Diffusion of innovations in the sectors based on biological processes. The case of sugarcane in Tucumán, Argentina.

Gutti, Patricia Noemi; Kababe, Yamila; Peirano, Fernando

National University of Quilmes, Argentine Republic

Abstract

The power of innovation diffusion to create productivity improvements and strengthen regional economies has been briefly explored, especially in developing countries. Basing on a systemic model of diffusion of innovations, this work suggests that it is possible to hold broader and diversified productive structures, in terms of the number of producers that make up a value chain in the agricultural sector, even within the framework of significant advances of productivity in the primary sector. Applying the case study methodology, we analyse the process of diffusion of innovations in the sugarcane sector in the province ofTucumán, Argentina. The results show that when the generation and diffusion of innovations is concentrated in public R&D institutions there is a broad producers´ access to the technology. Therefore, producers increase their productive capacities, one of the pillars of productivity improvement is solved and the concentration of production as a way of gaining productivity through economies of scale in the production of raw material is attenuated. In this way, one of the main implications of our work for the theory is that a systemic approach is required for the study of the diffusion of innovations, due to the fact that it is a process and not a unilateral action. The second contribution is that the presence of public R&D institutions is a fundamental basis of the technological dynamics in systems with a wide base of small and medium producers.

1. Introduction

Within the framework of the economics of innovation, the analysis of the process of technological change has been subject to wide debates. As a result of the progress made, it became clear that the diffusion of innovations is as important as the innovation itself because the diffusion is not only a process by which the use of a technology is disseminated, but also a process by which technology is developed (Geroski, 2000). The actions carried out in each of these steps have a direct impact on the other stages of the process. Thus, during the diffusion of a new technology there are several incremental innovations produced simultaneously which come from user experience *(learning by using),* new findings from ongoing research of suppliers *(learning by doing)* (Rosenberg, 1979), interaction with other users and suppliers during the adoption process *(learning by interacting)* and the learning process that takes place along the whole path *(learning to learn)* (Lundvall, 1988; Lundvall & Borras, 1998). Therefore, the public policy measures required to drive these processes are different (Rodríguez & Sánchez, 1992). In this sense, the study of the diffusion of innovations acquires relevance by itself and its results contribute directly to the processes of economic development.

---

*Professor and researcher at National University of Quilmes, Buenos Aires, Argentina.
patricia.gutti@gmail.com;ykababe@gmail.com;fer.peirano@gmail.com

In the last decades, the agricultural sector has been one of the most dynamic sectors in the incorporation of technology to the productive processes, not only for the innovations of product and process that it incorporates but also for being promoter of innovations in other related areas (Alvarez & Labra, 2013; Marin *et al, 2015;* Katz, 2015). Along with this progress, the development of agriculture in developing countries has had to face a series of challenges related to the sustainability of development strategies based on natural resources and the possibility of forming inclusive agricultural systems. In this context, the study of the innovation diffusion process in the sector becomes relevant. It provides evidence on the way in which technology is disseminated among the actors of the system, the mechanisms that validate the technological development and the accumulation of skills so that other innovations arise andmore diversified productive structures can be substained.

The first theoretical framework of analysis of the innovation diffusion process was Everett Rogers' in the year 1962. It collected the empirical experiences that the author carried out and the contributions of Ryan & Gross (1950) on the diffusion of hybrid corn seeds in Iowa, United States. In his proposal, Rogers argues that the diffusion of innovations is a process by which an innovation is communicated to other members of a given system. This approach was criticized for its overemphasis on the role of the demand for innovations and transmission mechanisms (Atewell, 1992; Stephenson, 2003). As a reaction to this proposal, systemic approaches arise. They consider that innovation diffusion takes place in the interaction between the different actors that make up the innovation system emerged *(*Kilelu *et al., 2011;* Abebe *et al.,* 2013).

In this context, and following a systemic approach, this work aims to analyze the path of an innovation from its conception to its adoption by the end user within the framework of specific social system. Diffusion is understood as a fundamental stage of the process of technological change and improvement of productivity in the agricultural sector. Based on a case study, the proposal applies to the analysis of the process of diffusion of high-quality sugar cane seed in the value chain of sugar cane in the province of Tucumán, Argentina. This process was consolidated in Tucumán as one of the most inclusive innovations of the agricultural sector because it allowed the access to the technology to most of the local producers, bringing about generalized increases of productivity.

The paper is organized as follows. In section 2 the conceptual framework of the work is presented, highlighting the main contributions of the theory of the diffusion of innovations and the central characteristics of the systemic approaches. Section 3 briefly describes the case study and the research methods. The results achieved in the fieldwork are summarized in section 4, offering an explanation of the technological development and the innovation diffusion process of high quality sugar cane seed. In section 5, the results are analized and discussed based on the dimensions proposed in the conceptual framework. The work ends with the conclusions in section 6.

2. Conceptual framework

Since the 1950s, there have been numerous academic works on different processes of diffusion of innovations that enabled the accumulation of a large amount of empirical evidence and the emergence of the first explanatory models of this phenomenon. One remarkable work was the one done by Ryan & Gross (1950) on the diffusion of hybrid corn seeds in the State of Iowa, United States. The sum of these contributions allowed to delimit the problem of study and to establish a certain consensus as regards what is understood by diffusion of innovations. Indeed, Everett Rogers, father of the classical approach to diffusion of innovation, defined the diffusion of innovation as the process by which "an innovation is communicated through certain channels over time among members of a social system" (Rogers, 2003, p.5). For this author, there are four central elements present in every diffusion process: innovation, communication channels, time and social system. An innovation is an idea, a practice, an object that is perceived as new by an individual or a company. Communication channels are the means by which information is transmitted from one user to another. Mass media (radio, television, newspapers, specialized magazines, the Internet, among others) is the fastest and most efficient way to inform a potential adopter audience about the existence of innovation. The time dimension refers to the process of deciding whether or not to adopt an innovation, the innovative capacity of an enterprise compared with other members of the system and the rate of adoption of an innovation in the system (the relative speed at which an innovation is adopted by members of a social system). Finally, the social system in which innovation is disseminated is defined as a set of interrelated units that are committed to the goal of achieving a common target. These units can be individuals, informal groups, organizations, companies and even sub-systems, among others.

Rogers' (2003) proposal has been criticized for skewing the diffusion process to the characteristics of the demand, determining the diffusion of innovations to be a function of the number of adopters over time and the communication channels to be the key factor in the process (Attewell, 1992; Stephenson, 2003). In general terms, it is stressed that the most important weakness of the dominant approach is the little attention given to innovation supply, intermediary institutions and market structures through which innovations reach users (Kilelu *et al.,* 2011).

With the aim of improving the dominant approach of innovation diffusion process, this work takes into consideration a series of contributions from literature. These contributions analise relevant elements that are not included in traditional models of technology diffusion. For instance, Atewell (1992) sustain that the lackof*know how* and organizational learning, are often potential barriers to the adoption. Therefore, knowledge and learning institutions can take action to progressively reduce these limitations. In this vein, it is extremely important to consider them as a leading player in the innovation diffusion process. In line with this approach, several authors have also stressed the role of external technology absorption capacities, the links with the environment, the existence of standards and certifications and the participation of innovation brokers (individuals, firms and institutions) as important elements in adoption processes (Cohen and Levinthal, 1989; 1990; Lall, 1992; Geroski, 2000; Giuliani, 2005; Klerkx *et al., 2009;* Tran *et al., 2013).*

Comparatively, Rogers' (2003) approach responds to a linear model where adopters are passive, technology is developed in research centers and adoption decision is autonomous. On the contrary, the broader proposals follow a systemic model where adopters are one of the different actors that make up the process of generation and diffusion of innovations that takes place in the interaction between them and the suppliers, institutions and research centers (Abebe *et al.,* 2013).

