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A Sectoral System of Innovation Analysis of Technological Upgrading in the Food Processing Sector in Argentina, Brazil and Chile

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Abstract: This paper analyzes innovation in firms using a Sectoral System of Innovation approach on the food processing sector in Argentina, Brazil and Chile. The principal component analysis performed using data from the World Bank Investment Climate Survey shows that firms' knowledge bases have evolved largely through acquiring new equipment and foreign technology, while the embedding institutions have impeded rather than assisted innovation. The Probit estimation results confirm that only a few of the sectoral system of innovation variables have had a positive impact on innovation. Overall, the evidence shows that these countries should invest more on indigenous capabilities, thus effecting institutional change for facilitating innovation.

Keywords: food, Latin America, sectoral system of innovation, technological capabilities

JEL classifications: O31, O32, Q18, N56

1. Introduction

One effect of external liberalization in Latin America has been the increase in opportunities to access knowledge and technology from abroad, which has impacted food processing in at least two ways. On the one hand, falling tariff and non-tariff barriers has promoted the importation of technology, thus the local capital goods industry has suffered a major setback including engineering departments of many industrial firms (Katz, 2001). On the other hand, access to foreign knowledge has allowed firms to incorporate technological advances in important areas, such as biotechnology, packaging and transport techniques (Marsden and Arce, 1995; Bisang and Gutman, 2005).

The three Latin American countries *viz*. Argentina, Brazil and Chile[1] were selected because their combined food processing sectors represent around 40-50 per cent of Latin American exports, 10-15 per cent of GDP, and 15-30 per cent of employment. The importance of food processing increased between 1970 and 2003 with exports growing rapidly over the last decade. The successful upgrading enjoyed by the sector has enabled exports to different destinations on the basis of higher processing degrees (from raw to manufactured food), with Asian countries increasingly emerging as the main destination (ECLAC, 2007).

Another reason of interest is that the food processing sector appears to offer an opportunity to examine the heterogeneity of modern production systems (Murdoch *et al*., 2000). In food processing, idiosyncratic production systems with specific productive and organizational structures and specific features of domestic demand coexist with others that are more standardized and global in nature.

Finally, the food sector is tending strongly towards greater technological sophistication and innovation, as a result of product differentiation and consumer feedback, such as food origin and safety, as well as the indispensable incorporation of marketing services – e.g. logistics, packaging, transport and distribution, including the improvement of customs offices and port logistics for exports (ECLAC, 2008; Wilkinson, 2003).

The food processing sector has often been analyzed through case studies. The main drawback of the case study approach is that it focuses on a single dimension such as innovation, firms' competencies, structure of production and so on. As a consequence, the possibility of having an integrated and consistent analysis of sectors to understand their workings fully, and to compare the different sectors using important dimensions – such as the type and role of agents, the structure and dynamics of production, the rate and direction of innovation and the effects of these variables on the performance of firms and countries – is still very limited (Malerba, 2002). This paper attempts to fill this gap, though it is difficult to draw implications from the findings because the food processing sector comprises highly heterogeneous activities that must be analyzed individually and carefully. However, the paper only aims to provide a glance at the whole, while leaving for future research the analysis of the parts. The main advantage of the approach adopted is that it allows us to compare the same sector from three countries.

The innovation process is an intricate interplay between micro and macro agents, where macro-structures interface with micro-agents, and such interactions shape change in both of them (Lundvall, 2007). Hence, the frequent use of R&D statistics and patents as proxies for measuring innovation is acknowledged to be unsatisfactory (Winter, 1987; Bell, 1984; Freeman, 1994). Especially for developing countries, other factors matter for innovation. R&D is only complementary to 'efforts' embodied in people and firms, which are obviously more difficult to trace (Dosi, 1988). For these reasons, we approach the innovation process in food processing through a systemic view.

Innovation can be studied in the different sectors of the economy using different study approaches. In this study, the Sectoral System of Innovation (SSI) approach that has been widely used to study different manufacturing sectors (Malerba, 2004; Malerba and Montobbio, 2004) is employed to analyze the food processing sector. The SSI framework is deemed appropriate to explain the complex knowledge base and qualitative shifts in an economic sector (Murdoch *et al*., 2000). Moreover, the SSI captures the crucial importance of networks, as well as how capability and institutions have been coping with the changes in knowledge and technological base in a sector (Malerba and Nelson, 2010).

We first trace and map the main building blocks of food processing using the SSI approach. Under an integrated and systemic view, agents, linkages and institutions affect firms' probability of introducing new products and new processes. On the one hand, firms require indigenous capabilities to search for and create new knowledge, partly by formal R&D and partly by less formal types of technological effort. On the other hand, university research, vertical and horizontal links among local firms, user-producer interactions, and the level of firms' innovative efforts are extremely important in generating opportunities or constraints for firms (Nelson, 1991).

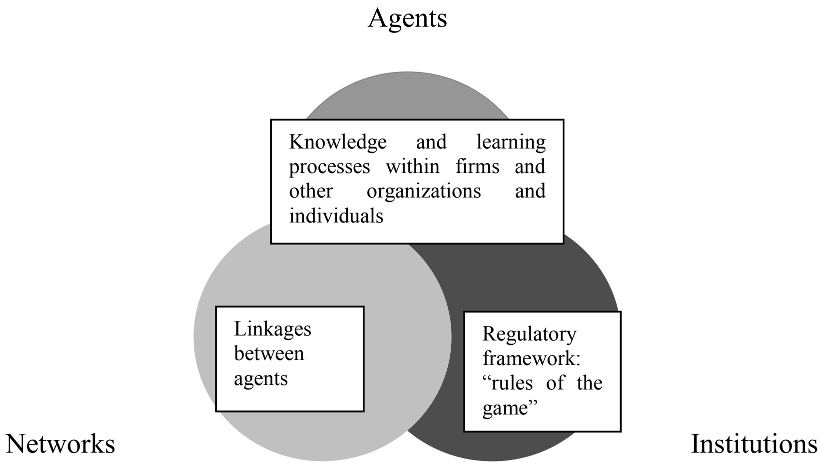
Given the logic of general system theory, we focus the empirical analysis on firms, which are the main actors of the system that undertakes innovation activity (von Bertalanffy, 1950). Using a descriptive analysis of the food processing SSI components, our research question seeks to identify the factors affecting innovation and the interaction between firms' knowledge base and other stimuli that is generated by the supply of the appropriate level of education and skills (including training) and investments in R&D and new equipment (first SSI building block), their linkages and networks (second SSI building block), and the shaping institutions (third SSI building block) that eventually stimulate the introduction of new products and processes.

In the next section, we present the SSI approach in the food processing sector. In section three, we study the SSI of the food processing sector in Argentina, Brazil and Chile. In section four, we examine food processing firms using the SSI approach to the innovative performance. In section five, we present the model, analysis and results, and finally in section six, the conclusions.

2. The Sectoral System Approach in the Food Processing Sector

Combining the Sectoral System and Innovation[2] concepts, Malerba (2002) suggests an integrated and dynamic view of sectors – the Sectoral Systems of Innovation[3] (SSI) – which includes microeconomic, technological, and institutional factors as sources of differential innovativeness across sectors.

Figure 1: The SSI's Building Blocks



Source: Adapted from Malerba (2005).

This notion provides a set of variables and concepts that can be identified in three building blocks: a) knowledge and learning processes, b) actors and networks, and c) institutions (Malerba, 2006). These blocks have many overlaps, as is natural under a systemic conception (see Figure 1). We consider that knowledge and learning are crucially built by agents. Thus, for the purpose of this study, we name the first building block '*agents*'.

The three building blocks should not be seen as just a static structure. Change is a distinctive feature of Sectoral Systems, which means transformation and evolution (Malerba, 2002), as well as the need for continuous innovation. Connecting the second and third building blocks (networks and institutions), network analysis implies that market activities are never purely economic but are embedded in social norms and institutions which mediate their effects (Polanyi, 1957). Moreover, institutions (in one of the most highly regulated sectors in the global economy) matter a lot and political regulation guides agro-food chain governance and shapes meanings and practices across agro-food networks (Ponte 2002a, 2002b; Raynolds, 2004).

Within an interactive innovation model there is a plurality of production systems and innovation processes, where informal practices and institutions frame networks and agents (Storper and Scott, 1995). Indeed, agents can be fostered or hampered by institutions. Moreover, firms can encounter opportunities related to the availability of an adequately educated labor force, but they may find obstacles due to governments' labour regulations. In the same fashion, firms can be encouraged to build their own capabilities – and finally to innovate – through regulations' flexibility,[4] knowledge and research availability, and tax incentives, or may find many obstacles in each of the fore-mentioned issues. Non-firm agents, such as universities, research centres and other sector organizations, may also encounter the same alternatives of opportunities or obstacles. Thus, within this SSI, there is always a feedback loop due to inherent dynamics and reciprocal influence: the creation, the diffusion and the application of knowledge that takes place through interactions between various actors of the innovation system (Lundvall, 1992; Nelson, 1993; Malerba and Nelson, 2010), influenced by surrounding institutions. In the following paragraphs, we will look deeply into each building block for the SSI agro-food.

