Knowledge organisations in less innovative regions: what factors explain the emergence and development of their links with firms? A case study in Argentina

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Abstract: This paper explores the factors that condition the links between knowledge organisations and firms in a medium-sized city in Argentina. The study is motivated by two aspects related to innovation: 1) the conceptualisation of innovation as a local and urban phenomenon; 2) the growing importance of scientific knowledge generated in universities and science and technology (S&T) centres. This topic acquires special interest in Latin America based on the low innovative dynamism of firms, the high concentration of national R&D expenditure in public knowledge organisations and the weak link between such organisations and firms. Unlike other case studies, this paper adopts the theoretical approach of the regional innovation systems and employs a temporal perspective analysis. Among the main findings, the following factors condition the links at local level: 1) the influence of the national institutional context, in particular the active role of the national state; 2) the catalytic action of certain local agents; 3) the weak demand for knowledge. Based on the identification of these factors, it is expected that this paper may contribute to the formulation of policies that foster the links between knowledge organisation and firms in less innovative regions.

Keywords: knowledge organisations; science and technology; links with firms; city; regional innovation systems; RISs; Argentina; case study; national state; local agents; knowledge demand.

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1 Introduction

A special feature related to innovation refers to the role played by knowledge organisations – universities, R&D laboratories and science and technology (S&T) centres – in the generation and diffusion of knowledge. Among the different types of agents involved in the innovation process, such organisations are considered a source of knowledge for the productive sector and stand out for their active role in the development of transverse technologies (ICT, biotechnology, nanotechnology, new materials) (Audretsch and Stephan, 1996; Etzkowitz and Leydesdorff, 1995; Nelson, 2007; Rosenberg and Nelson, 1994; among others).

Another feature related to innovation refers to its local and urban nature (Camagni, 2004; Capello et al., 2013; Diez, 2002). Despite the large and diversified urban agglomerations are identified as centres of innovation par excellence, since the 90s, academic studies and European territorial development strategies, point to the potential of medium-sized cities to become centres of innovation and economic growth in less developed regions. From the perspective of different experiences in developed countries, this innovative potential results in the formation of local productive systems, industrial districts, clusters or regional innovation systems (RISs) (Camagni, 2004; Caravaca et al., 2007; Cooke, 2002, Hildreth, 2006; Méndez et al., 2008). The provision of R&D infrastructure, qualified human resources and advanced production services are the most important assets of these cities. Thus, the so-called 'university medium-sized cities' are distinguished by the formal and informal exchanges between universities and firms, the creation of spin-off firms and the attraction of knowledge-intensive firms (Hildreth, 2006).

In the case of the Latin American countries, studies related to the role of knowledge organisations in innovation processes are relevant if the following aspects are considered: the low innovative dynamism of firms, the high concentration of national R&D expenditure in public knowledge organisations and the weak link between such organisations and firms (Arocena and Sutz, 2006; Arza, 2012; ECLAC, 2010).

This study explores the factors that condition the links between knowledge organisations and firms in a medium-sized city in Argentina. It is expected that the study can contribute:

1 to the literature on links between universities, S&T centres and firms in Latin America since it adopts a territorial theoretical perspective, which is relatively less diffused compared to the number of studies at national level (see Arza and López, 2011a, 2011b; Cimoli et al., 2011; ECLAC, 2010)

2 to the formulation of policies aimed at taking advantage of the S&T potential of the public knowledge organisations in the region.

Considering that knowledge organisations can participate in local innovation processes both as a source of knowledge for mature productive sectors and agents that induce the creation of high-tech innovation systems (Asheim and Coenen, 2005; Boschma, 2007; Cooke, 2002) the specific objectives of this study are to:

1 characterise the links between knowledge organisations and firms, in relation to the geographic scope of such links, the complexity of the knowledge demanded and the type of linked firms

2 identify the factors that explain the role of knowledge organisations both as agents that serve the innovation processes of firms in the city and as agents that foster the emergence of local innovation systems.

The case study methodology will be here applied to the S&T system integrated by universities and R&D centres of a medium-sized city in Argentina, with special attention to the S&T centre called Chemical Engineering Pilot Plant (hereafter called Chemical Engineering Centre)[1]. Within a National Innovation System characterised by weak links between knowledge organisations and firms, the extensive trajectory of linkage of this S&T centre is highlighted by specialised industrial literature (Chudnovsky et al., 1992; Gatto, 1990; Yoguel et al., 2007).

In a distinctive way, the proposed study adopts the theoretical approach of the RISs (Cooke et al., 1998; Cooke, 2001 and 2008), not very frequently used in the analysis of innovation in Latin America (Llisterri and Pietrobelli, 2011). This approach contemplates the influence of factors of different nature (productive, institutional, organisational), both local and extra-local and provides an adequate theoretical framework for the study of innovation in urban areas (Diez, 2002).

Another distinctive feature of this paper lies in the performance of a comparative static exercise. Although the case study is a widely disseminated methodology in the territorial approach to innovation, a historical perspective will be applied to the proposed case study. This will allow us to recognise changes in the types of linkages with the productive sector and to identify factors underlying the emergence, development and subsequent dissolution of such links.

The following questions guide the proposed study: What is the path and what kind of linkages have emerged between the local S&T system and the productive sector? What kind of factors influences the characteristics and dynamics of these linkages? In relation to this last question, what is the incidence of the policy implemented by the National State? Is local policy a prerequisite? What characteristics of the productive sector condition the links between the local S&T system and firms?

Following the introduction, four sections will be developed. The second one presents the theoretical guidelines followed. The third section details the methodology adopted and sources of information used. The fourth shows an analysis of the proposed case study. This section is divided into two subsections. Each subsection corresponds to each

phase that makes up the trajectory of the links between the S&T system under study and the productive sector. These subsections describe the phases and identify the factors that explain them. Finally, in section five, a synthesis and the final conclusions are presented.

2 Literature background

In a context of valorisation of the region as a source of innovation and competitive advantages, cities are considered privileged sites for innovation. Physical proximity between agents; diversified productive structure; communication and transportation infrastructure; the presence of universities and R&D centres; a wide consumer and labour markets are some of the factors behind innovation as an urban phenomenon (Duranton and Puga, 2001; Glaeser et al., 1992; Jacobs, 1969).