In this way, a systemic analysis of the diffusion process of innovations can be organized from a set of general attributes, grouped in four dimensions, which include the different elements that affect innovation diffusion. The first dimension consists of the attributes related to the demand (potential users); the second, the attributes of innovations (intrinsic issues of innovation); the third, contains the attributes associated with the supply (producers and distributors of innovation); and the fourth dimension, includes the attributes of the environment (linked to public policies and institutions).

2.1. Attributes related to the dimension of the demand

These are factors associated with the characteristics of the adopting agents and the interaction between the internal and external knowledge sources in a system, which facilitates the process of incorporating innovations. Regarding the characteristics of the adopters, the capacity of absorbing external technology plays a central role (Cohen &Levinthal, 1989), because it represents the ability to learn and to solve problems (Kim, 1998). These skills can be internally developed, incorporated through new professionals or acquired through a service (Attewell, 1992). In this sense, the adoption of a new technology includes the regular performance of the activities involved in the generation of capacities (Lall, 1992) that implies a significant investment process, particularly in intangible assets and also in capital goods when it comes to the adoption of incorporated technology[1]. The incorporation of intangible assets is one of the most important aspects in the agricultural sector for the accumulation of capabilities (Alvarez & Labra, 2015), since the acquisition of incorporated technology is permanent in the seeds, the varieties, the agrochemicals and biofertilizers regularly used for production.

At the same time, it is emphasized that firms do not act in isolation, but are part of a system in which they interact with other actors on the basis of institutions that determine the rules for the development of these connections (Criscuolo&Narula, 2008). Therefore, the absorptive capacity of firms also depends on the interrelation generated between the internal knowledge system (knowledge spillovers, tacit knowledge and social relations), the knowledge base of the companies that are part of the system (the set of knowledge, skill and information inputs) and the external knowledge system (the availability of knowledge from the connection with multinational companies) (Giuliani, 2005; Giuliani & Bell, 2005).

Therefore, the construction of the absorptive capacity must be understood not only from the skills and training of human resources and the impact on the organizational knowledge of a company, but also from the links with the local and external knowledge system of the unit under analisys, may it be a company, a value chain, a region or a country (Criscuolo & Narula, 2008).

[1]In this case, the sunk cost (the investment made to buy previous technology) may be a barrier for the diffusion process and delay considerably the decision of introducing an innovation. Due to this reason, it is often argued that new companies are more likely to adopt the latest innovations (OECD, 1996; Geroski, 2000).

2.2. Attributes related to the innovation dimension

Innovation, as an object, also influences the process because its design and content are part of the traits that potential adopters evaluate when deciding their incorporation. The innovation attributes that affect the diffusion process are the kind of knowledge involved, the characteristics of the innovation, the systemic character and the consequences of its implementation. The extent to which a new technology meets the specific needs of the business determines the probability of adoption (OECD, 1996). If a new technology allows to directly solving a company problem, the possibilities of immediate incorporation are maximal and this is often considered to happen when it comes to coding technology. These possibilities diminish depending on the type of knowledge involved (more or less tacit content) and effort (modifications, additional requirements, etc.) that the company must perform to identify the usefulness of the new advance.

This means that companies' perception of an innovation influences the adoption process and, in this sense, the characteristics of the innovations help to explain the different adoption rates. In this way, the extent to which an innovation is perceived as: a) better than the idea it replaces (relative advantage); b) consistent with existing values, past experience and the needs of potential adopters (compatibility); c) difficult to understand and use (complexity); d) easy to learn by using it (trialability); and, e) easily observable in relation to its results (observation); will determine if they will be adopted more quickly than others (Rogers, 2003).

At the same time, the systemic characteristics of innovation also affect the diffusion pace (OECD, 1996). They include the extent to which a certain field of knowledge is cumulative, the expectations about the future development of technology and the uncertainty about how the market responds to this new technology. Based on these aspects, the rate of progress is expected to be very slow, in the early stages of the diffusion of a new technology, as companies are reluctant to adopt it because they hope that the following modifications will be better and will allow for greater cost reduction (OECD, 1996). In this line, the contributions of Teece (2003), on the determination of the dominant design and the process innovations that take place later, as well as the risks associated with the use of "move first" positioning strategies in the market explain the attitude of companies towards the systemic aspects of technological development.

2.3. Attributes related to the dimension of the supply

Technology suppliers are also responsible for the diffusion of innovation. The main aspects to be considered about this dimension are the flow of information, the innovation design, the associated service offer, the competition among technologies, the profitability of innovations and the structure of the supply market. The flow of information on innovations is one of the basic elements of the traditional diffusion theory, in this case they are regular channels such as mass media advertising, participation in fairs, demonstration meetings, distribution of leaflets, among others (Rogers, 2003).

However, the diffusion of information on innovation may not be enough for users to adopt the technology. Several studies showed that even though users know the benefits of innovation there are other obstacles that hinder the progress of the process, for example, that the innovation design is rejected by the producers´ customers (Abebe *et al.,* 2013). In this sense, prior knowledge of the target market, this means the knowledge providers have about the needs of potential users, is a key issue for the development of an innovation (Geroski, 2000). To counteract these problems, Ndyabawe and Kisaalita (2014) pointed out the importance of the creation of a technology society with producers and users for the adoption to be successful. An additional difficulty is given by the skills required to use the technology (knowledge barrier), mainly associated with the diffusion of complex technologies. In this case, suppliers can spread the technology as a part of a technological package that includes not only innovation but also specialized services for use and application in the production process (Attewell, 1992).

Supply also has a clear role in the competition between new and old technology. When the supplier controls the two technologies he has a greater influence on the process of diffusion of the new technology because he can promote or limit the process (Geroski, 2000). On the other hand, when technologies belong to different suppliers, diffusion also implies change of supplier, which could slow down the diffusion take off. At the same time, the incorporation of innovations affects the profitability of the producer, due to the direct and indirect costs of the acquisition of the new technology (Geroski, 2000; Stoneman, 1987).

Finally, the role of the supplier market structure on the diffusion of innovations has been widely debated. Evidence indicates that, in general, competition accelerates the diffusion rate because it stimulates the precautionary motive for technology adoption (Arrow, 1962; Allen *et al*., 2008). However, under certain circumstances, monopolistic behavior is the best for securing the rate of innovation and diffusion (Schumpeter, 1942; Stoneman, 1987). Between the two interpretations are the results obtained by Dasgupta and Stiglitz (1980), who demonstrated that the inventive activities are more intense in intermediate structures between the monopoly and the market economies, and that the differences in R&D expenses are explained by the relative size of the markets and the technological opportunities of each sector. Thus, although the results of the research do not allow being conclusive on the relationship between market structure and the process of technological change, it seems feasible to think that a certain degree of concentration is positive to encourage inventive activities although this depends on several convergent elements. In short, there is no single structure to stimulate the diffusion process; the best structure will depend on various factors that interact in each case.

2.4. Attributes related to the environment dimension

External conditions of a company can also facilitate or hinder the diffusion process of a new technology. In this case, public policy, regulations and structure of the social system are included. In general, public policy instruments have a direct effect on potential adopters because they improve the conditions for adopting innovations (OECD, 1996). Likewise, for some innovations, regulations[2]have a direct impact on the diffusion pace of a new technology because they not only affect the adoption decision but also the production of new technologies (Geroski, 2000), since they reduce the uncertainty about the possibility of achieving widespread use of this alternative (Temple *et al.,* 2005).

In turn, the structure of the social system in which the diffusion process takes place determines a system to be more prone to change or to maintain the *status quo* (Rogers, 2003). In recent years, there has been progress in the characterization of driving agents of these structures. Among the most outstanding contributions are those related to innovation brokers or intermediaries and the role of opinion leaders.

