaces between companies and other agents of the national innovation system.[2]

Therefore, the main hypotheses of this paper are derived from the integration between complexity and the production network approach. Beginning with the existence of feedback mechanisms among absorption and connectivity capacities in firms belonging to production networks that determine the innovation process, the main hypotheses of this paper highlight some characteristics of these dynamics in a developing country like Argentina. The first hypothesis proposes that the feedbacks reach different intensities depending on the kind of agent the firms are connected to. The second one stresses that, regarding the existence of feedbacks, the absorption capacity mainly explains the innovations due to the weakness of linkages.

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3. Feedbacks between absorption and connectivity capacities: innovation and structural change

This section proposes a theoretical model that accounts for the interaction among agents and the development of capacities built upon those interactions.

Departing from the theoretical framework described in the previous section, we argue that innovation could be seen as a result of non-linear dynamics of a learning process driven by the mutual reinforcement between absorption and connectivity capacities of the system components.[3]

The absorption capacity of the system components can be regarded as the ability to recognize new external information, assimilate it and apply it (Cohen and Levinthal 1989). This capacity is not only related to the possibility of accessing the existing knowledge in the environment, but also implies the ability to identify useful knowledge and to generate new knowledge. As a result, the absorption is not an ability that can be automatically developed nor is it equally accessible to all systems, but requires the development of skills within the previous evolutionary path of the system, instead. In this sense, it can be assimilated to the ideas of routines (Nelson and Winter 1982), dynamic capabilities (Teece and Pisano 1994) and endogenous skills (Novick and Gallart 1997).

The absorption capacity of firms can be defined in terms of the work organization and learning processes, the quality management and the extent of embodied and disembodied innovation activities, among other variables (Cullen 2000; Coriat and Weinstein 2002; Zahra and George 2002; Roitter et al. 2007).

The capacity of connectivity is associated with the potential of system's components to establish relationships and generate interactions with other agents with the objective of increasing their knowledge base. Therefore, the different levels of development of this capacity provide options for access to knowledge, resources and opportunities (Grandori and Soda 1995; Cullen 2000; Norman 2002). As with absorptive capacity, the ability to examine beyond mere connectivity and interaction involves the selection of linkages and the prioritization of relationships that are established with other system's components. Ultimately, this ability is what defines the degree of openness or closeness of a system at different levels of aggregation.

Different levels reached by the capacity of connectivity in firms can be identified from a quantification of connections and linkages. However, the definition of this capacity restrains us to assign all of them with identical importance, since only those linkages aimed at increasing the firms' endogenous capabilities increase the connectivity capacity. In that sense, the linkages developed by firms in terms of both goals[4] and component type[5] should be ranked in terms of their ability to generate additional knowledge and increase the initial capacity of absorption.

The firms' absorption and connectivity capacities are mutually reinforcing. These feedback effects, that mainly occur locally (Antonelli 2008), explain the ability of the system to develop appropriation, destructive creation and then structural change processes. Systems made up by components with higher levels of development in their absorptive capacity tend to be more open and sustain a higher density in their relations. In turn, these are systems that are in a better position to reap the benefits arising from generated interactions. At the same time, the density of relations and the degree of openness of the system, defined by the connectivity capacity, aid in developing a greater capacity of absorption, when agents are exposed to significant flows of knowledge that they must select and use to obtain quasi-rents. Despite the existence of a bi-directional relationship, it can be argued that the absorptive capacity is a necessary condition for the development of connectivity (Erbes, Tacsir, and Yoguel 2008). This result is also present in the

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percolation approach (Antonelli 1997), stating that knowledge absorption in a particular system requires minimum thresholds in both the absorption and connectivity capacities. However, the probability of percolating is higher in systems with imperfect connectors and high absorption than in the opposite cases. In this sense, the system's boundaries are affected by this property because the scarcity of agents with high-absorption capacity in the neighbors of a firm limits the likelihood of its connectivity and, hence, the probability of expanding in a direction that implies an improvement of its absorption capacities (Antonelli 1997).

The significance acquired by the absorption and connectivity capacities as well as the existing feedbacks between them conditions the potential to develop learning processes in the firms, and hence generate innovative processes. In the first place, the connectivity capacity acquires significance due to the implicit need in the innovative process of relying on knowledge, which exceeds those internally developed. This implies that the firms should actively seek complementarities that facilitate the development of the innovation process, by means of the generation of interactions with other agents (Richardson 1972; Teece 1992; Mowery, Oxley, and Silverman 1996; Ahuja 2000; Coombs and Metcalfe 2000; Santoro and Gopalakrishnan 2000; Caloghirou, Kastelli, and Tsakanikas 2004; Laursen and Salter 2004; Antonelli 2008). Secondly, even when the complementary knowledge necessary exists, the firms should rely upon the absorption capacity that allows them to assimilate and exploit external knowledge in order to innovate. In this regard, it is possible to recognize the significance of dimensions such as R&D (Cohen and Levinthal 1989, 1990) and the organizational form (Coriat and Weinstein 2002) in the differential capacity of the firms in order to obtain a relatively improved economic and innovative performance.

In turn, the feedback dynamic between absorption and connectivity capacities results in innovation as an emergent property of the system. That signifies that innovation can be understood as the integrated consequence of micro- and meso-interactions with structural characteristic of an economic system (Antonelli 2007) described by processes of creative destruction, appropriation and structural change. These processes also have an impact on the development of component's capacities, and then on innovation results.

From the Schumpeter perspective (1934, 1942, 1947), competition among agents is understood as a process of creative destruction that generates variety and reduces it through selection mechanisms, which depend on market institutions. While the selection mechanisms tend to diminish the micro-diversity, the creative component of creative destruction process helps to increase it. In this sense, they are opposing forces and so interdependent that they should have an impact both on competition and on development (Metcalfe, Ramlogan, and Uyarra 2003; Metcalfe, Foster, and Ramlogan 2006). Innovation is a cause and consequence of creative destruction process, because it transforms the routines of firms and institutions through formal and informal learning processes, and constitutes the major source of variety. Although innovation is a key part of creative destruction process, several mechanisms of selection that limits the set of agents obtaining quasi-rents are needed.