Within the urban hierarchy, large urban areas -city regions- are seen as privileged sites for growth in the world economy (Scott and Storper, 2003). They show a higher innovative behaviour than smaller cities, as their economies are usually highly diversified (Duranton and Puga, 2001; Henderson, 1997). However, in the last decades, academic literature and European territorial development strategies have diverted attention to medium-sized cities and their innovative potential[2]. This innovative potential stems from the emergence of local innovation systems around two attributes: the specialisation of these cities in mature industrial sectors (Caravaca et al., 2007; Méndez et al., 2008), or the localisation of universities and other research organisations (Hildreth, 2006). According to empirical evidence from developed countries, high-technology local systems (ICT, biotechnology) share the presence of exceptionally well-developed scientific organisations, public funding, local venture capital, entrepreneurship and appropriate infrastructure for the commercialisation of knowledge (Cooke, 2004, 2002; Feldman and Francis, 2003; Saxenian, 1996).

Within the territorial models of innovation [clusters, industrial districts, milieux innovateurs (see Moulaert and Sekia, 2003)], the RIS approach (Cooke et al., 1998; Cooke, 2008) offers theoretical tools to analyse knowledge linkages in cities (Diez, 2002). This approach adopts a regional scope, broader than the sectoral one proper of the cluster approach, compatible with urban productive diversification (Cooke et al., 1997). It is possible for a region to include several clusters that can interact with each other, with knowledge organisations and with other regional, national and global agents. Moreover, research organisations are prominent in the structure of a RIS, which can be defined as a system composed of two linked subsystems in a collective learning process: on the one hand, a subsystem of knowledge generation and infrastructure, made up of public and private research laboratories, universities, technology transfer agencies; on the other, a subsystem of knowledge exploitation or regional production structure made up of firms and their links with other firms, suppliers and customers (Asheim and Coenen, 2005; Cooke, 2002).The links between these subsystems take different forms, such as spin-off firms, patent licensing, jointly R&D projects, services and technical assistance, human resources training (Bercovitz and Feldman, 2006; Cohen et al., 2002; D'Este and Patel, 2007; Fritsch and Schwirten, 1999).

The geographical proximity between agents and the specific institutional configuration of a region, together with cognitive, social and organisational proximity, are factors that condition the tacit and codified exchanges required by innovation

(Boschma, 2005; Camagni, 2004; Shaw and Gilly, 2000). Following Cooke (2001, 2002) and Cooke et al. (1997, 1998), the potential of a region to adopt a systemic innovation dynamic will depend on the following factors[3]:

1 regional institutional configuration, such as culture of cooperation and association, predisposition for learning, experience and capacity to carry out institutional changes, public/private consensus

2 firm organisational factors, such as harmonious labour relations, cooperation at work, firm commitments to social welfare

3 organisational and institutional factors at universities and other research organisations, such as formal and informal rules on the dissemination of knowledge, foundational mission, the presence of an Office of Technology Transfer (OTT) and its functioning (Bercovitz et al., 2001; Chapple et al., 2005; Debackere and Veugelers, 2005; Landry et al., 2013)

4 external influences, such as policies and instruments of the National Innovation System, links with other RISs and international organisations.

RISs are open systems that interact with their environment, through the production of new knowledge and new technologies, while factors external to the region condition their own functioning.

Applying the concept of place-dependence to the genesis and development of an urban innovation system, the presence of research organisations and/or an industrial sectors are initial conditions for the potential emergence of local innovation systems (Martin and Simmie, 2008). According to Asheim and Coenen (2005) and Jensen et al. (2016), an RIS based on synthetic knowledge (mature industries) requires the pre-existence of mature industrial sectors, which follow a doing, using and interacting (DUI) model of innovation based on the links between firms. In this case, the knowledge organisations assist the firms in the resolution of their short term technical problems. A high-tech RIS is based on analytical knowledge (ICT, biotechnology, nanotechnology) and emerges near a university or an S&T centre. This type of RIS follows science, technology and innovation (STI) model based on R&D activities and codified knowledge. In this case, research organisations foster the ex-ante creation of high-tech RISs, which can adopt the modality of high-tech clusters, technopoles or S&T clusters.

Starting from innovation as the result of the interaction between scientific knowledge and demand market forces (Mowery and Rosenberg; 1979; Kline and Rosenberg, 1986; Lundvall, 2010; Di Stefano et al, 2012), the differential role of knowledge organisations according to the knowledge base of an RIS allows reviewing two aspects related to the interaction between knowledge organisations and firms. On the one hand, the characteristics of the firms and their influence on the propensity to be linked: size and productive sector (Laursen and Salter, 2004; Cohen et al., 2002; Arundel and Geuna, 2004; Veugelers and Cassiman, 2005) or the geographic proximity to a knowledge organisation (D'Este et al., 2013; Laursen et al., 2011; Arundel and Geuna, 2004). In studies on Latin America, the influence of the participation of foreign capital in the firm ownership is also taken into account (Avellar and Kupfer, 2011; Arza and López, 2011a, 2011b).

On the other hand, scientific knowledge and, therefore, universities and S&T centres have growing importance in the innovation process, particularly in radical innovations

(Mowery and Rosenberg, 1979; Kline and Rosenberg, 1986; Mazzucato, 2011). The recent contributions of Mazzucato (2011) and Mazzucato and Penna (2015) take into account the importance of basic R&D carried out in knowledge organisations and go even further. According to these authors, the state not only contributes to innovation by financing basic R&D (through universities and S&T centres) and promoting the creation of networks, but it also has a key role in guiding the technological change through the formulation of mission-oriented policy. An example is the entrepreneur role that the state of developed countries had in the gestation and diffusion of radical technologies (ICT, biotechnology, nanotechnology).

In the case of Latin America, Pérez (2001) and Katz (2006) point out the leading role that the public sector must fulfil in exploration of the basic knowledge frontier in areas that are relevant for technological progress in economic sectors based on natural resources (biotechnology, biology, genetics, human and animal health). In these sectors, such as agriculture, the strong dependence on local geographical conditions offers an opportunity for latecomer countries to develop their own technology based on synergies between firms, universities and S&T centres (Figueiredo, 2016).