2.1 Agents

SSI is composed of heterogeneous agents that include organizations and individuals. In the first group, there are firms (users and producers) and non-firms (universities, research centres, etc.). In the second group, there are consumers, entrepreneurs, and scientists. Knowledge and technologies are important constraints or strengths of agents, and consequently of sectors.

Focusing on the food sector, it is not 'immune' to increasing importance and change in the roles of user-producer interaction (Lundvall, 1988; Gertler, 1995). Knowledge does not flow unidirectionally from technology producers to users, as users provide tacit and codifiable[5] knowledge to producers, in order to enable the latter to solve their practical concerns (Asheim and Gertler, 2005). This is made evident in consumers' increasing demands for product quality and safety. Focusing on firms' efforts, these are then directed to quality and safety characteristics. Such issues constitute 'credence attributes' and comprise: (1) food safety; (2) healthier and more nutritional foods (low-fat, low-salt, etc.); (3) authenticity; (4) production processes that promote a safe environment and sustainable agriculture; (5) 'fair trade' attributes (for instance adequate working conditions).

The specific knowledge base tends to vary across industrial subsectors within the food processing SSI, and shapes the innovation process of firms (Pavitt, 1984). This knowledge base can be 'analytical' or 'synthetic' (Laestadius, 1998), entailing different 'mixes' of tacit and codified knowledge, different skills, and reliance on different organizations. Some industries are dominated by an analytical knowledge base, where knowledge creation is based on codified science (genetics, biotechnology, nanotechnology, etc.) (Asheim and Gertler, 2005). Firms typically have their own R&D laboratory, but they also rely on the research undertaken in national research centres and universities for shared scientific principles. Knowledge inputs and outputs in this type of knowledge base are often more codified than in the case of synthetic knowledge (Asheim and Gertler, 2005), but always coexist with tacit knowledge (Johnson *et al.*, 2002). Knowledge application frequently takes the form of radical innovations and results in new firms and spin-off companies (Asheim and Gertler, 2005).

In other industries (production and packaging of chocolates and sweets; processed meat, fish, fruit, vegetables, etc.), a synthetic knowledge base prevails, mainly applying industry-specific technical knowledge (Asheim and Coenen, 2005). Innovation takes place through the application or novel combination of existing knowledge, and takes the form of applied research involving incremental changes through the modification of existing products and processes development (Asheim and Gertler, 2005). Constant improvements of pre-existing product standards, packaging, design, and labelling characterize innovation in these industries (Onsager and Aasen, 2003). Thus, additional aspects call for investment in technological assets and knowledge, such as the product differentiation and the specialization strategy geared towards consumers demand in the international market, and also to the increasingly demanding domestic market (Reardon *et al.*, 2001). Knowledge is created through testing, experimentation and practical work. Consequently tacit knowledge, craft and practical skills, and training, remain more important and are created from experience through learning by doing, using, and interacting. New firms and spin-offs are less frequent than in industries dominated by analytical knowledge (Asheim and Gertler, 2005).

Regarding non-firm agents, a special mention should be made of public research institutes in the food processing sector. Activities of public science and technology institutions play a crucial role, especially if oriented towards fundamental research. Non-firm agents such as universities, research centres and other research organizations, at both the national and regional levels need to be "hands-on", which means they should establish systemic relationships with local industries, actively tailored to them (Asheim and Coenen, 2005).

2.2 Networks

Networks are important and complex within the food processing sector, and this aspect can differ depending on specific subsectors. Links between research centres and universities with firms can underpin original scientific ideas for food companies (Asheim and Coenen, 2005). Agents interact through processes of communication, exchange, cooperation, competition, and command. 'Social capital'[6] (seen for instance as mutual trust), is a prerequisite to promote cooperation within networks, however it is not a guarantee for long-run innovativeness (Asheim, 1999).

Knowledge networks and flows are then, important sources of innovative ideas (Asheim and Gertler, 2005). Networks perform important missions,[7] such as promoting knowledge sharing and competence dissemination among firms, educational and R&D organizations. Fluency of communications depends on the firms' knowledge base, structure, and internal mechanisms. If well developed, they could simplify the transfer or reception of knowledge. Indeed, firms' background knowledge may contribute, for instance, to facilitate or hinder their relationship with both buyers and suppliers, and also with R&D centres, universities, etc.

Interactions between actors produce, frequently, a shift from 'mass markets' (with broad commodities) to markets with differentiated products and niches. The demand side is pushed by mature consumers with sophisticated and varied tastes and the supply side is shifted by production, processing, and distribution technologies that allow product differentiation and market extension and segmentation (more concerned with health and quality considerations) (Murdoch *et al*., 2000).

2.3 Institutions and Norms

The third building block includes institutions and norms. Institutions are the 'rules of the game' in a society, and affect economic performance by determining the costs of transacting and producing. Efficient rules also provide incentives for the acquisition of knowledge and learning, and also induce innovation (North, 1992).

"Agents' cognition, actions, and interactions[8] are shaped by institutions, which may be formal or informal, including norms, rules, laws, standards, informal constraints, conventions, routines, common habits, and established practices, etc. They may range from ones that bind or impose enforcements on agents, to ones that are created by the interaction among agents (such as contracts)" (Malerba, 2005). Sometimes, they have the goal to prevent 'opportunistic behaviours' among competitors (patent protection) or to alter the terms of agreements. At other times, they develop problems of bureaucracy that may result in income dissipation and lack of flexibility (North, 1992).

Many institutions are national and shared by all sectors (such as the patent system), while others are specific to the specific sector (sectoral labour markets or sector specific financial institutions) (Malerba, 2005). Considering the food sector, some institutions are committed to the communication of quality and safety through grades and standards[9] (G&S) reflected in certification and labels. These mechanisms are needed in order to meet public and private quality and safety requirements and reduce transaction costs (Reardon *et al*., 2001).

Financial support is crucial for this SSI (Intarakumnerd, 2011). It can enhance investments in R&D, machinery and equipment, as well as expenditures in marketing and processes improvement. The public sector plays a major role in funding R&D activities[10] and in supporting SMEs (Grunert *et al*., 1997). In this sense, prizes for discoveries or subsidies for exports (Wilkinson, 2003) and innovation should not be neglected – they promote specific industries or activities, can help to deal with uncertainties regarding the benefits of innovation, and can spawn social gains (not limited to producers but extendable to consumers).

Regarding the regulatory framework, tariff and non-tariff barriers also affect this SSI. Besides trade barriers, other policy protective interventions are related to public subsidies and price support measures. If correctly targeted, protection measures can be extremely useful. However, sometimes they result in firms' inefficient performance, lack of innovation, or lack of stimulus for exports.

3. The SSI Food Processing Sector in the Selected Countries

The food sector, broadly defined for the purpose of this study, is being shaped by a number of processes of changing knowledge and technology in the selected countries. Inside this broad vision there are very different activities and realities: from the 'big chains' of commodities to the production of wines, from the production of citric juices to the production of sunflower oil. There are extremely different sub-sectors under this classification and consequently it is difficult to make deep characterization of them, even if they share many patterns regarding innovation.

Agents in the sector are very heterogeneous in terms of the scale of activities, age, specialization profiles, and human and economic resources in these countries. There is however, a highly diffused common pattern: firms face problems related to the lack of competiveness and quality, as well as the need of adaptation to the challenges of new markets (Bocchetto, 2001).

Non-firm agents play a fundamental role and can help firms overcome the previously mentioned problems, bringing the necessary means to face technological changes. For instance, *Programa Cooperativo para el Desarrollo Tecnologico Agroalimentario y Agroindustrial del Cono Sur* (PROCISUR) carries on joint research at a regional level. It represents the cooperative effort of the different Agricultural National Research Institutes from Argentina, Bolivia, Brazil, Chile, Paraguay, and Uruguay. Its objectives are to promote technological integration in the region and to develop regional systems of innovation focused on the generation of the knowledge and technology needed within the Mercosur (Bocchetto, 2001).