Intermediaries are organizations that are aimed at creating links, coordinating and facilitating interaction among the multiple parties interested in the innovation process, providing a variety of services related to different aspects of the process (Kilelu *et al.,* 2011). This actor has been extensively studied in the industrial sector (Klerkx *et al.,* 2009; Shapira *et al*., 2015); however, in the agricultural sector, it just started to be discussed because it is difficult to identify them due to the ambiguity of functions between intermediaries and research centers. In this sense, "pure" intermediaries should be considered as facilitators of innovation and traditional institutions of R&D and knowledge intensive services should be considered as sources or carriers of innovation (Klerkx&Leeuwis, 2008).

Opinion leaders are leading players because they are often the innovators and have quick access to the information about new products. Therefore, they become influencers for potential adopters that, given the uncertainty and risk of adopting an innovation, turn to these actors to clear doubts and to make decisions (Geroski, 2000; van Eck *et al*., 2011). In general, influencers increase the adoption pace, although there are two situations where the opposite might happen. One is when the leader is too avant-garde. In this case, probably the other members of the system see him as too risky, and therefore disregar imitation. The other option is when the leader is risk adverse and an active opponent to change. In this case imitation will lead to a significant delay in the adoption of innovations. The outcome of these behaviors may lead to the well-known herd effect or network effect (Rogers, 2003).

3. Research methods and case study description

The research was developed following a methodology of case study (Yin, 2014). In line with other studies on innovation in the agricultural sector (Kilelu *et al.,* 2011; Mmari, 2015), the purpose of the study was to find regularities in the behavior of the actors that make up the value chain of sugar cane in order to draw conclusions about how the diffusion of innovations in this specific social system takes place. To guarantee the reliability and validity of the study, the usual tests for this type of research were used, such as the validity of the evidence construction, internal validity, external validity and reliability, as well as the information triangulation method to achieve consistent interpretations (Eisenhardt, 1989).

[2] It refers to the establishment of formal (mandated by law) and informal (non - compulsive and adopted voluntarily) standards.

The methods for collecting the information were the semi-structured interview and the survey. The collection of information was carried out between March and August of 2015. In total, 41 interviews and 95 surveys were conducted. Actors involved in the study include sugar cane producers, directors of producers' associations and cooperatives, managers of sugar mills, researchers and directors of technological R&D institutions, public officials and sector experts.

The case study is presented following the value chain framework. The sugar cane value chain in Tucumán was chosen because it combines a series of interesting characteristics to analyze the innovation diffusion process. At the macroeconomic level, it is a value chain of an industrial crop anchored mainly in the local market in a relatively less developed region of Argentina. In the period 1993-2012[3], the GDP of the province of Tucumán accounted for 2.2% of Argentina's GDP and the GDP per capita of Tucumán was near the 50% of the national one, showing the wide difference of the region compared to the general level of the country. At the same time, Tucumán is the main sugar producer at national level, accounting for 65% of the total sugar produced in the country, and also concentrates the largest amount of sugar cane producers and sugar mills. At the hinterland of the province, the value chain of sugar cane accounts for 25% of the province GDP (Lódola *et al.,* 2010) distributed among the primary, industrial and services related activities.

The structure of the chain characterises for being heterogeneous, with a relatively closed operating system, many years of tradition and, at the same time, a high degree of atomization of producers. In this context, the diffusion of innovations is relatively transparent because one of the central players of the system is a centennial public institution, the Obispo Colombres Agroindustrial Experiment Station (EEAOC for its acronym in Spanish, *Estación Experimental Agroindustrial Obispo Colombres*), which is in charge of the generation and production of technology of all the agricultural sectors in Tucumán. The other relevant actors in the chain are the mills involved in the industrialization of raw materials, whose function is concentrated in 15 companies belonging to 9 national economic groups except for one belonging to a US group, and a high number of raw material producers amounting to 5,364 (INDEC, 2003; PROICSA, 2014; CAA, 2015). Of the total operations, 91% correspond to small sugar cane producers who account for only 28% of the total area planted with the crop in the province; 8% belong to medium-sized farms with 36% of the total area; and the remaining 1% belongs to large producers representing the other 36% of the cultivated area.

National and multinational mill enterprises are in charge of production process. Sugar cane producers sell the raw material to sugar mills as commodity, at the market price (without prima to quality). Public institutions such as the EEAOC carry out the process of generation of technology. In this context, enterprises and producers adopt technology from public institutions as club goods. Due to this, in this case and in contrast with what happens in other natural resources value chains (such as soya, wheat, maize, among others), multinational mill enterprises don´t directly participate in the technology generation process. Therefore, the role of the multinational group in the case under study is the same as national companies.

[3] Last data available.

Regarding production technology, sugar cane is one of the Argentine industrial crops with a high incorporation of innovations because it is not a native crop and requires genetic modifications for its adjustment to the environment. This has made the use of technology in this chain a regularity rather than an exception. Therefore, technological change is very important in the operation of the productive circuit, especially during the last decades, being responsible for major increases in crop yields. The most outstanding technologies are associated with the implementation of genetic improvement programs that resulted in new varieties of seeds introduced to the sector by local R&D institutions and the achievement of high quality seeds. High-quality sugar cane seed is a pathogen-free and disease-free seed that substantially increases the yield of sugar cane plantations and therefore productivity[4], bringing about a real revolution in the value chain of Tucumán sugar cane.

In addition, the unique feature of this situation is that innovations take place in the public sector and are disseminated to the Tucumán private sector through extension programs, allowing the generated knowledge to be available for application in other researches and to other crops, unlike what happens when the technological developments are carried out by private companies.

4. Findings

This section presents the results achived in the fieldwork. Taking into account the systemic approach, we describe the diffusion process of high-quality sugar cane seed under the framework of the value chain in Tucumán. For doing so, we explain the main characteristics of the technological package, which include the high-quality sugar cane seed, the key actors´ capabilities for developing the technology, and the main organizational process (like the seedbed systems).

Sugar cane production in Tucumán is associated with the implementation of a technological package, which consists of a high-quality sugar cane seed, its varieties, an appropriate agricultural and phytosanitary use of crops and a semi-mechanized or whole crop harvesting[5]. Large and medium producers use this technological package, directly or through contractors. Small producers do not usually have access to the complete package either due to lack of resources, to continuing with family tradition of crop management or because they are smallholders who practice subsistence agriculture. These circumstances establish high productive gaps among sugar cane producers. In some cases, effectively diffusing and transferring the available technologies may reduce this gap, but in others a higher assistance is needed, which implies organizing small producers and adapting technology so that it can be used at smaller production scales.

---

[4] Between 2005 and 2012 the average sugar cane yield per hectare increased 18,3%. In 2012 the average sugar cane yield per hectare was 61,5 tons, compared with 52 tons/ha in 2005. This result also drove an increase of 28% in the area implanted with sugar cane in Tucumán (EEAOC, 2012).

[5] An appropriate agricultural and phytosanitary management implies carrying out several tasks to improve sugar cane plantations and increase crop sustainability. These tasks include: plantation planning and design, crop rotation, weed control (herbicides), fertilization and application of ripening products.

A highlight feature of this technological package is the innovative high-quality sugar cane seed. This seed is essential to obtain a higher crop yield, which is improved by an appropriate agricultural management of each plot, even in the case of precision farming practised by large producers[6], and with green cane harvesting[7]. Historically, sugar cane producers never considered the quality of the seeds used in commercial plantations. They normally used as seeds the same sugar canes they would later send to the industry without any plant health controls. This practice contributed to the proliferation of systemic diseases, which translated into a significant loss of productivity of sugar cane plantations (Digonzelli & Giardina, 2014). This situation combined with the economic openness of the sugar industry in the nineties led to a very important crisis in the production of agricultural and industrial sugar cane, which was overcome since the early 2000s, with the incorporation of technology to obtain high-quality cane seeds and new varieties (Scandaliaris, 2010).