At this point it is necessary to stress some distinctive features of the national innovation systems in Latin America. First, in the countries of Latin America, expenditure on R&D is low compared to OECD countries and the new industrialised countries in Asia (Arocena and Sutz, 2006). In general, R&D activities are carried out by public knowledge organisations with low participation of firms in national R&D expenditure (ECLAC, 2010, Sutz, 2012). Second, there is a weak link between public knowledge organisations and the productive sectors (Arocena and Sutz, 2006; ECLAC; 2010; Llisterri and Pietrobelli, 2011; Sutz, 2012).

At a regional level, Llisterri and Pietrobelli (2011) find that, the links between firms and knowledge organisations in RISs in Colombia, Brazil, Mexico and Chile, are based on laboratory services, technical assistance and training of qualified human resources. The development of collaborative R&D projects is limited. In the same direction, in a study on the Metropolitan Region of Buenos Aires (Argentina), Borello et al. (2009), recognise that there is no interaction between universities, S&T centres and firms; the available technological supply tends to be less oriented to the needs of the productive sector; many firms do not have the necessary skills to access certain knowledge; and there are serious problems of knowledge diffusion.

However, exceptional cases of linkage between firms and knowledge organisations are identified. In the case of Brazil, the role of the EMBRAPA centre and its contributions to the production of soybeans (Figueiredo, 2016); the links between the Federal University of Mina Gerais and the mining and the steel sector (Suzigan and Albuquerque, 2008); the interactions with different universities by the energy company Petrobras (Suzigan and Albuquerque; 2008; Dantas and Bell, 2009) and the mining company Vale, (Figueiredo and Piana, 2016); agreements with firms in the area of human health of Butantan Institute, University of Mina Gerais, Oswaldo Cruz Institute (Cooke, 2013, Suzigan and Albuquerque, 2008).

At the regional level, the following cases of linkage stand out: the aquaculture in Los Lagos (Chile); the aeronautical sector in Querétaro (Mexico) (see Llisterri and Pietrobelli, 2011); telecommunications and the State University of Campinas (Brazil) (Brisolla et al., 1997); the National Commission of Atomic Energy and the knowledge-intensive companies in Bariloche (Argentina) (Lugones and Lugones, 2004).

3 Methodology and data collection

According to Yin (2003), the need to apply the case study methodology stems from the desire to understand complex social phenomena; and it allows researchers to preserve the holistic and significant characteristics of real-life events, such as organisational and managerial processes and maturing of industries, among others.

The present paper adopts as a case study the S&T system located in the city of Bahía Blanca (Argentina), integrated by the Southern National University and its 11 related S&T centres, which depend on this University and on the National Council of Scientific and Technical Research. Several factors explain this choice:

1 Among Latin American and Caribbean countries, Argentina has a long tradition of research (Albornoz and Gordon, 2011). This country shows a marked concentration of national R&D expenditure on public research organisations, approximately 74% in 2013 and a sustained growth in its R&D/GDP ratio, from 0.42% in 1996 to 0.59% in 2014[4]. Among public research organisations, the National Council for Scientific and Technical Research and national universities are the main beneficiaries of R&D expenditure. However, both kinds of organisations have a rather weak connection with the needs of the national productive structure and have been led by a 'laissez faire' S&T policy (Chudnovsky et al., 2004; Yoguel et al., 2007). Since the 2000s, changes in this policy have been identified in the creation of strategic plans to promote links between research organisations and firms and in the promotion of areas of knowledge (ICT, biotechnology and nanotechnology), which are key to economic development.

2 Bahía Blanca is a medium-sized non-metropolitan city[5]. Its industrial sector is composed of a few large export-oriented firms (petrochemical and agro-food industry), with few links with the local productive structure and a heterogeneous group of micro and medium-sized and small firms (SMEs) from low- and medium-technology sectors (food and beverage processing, textiles, wood and furniture sectors), suppliers of local and regional markets (Gorenstein et al., 2012).

3 Bahía Blanca becomes prominent at a national level for the number of local knowledge organisations taking into account that most universities and S&T centres are centralised in the Autonomous City of Buenos Aires (national capital), in its metropolitan region and in the major cities of the country (Lugones et al., 2006). Within Bahía Blanca's S&T system, the Chemical Engineering Centre stands out for its extensive linkage history with the productive sector. This extensive linkage history is exceptional in a National Innovation System where the links between firms and knowledge organisations are scarce and mostly concentrated in technical services and technical assistance, in detriment of links involving greater use and generation of knowledge, such as R&D projects or the creation of spin-offs (Arza, 2012).

The present study is based on qualitative and quantitative data collected from primary and secondary sources of information (Table 1). Based on secondary information available, the types of links analysed in this study are restricted to R&D projects, technical assistance and technical services[6]. It should be noted that, in developing countries, the statistical information available on innovation links is scarce and even more so at local/regional level (Llisterri and Pietrobelli, 2011).

Table 1 Sources of information and information reported

Sources of information		*Information reported*
Primary	Semi-structured interviews to qualified agents. Guide of questions elaborated according to the activity developed by the interviewee: teacher-researcher, personnel of the offices of technological transference (OTT)	Organisational and institutional factors that condition the links with firms Channels through which knowledge is generated and disseminated Experiences highlighted
Secondary	Self-assessment reports and web pages of the organisations that make up the local S&T system: Southern National University and annexed S&T centre. Curriculum vitae of teachers and researchers available on internet	Link features: • Number of technical assistances, technical services and R&D projects • Linked firms • Fields of application

Source: Developed by authors

4 Case study analysis

The trajectory of the links of S&T system of the city of Bahía Blanca can be differentiated into two phases (Table 2). The first one extends from the early 1970s to the mid-1990s and is defined by the emergence and consolidation of the S&T Pole formed by the Chemical Engineering Centre and the firms that integrated the Bahía Blanca Petrochemical Pole (BBPP). In this phase, the links are concentrated in the geographical area of the city and specialised in a single scientific discipline – chemical engineering – and in large sized petrochemical firms. A second phase, from the mid-1990s to the present, is defined by the:

1 dissolution of the S&T pole in petrochemical industry and the expansion the links of the Chemical Engineering Centre to new productive sectors, extra-local firms and SMEs

2 the diversification of scientific disciplines offering knowledge at the local S&T system

3 the initiative to form a local S&T Pole in the field of ICT.