Among non-firm agents, national R&D centres, related to industries dominated by analytical knowledge, cover each country through regionalized centres,[11] focused on specific agricultural outputs that prevail in the particular area. Outstanding examples of successful cooperation for promoting innovation in Brazil are the 'green revolution' fostered by Embrapa in Cerrado, as well as the targeted efforts of firms, universities and research centres, to develop breakthrough innovations in genetics for Eucalyptus. Other positive experiences are related to collaboration in biotechnology, such as the Argentinean alliance between local firms and research centres to develop a new type of bio-milk (Marín *et al*., 2009) and the Chilean vaccine for salmon (Maggi, 2007; Marín *et al*., 2009). Almost every public research institute has serious budgetary problems (associated in part with the financial crises of the States in question) which have led to budgetary cuts (Beintema *et al*., 2001; Bisang and Gutman, 2005). At different levels, the three countries' R&D public investments are low and inferior to US or EU expenditures in the food processing Sector (Anlló and Suárez, 2008).

Even less frequent is public research involving synthetic knowledge. Research centres need to work in tune with firms, but unfortunately weak links characterize the relationship between different public research institutes and firms within this SSI (Ekboir, 2003). Most of the time, they deal with partial aspects and have no global strategies. In Argentina, CIDCA is a multidisciplinary centre (between University of La Plata and other research centres), focused on food processing and conservation, which undertakes research and also delivers regulations and quality standards, training, and transfers knowledge to firms. A similar role is played by Intal Brazil and Inta Chile. Albeit one of these research centres' goals is interaction with the private sector, the cooperation among both groups is not very diffused, and not always related to applied research.[12] Nonetheless, concerning synthetic knowledge, there are successful examples of cooperation such as the Zero Tillage package in Brazil (Ekboir, 2003) and the association between machinery domestic producers and research centres in Argentina (Marín *et al*., 2009), which managed to give the appropriate responses to market challenges related to new agricultural equipment. A plausible explanation for this success is given by the convergence of specialized (with the appropriate knowledge base) suppliers of machinery and the strong role played by research institutions.

Different types of networks characterize these countries, and in all of them there are firms operating at different levels of knowledge base, diverse linkages with clients and suppliers, disparities in the levels of information access and quality, and different economic scales (Bisang and Gutman, 2005). Recent studies[13] confirm that the main agro-food networks in the selected countries are efficient forms of business organization for achieving higher levels of innovation and having a competitive position in world markets

(Farina, 2002). 'Champion networks' like those created around Chilean Salmon, Brazilian Eucalyptus and Ethanol, and Argentinean Soya (Marín *et al*., 2009) contrast with others, where only weak linkages are established, for instance due to mistrust (Moguillansky *et al*., 2006). Within weak networks there are greater difficulties to increase efficiency and reduce transaction costs, to facilitate the process of innovation, to establish mechanisms for limiting risks – of natural and biological factors that characterize the sector – and to lead to the formulation of strategies for the future evolution of the overall set of firms (Bisang and Gutman, 2005).

Institutions and norms affect this sector in a particular way, as markets are highly influenced by institutions through international regulations (Bocchetto, 2001). Despite the three countries belong to Mercosur, they have still not built a common regulatory apparatus, such as antitrust policies, consumer protection laws, standards of health and hygiene requirements for food products, packing, and trade regulations (Boccheto, 2001; Trienekens and Zuurbier, 2008; Santana, 2009). Thus, norms coordination and collective action supporting the sector seem indispensable.

At the international level, there are supra-national institutions (e.g. the Regional Fund for Agricultural Technology that promotes strategic agricultural research of relevance for the Latin American and Caribbean Region), international donors, and development agencies that support firms as they strive to access technology and new products' development. An example of success can be found in the Chilean salmon industry due to the financial and technical support provided by international agencies during the first years of the industry (Maggi, 2007).

National R&D organizations such as the *Fondo para la Investigacion Cientifica y Tecnologica* (Argentinean Foncyt) and *Fondo Tecnologico Argentino* (Fontar), *Financiadora de Estudos e Projetos* (the Brazilian Finep), and *Corporacion de Fomento de la Produccion en Chile* (the Chilean Corfo) share the objectives of financing different extension services and acquisitions of new equipment. Indeed, institutional financial support is necessary, not only for investing in R&D but also for acquiring new equipment. As pointed out by Farina (2001), the Brazilian agro-food sector grew more quickly due to public support (minimum prices and by subsidized credit). Conversely, the lack of resources can result in failures, especially for small and medium firms. This is the case for the benefits of producing biocides in Argentina, which has been limited to large firms that hold the financial power to access foreign inputs and technology (Bisang and Gutman, 2005).

Also at provincial levels, there are programs that finance innovation, such as the *Programa de Servicios Agricolas Provinciales* (Prosap) in Mendoza, Argentina. It represents a good example of public financing services aiming to transfer knowledge and technology and to improve management practices to grape producers. The results obtained (e.g. increase of yields, increase of grape quality, etc.) demonstrate two interesting points. First, the program has not been as effective as expected, because it has not been directed to target the complete needs of beneficiaries. Second, the positive results were conditioned by producers' characteristics (Cerdán-Infantes *et al*., 2008).[14]

4. Firms within SSI and their Innovative Performance

Our empirical analysis is based on the SSI approach as useful tools in various respects: for a descriptive analysis of sectors; for a full understanding of their dynamics and transformations; for the identification of factors affecting the performance, competitiveness, and innovation of firms and countries (Malerba, 2002); and for technology and innovation policy (it provides the identification of 'system failures' and the related variables which should be policy targets) (Malerba, 2005). However, rather than focusing on case studies (Malerba and Montobbio, 2004; Bell and Giuliani, 2005; Malerba and Nelson, 2010) this study put firms at the fulcrum of the empirical analysis, based on the General System Theory, "the components are themselves systems of a next lower order" (von Bertalanffy, 1950: 151). Firms are then our next lower order, and the ones which undertake innovation within systems. Indeed they are suppliers and users in the value chain that become relevant in the organization of innovative activities (Malerba, 2005), they build linkages with others agents (second building block), and are framed by specific institutional contexts (third building block). Focusing on this 'new system', the second step is to econometrically evaluate how these building blocks' patterns affect their propensity to innovate.

4.1 Firms' Knowledge Base

Firms build their own capabilities and innovate through their individual learning process. This process has two important elements that are extremely interrelated: existing knowledge base and intensity of effort[15] (Cohen and Levinthal, 1990). Success in manufacturing development depends on the creation and strengthening of indigenous capacities that are analyzed in this paper under the concept of Technological Capabilities (TCs) (Lall, 1996; Benavente *et al*., 1997; Bell and Giuliani, 2005). Kim (2001: 9) defined TCs as the "ability to make effective use of technological knowledge in production, engineering and innovation…. It also enables a firm to create new technologies and to develop new products and processes in response to their changing economic environment". We also aim to include under this concept the creation of all the other Dynamic Capabilities (Eisenhardt and Martin, 2000; Teece *et al*., 1997) needed for properly adapting, innovating and changing while the environment evolves.

Firms operate at different levels of TCs – within the SSI – and consequently have different innovation proneness. To measure the main patterns of TCs we introduce Lall's taxonomy (1992) that includes major firms' technical functions considering also the degree of complexity[16] or difficulty of them. Under this taxonomy there are then, investment, production, and linkages' capabilities.

Table 1: Technological Capabilities – Lall's taxonomy (1992)

Investment Capabilities	From prefeasibility and feasibility investment studies (as examples of the simplest ones) to basic process and equipment design (as the most complex).
Production Capabilities	From adequate levels of education, skills, and training in production workers, to the ability of assimilating product design and introducing minor adaptations in products following market needs (as the simplest ones) to quality controls,[17] in-house product or process innovation, and basic research (the most complex).
Linkages Capabilities	From exchanging information with suppliers to licensing own technology to other firms.

Source: Adapted from Lall (1992).

Apart from the traditional mentioned technical functions, we are interested also in analyzing education, skills, and training, at the firm level. Indeed, these elements enhance people's ability to receive, decode, and understand information and this is important for performing or learning to perform many jobs (Nelson and Phelps, 1966). Notable literature contributions have been given by different authors in this sense. Criscuolo and Narula (2002) emphasize the role of human capital (as qualified human resources), which are essential in monitoring the evolution of external knowledge and in evaluating the relevance of technologies that should be integrated into productive activities.

4.2 Linkages

Concerning networks' building block, firms systematically diverge in the extent to which they build external collaborative linkages,[18] and their specific attributes affect the value that firms derives from such relationships (Teece, 1986; Nelson, 1991; Intarakumnerd, 2011). To incorporate external technology is not a straightforward process. Even at an imitative stage, it becomes difficult to convert knowledge, and special indigenous skills are needed to allow firms to absorb and adapt external knowledge.