The process of appropriation (Antonelli 1997, 2007; Norman 2002; Erbes et al. 2006) refers to a set of mechanisms and skills that allow players to transform knowledge into quasi-rents. This process depends on the kind of technology regimes (Malerba and Orsenigo 1997) and on the dynamics of the processes of creative destruction embodied in the market structure. The agents – through differentiation of their routines – attempt to appropriate quasi-rents and extraordinary profits derived from the competitive process. In this sense, appropriation has a key role in the complex system described in Figure 1 because it specifies the institutional framework (Rivera Ríos, Robert, and Yoguel 2009), which constrains or

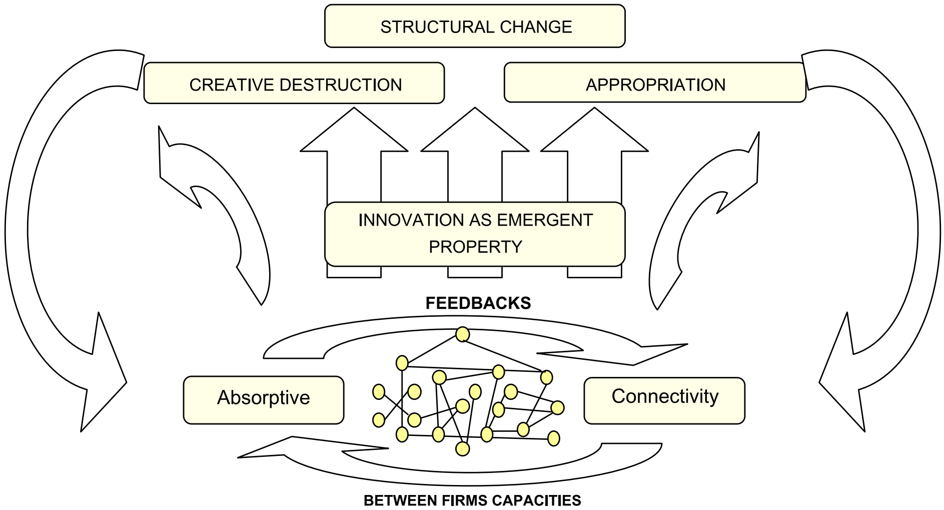

Figure 1. Complexity of an economic system.
Source: Rivera Ríos, Robert, and Yoguel (2009) based on Chris Langton's vision of emergence in complex systems (Lewin 1992).

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incites the creative reaction of agents' intentional behavior (Antonelli 2007).[6] When the process of creative destruction is significant and specialization is based on activities with increasing returns, the prices of goods and services will constitute a dependent variable of innovation.

Finally, the process of structural change (Ocampo 2005; Ross 2005; Palma 2005; Reinert 2007, among others) includes (i) the reallocation of production factors to higher productivity sectors aimed at reducing the structural dualism and collecting the gains from increasing returns, (ii) the development of complementarities between agents, (iii) changes in the external specialization pattern oriented toward differentiated products with a higher income elasticity and (iv) the development of policies to promote coordination of investment decisions in a context characterized by technological indivisibilities (Cimoli et al. 2005). Therefore, the structural change process occurs when innovation and the processes of creative destruction and appropriation jointly drive the specialization pattern toward sectors with both Schumpeterian and Keynesian efficiency (Cimoli, Porcile, and Rovira 2010). Thus, the process of structural change is not spontaneous: it is the result of a strategic development implying that players are able to define their behavior in a game in which coordination and information problems are present (Cimoli et al. 2005).

These three processes explain the macro structure and dynamics of change and evolution of the economic system as a whole. In turn, the degree of development of these processes that jointly explain economic development is conditioned by the level reached through absorption and connectivity capacities and the feedback mechanisms between them. Therefore, building capacities determines the degree of development of the processes of appropriation, creative destruction and structural change through innovation. This relationship between capacities and processes is reciprocal and reinforcing over time (Figure 1).

In particular, the absorption and connectivity capacities of components affect the dynamics of the processes. Any system, in order to regenerate itself requires not only internally produced knowledge but also knowledge derived from localized interaction. Therefore, the dynamic of change requires the existence of linkages with other components that are functional – connectivity capacities – and skills associated with the identification and implementation of useful knowledge – absorption capacity.

Both capacities jointly define the minimum thresholds that the firms need to meet in order to take advantage of the local externalities, positive feedbacks and the internal learning processes. Thus, knowledge dissemination is not a randomly governed event. Instead, there is a wide variety of capacities associated with the knowledge absorption and to its connection with other components of the system.

When both absorptive and connectivity capacities of firms reach significant levels of development, the system can profit from the local conditions, including through opportunities and risks. In these cases, the system can reach an important development in processes innovation, creative destruction, appropriation and structural change. However, for this to happen, we require the presence of channels of communication allowing the system to react to changes (in terms of feedbacks). These feedback effects enable firms to absorb knowledge that enhance endogenous competences. As it will be demonstrated, the main characteristics of connection architecture define the capacities of firms to absorb knowledge from the local context, defined by the production network. The firms' interactions with universities or technological centers have a different effect than those interactions with suppliers and customers or intermediate institutions. Likewise, the linkages' quality in terms of the interaction goals may affect the occurrence of feedback mechanisms.