4.1 First phase: S&T pole in petrochemical industry

4.1.1 Description of the first phase

Figure 1 depicts the systemic dynamics followed by the Chemical Engineering Centre and the firms of the BBPP. The local petrochemical industry operating in gas and specialised in the production of ethylene and derivatives was made up of six large mixed and privately owned firms. The main firm was Petrochemical Bahía Blanca SAIC. It is mostly owned by the government and produces ethylene. The remaining five were satellite firms specialised in the production of low and high density polyethylene, chlorine, caustic soda, vinyl chloride monomer (CVM), polyvinyl chloride (PVC). The creation of the BBPP by the National Government dates back to 1971. In 1977, the

construction of the main plant was completed and it did not operate until 1981, when the gas separation plant became operational. Between 1981 and 1987, the satellite plants were opened.

Table 2 Links between the local S&T system and the productive sector (two phases)

Links of the local S&T system	*1st phase early 1970s to mid-1990s*	*2nd phase mid-1990s to the present*
Local systemic dynamics	Emergence and consolidation of S&T Pole with the local petrochemical industry	Dissolution of the S&T Pole with the local petrochemical industry
		Initiative for the emergence of S&T Pole in ICT
Complexity of the linkages	Links involving low use and generation of knowledge predominant	Links involving low use and generation of knowledge predominant
Scientific disciplines involved	Specialization in chemical engineering	Diversification in chemical engineering
		Electronics and software, biology
		Agrarian sciences, geology and oceanography
		Miscellaneous engineering (civil, mechanical, industrial)
Linked firms	Specialization in large local firms of the petrochemical industry and food industry	Diversification productive sectors
		Incorporation of SMEs
		Predominance of extra-local firms in links of greater complexity

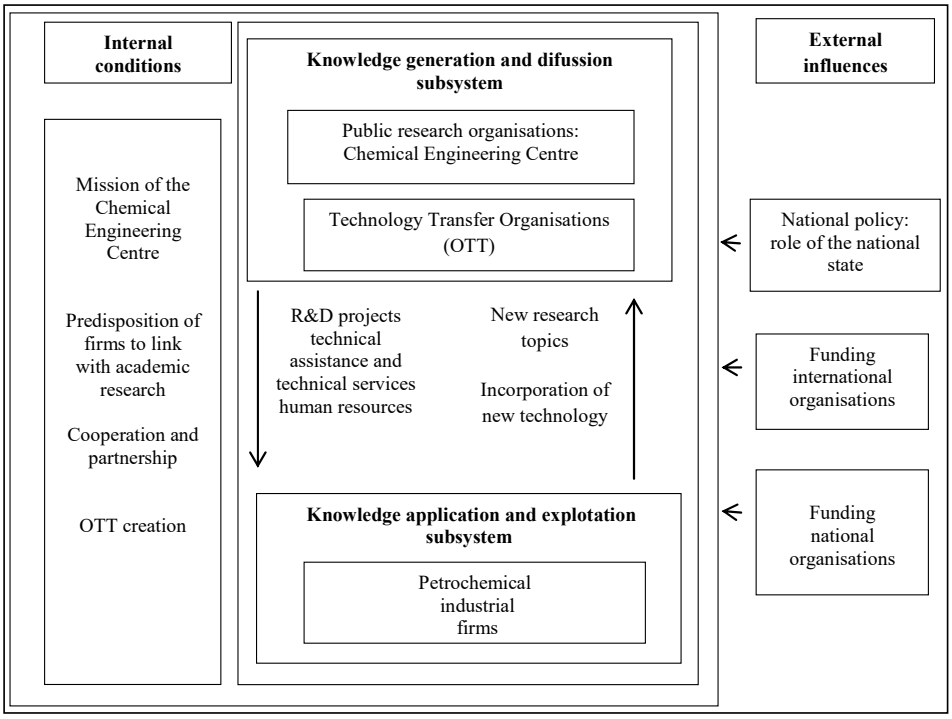
Source: Developed by the authors

The links between the Chemical Engineering Centre and the firms of the BBPP, viewed from the perspective of the RIS approach, can be conceived as a kind of local innovation subsystem composed by frequent and sustained knowledge exchanges which took the form of assistance and technical services and R&D projects.

The simulation and optimisation of plants and equipment, the regeneration of an exhausted chemical catalyst and the development of a new one to eliminate acetylene (impurity that is detrimental to the quality of the polymer) revealed the local capacities in the Chemical Engineering Centre laboratories in terms of adaptation and generation of technology. On the other hand, new lines of research emerged inspired by the problems of the industry.

The different types of proximity (geographical, institutional, cognitive, social) included in recent theoretical contributions were articulated in this experience. The frequent exchanges between researchers and firms resulted in an institutional framework that fostered lasting links of knowledge and human resource exchanges. Prior to the construction of the BBPP, the informal and frequent interactions between the Chemical Engineering centre and the main stakeholders of the BBPP (particularly, the National Government), resulted in an agreement to use the Chemical Engineering Centre as an ‘external laboratory’ for all the petrochemical firms. To this end, in 1975, the Chemical Engineering Centre and those responsible for the city’s Petrochemical Pole project outlined the bases of the Research and Development Program of the BBPP (PIDCOP acronym in Spanish).

Figure 1 S&T pole



Note: Chemical Engineering centre and the local petrochemical firms.

Source: Elaborated by authors based on Cooke (2002)

Through this program, funded by the United Nations (UN) and the national government, the Chemical Engineering Centre contributed to the absorption, adaptation and optimisation of technologies. In addition, the cognitive and social proximity that emerged from the training programs that the Chemical Engineering Centre offered to the firms of the local petrochemical industry also explain the continuous interaction between the Chemical Engineering Centre and such firms.

4.1.2 Explanatory factors behind the first phase

The factors that drove the emergence and development of the S&T pole in petrochemical industry can be summarised as follows:

1 *The founding objectives of the Chemical Engineering Centre* revealed the predisposition of its researchers to link with the productive sector and meet the needs of the local petrochemical industry. The Chemical Engineering Centre was created in 1963 by a group of teachers and students of the chemical engineering career of the Southern National University. The founding objectives, which today mark the performance of this S&T centre, were oriented to improving and updating the teaching and professional training; strengthen R&D in chemical engineering and promoting technology transfer.

This last objective distinguished the Chemical Engineering Centre from other S&T centres created in the scope of a public university; it fostered its members' decision of training abroad; and it contributed to defining lines of research in fields relevant to the development of local and regional industries: gas-based petrochemical firms and the food industry.