The network concept is used in several studies for analyzing the horizontal and the vertical relationships among manufacturing firms (Henderson *et al.*, 2002; Raynolds, 2004). For the purpose of our work, we focus on one aspect of firms' relationships within networks, the vertical linkages and in particular firms' use of domestic or foreign inputs, and foreign technology. We analyze functions related to the use of foreign technology, both type embodied (inputs) and non-embodied (licences), to understand how much firms rely on innovative technology from outside the country. External linkages are highly fruitful, allowing firms to be aware of more technologically advanced knowledge. However, if firms are mostly focused on foreign relationships, they also reflect weak technology support from the national innovation system (Muchie and Baskaran, 2009) for its industries.

4.3 Institutions' Perception

Firms are embedded within a national regulatory framework that can reinforce or hinder their innovative activity. Labour market structures can foster stable employment relationships, facilitating learning by doing and stimulating employers' incentives to train employees (Asheim and Gertler, 2005). Indeed, under a divergent set of national institutions governing labour market and corporate governance, the kind of relationships between economic actors can be very different (Christopherson, 2002). More closed, rigid and hierarchical systems tend to perform worse than more open and flexible ones (Saxenian, 1994). We concentrate our attention on firms' perception about institutions. In particular we are interested in administrative obstacles, labour conditions and environmental restrictions.

4.4 Firms' Innovative Behaviour

Innovation is considered both a demonstration of the firms' most complex level of TCs and also an output, reflecting firms' technological achievements. Consequently, as the process of building TCs is cumulative and path dependent (from basic to more complex TCs), we assume that product and process innovation are possible only if firms have accumulated and upgraded their TCs.

Even if the innovation *per se* is undertaken by a single firm, it is an actor's decision that has systemic characteristics. Literature and evidence agree that innovation is a cumulative and social process, involving interactions among people and information flows (Nelson, 1991). Thus, it reflects also "a collective learning and socially embedded process that is crucially dependent on tacit knowledge and untraded interdependencies" (Crescenzi, 2005: 472) that may not be simply duplicated.

We are also interested in analyzing the role of firms' size that frequently exerts a great influence over their proneness to innovate: large firms have facilitated access to finance, scale economies, and better organizational structures (Mairesse and Mohnen, 2002). However, only in certain technologies large firms do the bulk of innovative activities, while in others, small firms are also quite active (Malerba and Orsenigo, 1996). Thus, size advantages and disadvantages strongly depend on sectors (Pavitt *et al.*, 1987; Rothwell and Dodgson, 1994). And incidentally, when needed, linkages and networks between enterprises can be an option to go beyond firms' size limits. In the following section we aim to empirically analyze the importance of size for innovation in this SSI.

5. Empirical Analysis and Results

The empirical part is based on data from the World Bank Investment Climate Survey. The surveys were conducted on a sample[19] of representative enterprises in Argentina (2006), Brazil[20] (2003), and Chile (2006). The three countries' data were matched to a standard set of questions, with the surveys becoming highly comparable in addition to the format that allows cross-country comparisons and analysis. The samples of firms were stratified by size, location, and sectors. Regarding the latter aspect, the surveys covered registered industrial and certain service firms at the two digits ISIC[21] level of aggregation. For the present study we focus only on firms of the food processing sector.

Regarding size, the total employment is used to divide firms into small (less than 20 employees), medium (20-99 employees), and large (more than 100 employees) (see Table 2). For stratification purposes, the number of employees was defined on the basis of reported permanent, full time

Table 2: Surveys' Composition Regarding Size within Food Processing Sector

	Argentina	Brazil	Chile
Number of firms	167 (100)	129 (100)	160 (100)
Small firms (5-19 employees)	100 (60)	17 (13)	66 (41)
Medium firms (20-99 employees)	50 (30)	45 (35)	59 (37)
Large firms (>100 employees)	17 (10)	67 (52)	35 (22)

Note: Percentages in parentheses.
Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

Table 3: Innovative Firms in the Food Processing Sector

	Argentina		Brazil		Chile	
Firms' Size	Product Innovation	Process Innovation	Product Innovation	Process Innovation	Product Innovation	Process Innovation
Small	65 (65)	63 (63)	9 (53)	9 (53)	27 (41)	28 (42)
Medium	35 (70)	35 (70)	30 (67)	31 (59)	40 (68)	32 (54)
Large	16 (94)	12 (71)	39 (58)	39 (58)	25 (71)	28 (80)
Total	116 (69)	110 (66)	78 (60)	79 (61)	92 (57)	88 (55)

Note: Percentages in parentheses.
Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

workers. Although the surveys were not conceived for analyzing TCs, we found in them some useful questions for evaluating them under a SSI approach.

5.1 Innovative Output

As expected, size matters for innovation in the food processing sector (with the exception of Brazil, where medium firms are the leaders in innovation) – the larger the firms, the more likely they are to innovate (see Table 3). A very interesting finding is that more than 50% of medium firms introduce product and process innovation in the three countries, and more than 50% of small Argentinean and Brazilian firms introduce similar innovations (Chilean small firms are the least innovative among the group).

In the three countries, when small firms innovate in product, they innovate in process as well. Medium firms tend to innovate more in product, except Argentinean firms, where the same number of firms introduce process and product innovations. In Argentina, large firms achieve more product innovation, while in Chile, they achieve more process innovation. Brazilian large firms behave as small ones – when they introduce product innovation they also introduce process innovation.

5.2 Variables

The choice of the proxies for empirically measuring the agents' knowledge base, linkages and institutions' perception is determined according to Table 4.

Table 4: List of Variables and Definitions

Firms' knowledge base (First Building Block)
Education Level: average education attainment of a typical production worker. The levels vary between 1 (as the lower) and 4 (as the higher) level.
Skilled production workers: considers the percentage of skilled workers (having some special knowledge or ability in their work) among the total production workers.
Training Programs: a dummy variable that reflects if the firm has programs that have a structured and defined curriculum. May include classroom work, seminars, lectures, workshops, and demonstrations.
Buy new equipment and machinery (USD)[22]: reflects the annual expenditure on purchase of machinery, vehicles, and equipment.
Quality: a dummy that takes value 1 or 0, considering if the firm is or is not quality certified (only internationally recognized certifications such ISO and HACCP are included).
Investment in R&D (USD): this variable takes account of how much the sample firms invests in in-house R&D or contracting with a third party (see Note 17).
Firms' linkages (Second Building Block)
Per cent of inputs/supplies from domestic companies: considers the per cent of inputs and supplies that a firm receives from domestic companies.
Per cent of inputs/supplies from foreign companies: consider the per cent of inputs and supplies that a firm receives from foreign companies.
Technology from foreign companies: a dummy that takes value 1 or 0, considering if the firm receives or does not receive technology from foreign companies.
Firms' perception of institutions (Third Building Block)
Administrative Conditions: represents the level of obstacles faced by the firms when dealing with licensing and permits, and also per cent of total senior management's time dealing with government regulations, inspections, and bureaucracy.
Labour Conditions: considers firms' perception about the availability of educated labour force and labour regulation.
Environmental restrictions: reflects the degree of obstacles due to environmental restrictions.

Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

5.3 Method and Results

Under an SSI framework, we link the firms' knowledge base (first building block), linkages (second building block), and institutions (third building block), and perform a Principal Component Analysis (PCA) with two main scopes. The first one is referred to as parsimony. This means to provide a synthetic index that reduces a multivariate situation in a reduced dimen-sionality while retaining most of the information of each SSI's building block. The second one means to serve as a basis for imposing a structure to the domain (Dunteman, 1989), that is to identify firms' shared patterns within the food processing SSI as well as the presence of outliers among the three countries.

There are many different ways to determine the optimum number of principal components[23] to retain, which have the potential to represent the data variability with a criterion of 'efficiency'. How many and which principal components to retain depends on the goals of the analysis (Dunteman, 1989). As we have a small number of components and simply want to describe the variable set, for the first building block we elect to stop at the third largest one, and for the third building block we stop at the second largest one.

Principal Component Analysis

Focusing on firms, we aim to evaluate their main knowledge base (first building block). Our analysis follows Lall's taxonomy of TCs, but only includes production capabilities (no information was available for investment capabilities in the surveys) for the first building block. Linkages capabilities are TCs on the one hand (Lall, 1992) and on the other hand, (under the systemic view) they are an overlapping area between the first and second building blocks. Due to their importance, as stated previously, we evaluate them as an evidence of the second building block. The analysis is replicated for the institutions building block considering some interesting characteristics.

We obtain the same number of Principal Components (PC) and variables, which proves that there are no exact linear dependencies among the variables. The first PC explains only between the 28% and 38% of the total variance of the six components, depending on the country. The explained variance increases substantially by retaining the third PC[24] (see Appendix A), thus we retain three PC to have the variables adequately represented by the PC.