These technologies are part of the innovations in the crop's genetic base and represent the most equitable set of technologies applied to sugar cane harvest currently available in Tucumán, since they can be used independently of the plantation size because no minimal production scale is needed to make them profitable. The main reason for this is that exclusively public institutions develop agricultural technology in the province of Tucumán, which subsidise and distribute it among the producers at production cost. In the province, the most prominent development related to genetic base innovations take place at EEOAC, and at a national level at the National Institute of Agricultural Technology (INTA for its acronym in Spanish, *Instituto Nacional de TecnologíaAgropecuaria*).

Sugar cane seeds can be obtained applying two technologies: a) the growing of meristems and micropropagation[8], based on biotechnology; and, b) hydroheat therapy, employing water as a therapeutic agent for treating sugar cane stems[9]. In both cases, the genetic improvement programs run by research institutions provide the sugar cane seeds used for reproduction. These seeds are conventionally modified by cross-breeding. The complete process to obtain a new variety takes at least 10 years and the outcome is highly uncertain. Both technologies are employed in Tucumán to produce healthy seeds. Nevertheless, this work focuses on the diffusion of the innovation of high-quality sugar cane seeds obtained from the growing of meristems and micropropagation, due to the technological challenge it implies. This technology is produced by EEAOC.

In this regard, it has been verified that the EEAOC went through an intense development process of its technological and scientific abilities to obtain high-quality sugar cane seeds from

---

[6] In the case of sugar cane in Tucumán, there are not many agricultural precision tools being used and very few producers resort to them, mainly due to the relatively low cost of fertilisation (Bongiovani, 2008).

[7] Sugar cane harvest can be manual, semi-mechanical or mechanical. While manual harvest implies the burning of sugar cane plantations, which is currently forbidden, the other two methods do not, and that is why they are referred to as "green cane harvesting".

[8] The growing of meristems and micropropagation is technologically complex because seedlings must be created *in vitro*, which requires organ, tissue, and cell culture of the plant in an artificial nutritive environment (Noguera *et al.*, 2010).

[9] Hydroheat therapy technology consists of the immersion of sugar cane seeds, in pieces and in baskets, in hot water for a period at a temperature between 50 °C and 52 °C, depending on the type of pathogen to be eliminated (Ulivarri & Vallejo, 2014; Romero *et al.*, 2009).

the growing of meristems and micropropagation. This challenge involved a learning process of several years, during which a series of learning acquisition strategies were combined, such as building links with local and foreign research institutions, attending conferences, publishing in scientific journals, repatriating researchers, and specializing human resources.

The abilities developed by the institution were reflected on the project success. A few years after its inception in 2003, a significant amount of high-quality sugar cane seeds was distributed among producers in Tucumán through the complementary innovation of the seedbed system. In order to illustrate, in 2007/2008 campaign 48% of the production area of sugar cane in Tucumán was implanted with seeds from this project. In addition, as a result of these achievements, the biotechnology section was created in the EEAOC to internalise scientific knowledge to develop and adapt technologies designed to increase the productivity and sustainability of agricultural industries in the province (Castagnaro *et al.*, 2011).

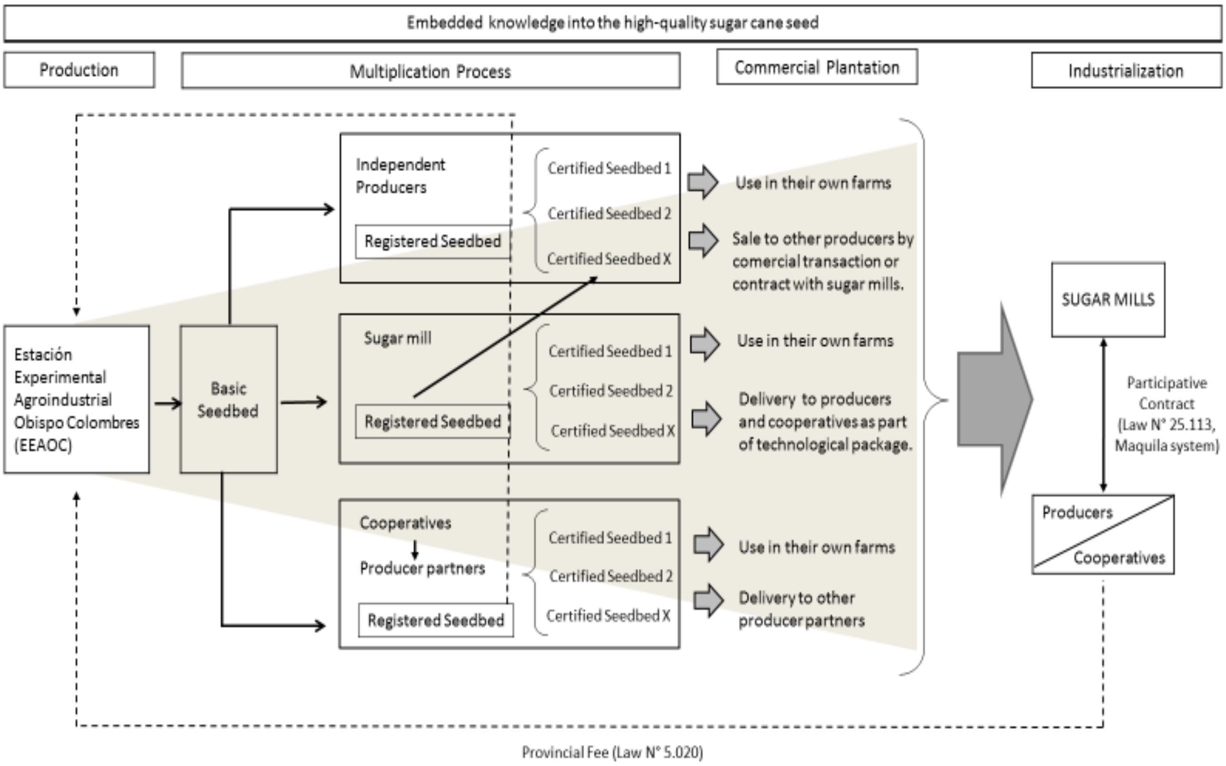
4.1. The diffusion process of high-quality sugar cane seeds.

The value chain of sugar cane in Tucumán forms a complex net of relations, dominated by cross-claims between producers and industry groups about the redistribution of the output derived from raw materials[10]. Despite this constant tension, the diffusion of innovations in sugar cane production has been very good because producers from Tucumán are generally very receptive to technological changes. In this regard, it was noticed that most producers use high-quality sugar cane seed and usually incorporate the innovations suggested by public R&D institutions and sugar mills, after a first observation period.

The Figure 1 shows a simplified diagram of the diffusion of high-quality sugar cane seeds produced by the EEAOC and distributed through the seedbed system, with the involvement of sugar mills as the main players.

[10] Redistributive conflicts in the sugar industry, both in Tucumán and in the rest of the country, are enormous and have a long history. One of the reasons of this problem is the inadequacy of the regulations of output ownership, partly due to the influence of the powerful sugar mill lobby.

Figure 1. The diffusion of high-quality sugar cane seeds



Source: own elaboration

The seedbed system represents an important innovation to the sugar cane value chain of Tucumán and is a key factor in the diffusion process, since it enables technology to reach the producers. The seedbed is a system of sugar cane seed multiplication from the laboratory to its commercial stage, and therefore, a diffusion system of new varieties, controlled and assisted by professional technicians who make sure that sugar cane seeds maintain their phytosanitary quality until they are delivered to the commercial plants. The entire production process, from the lab to the producer's field, takes approximately four years. It is a slow process at the beginning, but once it is set in motion, if producer planned it correctly with the EEAOC assistance or by the mill, the number of seeds required annually to renew the sugar cane plantations is obtained. The employment of the seedbed system to distribute sugar cane seeds has many advantages: it guarantees the health of the material being multiplied and the genetic identity of the plants, which ensures a high physiological vigour and favours the incorporation of new varieties.