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4. Empirical findings about feedback mechanisms between absorption and connectivity capacities in Argentina

This section is based on recent empirical evidence about linkages between absorption and connectivity capacities in 403 firms associated with different production networks in Argentina (Erbes and Yoguel 2007; Roitter et al. 2007; Yoguel et al. 2009, among others): iron and steel (19.6%), automotive (21.9%), clothing industry (10.3%), agricultural machinery (14.1%), services related to oil industry (6.8%) and ship building (4.8%). This sample includes also a group composed by a set of industrial firms localized in the same geographical region (LSR)[7] (22.6%). The sample of the firms corresponding to each production network and the LSR group were selected beginning with the records proceeding from the various public institutions and the associations of companies that are at the core of the considered activities.

In virtually all of the production networks analyzed, the sample represents a high proportion of the frame. While in the first and second tier of car makers' suppliers is near 35%, in steel it reaches 30%, in agricultural machines 25% and almost 25% in the LSR group. On the contrary, this ratio is lower in ship building and the clothing industry. In the first case it reaches around 10% of firms and in the second one, the sample represents near 20% of the total firms associated with the sectoral chamber oriented toward design.

The absorption and connectivity capacity levels were defined departing from an association of dimensions, which give an account of the endogenous competencies and of the linkages established by the firms with different agents who belong to their networks.

In order to estimate the absorption capacity index, the average of the following four variables was taken into account: (i) the quality management, (ii) the training activities, (iii) the work organization and (iv) the presence and type (formal or informal) of the R&D team. The multifaceted approach used to evaluate the absorption capacity is in response to a mismatch between the very rich theoretical definition of this capacity and a generally simplistic attempt to estimate it, in which just the R&D spending is considered (Cohen and Lenvinthal 1989; Zahra and George 2002).

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Related to the quality management, the dimensions associated not only with the improvement of products and processes, but also with the structures of involvement of the personnel that guarantee the quality products, were considered. Therefore, although these processes involve knowledge exchange, the actions carried out in relation to the quality management are also important in determining the level achieved by the absorption capacity of the firms. Thus, the activities related to the control of the products and processes, the development of a culture toward quality and the use of devices toward improvement and innovation were taken into account (Formento, Braidot, and Pittaluga 2007). Training as a mean of gaining knowledge refers to the actions taken by the company in order to generate new learning and thereby constitutes a basic complementary level for the development of endogenous competencies. In this way, the training is central in the dynamic of learning given that it allows the integration of tacit and codified knowledge. As far as the absorption capacity is defining in this case, a suitable structure in charge of the development of the activities in the firm and its degree of differentiation in terms of the performed activities were considered.

The work organization considers a set of technical and social aspects that intervene in the production of goods and services. This definition takes into account the combination between the productive processes, the generation and the circulation that impact on the dynamics of learning processes (Novick and Gallart 1997). Thus, an indicator that considers the degree of autonomy of the workers in the workplace and the significance reached by the acquisition of the experiences was designed.

In a similar manner, the existence and formality of the R&D departments contribute in explaining the absorption capacity. The R&D departments allow the firms not only developing endogeneous knowledge, but also allow for the defining of a larger capacity to access existent knowledge in their environment (Alm and Mckelvey 2000; Armour and Teece 1980). In order to analyze the importance of this dimension, the existence and degree of formality of the R&D departments were considered.

The absorption capacity indicator was estimated as a simple average of the four dimensions mentioned above.[8]

In turn, in the building of connectivity capacity (Richardson 1972; Grandori and Soda 1995; Cullen 2000; Norman 2002), we considered three different types of partners related to the quality of the firms' linkages: (i) other firms, such as customers, suppliers and competitors, (ii) intermediate institutions, such as chambers of commerce and consultants and (iii) science and technology (S&T) institutions, such as universities and S&T centers. In order to evaluate the quality of the relationships, we took into account the quantity of objectives involved in the linkage, considering a higher number of objectives as a preferred situation.[9] An indicator for each of the three types of agents considered was designed.[10]

The theoretical framework allows analyzing the importance of absorption and connectivity capacities for achieving innovation results. In this way, two indicators were considered. One of them synthesizes innovation results in products and or processes, the other one in commercialization and organization. For every one of these cases, it was considered whether the company obtained results in neither one of the two areas, in one of the areas or in both areas.

4.1. The data

The distribution of firms by size is relatively homogenous. Firms with less than 10 employees account for one-fifth of the sample, 27% employ among 11 and 30 people; a little under one-third employ among 31 and 100 people and the rest more than 100 people. The firms with foreign direct investment (FDI) are the 12% of the sample, with prominence in the firms of the automotive sector and in the firms of more than 100 employees. In terms of the firms' age, 38% have been found over 30 years ago, 11% during the first phase of the democratic government (1983–1990), 27% during the convertibility model phase under the Washington consensus (1991–2001) and the remaining 12% after the devaluation of the peso beginning in 2002. The coefficient of the average export (18%) is inferior to the direct imports (28%). More than two-thirds of the firms achieved exports and imports at the same time, with significant differences between size and sectors (Table 1).

The data reveal low levels of absorption and connectivity capacities and an asymmetric distribution on these variables with a bias toward lower levels. This issue on its own would allow inferring the absence of externality and feedback effects in the perspective of Antonelli (2008) (Tables 2 and 3).

Table 1. Structural data.

	Production networks								
Variables	*A*	*B*	*C*	*D*	*E*	*F*	*G*	Total	Sign.[a]
No. Firms	56	41	27	26	87	77	89	403	
Employment 2006 (mean)	111	69	74	22	155	98	38	90	***
Sales (mean, millions of pesos) 2006	39.5	7.2	14.5	3.4	41.2	15.6	10.2	21.6	***
Sales/employment ratio (mean, thousands of pesos)	287	83	172	149	259	190	163	198	**
FDI (%)	5	2	7	0	36	8	5	12	***

[a]Chi square or ANOVA tests.
**Significant difference: 5%.
***Significant difference: 1%.
Notes: Production networks: *A*, agricultural machinery; *B*, clothing industry; *C*, services related to oil industry; *D*, ship building; *E*, automotive; *F*, iron and steel; and *G*, industrial firms localized in the same geographical region (LSR).

