Networks and Interactive Learning Among Academic Institutions, Firms, and Government: Knowledge-Based Social Capital for Local Development

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Introduction

Network building among academia, firms, and government aiming at mobilising scientific and technological knowledge to meet solutions to specific problems of the productive sectors and eventually to stimulate the innovation process, is a subject that deserves analytical and theoretical attention from an innovation analysis perspective, particularly in the South and more specifically in Latin America. As is well known, these countries have weak innovation systems and S&T capabilities built within the academic sector that are characterised by a lack of coordination among different agents, which limits innovation activities.

There is evidence in several Latin American countries that generation, transference, and interchange of knowledge is a phenomenon that takes place among firms, academic institutions, and local governments. This phenomenon is difficult to document, as it implies processes that cannot be easily observed and that are basically supported by intangibles. These interactions imply an interactive learning process, creation of knowledge networks, the development of trust, and knowledge flows among different actors, elements that from the perspective of this paper could be understood as knowledge-based social capital.

In the literature on innovation studies, emphasis has been from some time ago on the learning process and network creation, mainly to processes built upon collaborations of firms. Such analytical efforts are also important ingredients in the creation of social capital. Consideration of the learning process and networking has relevance for policy-making in the sense that creation of social capital could be enhanced and stimulated by policy measures to develop well-coordinated local and strategic innovation systems.

Social capital is not a recently developed concept. It has been used in economics and social sciences, particularly in the latter applied to the study of communities with regard to the satisfaction of the social needs of individuals (Hanifan, 1920). During the last several years, social capital theory has advanced because important contributions have been made (Ostrom and Ahn, 2003) toward definition of this conceptual category. It has been empirically applied to study several social, economic, and political phenomena. Nonetheless, it still remains to be discussed whether conceptual and analytical contributions

already developed within that framework can work in different social and institutional contexts, particularly in innovation studies.

The purpose of this paper is to discuss whether the concept of social capital could be used to characterise what is happening in the area of creation of interactions among academia, firms, and government aiming at production and transference of scientific and technological knowledge among these sectors.

Research systematised in this paper is based on empirical work conducted in Mexico in two projects already terminated (Casas, ed., 2001 and Luna ed., forthcoming) on analysis of knowledge network dynamics. In these investigations, a set of case studies of collaborations among different actors in technological sectors and knowledge areas, in which knowledge networks are built, were analysed. Case studies were developed in fields such as material sciences, polymers, metallurgy, agricultural research, biotechnology, and telecommunications. Qualitative information was gathered by case study techniques using direct interviews conducted with different actors participating in a set of collaboration projects into which networking and interactive learning have been built during medium- and long-term processes.

The paper is divided into three sections: a) in the first, a short review of social capital notion is presented, and discussed is conducted on the manner in which social capital could be understood for the analysis of relationships among academia, firms, and government, which are relevant to innovation studies; 2) in the second, general characteristics of analysed case studies are introduced, making reference to the geographic dimension in which they were identified to situate the creation of local social capital; 3) in the next section, several aspects that could be used to define knowledge-based social capital are analysed, including creation of coordinated actions (knowledge networks), long-term interactive learning process, building of trust among actors, interactive flows of scientific and technological knowledge, and the creation of regional and local knowledge spaces. Examples are introduced to demonstrate that a kind of knowledge-based social capital is being created in different regions of the country, and 4) finally, discussion is presented on the definition of social capital when applied to analysis of regional and local knowledge[1] spaces and on its importance for building local innovation environments.

1. On the Concept of Social Capital

Use of the social capital concept dates back to the beginning of the Twentieth Century and applied to community studies with regard to satisfaction of individual social needs. Hanifan (1920) used the social capital concept to highlight community responsibility in support of democracy and development. The first theoretical developments were carried out by Bourdieu (1986), Coleman (1990), and Putnam (1993a, 1993b, 1996). Putnam (2003) defines social capital as "the characteristics of social organisations, such as trust, norms, and networks, that can improve the efficiency of society by means of well co-coordinated actions". OECD (OECD, 2001) defines social capital as "networks with shared norms,

[1] These concepts were used in Casas, De Gortari, and Santos, 2000.

values, and understanding that facilitate within and between groups". In a study performed by the World Bank, Grootaert and van Bastelaer (2002) define social capital as "institutions, relationships, attitudes, and values that govern the interactions among people and contribute to economic and social development".