The circuit begins at the EEAOC with the breeding program and the Vitroplantas project. The EEAOC produces micropropagated seedlings at the lab and puts them through a rustication process in different stages until the basic seedbed is reached and the first stage of multiplication takes place in the field. The material from the basic seedbed is delivered to the registered seedbeds to continue the multiplication process of the pathogen-free (or with low incidence) sugar cane seeds, always under the supervision of the Station technicians, in the second stage of the multiplication in the field.

Registered seedbeds are installed in the farms of the independent producers (large producers), sugar mills and some cooperatives. To install a registered seedbed it is necessary to sign an agreement between the EEAOC and the producer establishing the rights and responsibilities of each part, including the price producers shall pay for the seeds. Once the registered seedbed is in operation, the producers may install the number of certified seedbeds required to meet their annual seed requirements or to sell them to other producers, which would be the last stage of the seed multiplication.

The use that producers give to high-quality sugar cane seeds obtained from their seedbeds is not regulated. Independent producers usually use it in their own farms and occasionally sell the remaining seeds to other producers. They also tend to sign agreements with sugar mills, mainly with those who do not have lands, to distribute high-quality sugar cane seeds to the producers who sign contracts to deliver raw materials to them.

Sugar mills use high-quality sugar cane production for their own farms and to give to the producers as part of the technological package transferred by the sugar mill. In this case, high-quality sugar cane seeds are also used by the sugar mill as an attraction element to negotiate long and medium-term production agreements with the producers. The relation among the parts is controlled by a commercial transaction, which set the service prices and payment conditions.

In the case of cooperatives, most organisations do not have communal farms. Therefore, the registered seedbed is installed in a farm belonging to one of the producer partners. The seeds produced are used to install as many certified seedbeds as partners can use part of their plots to produce seeds. Produced seeds are used in their own farm and to be delivered to other producer partners according to the rules established by the organisation. In this case, there are no market transactions because high-quality sugar cane seeds are not sold among partners, who reach distribution and compensation agreements on the use of the plot and adopt a bartering system to install the seedbed. It is important to stress the fact that there are not many cooperatives in the system.

Through this circuit, the technology developed by the EEAOC is diffused across the production system. From the laboratory to the rustication, which is the most complex stage, not only in technological terms but also because of the risk of losing the seedling production due to poor agronomic care, the technology stays in the R&D public institution. Since the distribution of the first sugar cane seeds to install the seedbeds in private fields, the diffusion rate increases outstandingly because the seed production is multiplied in each stage of the seedbeds, enabling technology to be widely distributed.

The industrialisation segment is homogeneous for all the producers because sugar cane can only be processed in the sugar mills. As it has already been mentioned, sugar mills are regarded as the main players boosting the economic circuit of the sugar cane industry by most producers, except for a few cooperatives and some medium and large producers, who own agricultural machinery and the equipment required for a comprehensive cultivation practice.

As a general counterpart of the technology diffusion system, both the producers and the industrialists must pay a provincial fee that provides the funds for the EEAOC, as established by the provincial law 5.020. This fee is applied to ground sugar cane and the payment is equally distributed among sugar mills and sugar cane producers. Sugar mills are withholding agents and every month present an affidavit at the EEAOC declaring the amount of ground sugar cane and the payments made.

Regarding public investments on sugar cane research, they are carried out at the Provincial level by EEAOC. EEAOC is a public institution[11], with private management, and responsable to research and develop technology on sugar cane. The origin of its funding resources is public and private. Related to private financing, resources came from the provincial fee (mentioned previously). In regard to public financing, resources are mainly obtained from two sources. On one side, research institutions apply to competitive financing instruments avaible in the National Ministry of Science, Techonology and Productive Innovation. On the oher side, the National Council on Scientific and Technological Research (CONICET for its acronym in Spanish -Consejo Nacional de InvestigacionesCientíficas y Técnicas-) provide funding by the payment of monthly salaries to most of researchers in the sugar cane sector.

Lastly, it is stand out that there is not an explicit innovation policy in the sector. Most important innovations arise from agronomic improvements produced by EEAOC which are diffuse to producers. At the same time, as sugar cane is a commodity commercialized in national market, without quality and environment requeriments, there are low innovation incentives in the industrial sector.

5. Analysis and Discussion

Unlike other agricultural products with a prevalent traditional diffusion model, where diffusion spreads from the centre to the outside and the users (Dearing, 2008; Nordin*et al.*, 2014)[12], the diffusion system organised by the EEAOC in Tucumán follows a systemic model. Under the system studied, research institutions play a major role and are constantly interacting with the other agents, thus creating a participative model that promotes the adoption of the innovations. Consequently, through the analysis of innovation diffusion from a systemic perspective and since the incorporation of the different dimensions affecting technology diffusion, it is possible to understand the process and the interactions between the different players. The analysis and discussion of the empirical findings is presented according to the dimensions of the demand, innovation, supply, and environment established in the conceptual framework.

The **demand** dimension sums up the behaviour of the subordinate agents of the chain in relation to the absorption capacity of external technology. In this sense, it was observed that sugar cane producers were informed and receptive to new technologies, although they required external technological and financial assistance to incorporate them. These findings

[11]EEAOC was founded last century, in the year 1909.

[12]For example, Abebe *et al* (2013) point out the producers´ difficulties to adopt improved potato varieties in Ethiopia under a lineal model framework. Therefore, authors hightlight the importance to use systemic approaches to develop and diffuse technologies.

coincide with the works of Giuliani & Bell (2005) and Criscuolo & Narula (2008), who emphasise the importance of the interaction of internal and external sources of knowledge to increase the absorption capacity of the producers, as well as the contributions from Navas-Aleman *et al.* (2012) y Tran *et al.*, (2013), who noticed the financial dependence of the producers on the leading company to adopt technology. In some cases, sugar cane producers delegate primary production to sugar mills; in others, they stay in their farms, but technical assistance to implement technological changes is provided, mainly, by sugar mills and, to a lesser extent, by public R&D institutions. In the first case, there is an increase in productivity but producers do not develop the capabilities accumulation and learning process. In the second case, technology adoption is complemented with a learning and knowledge acquisition process, which increases the absorption capacity of external technology, as suggested by Alvarez & Labra (2015).

Even though producers go through a knowledge accumulation process, they maintain their technological dependence on sugar mills because, as producers do, products also learn, and thus it is a learning process on a “moving target” (Anlló et al., 2015). Therefore, successive advances in cultural practices, agrochemicals, and varieties leave producers, especially small and medium ones, at a permanent disadvantage compared with sugar mills and large producers. In this way, producer’s chances to improve depend on the form of government of the value chain and the diffusion of knowledge (Pietrobelli&Rabellotti, 2011).

This situation highlights the importance of the producer´s size (large-medium-small) in the process of innovation diffusion. In the case of sugar cane in Tucumán, it was noticed that, as it was expected, the size of producer is relevant when considering the suitable moment of adopting the innovations. However, it does not affect the possibility of adopting them. The reason for this is that innovations are a public good and producers do not have to pay any extra fees to access the technology, thus it is verified that, in accordance with the works of Aoudji *et al.*, (2012), Mancini (2013), and Silvestre & Silva Neto (2014), the adoption of new innovations depends on other features that affect mainly small producers, such as financing, cultural issues, and the distribution system organisation.

With regard to the **innovation** dimension, the introduction of the high-quality sugar cane seed technology was particularly analysed. This technology showed a clear relative advantage to sugar cane producers, whom got a better output than the one obtained with seeds provided by uncontrolled sources. This innovation does not create controversy about the origin because it is produced by the traditional cross system with no genetic transformation from the lab; thus, there is no questioning on the value system of the producers, who keep receiving the exact same seed as before, but with a greater quality. Sugar cane production has an additional advantage associated with the possibility to experiment in small plots with new seeds and varieties and to observe directly the innovation results before deciding on the adoption. In this case, the observations made by Ryan & Gross (1950) on the importance of a gradual adoption of innovation in the agricultural sectorfor a successful diffusion are once again verified. This enabled the introduction of high-quality sugar cane seeds in sugar cane plantations of Tucumán to be relatively fast and simple. That is why the use of healthy sugar cane seeds is compatible with the production system employed by the producers and its implementation is not of great complexity.