Table 2. Absorption capacity.

	Production networks								
Variables	*A*	*B*	*C*	*D*	*E*	*F*	*G*	Total	Sign.[a]
Degree of control over productive processes	56	17	73	32	88	58	35	54	***
Quality culture	24	12	41	20	52	25	19	29	***
Tools of continuous improvement and innovation	12	15	22	0	81	33	13	31	***
Autonomy of workers	34	18	31	57	46	24	36	34	***
Flexibility of tasks	25	8	46	30	38	11	15	24	***
Training activities performed	43	10	48	27	77	53	19	46	***
Existence of training department	56	29	88	46	96	83	49	68	***
Presence of formal or informal R&D groups	52	37	26	8	58	49	25	40	***

[a]Chi square or ANOVA tests.
***Significant difference: 1%.
Notes: Production networks: *A*, agricultural machinery; *B*, clothing industry; *C*, services related to oil industry; *D*, ship building; *E*, automotive; F, iron and steel; and *G*, industrial firms localized in the same geographical region (LSR).

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Table 3. Connectivity capacity.

Variables	Production networks								
	A	*B*	*C*	*D*	*E*	*F*	*G*	Total	Sign.[a]
Quality linkages with other firms	59	28	23	13	44	18	15	30	***
Quality linkages with intermediate institutions	26	33	31	4	32	15	12	21	***
Quality linkages with S&T institutions	33	21	19	4	24	14	20	21	***

[a]Chi square or ANOVA tests.
***Significant difference: 1%.
Notes: Production networks: *A*, agricultural machinery; *B*, clothing industry; *C*, services related to oil industry; *D*, ship building; *E*, automotive; *F*, iron and steel; and *G*, industrial firms localized in the same geographical region (LSR).

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The absorption capacities of the firms evidence sectoral differences. The automotive sector stands out because of its larger presence of firms with elevated levels in the quality management, training and R&D teams. In the services related to oil industry, the quality management, the work organization and training stand out. Finally, in the ship building, organization of work is the key dimension of absorption capacity.

In turn, in the connectivity capacity there are also differences among production networks. The automotive sector stands out because of its linkage density established with other commercial agents and the intermediate institutions. In addition, the agricultural machinery sector stands out for its interactions with commercial agents and institutions of S&T, and clothes firms with intermediate institutions (Table 3).

The innovation results also appear tied to the sectoral specificities. In this light, a larger proportion of the firms belonging to the agricultural machinery and automotive sectors have obtained results associated with new products and/or processes introduced in the market (Table 4).

Finally, the four instrumental variables selected to analyze the existence of feedbacks show differences among production networks. In particular, among firms that registered international quality standards, those belonging to automotive, iron and steel and the oil-related service sectors stand out. Additionally, the agricultural machinery and automotive production networks stand out by the high-worker turn-over. Training oriented toward R&D is found mainly in the firms of the agricultural machinery, automotive and iron and steel industry sectors. Finally, agricultural machinery, automotive and iron and steel are the sectors with greater R&D teams (Table 5).

Table 4. Innovation results.

Variables	Production networks								
	A	*B*	*C*	*D*	*E*	*F*	*G*	Total	Sign.[a]
Product and process	73	63	63	60	73	41	52	59	***
Organization and commercialization	33	37	30	20	17	16	18	45	***

[a]Chi square or ANOVA tests.
***Significant difference: 1%.
Notes: Production networks: *A*, agricultural machinery; *B*, clothing industry; *C*, services related to oil industry; *D*, ship building; *E*, automotive; *F*, iron and steel; and *G*, industrial firms localized in the same geographical region (LSR).

Table 5. Instrumental variables.

Variables	Production networks								
	A	*B*	*C*	*D*	*E*	*F*	*G*	Total	Sign.[a]
Certification of standard quality assurance	43	12	88	32	65	70	33	49	***
Work turn-over	57	21	19	19	37	–	18	36	***
R&D training	58	27	56	40	38	–	32	43	**
People on R&D	2.2	1.9	1.8	1.6	2.2	2.1	1.6	1.9	***

[a]Chi square or ANOVA tests.
**Significant differences: 5%.
***Significant differences: 1%.
Notes: Production networks: *A*, Agricultural machinery; *B*, clothing industry; *C*, services related to oil industry; *D*, ship building; *E*, automotive; *F*, iron and steel; and *G*, industrial firms localized in the same geographical region (LSR).

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4.2. The models

In this section, we present two sets of Oprobit models to evaluate, on one hand the capacity of absorption as a determinant of connectivity and the capacities of absorption and connectivity as determinants of innovation results, on the other. These models were corrected by the endogeneity of the main independent variable, using the instrumental variables method. This second stage allows determining the presence of feedback effects, tested by a graphical methodology. This technique consists in comparing the original model with the model corrected by a bivariated ordered probit (BIOPROBIT).

In the fist group of models, the dependent variables are proxy variables of connectivity capacity; in the second one, two types of innovations results were taken into account: products and processes on one hand, and organization and commercialization on the other. Meanwhile, the main independent variable was derived from the proxy variables of absorption capacity, as it was described above. In terms of the control variables taken into account, were the size of the firms (logarithms of employment and its square), the existence of FDI and six dummy variables, which represent the seven different productive networks.

The five models were corrected by simultaneity bias using the instrumental variable method, since the theoretical approach assumes feedback effects between absorption and connectivity capacities; and between capacities and innovation. The instrumental variables chosen reflect the four dimensions of absorption capacity: certification of standard quality assurance (for quality management); labor turn-over (for labor organization); R&D training (for training activities) and people on R&D (for R&D formal and informal departments) (Figure 2). Selecting the appropriate set of instruments constitute the key element in the procedure of instrumental variables. For this purpose, the selected variables should meet two conditions (Angrist, Imbens, and Rubin 1996). First, the instrument chosen should not be correlated with the variable response of the model once all the information relevant to the problem is controlled. This eliminates the possibility of the existence of omitted variables.[11] The second condition stipulates that the instrumental variables are correlated with the endogenous variable, once controlled by the statistical set of variables relevant to the problem. This condition requires that the variables selected are orthogonal to the determinants undetected by the variable response of the model and its effect on the response variable is through the endogenous variable, with the meaning of conditional expectation value.