2 *The 'public policy regime' at the national level* (Katz, 2007) not only influenced the emergence of the local petrochemical industry, but also influenced the beginnings of the local S&T pole. This S&T pole in petrochemical industry emerged under the macroeconomic regime of import substitution. In this regime, the government acted as a coordinating agent for the productive sector, direct producer of goods and services and founder of R&D institutes (Katz, 2007). Thus, the government in its different political-administrative levels demanded knowledge from the Chemical Engineering Centre. In the 1960s, the public sector at the national level (through the Government's Gas del Estado Company) and at provincial level (Government of the Province of Río Negro) demanded knowledge of this S&T centre for the manufacture of chemical substances and the development of an industry based on the cultivation of apples, respectively. In the early 1970s, the national government, as the main integrant of Bahía Blanca's Petrochemical Pole, decided to contact the Chemical Engineering centre to meet future technological demands and the specialised human resource needs of the local Petrochemical Pole[7].

3 *National and international financing* promoted the development of the local S&T pole in petrochemical industry .The exchanges between the Chemical Engineering Centre and the firms of the BBPP were funded by international and national organisations. As indicated above, it also got financial support from the UN and the national government under the research and development program of the BBPP (PIDCOP acronym in Spanish). These funds were destined to:

   a the training of human resources, both in Chemical Engineering Centre and in petrochemical firms

   b the acquisition of equipment for the Chemical Engineering Centre laboratories

   c the provision of computer resources.

   In addition, between 1979 and 1983, the Inter-American Development Bank (IDB) and the national government financed studies abroad and the hiring of international experts with the purpose of updating the training of human resources belonging to the centre.

4.1.3 Impact and limitations

The systemic dynamics described had a positive impact, but at the same time, there were factors that limited its functioning in terms of generation and diffusion of new knowledge:

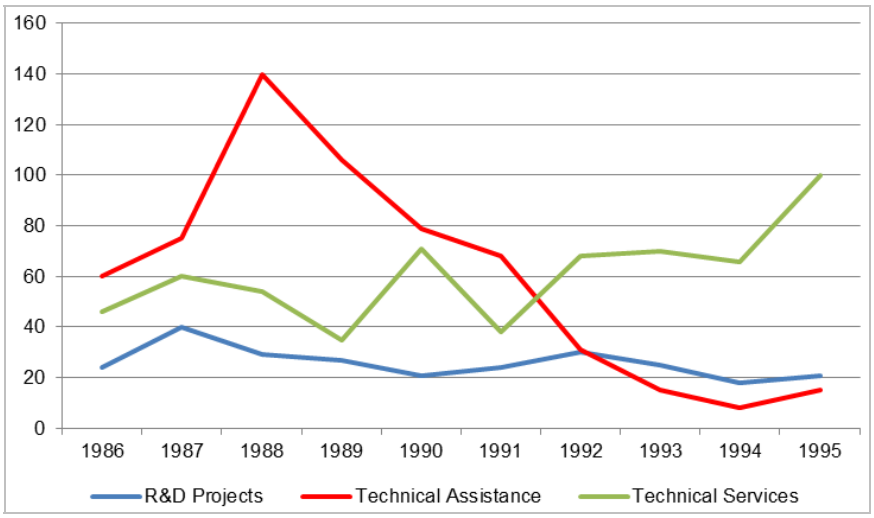
1 In a context of absence of national and local policies that promote links between research organisations and firms, the agents involved in the local experience under study created an institutional environment that fostered knowledge exchanges. This suggests that the institutional configuration does not necessarily determine the emergence of links and the innovative behaviour of a region. As Wolfe (1998) argues, history is not inexorably imposed; on the contrary, institutional learning and the catalytic effect of certain local actors are elements that can change the course of a region.

2 There was organisational innovation. For the administration of funds granted by national and international organisations and those received from firms in return for technical services, technical assistance and R&D activities, in 1979 the Chemical Engineering Centre created an OTT called 'Southern Foundation for Technological Development'. This organisational structure was novel for the Argentine National Innovation System and later served as a model of the 'Technological Linkage Unit' a type of organisation contemplated in the legislation formulated in the 1990s to encourage the interaction between universities, R&D centres and the productive sector. The Chemical Engineering Centre used this organisational structure to promote and facilitate links with other large local and extra-local firms in the petrochemical sector (upstream), gas and oil and agro-industries.

3 The links between the Chemical Engineering Centre and the local petrochemical firms were mainly based on technical assistance and technical services and to a lesser extent on links involving greater use and generation of knowledge, such as R&D projects (Figure 2). The largest firm of the BBPP, with capital owned mostly by the national government, was the main agent in links of greater complexity (Chudnovsky et al., 1992). The technological behaviour adopted by firms in Latin America led to the predominance of less complex links (Arocena and Sutz, 2006; Katz, 2006). Following Chudnovsky et al. (1992), the technological behaviour of entrepreneurs of the petrochemical industry in Argentina was defined by their underestimation of innovation activities and a tendency to acquire technology from abroad. These technological strategies were evident in Bahía Blanca's petrochemical industry in the decision to acquire 'turnkey' technological packages. In this way, assistance and technical services were sought for only a complement to technological packages acquired abroad (Chudnovsky et al., 1992).

4 In addition to technical services, technical assistance and R&D projects, training of human resources was an alternative channel for the diffusion of knowledge from the Chemical Engineering Centre to the local petrochemical firms. In a city with an industrial structure dominated by SMEs, a new labour market oriented to large firms in petrochemical industry emerged. In the same direction, the tasks carried out in the Chemical Engineering Centre in the area of engineering of processing and systems allowed training human resources in the field of ITC, which later, promoted the offer of a university career in computer systems. The existence of local labour supply in the field of ICT led to the formation of a cluster of software firms, counteracting the productive specialisation of the city in mature industries.

Figure 2 S&T Pole in petrochemical industry (number of links) (see online version for colours)



Note: Years 1986–1995.

Source: Elaborated by authors based on Arcodasi (1996)

4.2 Second phase: dissolution of the S&T pole in petrochemical industry, new scientific disciplines and productive sectors

4.2.1 Description of the second phase

In the mid-1990s, the BBPP was privatised, redefining its links with the Chemical Engineering centre. The privatisation process, not only meant the transfer of Government shares to multinational capital firms, but it was also accompanied by the expansion of the production capacity of the Pole through the construction of a new ethanol plant and the opening of a gas-based urea fertiliser production plant (Cincunegui and Brunet, 2012)[8]. In this new context, local subsidiaries directed their technological demands to their external technology suppliers and to R&D laboratories belonging to their head office (Cincunegui and Brunet, 2012). The immediate effects of the privatisation process consisted of a decrease in the number of links between the Chemical Engineering centre and the firms of the BBPP and the weakening of the links of trust built between both types of agents. Then, the links were based on the provision of services and technical assistance[9].