In accordance with these characteristics, it is worth mentioning that the improvement of features related to the production (output, resistance, costs) of sugar cane in Tucumán is decisive to the producers who decide to adopt innovative technologies, as opposed to othertypes of production where the quality related to the demand requirements of the finished products is the key factor (Abebe *et al.*, 2013).

The purchase cost of technology does not restrict the adoption. As it is the case with other agricultural systems, the cost of new technology is shared by the research institutions and the producers, who pay a service fee (Klerkx & Leeuwis, 2009; Lamprinopoulou *et al.*, 2014) to finance the EEAOC and contribute to the production with land, workforce, and supplies, while the EEAOC covers the technological development costs and transfers the main innovations without substatially increasing the production costs. When it comes to the development and diffusion of innovations, the close relation between producers and public R&D institutions minimises the characteristic uncertainty present in every technological change process. Producers trust the capabilities of R&D institutions, and thus delegate to the latter the decisions on the technological direction of sugar cane production.

In the **supply** dimension, it was noticed that the EEAOC and the sugar mills play a pivotal role in the process of technological change. The EEAOC is responsible for developing innovations, while sugar mills are the major players in the diffusion process, since they spread the technology across the largest part of the production system. The activities conducted by the EEAOC place it on a different level of that of R&D institutions. Considering the contributions made by Kilelu *et al*. (2011), the research findings make it possible to argue that the EEAOC is closely bound to the innovation broker, because not only does it develops and diffuses technology, but it also promotes the interaction between the different actors of the chain. At the same time, the type of knowledge produced by EEAOC facilitates diffusion process. The relevance of the EEAOC is sustained because the knowledge base to improve the output of sugar cane production is clearly analytical, with strong participation of scientific knowledge, and thus it is encoded (Asheim*et al.*, 2011; Martin &Moodysson, 2013).

Although one of the most important stages in the high-quality sugar cane seed diffusion process is the local innovation of the seedbed[13], the innovation gets to the producers through the sugar mills. Sugar mills offer a complete technological package to the producers in exchange for sugar cane produced to be milled. This technological package includes technology, services, technical support, and financing. In this case, as pointed by Atewell (1992), the innovation diffusion along with the provision of the additional services enables to deal with the producer’s lack of capabilities and to increase technology diffusion.

The preferential access that sugar mills have to technology is related to their centrality in the production process of sugar and the products derived from it. It is mandatory that all the producers get connected to one sugar mill to process the sugar cane. Therefore, the EEAOC considered that the best way to reach the largest number of producers was to have the seedbeds installed in the farms of the sugar mills, some large producers (opinion leaders), and a few cooperatives. This way, the EEAOC gave sugar mills a key technological asset. At the

[13] The seedbed system is used in most countries where sugar cane is produced (Castillo *et al.*, 2003; CanaVialis, 2008).

same time, this enables sugar mills to keep their control over the supervision and planning activities, in addition to the manufacturing activities, to protect their intangible assets (Morris *et al.*, 2012; Contractor *et al.*, 2010; Buciuni*et al.*, 2014), and to block the entrance to the sugar cane industry. This constitutes a clear strategic asset, which according to Kaplinsky *et al.* (2011) and Mahutga (2012), is of crucial importance for sugar mills to preserve their prevailing position in the value chain.

For these reasons, although sugar mills are not innovation developers, they are regarded by many producers as the main technological reference, hence sugar cane producers resort to them, as well as to neighbouring producers, and occasionally to the EEAOC, to obtain innovations, highlighting the role of the players who possess the knowledge (Cho *et al.*, 2012; Abdulai& Huffman, 2005).

In connection with the mechanisms used to diffuse the innovations, it was noticed a combination of traditional instruments (the diffusion of information on a novelty), the identification of opinion leaders, and the creation of contact networks between producers, typical of a system where both the diversity of players and the strategic interaction are recognised at the moment of deciding on the adoption of new technology (Stoneman, 1987; Geroski, 2000). Since there is only one supplier, highly specialized and with a deep knowledge of the destination market in innovation, no problems related to technology competence or innovation design were found. Nevertheless, it should be noted that the innovation design, as stated by Ryan & Gross (1950) several decades ago, is very important in terms of diffusion, since producers identify in the phenotype features of a variety the qualities needed and it is difficult for them to accept other varieties with different qualities, even if the information provided explains that the production output is superior.

Finally, in connection to the **environment** dimension, it was proved that sugar cane production is not subjected to specific regulations, just as there are no sectoral policies to promote industrial or primary production. Furthermore, international certifications are not very used in Tucumán because the largest part of the production is intended for the domestic market, where no quality or traceability requirements are needed, in contrast to other food and agriculture chains (Tran *et al.*, 2013; Jespersen *et al.*, 2014). In this regard, the low complexity of the market demand (sugar or biofuel buyers) was verified. Although, producers adopted enhanced varieties, productive improvements were limited both in the industrial and primary sectors, as proved by Kaplinsky *et al.* (2011) and Ponte *et al.* (2014), who emphasise the role of the target market to stimulate the local production.

The positive aspects of the player's environment are limited to an advanced development of public R&D institutions and to the availability of human resources for production and innovation, as it occurs in other sectors based on natural resources (Giuliani *et al.*, 2005). In this case, as it was mentioned in the supply dimension, the place occupied by public institutions, especially the EEAOC, is that of a proactive agent of the system, whether it is as an intermediary or as an innovation broker.

6. Conclusion

This work proves that the diffusion of innovations enables to sustain a large and diversified productive structure in the agricultural sector in terms of the number of producers that remain active. The significant factors that explain this situation are the degree of specialization achieved by R&D institutions to generate knowledge applied to the agricultural production and the distribution of technology as a public good. This reduces the struggles between the private players over the appropriation of the benefits derived from innovation, since no one controls the central technological assets, such as the genetic base innovations. In turn, a fast and wide diffusion of new technologies within the productive system is promoted.

One of the main implications of this paper for the theory is that the study of innovation diffusion requires a systemic approach, because it entails a process, not a unilateral action, as it appears to be established in the traditional diffusion theory. During this process, there is an interaction between the different actors involved in the development, diffusion, and adoption of the innovations. Likewise, the inherent features of the innovation involved and the system where this process takes place become relevant. A possible introduction to a systemic approach to the diffusion of innovations consists in analysing the diffusion process from four basic dimensions: the demand, the innovation, the supply, and the environment, as it is proposed in this work.

The second lesson learned from this paper is that the presence of public R&D institutions is the essential foundation for the technological dynamic of the local sugar cane system and that innovation diffusion explains the interaction between the agents who are part of the value chain. In this sense, this study contributes to add evidence to the line of works that previously proved that a strong public presence (domestic regulations and public support) is of central importance to the segment of small producers (Madlener, 2007; Wei *et al*., 2010; Aoudji*et al.*, 2012; Mancini, 2013).

A question that rises from this research is why public R&D institutions are so relevant to this sector. A possible answer is that the knowledge base of innovations in sectors based on biological processes is analytic, following the classification suggested by Martin &Moodysson (2013). This means that scientific knowledge is important, basic and applied research is relevant, new products and processes are systematically developed, and links and networks between the industry and public research institutions are more frequent than in other sectors. In the local case, it was observed that both producers and sugar mills (another key player in the chain) have no own R&D structures and do not directly invest in the development of new varieties. Consequently, knowledge gets to the local chain through R&D institutions. R&D institutions feed on the advances achieved in other countries (where sugar cane is produced) and make the adaptation to the local environment due to the importance of the agro-ecological areas in the production of biological origin (Lybbert& Summer, 2012), thus generating their own innovations.