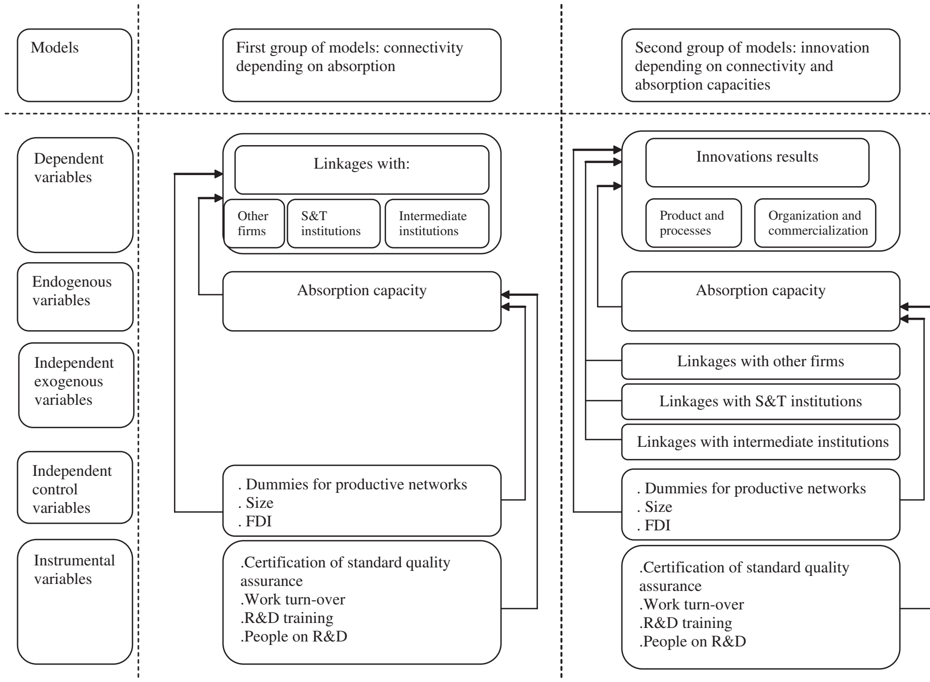

Figure 2. Model diagram.

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The systematic differences in the estimated coefficients and their impact on predicted probability of each outcome of the dependent variable, whether they are predicted by the original Oprobit model or the model corrected by Bioprobit, demonstrate the presence of simultaneity bias in the independent variable and the presence of feedback effects. The lower the correlation between the predicted outcome (without linkages, low, medium and high quality linkages) of each dependent variable (quality linkages with other firms, intermediate and S&T institutions), the greater the feedback mechanisms may be. Therefore, that signifies there are significant differences between the corrected and uncorrected models (see the graphs at Table 6).

The results for each of the first three models indicate that the absorption capacity explains the quality of linkages in (i) intermediate institutions and in (ii) universities and technological centers (Table 6). In turn, feedback effects are present in both cases but they are stronger in those linkages with intermediate institutions. It is possible to observe the relevance of minimum thresholds to reach feedbacks, manifested in the lower correlation between Oprobit and Bioprobit predictions at the high-quality linkages.

These results reveal three different situations. In the first place, the results reveal the weakness of productive networks in developing countries such as Argentina because of not only the absence of feedbacks but also because of the absence of a relationship between the skills and the building of quality linkages among firms. Secondly, it is demonstrated that minimum thresholds of absorptive capacities to access quality linkages with intermediate institutions is necessary. In turn, the low correlation between Oprobit and Bioprobit predictions rejects the exogeneity hypothesis; therefore the feedback effects are evident. The third case is similar to the previous one, where the linkages' quality with universities or technological centers depend on the absorption capacities and the feedback effects are

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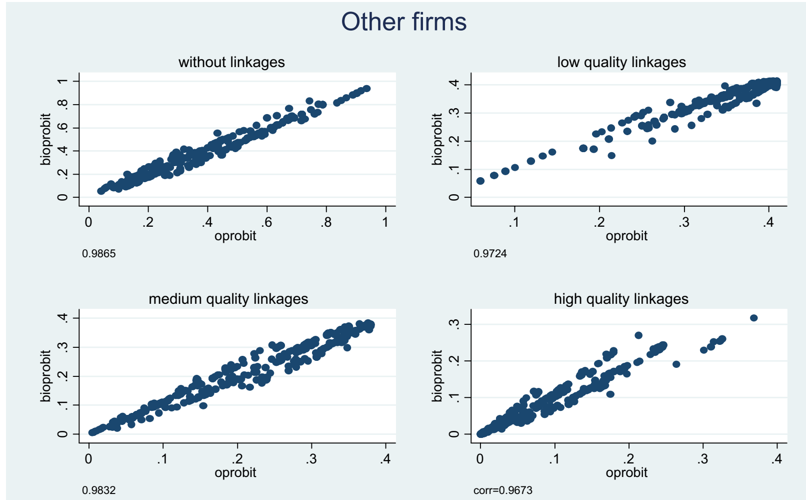
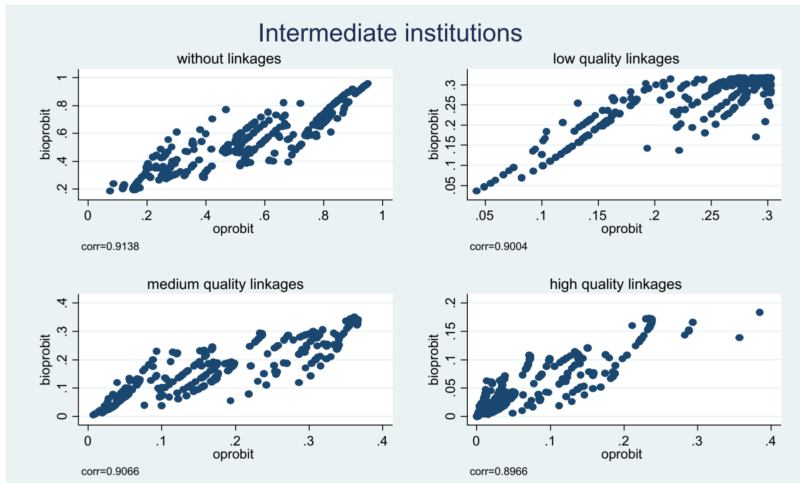
Table 6. Two-step Oprobit with endogenous regressors.