In this second phase, mid-1990s to present time, the links of the Chemical Engineering Centre are characterised by:

1 greater participation of extra-local firms

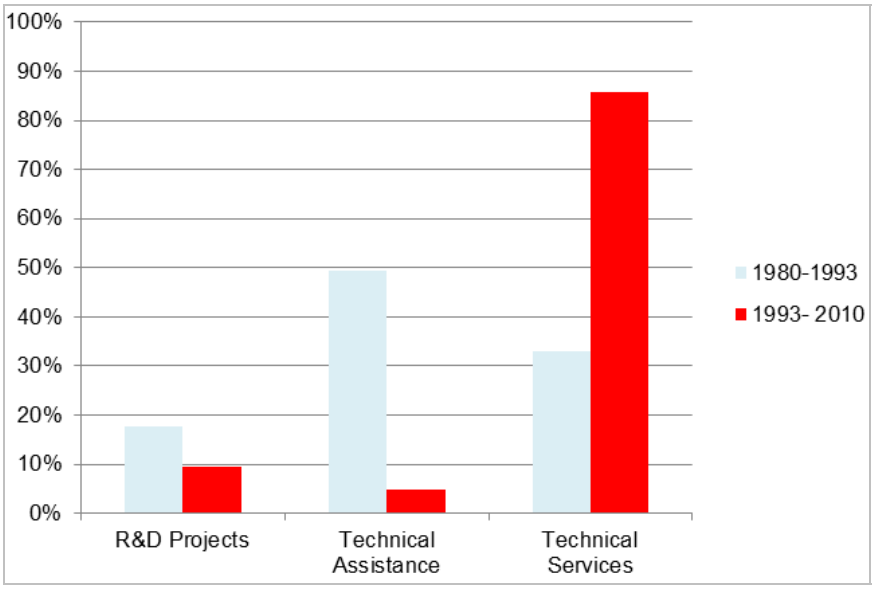
2 incorporation of SMEs as new agents in a link structure traditionally dominated by large firms

3 participation of new productive sectors.

The links are reoriented from large upstream petrochemical firms to large firms and SMEs producing PVC products located near major consumption centres (national capital city and its metropolitan region). Since 2008, the Chemical Engineering Centre has

responded to the demands of quality control of firms producing fuels and certifiers for export (Petrobras, SGS, Camin Cargo, among others firms) (CCT-Bahía Blanca, 2011). In relation to the complexity of the links between the chemical engineering and the productive sector, they concentrate on links involving low use and generation of knowledge. After the privatisation of the BBPP, the demand for technical services outgrew that of technical assistance and R&D projects (Figure 3).

Figure 3 Chemical engineering centre (number of links) comparison between two phases (see online version for colours)



Source: Own elaboration based on information provided by the Chemical Engineering centre

In this second phase, the Chemical Engineering Centre is still the main supplier of knowledge in the local S&T system[10]; while the rest of the city's S&T system shows sustained growth in their links with the productive sector[11]. Excluding the Chemical Engineering Centre, the rest of the organisations that make up the local S&T system shows a variety of links. First, there are links involving less use and generation of knowledge. The Agrarian Sciences provide technical services and technical assistance to the agricultural activity near the Bahía Blanca city. Civil, mechanical and industrial engineering assists local SMEs belonging to the construction and related services. Geology and oceanography provide technical services and technical assistance to extra-local firms in the mining and hydrocarbon sector. Second, there are links involving greater use and generation of knowledge but they are scarce and they are concentrated in extra-local firms. Electronic engineering and software, specifically the area specialised in Image Acquisition and Processing, established links with extra-local SMEs providers of knowledge-intensive services. In turn, biology and the agrarian sciences were linked with large local and extra-local firms of chemical and petrochemical industry. One aspect that stands out from the analysis is the absence of local SEMs in the most complex linkages.

In the face of this linking scheme, it is worth noticing the recent developments in electronic engineering and software. This area has witnessed the first academic spin-off in the local S&T system and fostered the development of a S&T Pole called Electronics Technology Platform (TEAC acronym in Spanish) which involves researchers and local firms and aims to promote an environment of cooperation between electronic firms, research groups and other organisations to produce electronic systems prototypes with macro, micro and nanoelectronics. Driven by the availability of public funds to carry out R&D activities through public-private partnerships[12], the S&T Pole mentioned is still in a developmental phase.

4.2.2 Factors leading to the second phase

To sum up, the local S&T system linkage system which has been operational since the mid-1990s is characterised by:

1 the diversification of scientific disciplines linked to the productive sector

2 the diversification of the types of linked firms, from large local petrochemical firms to extra-local SMEs and new productive sectors

3 the predominance of links involving less use and generation of knowledge

4 the predominance of extra-local firms and no local SMEs in the links involving greater use and generation of knowledge

5 the construction and equipping of an S&T Pole in highly complex electronics.

This new scheme of linkage responds to institutional, organisational and productive factors

1 *The change in the national 'public policy regime'* (Katz, 2007) from one with strong Government participation to a market-based regime caused the dissolution of the local S&T Pole in petrochemical industry. The privatisation of Bahía Blanca's Petrochemical Pole was carried out in 1995 in a macroeconomic scenario of structural reforms based on exchange rate convertibility, liberalisation, privatisation and deregulation of markets. In this context, the transition from a linkage scheme composed of agents belonging to the public sphere (both supplying and demanding for knowledge) towards a public-private scheme dominated by foreign capital, meant a decrease in the number and complexity of the links with the local petrochemical industry and prompted Chemical Engineering centre to seek new knowledge demanding firms for its accumulated stock of knowledge in chemical, petrochemical and derivative processes.