The coefficients for the first PC within the first building block of the SSI, in the three countries are all positive at different sizes (see Table 5). This highlights that firms that are concerned with one of the patterns of this building block are also interested in the other or others, at different levels. The size of the correlations (loadings) for a particular component reflects the importance of the component in explaining our blocks.

Table 5: PCA: Principal Components' Coefficients within First Building Block

	Argentina			Brazil			Chile		
Variable	PC1	PC2	PC3	PC1	PC2	PC3	PC1	PC2	PC3
Education	0.06	0.40	0.87	0.29	0.72	0.10	0.34	-0.24	0.69
Skilled	0.57	-0.28	-0.01	0.46	-0.31	-0.43	0.47	-0.01	0.30
Training	0.21	0.66	-0.15	0.50	0.36	0.24	0.43	-0.46	-0.32
Quality	0.27	0.52	-0.44	0.38	-0.06	-0.13	0.48	-0.25	-0.44
R&D	0.47	-0.14	0.15	0.16	-0.38	0.85	0.39	0.55	0.19
New Equip	0.56	-0.22	0.02	0.53	-0.32	-0.08	0.31	0.60	-0.32
Proportion	0.40	0.22	0.16	0.26	0.18	0.17	0.33	0.19	0.16
Cumulative	0.40	0.62	0.78	0.26	0.44	0.61	0.33	0.53	0.69

Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

There is a common pattern amongst the three countries in that the coefficients assign a large load to investment in skilled workers, confirming that firms are mostly concentrated in basic TCs. In Argentina and Brazil, the coefficients assign an important load to expenditures in new equipment, reflecting that the firms require increasing amounts of fixed capital in this SSI, as new forms of production raise the technical requirements (Farina, 2001; Bisang and Gutman, 2005; Anlló and Suárez, 2008). Other variables representing basic and intermediate capabilities demonstrate relevance – quality certification in Chile, and training in Brazil. It is also interesting to observe the important role that investment in R&D has in Argentina – under a PCA it should be interpreted that firms that spend in new equipment and skills, invest also in R&D in these countries.

Regarding firms' linkages (second SSI building block) there is a linear relationship between two variables – inputs from domestic and foreign origin. Thus, the knowledge of one of them helps to determine the other without error. Indeed these variables are complementary and sum to one – firms classified their one hundred per cent inputs between having domestic and foreign origins. With only two remaining variables within this building block the PCA analysis could seem redundant.[25]

Firms' perceptions about institutions (third building block) are highlighted here by some selected variables, which obviously represent only a part of the complex dimension of institutions. Nevertheless, they point out some interesting issues regarding administrative and environmental obstacles, and labour conditions that sometimes act as crucial determinants behind firms' innovative performance.

Table 6: PCA: Principal Components' Coefficients within Third Building Block

	Argentina		Brazil		Chile	
Variable	PC1	PC2	PC1	PC2	PC1	PC2
Administrative Obstacles	0.60	-0.49	0.65	-0.32	0.58	-0.46
Labour Conditions	0.64	-0.19	0.67	-0.20	0.59	-0.33
Environmental Restrictions	0.49	0.85	0.37	0.92	0.56	0.83
Proportion	0.47	0.29	0.42	0.32	0.53	0.25
Cumulative	0.47	0.76	0.42	0.74	0.53	0.77

Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

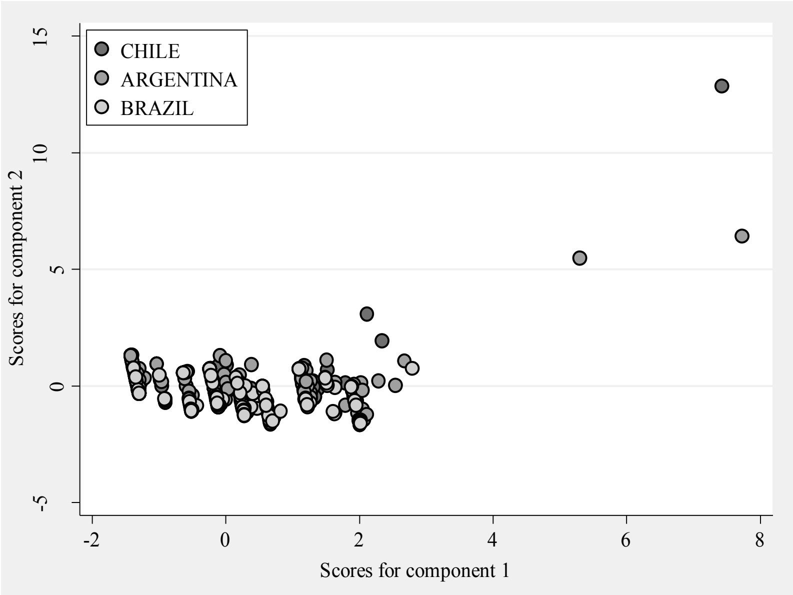
In Table 6 the PCA's coefficients assign high weightings to obstacles faced by firms for operations, due to administrative and environmental restrictions, and also firms' perception about labour conditions, in Argentina and Brazil. These positive and high weightings mean on the one hand, heavy difficulties for the enterprises' development and important obstacles to innovation and on the other hand, the availability of educated labour force and labour regulation. Concerning Chile, the coefficients are again positive and have almost the same loadings for the three analyzed variables. This means that each variable is equally represented in the linear composite, and that manufacturing firms give the same importance to these two different types of indicators – the administrative obstacles and the environmental restrictions, and the labour conditions. Further research is needed to understand in which way regulations may foster a more homogeneous and sustainable[26] SSI development.

Comparative Graphical Principal Component Analysis

Under a comparative view, we inquire about shared building blocks' characteristics between the three studied countries. We merge countries' datasets into one, perform the PCA for firms – related to each building block – and plot their scores in a two dimensional space. A major advantage of PCA is that, if the two PCs account for a substantial portion of the total variation, it is possible to approximate the distribution of the observations in the variable space by plotting the PC scores (Dunteman, 1989). PCA allows then, to lower the original dimensional space into a two dimensional subspace using the first two[27] PCs as coordinate axes. The PC analysis permits one also to visually search for clusters and outliers between firms.

In Figure 2 we observe that the three countries' firms have similar characteristics[28] regarding the knowledge base building block. Firms from the three

Figure 2: First Building Block – Scores from PC1 and PC2 in Argentina, Brazil and Chile

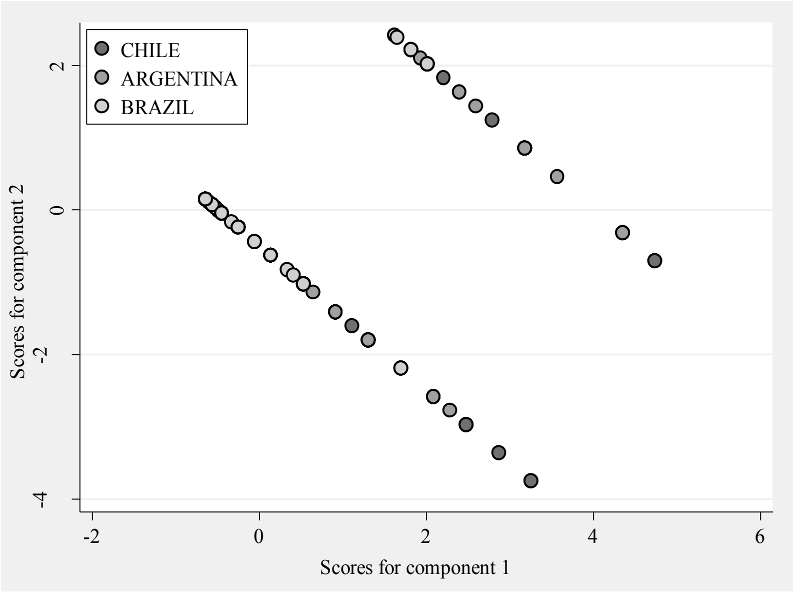


Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

countries are found close to each other, revealing shared patterns of TCs. There are only a few firms that can be considered outlying observations, as they lie at a considerable distance from the rest of the firms. Since the skilled production workers and new equipment variables have high loadings in Argentina, similarly skilled production workers and quality in Chile, it is expected that these few outlying firms – two from Chile and one from Argentina – had high values on one or both variables, depending on the country. The evidence again confirms the hypothesis that firms invest and put their efforts in the most basic TCs, in particular new equipment and skilled production workers, in these three SSI. This strategy is just a starting point for achieving more complex capabilities, and only when sustained by the other pillars of the system (networks and institutions) may allow firms to innovate.