Ostrom and Ahn (2003) extended the concept of social capital in a way that it has become attractive for both theorists and public policy makers, including the idea that trust and reciprocity are useful forms of social capital to build effective institutional arrangements to drive common resources.

One of the central ideas of the social capital theory is that social networks are important because they have value (mainly for those that form part of them) and are oriented toward the solution of problems. In this sense (in microeconomic terminology), it could be stated that networks produce public and private benefits. Acting in a coordinated manner within networks, participants obtain more by time unit devoted to joint activities. Local knowledge is very important for building effective social capital.

In recent years, a set of investigations has been developed that consider the role of social capital in the innovation process at national, regional, and local levels, which constitutes important precedents for its discussion within the framework of this paper (Cook and Wills, 1999; Fountain, 1997; Owen-Smith, et al., 1999). It has been sustained that the performance of advanced market economies depends in great measure on industrial research and development, which require coordinated efforts among the scientists and engineers belonging to one research centre and others working in business, government, and academia. For these authors, the most important form of social capital from the perspective of research and development (R&D) is the network of organisational actors at the regional and national levels (Ostrom and Ahn, 2003: 199-200). Likewise, it has been argued that each region can develop its own specific regional innovation system in accordance with its distinctive regional characteristics, in which building of social capital stocks and promotion of local and global networks are distinctive elements (Sam Ock Park, 2001).

Thus, from previous ideas the fundamental meaning of social capital for innovation and hence for science and technology policies is an issue that deserves research efforts and consideration from policy makers and must be captured in the design of policy instruments.
In this paper, it is assumed that collaborative actions among academia, firms, and government could be conceptualised as knowledge networks (Casas, ed. 2001), given that they involve the generation and transfer of scientific and technological knowledge, interactive learning, trust building, and the creation of regional and/or local knowledge spaces. Given that these ideas are very close to what is being understood as social capital, it is discussed whether the characteristics already mentioned could help in defining what will be termed as knowledge-based social capital. This idea will be taken up again in the last section of the paper.

2. Characteristics of Case Studies

The study of collaborations among academia, firms, and government reveals a complex set of relationships that are proper to an interactive model of knowledge production. Creation of knowledge networks has been stimulated by the learning process among actors and a set of policy mechanisms applied at regional and local levels that favour development and transmission of scientific and technological knowledge.

University-industry collaborations in Mexico are taking place on a regional basis, given the geographic proximity between research institutions and the specific problems related to local natural resources and industrial activities. Certain regions stand out due to their dynamism regarding knowledge networks and creation of knowledge spaces, providing better conditions for the emergence of innovation environments (Casas and Luna, 2001). Among these, the Bajío[2], the Northeast[3], and the Northwest[4] regions of the Mexico are characterised by knowledge capabilities accumulated in different research institutions and important productive sectors, and different kinds of networking among academia and several economic sectors, creating the conditions for knowledge-based social capital.

This Bajío region (Region 1), has a very diversified production (agriculture and livestock, agroindustry, petrochemistry, clothing and textiles, metal-mechanics, the automotive industry, and electronics) (Villagómez, 1996; 103). Similarly, approximately 35% of the nation's R&D capacity is concentrated in the Bajío, mainly in public research centres located in the states of Querétaro and Guanajuato. In addition, the state of Querétaro is characterised by an emerging rise in the number of innovative firms principally in electronics, machinery, and equipment design, home electrical appliances, and the services sectors.