2 *Changes in the national science, technology and innovation policies* led to the emergence of new linkage initiatives. As indicated in Section 2, the national S&T policy adopted a historical laissez-faire stance. During the 1980s and 1990s, national public S&T universities and centres faced budget reductions, which were an additional motivation in the Chemical Engineering Centre for the search of new knowledge demanding firms. Since the first half of the last decade, the national S&T policy has undergone various changes, such as an increase in the public budget for R&D activities, the development of strategic plans, which specify key knowledge areas for development (ICT, biotechnology and nanotechnology). In this context, the

availability of financing lines was one of the factors that led to the creation of the electronics S&T Pole described above.

3 *The lack of local S&T policies* limits the use of the local S&T potential. Bahía Blanca is among the 15 most populous cities in the country and is home to municipal administrative and political authorities. However, it lacks a tradition of formulating policies aimed at reversing the deficient links between the numerous local knowledge organisations and the urban productive structure. Recently, within the municipal government, new municipal offices were created to promote entrepreneurship and productive innovation.

4 *The role of local researchers and the linkage history* are added to the aforementioned institutional factors. The history, culture and behavioural norms of each university play a key role in their predisposition to diffuse knowledge (Bercovitz et al., 2001; Bercovitz and Feldman, 2006; O'Shea et al., 2007). From a regional perspective, Gunasekara (2006) highlights the influence of the past trajectory on the role played by non-core-metropolitan universities in Australia. In the present study, the local S&T system is made up of two types of research organisations: a national public university and S&T centres dependent on this university and the National Council of Scientific and Technical Research. Both knowledge organisations show a historical lack of interest in disseminating knowledge to the productive sector (López, 2002). In this scenario, the current position of the Chemical Engineering Centre as the main knowledge supplier in the local S&T system is explained by the deliberate action of the founding researchers and the learning and accumulated knowledge regarding the interactions with the productive sector.

   In the rest of the local S&T system, the links with the productive sector are driven by demand. They do not respond to an institutional strategy aimed at promoting knowledge diffusion. However, the actions of the researchers responsible for the first academic spin-off of the local S&T system and for getting funds for the development of a highly complex electronic S&T Pole counteract the passive attitude of the local S&T system (excluding the Chemical Engineering centre) in terms of linkage.

5 *The weak performance of the OTT in the local S&T system* is an organisational factor that bounds the generation and diffusion of new knowledge towards the productive sector. Several studies acknowledge that OTTs are a key organisational factor in the links between universities, S&T centres and firms. In the case of the Chemical Engineering Centre, its OTT participated in the search for new knowledge demanding firms after the privatisation of the local petrochemical firms. In the rest of the S&T system, the OTTs have a marginal role. At the beginning of the 1990s, the rest of the local S&T system decided to open its first OTT given the restriction of public funds prevailing and the recent national legislation aimed at promoting innovation in the productive sector and the links between firms and research organisations (Yoguel et al., 2007). However, this OTT does not have specialised human resources for the active search of knowledge demanding firms. Its activities are directed to the administration of funds granted to faculty-researchers through public funding for R&D and funds derived from links with knowledge demanding agents.

6 *The national productive structure.* From the 1970s until the present, the Chemical Engineering Centre shows a tendency towards links involving less use and generation of knowledge. This pattern can be explained by the predominance of low and medium technology industrial sectors in the local and national productive structure. Following the import substitution industrialisation period, in the mid-1970s, the industrial sectors with greater technological complexity were undermined and the activities moved towards the upstream of the supply chains (Yoguel et al., 2007). According to recently released data, industrial firms concentrate their innovation efforts on the acquisition of machinery and equipment[13]. This behaviour is widespread in Latin American industrial firms (Katz, 2006).

7 *The local productive structure* does not demand knowledge. After the dissolution of the systemic dynamics between the Chemical Engineering Centre and the firms of the BBPP, the S&T system under study is not linked to local firms for the development of new and/or improved products and processes. This can be explained by the presence of a few local large firms that benefit from laboratories and R&D activities carried out in their head offices and a large group of micro and small firms in the medium and low technology sectors (suppliers of the local and regional market) with an innovative behaviour based on the purchase of machinery and equipment (Gorenstein et al., 2012). Recently, a number of software and computer services firms have emerged in the city. This sector only links to the S&T system for the demand for qualified human resources (Pasciaroni et al., 2014).

5 Synthesis and final conclusions

The proposed study is based on two aspects related to innovation:

1 the conceptualisation of innovation as a local and urban phenomenon

2 the growing importance of scientific knowledge generated in universities and S&T centres, simultaneously, with the limited use that Latin American countries make of their potential S&T.

Combining these aspects, the present explored the factors that condition the links between knowledge organisations and firms located in a medium-sized city in Argentina. The case study was selected for its extensive trajectory of linkage in a weak NIS. The analysis focused on the comparison of two phases: a first phase, since the early 1970s, defined by the emergence and consolidation of the local S&T Pole in the petrochemical industry; and a second phase, from the mid-1990s to the present, defined by the dissolution of the mentioned S&T Pole and the initiative to form a local S&T Pole in the area of ICT.

Contributing to the scarce literature on knowledge organisations and RISs in Latin America (ECLAC, 2010; Llisterri and Pietrobelli, 2011) the study identifies a set of local and extra-local factors that influence the links of knowledge organisations under study. The main findings and policy implications are summarised below.

5.1 Main findings

First, as pointed out in the RIS approach, the relevance of institutional factors arises from the study. However, it is not the pre-existing local institutional configuration that explains the emergence of the systemic dynamics described, but rather the influence of the national policy (macroeconomic and innovation policies). In the case of the S&T Pole integrated by the Chemical Engineering Centre and the firms of the local petrochemical industry, the impact of the prevailing public policy regime is clear: the national government fosters knowledge diffusion through its role as knowledge supplying (through financing the S&T system) and its role as knowledge demanding (through its status as the majority owner of the main company in the petrochemical sector of the city). In a national context defined by structural reforms (liberalisation, privatisation and deregulation of markets), the privatisation of the local petrochemical firms signalled the dissolution of the mentioned S&T Pole. Similarly, as for the initiative of establishing S&T Pole in electronics (still under development), the recently formulated national S&T policies -with their consequent availability of public funding for the development of local alliances for technological development in ICT, nano and biotechnology – are a key factor in explaining the emergence of such an initiative.

It should be noted that, except for the last decades, the national S&T policy in Argentina was governed by the principle of 'laissez-faire' and did not occupy a prominent place in the public agenda. In a similar direction, during the entire period under study, the lack of a local policy to promote the use of the knowledge accumulated in the S&T system of the city to improve the competitive capacity of local industries and favour the emergence of high-tech sectors is an additional institutional factor.