We now perform PCA and graphically analyze the results for the second building block and compare the three countries' position regarding the use of foreign technology in both types embodied (inputs) or non-embodied (licences).

Figure 3: Second Building Block – Scores from PC1 and PC2 in Argentina, Brazil and Chile

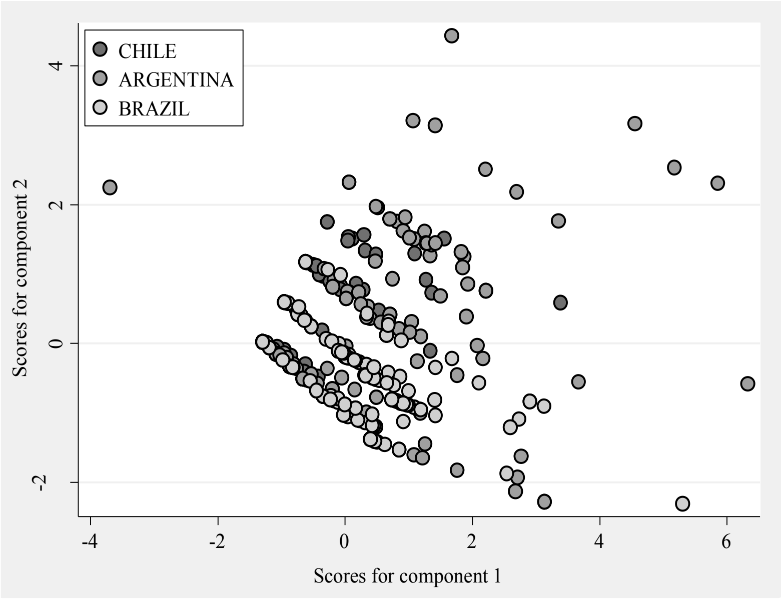


Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

Most of the Brazilian firms are found in the left area of Figure 3 with low loads of the variables, while Chilean ones are found on the right extreme. With the caveat that the availability of variables constrains our analysis only to some limited vertical relationships, and the consciousness that there are also many other vertical and horizontal interesting linkages to be analyzed, we extract some conclusions about this sector. Primarily, firms do not behave in the same way regarding their foreign linkages in the three countries – Brazilian firms tend to rely frequently on national technology (Ekboir, 2003; Bisang and Gutman, 2005; Marín *et al*., 2009). Since the acquisition of technology from external sources can be seen in two ways, either as being at the technological frontier level, or as the weakness of the national system of innovation, specific cases should be analyzed to understand the motivations underlying these options.

In Figure 4 we examine firms' perception about institutions (the third building block), again under a two-dimensional representation, expecting the plot of the scores of the first two PC to show shared patterns and possibly the presence of outliers. In the survey, questions are posed to firms to identify

Figure 4: Third Building Block – Scores from PC1 and PC2 in Argentina, Brazil and Chile



Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

obstacles and advantages for operating. Then, the presence of high loads should be interpreted as good labour conditions, administrative obstacles, or environmental restrictions.

There is a homogeneous clump of observations among the three countries, with short distances between them, coexisting with other observations that are evenly spread throughout the variable space. Most of the firms from the three countries are found very near to each other reflecting similar perceptions about the institutions. However, some firms are relatively far from each other, and there are also few outliers situated in the right side, meaning very important loads of the first PC. In the case of Argentina and Brazil, high loadings should be related to administrative difficulties and labour conditions, while in Chile high loadings should be homogeneously related to the three variables.

Econometric Analysis

Our purpose now is to enquire how the knowledge base, the networks and the institutions influence the probability of introducing new products and new processes within the food processing SSI. Each building block has been analyzed separately. Now the three of them are jointly evaluated to see how the whole system behaves regarding innovation in each country.

The likelihood function is posited to evaluate the binary outcome variable and is examined under the Probit model, as the dependent variables assume values 0 or 1. We expect to investigate the relationship between the response probability and the explanatory variables:

$$P(Y=1|X) = G(\beta 0 + \beta 1\ X1 + \ldots\ldots\ldots\ldots\ldots + \beta k\ Xk) = G(\beta 0 + Xi\ \beta)$$

where G is a function taking on values between 0 and 1. In our case G is the standard normal cumulative distribution function, which is expressed in Equations (1) and (2) to describe the general specification:

$$P\ (Y1i = 1) = \Phi\ (Xi\ \beta) \qquad (1)$$

$$P\ (Y2i = 1) = \Phi\ (Xi\ \beta) \qquad (2)$$

where $Y1i = 1$ indicates that the firm i introduced new or significantly improved products and $Y2i = 1$ refers to the fact that firm i introduced new or significantly improved processes. On the right side of the equation there is Φ – the standard normal density function of firms' explanatory variables Xi representing the three building blocks.

The econometrical models are run, and in Table 7 the product and process innovations are evaluated over the variables of the three SSI's building blocks. But there is a potential problem. The presence of heteroscedasticity makes some care necessary in interpreting the coefficients (Greene, 2002). Thus, we correct for heteroscedasticity running also the Heterogeneous Choice Model[29] (Williams, 2010) and we obtain similar coefficients.

As stated before, innovation is considered as a complex type of TC (Lall, 1992), but it is also an output of the process of building TCs (Freeman, 1995). The goal here is to consider it as an output, sourced by the selected variables, representing the three SSI building blocks, and to evaluate their joint significance over firms' innovative performance.

In Table 7, regarding the knowledge base, the basic TC education, increases the probability to introduce product innovation, while the variable training, increases the probability to introduce process innovation in Brazil. The former variable can reflect the fact that the sector is becoming always more 'science-based' where education is a key of success as it allows "the symbiosis between traditional industries and science" (Lundvall, 1985: 30). The variable training also increases the probability of introducing product innovation in Argentina, and both types of innovation in Chile. This fact is in line with the idea that knowledge is created less in a deductive process or through abstraction, but more often in an inductive process of testing, experimentation, thus training allows more efficiency and incremental change in the form of new processes

Table 7: Probit Model – Innovation in Product and in Process with the Selected Variables for Each Country

	Argentina		Brazil		Chile	
	In Product	In Process	In Product	In Process	In Product	In Process
Knowledge Base						
Education	0.3679	-0.1235	0.0192***	-0.0024	2.4976	-1.3444
Skilled Pr. Employees	0.4654	-0.0004	-0.2595	0.0530	0.1307	0.2742
Training	0.5416**	0.2919	0.1010	0.5345**	1.0148***	1.3751***
Quality	0.1799	0.0281	-0.2266	-0.1545	0.2676	0.3618
R&D	0.0000	0.0000*	0.0000	0.0000	0.0000	0.0000
New Equipment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Linkages						
Foreign Inputs	-0.4276	-0.3055	0.0158	0.0177	0.0514	-0.0405
Foreign Technology	-0.0123*	-0.0040	0.4850	-0.1198	-0.0008	-0.0054
Institution's Perception						
Administrative Conditions	-0.0015	0.0024	0.0048	0.0147	0.0064	0.0045
Labour Conditions	0.0344	0.0211	0.0556*	-0.0348	0.0041	-0.0156
Environmental Restrictions	0.0400	-0.0021	0.2555	0.2968	-0.1510	-0.1520
Log-Likelihood Value	-77.1934	-85.5143	-74.6600	-71.9957	-76.1083	-74.9021
Pseudo R-Squared[30]	0.1258	0.0673	0.1111	0.1120	0.1944	0.2111

Note: The dependent variables are Innovation in Product and Innovation in Process. * significant at 10%, ** significant at 5%, *** significant at 1%.

Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

(Asheim and Coenen, 2005). No other variables positively and significantly increase the probability to innovate in the three countries.

The variables related to linkages follow the same fashion: they do not increase the probability to innovate. Networks – considered only through this limited approach of vertical integration – seem to be not strong enough to foster innovation.

Considering the institutions building block, within the boundaries of the available information, there is only one significant positive coefficient for the probability of introducing new products in Brazil. It is related to the variable labour conditions that in this case are seen as opportunities for innovating. The explanation may be found in some Brazilian labour policies (Cella dall Chiavon, 2003) that are probably perceived by firms, as adequate labour measures for promoting innovation.

Our model includes firms' variables concerning knowledge base, linkages and institutions. Nevertheless we finally analyze some advantages of including the systems' variables as a whole, evaluating whether adding the second and third groups of variables as predictors (together and not just individually) leads us to obtain a statistically significant improvement in model fit. We perform the Likelihood Ratio (LR) test. Thus, two models need to be run. One model has a set of variables while the second model has all the parameters from the first one, plus the new variables belonging to the other groups. When including only the variables of the second group to the first one, no improvements in the fit of the model are made. However, when adding the third group's variables, we obtain the expected results – the LR test compares the Log Likelihoods of the two models, with and without the third group's variables, and confirms that the difference is statistically significant.