This work also highlights at least two future research lines of agricultural sector in developing countries, and especially on regional economies. On the one hand, a research line linked to a deeper analysis of research public institutions as intermediaries of the innovation (Klerkx & Leeuwis, 2008) playing a role not necessarily formalised, as a result of highly informal interactions with internal and external chain players (Giuliani & Bell, 2005). On the other hand, the other research line focuses on the study of innovation platforms (Kilelu*et al.*, 2013), which differs from the first research line in that they are formal spaces that make visible the technology transference function through the codification of knowledge.

References

Abdulai, A., & Huffman, W. E. (2005). The Diffusion of New Agricultural Technologies: The Case of Crossbred-Cow Technology in Tanzania. *American Journal of Agricultural Economics, 87(3)*, pp. 645-659.

Abebe, G. K., Bijman, J., Pascucci, S., &Omta, O. (2013). Adoption of improved potato varieties in Ethiopia: The role of agricultural knowledge and innovation system and smallholder farmers' quality assessment. *Agricultural Systems, 122,* pp. 22-32.

Allen, J., Clark, R., &Houde, J.-F. (2008). Market Structure and the Diffusion of E-Commerce: Evidence from the Retail Banking Industry. *Bank of Canada*. WP N° 32.

Alvarez, I., & Labra, R. (2013). Identifying the role of natural resources in knowledge based strategies of development. *ICEI*. *Universidad Complutense de Madrid.* WP 05.

Anlló, G., Bisang, R., & Katz, R. (2015). Aprendiendo con el Agro Argentino. De la ventaja comparativa a la ventaja competitiva. *Banco Interamericano de Desarrollo*, IDB-DP-379.

Aoudji, A., Adégbidi, A., Agbo, V., Atindogbé, G., Toyi, M., Yêvidé, A., Lebailly, P. (2012). Functioning of farm-grown timber value chains: Lessons from the smallholder-produced teak (TectonagrandisL.f.) poles value chain in Southern Benin. *Forest Policy and Economics, 15*, pp. 98-107.

Arrow, K. (1962). Economic Welfare and the Allocation of Resources for Invention. En K. Arrow (Ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors* (pp. 609-626). New Jersey: Princeton University Press.

Asheim, B., Boschma, R., & Cooke, P. (2011). Constructing regional advantage. Platform policies based on related variety and differentiated knowledge bases. *Regional Studies, 45(7)*, pp. 893-904.

Attewell, P. (1992). Technology diffusion and organizational learning: the case of business computing. *OrganizationSciences, 3(1)*, pp. 1-19.

Bongiovanni, R., & Vicini, L. (2008). Agricultura de Precisión en Caña de Azúcar. *IDIA XXI. Cultivos Industriales*, INTA. Año VIII (10), 83 - 88.

Buciuni, G., Coro, G., &Micelli, S. (2014). Rethinking the role of manufacturing in global value chains: an international comparative study in the furniture industry. *Industrial and Corporate Change, 23(4)*, pp. 967-996.

CAA (2015). *Centro Azucarero Argentino. Datos estadísticos.*Retrievedfrom:http://www.centroazucarero.com.ar/zafras/zafra2014.html.

CanaVialis (2008). *ProgramaMaisCanaVialis*. Retrieved from: http://www.canavialis.com.br/o-quefazemos/index.aspx?aba=multiplicacao.

Castagnaro, A. P., Filippone, M. P., Noguera, A. S., & otros (2011). Biotecnología para el desarrollo y sostenibilidad agroindustrial del Noroeste Argentino. *Journal of Basic & Applied Genetics, 22(1)*, pp. 1-5.

Castillo, R., Gómez, A., &Garcés, F. (2003). Multiplicación masiva de semilla sana de variedades de caña de azúcar mediante cultivo de tenidos vegetales.*Centro de investigación de la Caña de Azúcar del Ecuadro (CINCAE)*, Publicación técnica N° 1. Retrieved from: http://cincae.org/wp-content/uploads/2013/05/MULT-MASIVACA%C3%91A-DE-AZ%C3%9ACAr.pdf

Cho, Y., Hwang, J., & Lee, D. (2012). Identification of effective opinion leaders in the diffusion of technological innovation: A social network approach. *Technological Forecasting & Social Change, 79*, pp. 97-106.

Cohen, W., &Levinthal, D. (1989). Innovation and Learning: the two faces of R&D. *The Economic Journal, 99(397)*, p. 569-596.

Cohen, W., &Levinthal, D. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. Administrative Science Quarterly. Special Issue: *Technology, Organizations, and Innovation, 35(1)*, p. 128-152.

Contractor, F. J., Kumar, V., Kundu, S. K., & Pedersen, T. (2010). Reconceptualizing the Firm in a World of Offshoring and Outsourcing: The Organizational and Geographical Relocation of High-Value Company Functions, *Journal of Management Studies, 48(8)*, pp. 1417-1433.

Criscuolo, P., &Narula, R. (2008). A novel approach to national technological accumulation and absorptive capacity: aggregating Cohen and Levinthal. *The European Journal of Development Research, 20(1)*, pp. 56-73.

Dasgupta, P., & Stiglitz, J. (1980). Industrial Structure and the Nature of Innovative Activity. *The Economic Journal, 90(358)*, pp. 266-293.

Dearing, J. W. (2008). Evolution of Diffusion and Dissemination Theory. *Journal of Public Health Management Practice, 14 (2)*, pp. 99-108.

Digonzelli, P., &Giardina, J. (2014). Proyecto Vitroplantas: un análisis de 10 años de producción de caña semilla de alta calidad. *AvanceAgroindustrial. DOSSIER, 35(2)*, pp. 1-12.

EEAOC (2012), Estadísticas de cultivos tucumanos. *Estación Experimental Agroindustrial Obispo Colombres*. Retrieved from: www.eeaoc.org.ar.

Eisenhardt, K. M. (1989). Building Theories from Case Study Research. *The Academy of Management Review, 14(4)*, pp. 532-550.

Geroski, P. A. (2000). Models of technology diffusion. *Reserach Policy (29)*, pp. 603-625.

Giuliani, E., & Bell, M. (2005). The micro-determinants of the meso-level learning and innovation: evidence from a Chilean wine cluster. *Research Policy, 35(1)*, pp. 47-68.

Giuliani, E. (2005). Cluster absorptive capacity. Why do some cluster forge ahead and others lag behind? *European Urban and Regional Studies, 12(3)*, pp. 269-288.

Giuliani, E., Pietrobelli, C., &Rabelloti, R. (2005). Upgrading in global value chains: lessons from Latin America Clusters. *World Development, 33(4)*, p. 549-573.

Jespersen, K. S., Kelling, I., Ponte, S., &Kruijssen, F. (2014). What shapes food value chains?. Lessons from aquaculture in Asia. *Food Policy, 49(1)*, pp. 228-240.

Kaplinsky, R., A. Terheggen, & J. Tijaja (2011), China as a Final Market: The Gabon Timber and Thai Cassava Value Chains, *World Development, 39(7)*, 1177–90.

Katz, J. (2015). The Latin American Transition from an Inward-Oriented Industrialisation Strategy to a Natural Resource-Based Model of Economic Growth. *Institutions and Economies, 7(1)*, pp. 9-22.

Kilelu, C., Klerkx, L., Leeuwis, C. (2013). Unravelling the role of innovation platforms in supporting co-evolution of innovation: Contributions and tensions in a smallholder dairy development programme, *Agricultural Systems, 118*, pp. 65–77

Kilelu, C. W., Klerkx, L., Leeuwis, C., & Hall, A. (2011). Beyond knowledge brokering: an exploratory study on innovation intermediaries in an evolving smallholder agricultural system in Kenya. *Knowledge Management for Development Journal, 7(1)*, pp. 84-108.

Klerkx, L., &Leeuwis, C. (2008). Balancing multiple interests: Embedding innovation intermediation in the agricultural knowledge infrastructure. *Technovation, 28*, pp. 364-378.