Secondly, the case study reveals the influence of the deliberate action of local researchers from the S&T system, who act as a catalyst for national public policy, promoting initiatives with local repercussions. In this sense, the creation of the S&T Pole involving the Chemical Engineering Centre and the local petrochemical industry is explained not only by the national public policy adopted, but also by the scientists in the chemical engineering centre, who included the transfer of knowledge among the founding objectives of this S&T centre. Similarly, local researchers promoted the development of the previously mentioned S&T Pole in ICT from their initiative to access the public funding available in the past few decades. In their study of the Brazilian mining sector, Figueiredo and Piana (2016) show a similar result: the learning links are not promoted by systematic policies that encourage interactions but by the individual actions of specific agents.

Beyond the exceptional nature of the case of the study, based on the long and sustained trajectory of linkage, the empirical evidence shows the low complexity of the local links. Factors conditioning the supply and demand of knowledge allow us to understand this result. On the side of the supply of knowledge, unlike universities and S&T centres with outstanding performance in the generation and diffusion of knowledge at an international level, the local S&T system does not have, except for the Chemical Engineering centre, active OTTs and norms and rules – formal or informal – aimed at linking to firms. The institutional mission of the Chemical Engineering Centre is an exception within the group of public knowledge organisations that concentrate R&D at the national level.

On the side of the demand for knowledge, the productive structure, both nationally and locally, is based on low and medium technology sectors and shows historical adaptive-type innovative behaviour, focused on the acquisition of machinery and equipment. The influence of the origin of the capital of the firms is added to this. In a macroeconomic scenario of openness and privatisation (mid-1990s), the transfer of State actions in the local petrochemical industry to multinational firms implied the orientation of the most complex technological demands towards laboratories and headquarters abroad. This explains the increasing participation of less complex links to the detriment of those more complex links.

5.2 Policy implications

The study offers empirical evidence in favour of the influence of the national institutional context (role of the state in the economy, national innovation policies). Therefore, the policy implications that derive from the study exceed the local context. On the one hand, from the territorial point of view, the influence of extra-local factors allows to define policies with impact in different regions. Unlike local factors (hardly replicable in other regions) the above mentioned national can guide the formulation of national policies aimed at taking advantage of S&T potential in several regions. In this direction, the S&T plans formulated in Argentina in recent years recognise the need for a more equitable regional distribution of S&T activities.

On the other hand, the study shows the influence of the active role of the National State in the economy. As indicated above, the local S&T Pole in the petrochemical industry is explained, in part, by the role of the National State both as a knowledge supplying as a knowledge demanding agent. In this context, the State played a crucial role as the coordinating agent of economy, applying promotional policies to sectors considered strategic to advance the process of industrialisation (Katz, 2007).

These reflections are in line with the historical review that Mazzucato (2011) makes about the role of the public sector in the direction of technological change: "(…) the role of the government, in the most successful economies, has gone way beyond creating the right infrastructure and setting the rules. (....). Rather the state can proactively create strategy around a new high growth area before the potential is understood by the business community (from the internet to nanotechnology) (....). In this sense it has played an important entrepreneurial role" [Mazzucato, (2011), pp.18–19]. In Argentina and Brazil, the vision of the entrepreneurial state can be translated into the formulation of policies aimed at strengthening the capacity for innovation in specific sectors, for example renewable energy, involving a strategic exploitation of biomass and natural resources (Mazzucato and Penna, 2015; Mazzucato, 2017).

As a final synthesis, the proposed case study allows the derivation of policy recommendations oriented towards a more active role of the national state to take advantage of the potential S&T of universities and R&D centres. It recognises the need to formulate systemic policies aimed at both the demand and the supply of knowledge. These policies should be formulated taking into account that:

1 from the knowledge supply side, it is necessary to support the actions undertaken individually by teachers-researchers with a predisposition to link with the productive sector

2 the weak demand for knowledge, coming from the low innovative dynamism of the firms, can be mitigated through policies that encourage innovation in strategic sectors for economic growth.

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Notes

1 The S&T centre called Chemical Engineering Pilot Plant is recognised as PLAPIQUI (acronym in Spanish).

2 The interest in this type of cities as centres of regional growth dates from the policies of French territorial regulation formulated in the 1970s and inspired by the theory of the central places of Christaller and Lösch and the Theory of the Poles of Growth of Perroux (for a review see Gorenstein et al., 2012).

3 This paper adopts the distinction between institutions and organisations present in Cooke et al. (1998). Institutions refer to the rules of the game, norms, government policy, while organisations refer to agents, with different competencies and capabilities.

4 Information extracted from 'La Red de Indicadores de Ciencia y Tecnología Iberoamericana e Interamericana (RICYT)", network of indicators of S&T in which all countries of America participate, along with Spain and Portugal, http://www.ricyt.org/ indicators.

5 The city of Bahía Blanca, located in the south of Buenos Aires Province (Argentina), has 301,572 inhabitants according to the Population Census of 2010.

6 Technical laboratory services are standardised activities based on the use of highly complex equipment. Technical assistance refers to activities with interpretation of results and resolution of technical problems. R & D projects, which are more complex links, refer to the generation and diffusion of new knowledge.

7 Foundational lines of R&D were process engineering, catalysis, polymers, chemical reactor engineering, and process control.

8 In those years, there was a significant flow of foreign direct investment, based on the expansion of the local Petrochemical Pole, the location of a fertiliser processing plant and the execution of the project by the firm MEGA (separation of liquid gas components, Neuquén-Bahía Blanca pipeline, etc.)

9 The project of modelling and simulation of the granulated urea plant required by the firm PROFERTIL stands out.

10 According to information provided by one of the OTT (Foundation of the Southern National University Southern National University) associated with the local S&T system, the Chemical Engineering Centre concentrated 40% of the total income from links between local knowledge organisations and firms in the year 2007.

11 According to information provided by one of the OTT (Foundation of the Southern National University) associated with the local S&T system.

12 Sectoral fund for information technology and communications (FS ICT 2010 acronym in Spanish).

13 According to the MINCYT Report (2015), when analysing the structure of total industrial expenditure on innovation activities, there is a bias: more than half went to the acquisition of machinery and equipment (55%), secondly, expenditure on internal R&D (19%) and third place on industrial design (9%).