	Dependent variables: connectivity capacity	
	Quality linkages with other firms	
Independent variables	**Oprobit**	**Bioprobit**
Absorption capacity	0.049395	0.227972
Agricultural machines	1.0219716***	0.9965883***
Clothes	0.100472	0.104663
Services oriented to oil industry	0.045895	–0.02056
Ship building	–0.69608904*	–0.71882059*
Automobile	0.57524782**	0.441194
Iron and steel	0.56523426**	0.49047555*
FDI	–0.19941	–0.15865
Size (ln employment)	0.68646689**	0.60084125*
Size^2 (ln employment)^2	–0.06426037*	–0.05785
Tests	N. of obs = 341 Log likelihood = –379.99 LR chi2(10) =102.31 Prob > chi2 = 0.000 Pseudo R2 = 0.1186	N. of obs = 341 Log likelihood= –654.93 Wald R chi2(10) = 90.71 Prob > chi2 = 0.0000

	Dependent variables: connectivity capacity	
	Quality linkages with intermediate institutions	
Independent variables	**Oprobit**	**Bioprobit**
Absorption capacity	0.29417635**	.74205966***
Agricultural machines	0.171742	0.102719
Clothes	0.71667816**	0.69922385**
Services oriented to oil industry	0.6346901*	0.446069
Ship building	–0.3528	–0.37854
Automobile	0.64248311**	0.276425
Iron and steel	0.176405	–0.00682
FDI	0.280195	0.36958
Size (ln employment)	0.59831114*	0.368149
Size^2 (ln employment)^2	–0.05557	–0.03821
Tests	N. of obs = 332 Log likelihood = –329.45 LR chi2(10) = 80.35 Prob > chi2 = 0.0000 Pseudo R2 = 0.1087	N. of obs = 332 Log likelihood = –591.71 Wald R chi2(10) = 88.02 Prob > chi2 = 0.0000





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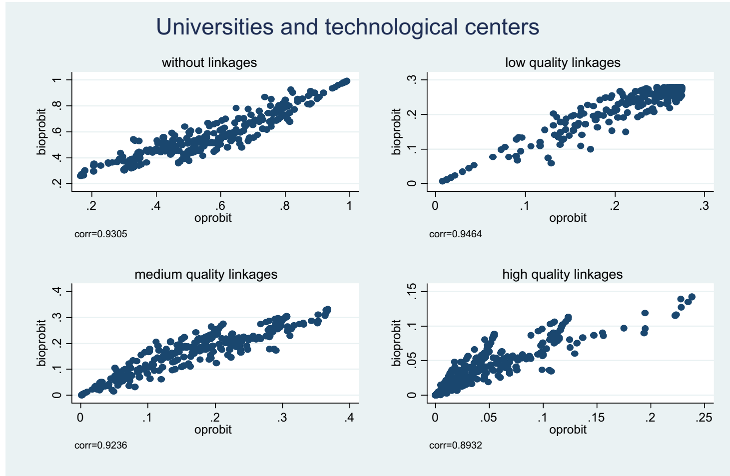
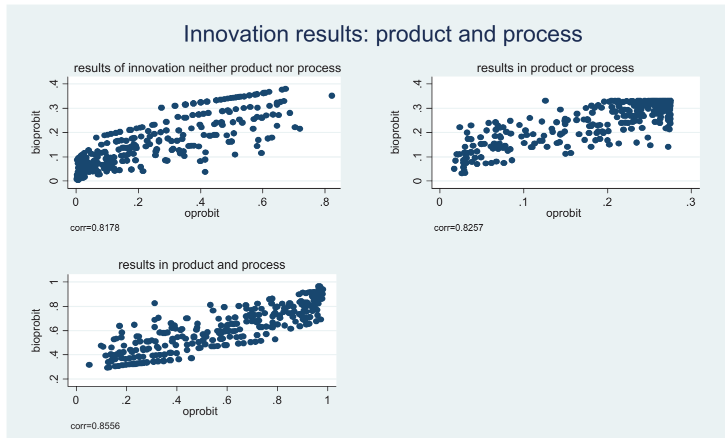
	Dependent variables: connectivity capacity	
	Quality linkages with universities and technological institutions	
Independent variables	**Oprobit**	**Bioprobit**
Absorption capacity	0.29417635**	.74205966***
Agricultural machines	0.171742	0.102719
Clothes	0.71667816**	0.69922385**
Services oriented to oil industry	0.6346901*	0.446069
Ship building	–0.3528	–0.37854
Automobile	0.64248311**	0.276425
Iron and steel	0.176405	–0.00682
FDI	0.280195	0.36958
Size (ln employment)	0.59831114*	0.368149
Size^2 (ln employment)^2	–0.05557	–0.03821
Tests	N. of obs = 342 Log likelihood = –347.05 LR chi2(10) = 51.05 Prob > chi2 = 0.0000 Pseudo R2 = 0.0685	N. of obs = 342 Log likelihood = –615.25 Wald R chi2(10) = 49.87 Prob > chi2 = 0.000