In Table 8 we show the T-statistics and P-values. The less restrictive model (the one with the institutions' variables) fits the data significantly better than the more restrictive one. The results confirm that the proposed empirical model, including the three building blocks together, is the most appropriate one.

Table 8: T-statistics and P-values for Adding the Third Building Block Variables

	Argentina		Brazil		Chile	
	In Product	In Process	In Product	In Process	In Product	In Process
T-statistics	58.1847	58.7926	18.5929	19.8093	34.1608	36.6404
P-values	0.0000	0.0000	0.0009	0.0005	0.0000	0.0000

Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

6. Concluding Remarks

We have studied the food processing sector via an evolutionary and systemic approach, providing a descriptive analysis of the sector which allowed identifying some factors affecting innovative performance within the SSI. The sector has been theoretically portrayed through the three main building blocks of the SSI. For the purpose of our study, we redefined the first building block as 'agents', and it has become the cornerstone of our research for understanding the systemic aspects that promote innovation within the food processing SSI.

The sector is characterized by the coexistence of mass/standardized and differentiated/technologically sophisticated production. There is, however, a rising demand of quality and safety in food products, as well as differentiation and sophistication (a shift from traditionally mass/standard products towards differentiated products and niches). The great challenge for the sector is, therefore, innovation. It needs to occur within a system composed of a set of interacting agents (firms and non-firm organizations), networks and institutions.

Analytical and synthetic knowledge, tacit and codified, characterize the knowledge base of the different industries within this SSI. Thus, depending on these characteristics, more equipment, training, skills, R&D and other technological capabilities are needed, in the process of learning by doing, using, or interacting. No preferences about which aspect should be emphasized can be assumed without a careful analysis of the specific case and without a systemic consideration.

Linkages with other firms and non-firm agents (R&D centres, universities, etc.) for building strong networks are always more important for innovation. As a natural consequence, public R&D plays a fundamental role, in both basic and applied research. Institutions frame these relationships, providing resources, rules and flexibility or hampering the agents' mission within the SSI.

With this theoretical basis, the present paper focuses on the food processing SSI in the selected countries. Different literature studies highlight some shared patterns – the interest on investing in new equipment, the crucial role of non-firm agents (research centres, universities and consumers) and low public R&D investments. Evidence of successful cases is found when strong relationships are created within networks and when adequate technological capabilities are present in firms. Moreover, the results are boosted when public resources are strategically assigned. The intuition behind these findings is that, the closer the agents work together (firms, consumers and research centres) the better results they achieve. The cooperation between firms and research centres regarding analytical and synthetic knowledge can result in widespread innovation.

We deepen the analysis focusing on firms as the main actors and generators of innovation. Relying on the systemic approach, we analyze their knowledge base, their linkages and their perception about institutions. Empirically working with the World Bank Investment Climate Surveys for each country, we perform a PCA starting with firms' knowledge base (fundamental instrument to face technological change) and studying it under the Technological Capabilities (TCs) approach. As expected, the results show a common pattern in the three countries – large load to investment in basic capabilities such as skilled workers, and also to other basic capabilities (new equipment in Argentina, training in Brazil and quality certification in Chile). These findings can be seen as a good starting point, but not as a panacea. If firms continue operating without increasing their knowledge base's complexity, they will probably face difficulties in interacting with other agents and in taking advantages of the system's opportunities, lagging behind in technological changes.

The graphical PCA gives a comparative picture of the three countries' SSI. Many similarities between them highlight shared patterns of firms' behaviour and contextual conditions. Concerning firms' vertical relationships for the acquisition of embodied and non embodied technology, Argentina and Chile rely more on foreign technology than Brazil. There is a more homogenous behaviour regarding institutions in the three countries – most of the firms give high loads to all the variables.

The empirical research finally delves into innovation. We first gave an approach on firms' innovative proneness, finding that large firms (in Argentina and Chile) and medium firms (in Brazil) are the leading innovators. Then, we econometrically analyzed the influence of firms' knowledge base patterns, linkages and institutions' perception over product and process innovation. The empirical results, focused on firms, confirm that only a few SSI variables have a positive impact on innovation.

Connecting the theoretical with the empirical part, the evidence gives the idea that firms are focused on basic technological capabilities and depend on foreign technology, producing difficulties in innovating. Nevertheless, successful examples highlight that, when indigenous efforts are undertaken, strong linkages are created and are accompanied by helpful institutions, enabling firms to introduce new products and new processes.

Our first caveat, regarding analyzing such a wide sector with limited information, is justified through this paper's acknowledgement that we have provided only an initial overview of the SSI. We expect that this still gives a good platform to study in-depth this system by raising some food processing SSI characteristics and disentangling their three main building blocks. Our second caveat is related to the limited information available in these surveys for studying our building blocks. We constrain our study only to specific types of linkages and some interesting aspects of institutions. Nevertheless, they allow us to obtain some important findings about firms' relationships with their environment.

This study expects to make a conceptual and holistic contribution to the food processing SSI and an empirical analysis of the system through the vision of firms. With some expected and unexpected findings, the studied scenario suggests that, even if innovation is generated by individual firms in the three countries, their single efforts are frequently not enough when the surrounding system is not in tune with their requirements. Not only formal rules, but also informal relationships, need to be fostered within this system. The present findings should stimulate further research, including, case studies and aggregate statistical measures of the different subsectors, for a better understanding of their underlying realities.

Appendix A

Table A1: Principal Component Analysis: Eigenvectors – Food SSI, First Building Block (Argentina)

Variables	PC1	PC2	PC3	PC4	PC5	PC6
Education	0.0602	0.4012	0.8679	0.1411	0.2359	0.0817
Skilled	0.5692	-0.2795	-0.0100	-0.1707	0.2193	0.7215
Training	0.2130	0.6610	-0.1474	-0.6617	-0.2413	0.0028
Quality	0.2722	0.5249	-0.4441	0.6013	0.3009	0.0332
R&D	0.4658	-0.1355	0.1500	0.5689	-0.6404	-0.0919
New Equip	0.5586	-0.2249	0.0182	-0.2509	0.3330	-0.6806

Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

Table A2: Principal Component Analysis: Eigenvectors – Food SSI, Third Building Block (Argentina)

Variables	PC1	PC2	PC3
Administrative Obstacles	0.5974	-0.4870	0.6372
Labour Difficulties	0.6368	-0.1949	-0.7460
Environmental Restrictions	0.4875	0.8514	0.1937

Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

Table A3: Principal Component Analysis: Eigenvectors – Food SSI, First Building Block (Brazil)

Variables	PC1	PC2	PC3	PC4	PC5	PC6
Education	0.2922	0.7234	0.0998	-0.3212	0.3483	0.3961
Skilled	0.4607	-0.3122	-0.4281	-0.3177	-0.4365	0.4643
Training	0.5035	0.3603	0.2435	0.1706	-0.5696	-0.4516
Quality	0.3829	-0.0553	-0.1308	0.8248	0.2713	0.2817
R&D	0.1608	-0.3826	0.8510	-0.0706	-0.0060	0.3138
New Equip	0.5257	-0.3162	-0.0786	-0.2856	0.5386	-0.4957

Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

Table A4: Principal Component Analysis: Eigenvectors – Food SSI, Third Building Block (Brazil)

Variables	PC1	PC2	PC3
Administrative Obstacles	0.6473	-0.3226	0.6906
Labour Difficulties	0.6651	-0.2037	-0.7185
Environmental Restrictions	0.3724	0.9244	0.0827

Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

Table A5: Principal Component Analysis: Eigenvectors – Food SSI, First Building Block (Chile)

Variables	PC1	PC2	PC3	PC4	PC5	PC6
Education	0.3389	-0.2400	0.6871	0.4971	0.1301	0.3022
Skilled	0.4676	-0.0121	0.3015	-0.7011	0.3817	-0.2304
Training	0.4303	-0.4596	-0.3186	0.3244	-0.0722	-0.6258
Quality	0.4771	-0.2542	-0.4411	-0.1905	-0.1939	0.6628
R&D	0.3934	0.5494	0.1914	0.0046	-0.6964	-0.1476
New Equip	0.3145	0.6038	-0.3231	0.3461	0.5564	0.0525

Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

Table A6: Principal Component Analysis: Eigenvectors – Food SSI, Third Building Block (Chile)

Variables	PC1	PC2	PC3
Administrative Obstacles	0.5835	-0.4554	0.6724
Labour Difficulties	0.5882	-0.3338	-0.7366
Environmental Restrictions	0.5599	0.8253	0.0731

Source: Adapted from World Bank Investment Climate Survey. Argentina and Chile (2006), Brazil (2003).