Klerkx, L., Hall, A., &Leeuwis, C. (2009). Strengthening agricultural innovation capacity: are innovation brokers the answer? (Fortalecimiento de la capacidad de innovación agrícola: ¿los gestores sistémicos de innovación son la respuesta?). *International Journal of Agricultural Resources, Governance and Ecology, 8(5/6)*, pp. 409-438.

Lall, S. (1992). Technological Capabilities and Industrialization. *World Development, 20(2)*, pp. 165-186.

Lamprinopoulou, C., Renwick, A., Klerkx, L., Hermans, F., &Roep, D. (2014). Application of an integrated systemic framework for analysing agricultural innovation systems and informing innovaion policies: Comparing the Dutch and Scottish agrifood sectors. *AgriculturalSystems, 129*, pp. 40-54.

Lódola, A., Brigo, R., & Morra, F. (2010). Mapa de cadenas agroalimentarias de Argentina. En G. Anlló, R. Bisang, & G. Salvatierra (Eds.), *Cambios estructurales en las actividades agropecuarias. De lo primario a las cadenas globales de valor*, Documento de proyectoLC/W 350, pp. 53-100. Santiago de Chile: CEPAL, PROSAP y MAGyP.

Lundvall, B.-A., &Borrás, S. (1998). The Globalising Learning Economy. Implications for Innovation Policy.*European Commission*. Working paper.

Lundvall, B.-A. (1988). Innovation as an Interactive Process: From User-Producer Interaction to the Nacional System of Innovation. Dosi, Freeman, Nelson &Soete (Eds.), *Technical Change and Economic Theory* (pp. 349-369). London: Pinter Publishers.

Madlener, R. (2007). Innovation diffusion, public policy, and local initiative: The case of woodfuelled district heating systems in Austra. *Energy Policy, 35*, pp. 1992-2008.

Mahutga, M. C. (2012). When do value chains go global? A theory of the spatialization of global value chains. *Global Networks, 12(1)*, pp. 1-21.

Mancini, M. C. (2013). Geographical Indications in Latin America Value Chain: A "branding from below" strategy or a mechanism excluding the poorest? *Journal of Rural Studies, 32,* pp. 295-306.

Marín, A., Navas-Aleman, L., & Pérez, C. (2015). Natural Resource Industries as a Platform for the Development of Knowledge Intensive Industries. *Tijdschriftvooreconomischeensocialegeografie, 106(2)*, pp- 154-168.

Martin, R., &Moodysson, J. (2013). Comparing knowledge bases: on the geography and organization of knowledge sourcing in the regional innovation system of Scania, Sweden. *European Urban and Regional Studies, 20(2)*, pp. 170-187.

Mmari, D. E. (2015), The challenge of intermediary coordination in smallholder sugarcane production in Tanzania. *The Journal of Modern African Studies, 53,* pp. 51-58.

Morris, M., Kaplinsky, R., & Kaplan, D. (2012). One Thing Leads to Another - Why Local Linkages may Become the Norm Rather than the Exception. M. Morris, R. Kaplinsky, & D. Kaplan (Eds.). *One Thing Leads to Another. Promoting Industrialization by Making the Most of the Commodity Boom in Sub-Saharan Africa.* (pp. 21-46). Cape Town, Sudafrica: Policy Research on International Services and Manufacturing (PRISM).

Navas-Alemán, L., Pietrobelli, C., &Kamiya, M. (2012). Inter-Firm Linkages and Finance in Value Chains. *Inter American Development Bank*,IDB Working Paper Series N° 349.

OCDE. (1996). La difusión de tecnología. *Redes, Vol. III (8)*, pp. 119.161.

Pietrobelli, C., &Rabellotti, R. (2011). Global Value Chains Meet Innovation Systems: Are There Learning Opportunities for Developing Countries? *World Development, 39(7)*, pp. 1261-1269.

Ponte, S., Kelling, I., Jespersen, K., &Kruijssen, F. (2014). The Blue Revolution in Asia: Upgrading and Governance in Aquaculture Value Chains. *WorldDevelopment, 64,* pp. 52-64.

PROICSA. (2014). *Caracterización de las cooperativas de productores de caña de azúcar de Tucumán*. Buenos Aires: Eudeba.

Rodríguez Romero, L., & Sánchez, P. (1992). The Interrelation between R&D and Technology Imports. The situation in some OECD countries. *OECD,*STI Review, 41-64.

Rogers, E. M. (2003/1962). Diffusion of Innovations. New York: Free Press.

Romero, E.; Digonzelli, P.; Scandaliaris, J. (2009). *Manual del Cañero*. Las Talitas, Tucumán: Estación Experimental Agroindustrial Obispo Colombres.

Rosenberg, N. (1979). *The Economics of Technological Change*. México, D. F.: FCE.

Ryan, B., & Gross, N. (1950). Acceptance and Diffusion of Hybrid Corn Seed in Two Iowa Communities. *ResearchBulletin (372)*, pp. 663-708.

Scandaliaris, J. (2010). *El Proyecto Vitroplantas: su concepción, sus inicios y su impacto en la Agroindustria de la caña de Azúcar*. Las Talitas, Tucumán: Publicación Especial de la Estación Experimental Agroindustrial Obispo Colombres.

Schumpeter, J. (1942). *Capitalism, Socialism and Democracy*. Harper and Row: New York. Edición en español: (1983) *Capitalismo, socialismo y democracia*, Orbis, Barcelona.

Shapira, P., Youtie, J., Cox, D., Uyarra, E., Gök, A., Rogers, J., &Downing, C. (2015). Institutions for Technology Diffusion. *Interamerican Development Bank,*IDB-TN-832.

Silvestre, B. S., & Silva Neto, R. (2014). Capability accumulation, innovation, and technology diffusion: Lessons from a Base of the Pyramid cluster. *Technovation, 34*, pp. 270-283.

Stephenson, G. (2003). The Somewhat Flawed Theoretical Foundation of the Extension Service. *Journal of Extension, 41(4)*, pp. 1-7.

Stoneman, P. (1987). *The Economic Analysis of Technology Policy*. Great Britain: Oxford UniversityPress.

Teece, D. (2003). Sacando partido de la innovación tecnológica: implicancias para la integración, colaboración, obtención de licencias y políticas *públicas. F. Chesnais, & J. Neffa (Eds.), Sistemas de innovación y política tecnológica* (pp. 131-169). Buenos Aires: Trabajo y Sociedad - CEIL - PIETTE/CONICET.

Temple, P., Blind, K., Jungmittag, A., Spencer, C., Swann, G. M., & Witt, R. (2005). The Empirical Economics of Standards. *Department of Trade and Industry, UK*. Retrieve from: https://www.immagic.com/eLibrary/ARCHIVES/GENERAL/UK_DTI/T050602D.pdf

Tran, N., Bailey, C., Wilson, N., & Phillips, M. (2013). Governance of global value chains in response to food safety and certification standards: The case of shrimp from Vietnam. *WorldDevelopment, 45*, pp. 325-336.

Ulivarri, E., & Vallejo, J. (2014). Raquitismo de la caña soca, su control y semillero de alta calidad. *Seminario Internacional "INTA CAÑA 2014"*. Famailla, Tucumán, Argentina.

van Eck, P. S., Jager, W., &Leeflang, P. S. (2011). Opinion Leader´s Role in Innovation Diffusion: A Simulation Study. *Journal of Product Innovation Management, 28(2)*, pp. 187-203.

Wei, J., Liu, L. R., &Xie, X. M. (2010). Diffusion of technical innovation based on industryuniversity-institute cooperation in industrial cluster. *The Journal of China Universities of Posts and Telecomunications, 17*, pp. 45-50.

Yin, R. (2014). *Case Study Research:design and methods*. Fifth edition. SAGE Publications, Inc. US.