	Innovation results	
	Products and processes	
	Oprobit	**Bioprobit**
Quality linkages with other firms	0.15023615	0.06798595
Quality linkages with universities and technological centers	0.19130485*	0.17612233*
Quality linkages with intermediate institutions	0.15881046	0.00885917
Absorption capacity	0.45311513***	1.2047031***
FDI	–0.00532151	0.31132535
Size (ln employment)	–0.08831044	–0.52179522
Size^2 (ln employment)^2	0.0042284	0.03736659
Tests	N. of obs = 324 Log likelihood = –279.22 LR chi2(7) = 59.13 Prob > chi2 = 0.0000 Pseudo R2 = 0.0957	N. of obs = 324 Log likelihood = –533.12 Wald chi2(11) = 154.97 Prob > chi2 = 0.0000



(*continued*)

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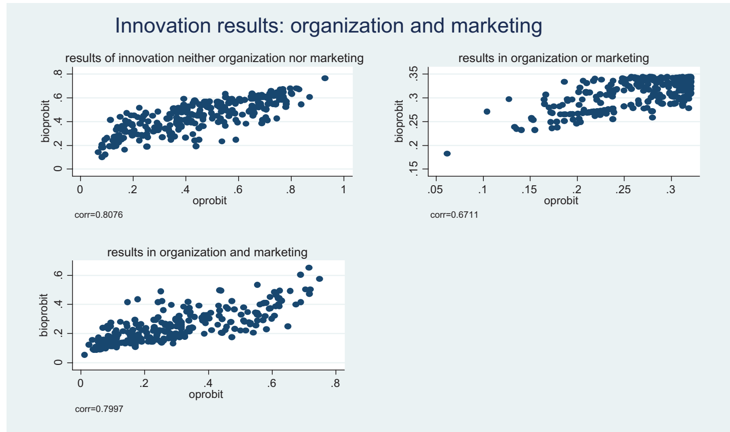
Table 6. (*Continued*).

	Innovation results	
	Organization and marketing	
	Oprobit	**Bioprobit**
Quality linkages with other firms	–0.0867065	–0.10442542
Quality linkages with universities and technological centers	0.21166969*	0.2058906*
Quality linkages with intermediate institutions	0.17802855*	0.07173391
Absorption capacity	0.21077665*	0.76341702***
FDI	0.17756839	0.41296416
Size (ln employment)	–0.28596681	–0.55287652*
Size^2 (ln employment)^2	0.03963285	0.05740481
Tests	N. of obs = 324 Log likelihood = –325.85 LR chi2(7) = 32.99 Prob > chi2 = 0.0000 Pseudo R2 = 0.048	N. of obs = 324 Log likelihood =–584.44 Wald chi2(7) = 58.13 Prob > chi2 = 0.000



$^{*}p < 0.05$.
$^{**}p < 0.01$.
$^{***}p < 0.001$.
Note: Oprobit, ordered probit regression with endogenity; bioprobit, bi-variated ordered probit regression corrected by instrumental variables.

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clear. The latter two cases imply not only the relevance of minimum thresholds but also the firms' capacities to learn from these linkages. These results support the first hypothesis, which stresses that the feedbacks reach different intensities depending on the kind of agent the firms are connected to.

Thus, the different ways in which absorption and connectivity capacities are manifested define different levels of complexity of economic systems that, in turn, result in the existence of countries with uneven developmental potential. In particular, several empirical papers carried out recently in Latin America reveal that both during periods of growth and economic stagnation, technological and organizational competencies are weak (Yoguel, Novick, and Marin 2001; Albornoz and Yoguel 2004; Albornoz, Milesi, and Yoguel 2005; Erbes and Yoguel 2007; Roitter et al. 2007; Arza and Lopez 2009; Benavente and Contreras 2008; Garrido and Padilla 2008; Bianchi, Gras, and Sutz 2008; Kupfer and Avellar 2008; Crespi 2008; Cimoli, Primi, and Rovira 2008; Silva Failde, Becerra, and Yoguel, forthcoming). At the same time, the connectivity of the agents, both among themselves and with institutions of the national innovation system, are reduced. These studies also show that there is some sort of non-virtuous association between competences and linkages. In such a context, reduced levels in both dimensions prevail.

As was proposed in the theoretical framework, in a complex system, the relationship between the absorption and connectivity capacities is reflected in strong creative destruction and appropriation processes, which in turn allow for structural change processes. These processes are measured in this paper by means of the innovation results in terms of products, processes, organization and marketing.

Finally, in the second set of models, the absorption and connectivity capacities were considered explicative variables of the results of innovation in process and product and organization and commercialization. As in the first group of models, the estimations are controlled by the agents' size, FDI and production networks. Also these models were corrected by endogeneity. In both cases, only the level of the capacities of absorption of the agents explains the importance reached by the results of the innovation of the product and process, on one hand and the organization and commercialization, on the other hand. These results demonstrate that only the individual capacities of the firms are central in explaining the results of the innovation and that the facets most tied in with the system do not have influence in those results. Therefore, regarding the existence of feedbacks, we can support the hypothesis that the absorption capacity mainly explains the innovations.

As it was shown in the theoretical framework, in a complex system the relationship between the absorption and connectivity capacities is reflected in the importance reached by the innovation results in terms of products, processes organization and marketing, which in turn are proxy variables of creative destruction and appropriation processes that allow structural change processes to happen.