Notes

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1. "The agri-food complex is crucial in Latin America and the Caribbean, for a number of reasons: it makes a valuable contribution to the food supply and to food safety, generates demand for labour (18% of employment in 2005), occupies national territory (at least 50% of surface area is devoted to crop and livestock farming and the first stages of related industry), creates linkages with other sectors and activities, contributes to exports (16% of the region's total in 2005 and more than 50% in many countries) and, lastly, represents a strategic alternative energy source" (ECLAC, 2008).
2. The Innovation System approach (Lundvall, 1992; Carlsson, 1995; Edquist, 1997) considers innovation as a collective and interactive process among a wide variety of actors. Firms interact with each other, but also with non-firm agents, putting learning as a key determinant of innovation (Edquist, 1997).
3. The earliest versions of this concept were coined by Freeman and Lundvall (Lundvall, 1985; Freeman, 1987). Carlsson and others developed the concept 'technological systems' at the beginning of the 1990s (Carlsson and Stankiewicz, 1991). In the meantime, the literature on 'Regional Systems of Innovation' has grown rapidly since the middle of the 1990s (Cooke, 1996; Maskell and Malmberg, 1999), while according to Chris Freeman, the first person to use the expression 'National Systems of Innovation' was Bengt-Åke Lundvall (Freeman, 1995). The concept of 'Sectoral Systems of Innovation' has been developed by Malerba and others (Breschi and Malerba, 1997; Malerba and Orsenigo, 1997; Malerba, 2002; Malerba, 2006). Some of the crucial ideas inherent in the innovation system concept (on vertical interaction and innovation as an interactive process) appear in Porter's industrial clusters as well as in Etzkowitz and Leydesdorff's Triple Helix concept (Etzkowitz and Leydesdorff, 2000).

4. As an example of the release of regulations in the sector, Bisang and Gutman (2005) report the elimination, in Argentina and other countries, of mechanisms regulating some production activities (in Argentina, the National Grain Board, the National Meat Board, the Dairy Industry Coordination Commission, etc.) and their replacement by the competitive pressure of foreign markets, after the changes in regulatory and institutional context in the 1990s.
5. Everything that can be articulable is codifiable. The dichotomy between codifiable and non codifiable is highly problematic as, on the one hand, any body of knowledge might be codifiable to a certain extent but on the other hand, it may not be completely codifiable, without losing some of its characteristics (Johnson *et al*., 2002)
6. Putnam defines 'social capital' as the "features of social organization, such as networks, norms, and trust that facilitate action and cooperation for mutual benefit" (Putnam, 1993: 1).
7. Asheim and Coenen (2005) consider two different situations within regions. One is about Rogaland cluster, where knowledge flow and cooperation are favoured by proximity. In the other case, within the Scania cluster, firms are involved in collaborative research at all geographical levels.
8. Productive activities have a form of 'collective action' (Callon, 1991; Storper, 1996; Murdoch *et al*., 2000) which relies upon the coordination of various entities within some type of action framework (network, filière, chain). Indeed, at the heart of any collective action there are "practices, routines, agreements, and their associated informal and institutional forms which bind acts together through mutual expectations" (Salais and Storper 1992: 174).
9. G&S consist of standards ("rules of measurement established by regulation or authority") and the grades thereof ("a system of classifications based on quantifiable attributes") (Jones and Hill, 1994; Reardon *et al*., 2001).
10. As for some agro-food products supply elasticities are relatively low, producer surplus is likely to decline with expanded innovation research. Then, in certain situations research is not feasible unless producers are compensated. For a broader analysis see Sunding and Zilberman (2001).
11. The Argentinenan national research institute, Inta, has 3 regionalized divisions with numerous research centres. The Brazilian national research institute, Embrapa, works as a network composed of 41 decentralized centres that are distributed among the Brazilian regions. The Chilean national research, Inia, is divided into 10 regional research centres.
12. For instance regarding the wine sector in Chile, firms' perception is that universities and national research centres do not play a coordinating role, and more local industrial applied research is needed (Moguillansky *et al*., 2006).
13. ECLAC, (1995); PROCISUR/IDB, (2000); ECLAC, (2002) and Giuliani *et al*. (2005).
14. "The average quality of grapes increased, especially for those at the top of the yield distribution" (Cerdán-Infantes *et al*., 2008: 34), which is in line with our proposition about the need for technological capabilities benefiting from contextual conditions.
15. The former element contributes to strengthen the latter through the spiral of technology learning. Cohen and Levinthal (1990: 128) labeled Absorptive

Capacity (AC) "the ability of a firm to recognize the value of new external information, assimilate it, and apply it to commercial ends". Regarding the second element, firms need to continuously undertake processes of local experimentation (Nelson and Winter, 1982) that are translated in *efforts* to assimilate external knowledge. The nature and degree of *efforts* is not uniform among firms and sectors: different activities have different requirements for capabilities acquisition (Lall, 1992).

16. Depending on the degree of complexity, TCs can be separated into basic (experience-based routines), intermediate (adaptative or duplicative), and innovative risky (research based) functions as in Table 1. Among them, there are also processes of sequences and cumulativeness. However in this work we do not explore 'degrees of complexity'. Working only with one year, it may be difficult to judge *a priori* whether a particular function is simple or complex (Teitel, 1984).
17. Quality Certification matters a lot in this sector, as food consumers are concerned about quality and safety. Nowadays, we cannot imagine the Food Sector without considering the interaction and evolutions of these concepts. The market is always asking for more sophistication and quality, safety requirements are always more global, and firms follow norms and standards.
18. Even if linkages are a category of TCs (see Lall's taxonomy in section 4.1), due to their importance we treat them as part of the network's building block.
19. The samples were selected using a stratified random method: all population units are grouped within homogeneous groups and simple random samples are selected within each group. This method allows computing estimates for each of the strata with a specified level of precision while population estimates can also be estimated by properly weighting individual observations. Weights take care of the varying probabilities of selection across different strata.
20. We use the 2003 Brazilian survey because, unfortunately, the 2009 World Bank Investment Climate Survey does not give information about R&D investments, and product and process innovation.
21. ISIC is a standard classification of economic activities, correspondences with Central Product Classification (CPC) and Standard International Trade Classification Revision 3 (SITC). The categories of ISIC, at the most detailed level (classes), are delineated according to what is, in most countries, the customary combination of activities described in statistical units (activity units). The groups and divisions, and the successively broader levels of classification, combine the statistical units according to the character, technology, organization and financing of production.
22. The variable was originally expressed in local currency but was translated into dollars (USD). For Argentina and Chile is the average interbank rate 2005 and for Brazil is the average interbank rate 2003. (http://www.oanda.com/lang/es/currency/historical-rates).
23. Jackson (1991) presents several ways of deciding "When to stop?", from significance tests to graphical procedure.
24. If we examine the sum of squares of the loadings of the first three PC, some variables have a substantial proportion of their variance explained by the largest three PC. This is the case of Education in Argentina and R&D in Brazil, which

have 90% of their variance accounted in the first three PC. In Chile the Education variable has the highest explained variance but with only 64%.

25. Analyzing the two remaining variables, Inputs from Foreign Origin and Foreign Technology, the coefficients for the first are both 0.71 and for second principal components -0.71 and 0.71. With only two variables there are only two PC that completely account for the variation in the two variables. Graphically, the first PC forms a 45 degree angle with the ordinate axes irrespective of the size of the correlation as long as the correlation is not zero (Dunteman, 1989).
26. For an extensive analysis of the impact of technology on sustainable agro-food processing development see Ekboir (2003).
27. For the first building block we stopped in the third PC, but as the data points defining PCs are most unlikely to define a smooth surface, any three dimensional view is unlikely to be much good in any case.
28. With the caveat that for the first building block we are considering only two and not three PC – as in the analytical analysis – for the graphic analysis, this plot remains a good approximation of the original space.
29. Since coefficients are always scaled (so that the residual variance is the same no matter what variables are in the model), the scaling of coefficients will differ across groups if the residual variances are different, making cross-group comparisons of effects invalid. The Heterogeneous Choice Model provides a means for dealing with these problems by simultaneously estimating two equations: one for the determinants of the outcome, or choice, and another for the determinants of the residual variance (Williams, 2010: 4).
30. Based on the Log-likelihoods we compute the pseudo R-squared and obtain low values. Goodness of fit is usually less important than interpreting the effects of the explanatory variables (Wooldridge, 2006), so we then concentrate our analysis on the latter objective.

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