5. Conclusions

In the previous sections, we have described a set of production networks as a complex system focused mainly in relation to the level and evolution of firms' absorption and connectivity capacities and their influence on innovation results. The econometric models estimated for production networks in Argentina support the hypotheses of the paper. Hence, only absorption capacities explain the innovation results which, in turn, would condition the appropriation and creative destruction process and the structural change. Besides, neither quality linkages with other firms, intermediate institutions or universities and technological centers are relevant in explaining the innovation results. Therefore, because of the low

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complementarities among firms derived from the prevalent specialization pattern, systemic dimensions are missing and only the firms' individual efforts are relevant. In any case, the feedback mechanisms between absorption and connectivity capacities and between innovation results and absorption capacities are the expression of some types of increasing returns in production networks.[12]

Hence, the low levels of firms' capacities, mainly connectivity, would act in Argentine productive networks as restrictions in generating innovations. Therefore, the improvement of these capacities – especially connectivity – and the upgrading of feedback effects would be a necessary condition in generating appropriation and creative destruction processes and thereby in enhancing structural change processes.

As a consequence, in spite of the important growth of gross domestic product (GDP) in the last 6 years, Argentina still has to face the challenge of improving the absorption and connectivity capacities of firms in order to develop at system level, processes of appropriation, creative destruction and structural change. Related to these three processes, it is possible to make some reflections beginning with both, the econometric results linked to the complex system approach and from some theoretical and stylized facts discussed recently in the literature, focusing on the problems that Latin American countries have in generating learning, innovation process and connectivity, as it is shown on the main results of regional innovation surveys. For example, as technological surveys show in Argentina (Arza and Lopez 2009; Lugones and Suárez 2008), Brazil (Kupfer and Avellar 2008), Chile (Benavente and Contreras 2008; Crespi 2008), Mexico (Garrido and Padilla 2008), Uruguay (Bianchi, Gras, and Sutz 2008) and Latin America (Cimoli, Primi, and Rovira 2008), the learning and technological processes are mainly of an embodied nature and are poorly fueled by knowledge derived from basic and applied science and firms' linkages with the environment, specially with universities and technological centers. From a macro perspective, Cimoli, Porcile, and Rovira (2010) have shown the relevance of structural change perspective for understanding the inexistence of convergence. Those authors emphasize that the problems of a deficit in Schumpeterian and Keynesian efficiency are explained mainly because income elasticity of the demand for imports in Latin America has an upward trend, which was not matched by a similar increase in exports.

Therefore, the appropriation process would be characterized by a low or null appropriation of quasi-rents because the low absorption and connectivity capacities would inhibit innovation and increase the costs of R&D, which in turn would affect the capacity to catch-up. As we propose in the theoretical model, weak absorptive and mainly powerless connectivity capacities in firms would condition also the significance of creative destruction processes. Low capacities would impact on innovation and hence the competition would be based mainly on prices and not on the increasing of variety and the improvement of selection mechanisms. The structural change processes would be constrained by the low feedbacks effects of absorption and connectivity capacities. A specialization pattern and an economic structure characterized by (i) the predominance of static comparative advantages and (ii) the low importance of sectors with high Schumpeterian and Keynesian efficiency (Cimoli, Porcile, and Rovira 2010) in the specialization pattern would condition the development of capacities of the system's components. The latter issue is also evident in the low complexity of networks, although this characteristic does not override the possibility that a few firms in more dynamic industries may exist, grow and compete globally within the prevalent dynamic profile of specialization (Erbes et al. 2006).

The low development of capacities and the prevalence of individual efforts explain why the predominant specialization pattern is able to be defined by limited processes of knowledge appropriation, creative destruction and structural change. This pattern would be associated with diminishing returns to scale, markets with strong volatility of prices, demands for unskilled labor and mainly embodied technical progress. This uneven production specialization would reflect a mechanism for the appropriation of knowledge closer to traditional forms of protection and weak spill-over on the productive structure.

When diminishing returns outweigh the increasing ones, which is the consequence of weakness of feedbacks mechanisms, the possibility of creating a development path and high-complexity levels is very low. In these cases, where the leakage of knowledge would be higher than knowledge appropriation, structural heterogeneity, low levels of complementarities and interactions and high productivity gaps among sectors would prevail. Therefore, the challenge is to make the specialization pattern more complex, switching to sectors in which the agents are price-setters rather than price-takers in international markets. In these kinds of sectors, the development of absorption and connectivity capacities becomes a key factor in agents' competitiveness.

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Notes

1. On the one hand the theoretical framework provided by the theory of complexity has not yet clearly identified feedback mechanisms between the macro and micro levels that lead to the existence of emergent properties. Furthermore, by the micro and meso nature of survey carried on, the econometric exercise is focused on the existence of feedbacks among skills and between them and the results of innovation.
2. The agents that allow those articulations were conceptualized by Casalet (2005) as bridges institutions or gatekeepers by Giuliani and Bell (2005).
3. Absorption and connectivity capacities would have strong influences on the agents' creativity, in the sense of Antonelli (2007).
4. For example, linkages oriented to improve quality assurance, human resources training, design and innovation activities.
5. Like other firms, consultants and business chambers (intermediate institutions) or universities and technological centers (science and technology).
6. So, within this approach, economic agents are not automata but instead they react intentionally looking for economic rents.
7. County of Morón, in the West of Buenos Aires Metropolitan Area. This group will be taken as a numeraire in the econometrics models.
8. Each component of absorption capacity index varies among 1–3 from low to high. The aggregated absorption capacity index may take three different values: (1) low (lowest through 1.85), (2) medium (1.85 through 2.4) and (3) high (2.4 through highest).
9. The goals of linkages considered in the survey were: relating to commerce, quality assurance, human resources training, designing and development activities, finance for innovation, sharing of infrastructure, reducing costs and risks of innovation, organizational changes and environment improvements.

10. These three proxy variables of connectivity capacity were defined in four different levels (i) the absence of linkages, (ii) low quality linkages (just one goal), (iii) medium quality linkages (from 2 to 3 goals) and (iv) high quality linkages (4 or more goals).
11. Variables that affect the response of the model and its inclusion were arbitrarily omitted.
12. In Albornoz and Yoguel (2004), it is shown that those increasing returns were absent during the 1990s with the Washington Consensus policies.

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