The Northeast region (Region 2) is characterised by important industrial development located mainly in the states of Coahuila and Nuevo León and by development of large national firms, some of transnational character. These concentrate on basic metallic industries, mineral and non-mineral products, as well as on electricity production, water, and gas. This is a region that also integrates an important number of educational and research institutions, both public and private, that possess abilities and capacities for building regional innovation systems. This explains the development of knowledge networks, particularly between large and medium firms, with academic institutions of the region in fields such as mining, metallurgy, the foundry industry, the agri-food sector, and in branches such as automotive, chemical, and service sectors.

The Northwestern region (Region 3) is characterised by great availability of marine resources, and scientists and engineers located at a set of research institutions and public universities, mainly those belonging to public research centres. This is a region with

[2] This region is located in the central part of Mexico and comprises the states of Aguascalientes, Guanajuato, Querétaro, and San Luis Potosí.
[3] This region integrates the following states: Coahuila; Nuevo León, and Tamaulipas.
[4] This region is composed of the following states or provinces: Baja California Norte; Baja California Sur; Sonora; Sinaloa, and Nayarit.

weakness in innovation dynamism and that is dominated by natural resources branches. There are some opportunity areas to be considered related to innovation, such as information technologies, biotechnology, aquaculture, and fisheries.

Analysis is based on a set of collaboration projects, analysed as case studies, and captured at a specific moment in their development, and have implied formal and informal interactions to mobilise scientific and technological knowledge for the solution of specific problems. Empirical work was conducted[5] in research institutions and firms where knowledge networks were identified with different actors including productive sectors of the regions and local and federal governments.

In Region 1, the following institutions were considered: a) CINVESTAV-Irapuato, located in the state of Guanajuato. This centre, created in 1981, is the principal institution in Mexico devoted to plant biotechnology with international recognition. Although its main objective is basic research, CINVESTAV-Irapuato has a strong orientation toward regional or local agricultural problems (see Casas, 2001); b) the Centre of Research and Technical Assistance (CIATEQ), a public technological centre, located in the state of Querétaro. CIATEQ is one of the most important actors in this region and maintains a permanent exchange of knowledge and capabilities with other research institutions in the field of materials, sustaining a long tradition of interactions with the metal-mechanical industries (see De Gortari, 2001) and, c) the Long Distance Supervision National Centre (LDSNC), a private service centre located in Querétaro that is in charge of the long-distance network of the main Mexican telecommunications firm (TELMEX).[6] This centre was created after privatisation of TELMEX and centralises the functions of supervision, maintenance, and negotiation to acquire long-distance technology for the firm. The LDSNC is strategic because it is one of the foundations on which the new image of TELMEX has been built (see Santos, 2001).

In Region 2, case studies were conducted in the Centre for Biological Research of the Northwest (CIBNOR), also a public centre, built in 1975, which was first oriented toward basic research and that at present constitutes one of the main institutions in that region involved in investigation of marine resources and that has established important networking with other academic institutions and the productive sector of the region. Marine cultures is one of the main orientations of this centre, a field in which collaboration programs with a set of economic and social actors have been established (see Casas, 2001).

In Region 3, case studies of collaboration projects were identified in a set of large Mexican-owned firms located in the Northeastern region (Enertec, Cemex, Hylsa-Mex, Peñoles, Galvak, Vitro) belonging to the manufacturing industry in the fields of metallurgy, new materials, and polymers, which have established important collaborations with universities and public research centres of the region (see Luna ed., forthcoming).[7]

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[5] Field work was conducted in two stages, the first from 1998 to 2000, and the second from 2000 to 2002.

[6] TELMEX was formerly a public enterprise until December 1993. It held the monopoly on telephone services in Mexico. It was bought by an alliance established by the CARSO Group, France Telecom, and Southwestern Bell.

[7] The cases analysed were the following: 1) Cemex / Universidad Autónoma de Nuevo León (UNICEMEX) case study, for the training of human resources in ceramics and cement industries; 2) Enertec/Cinvestav-

It is relevant to discuss knowledge networks identified in these regions with regard to whether their general characteristics are pertinent for thinking of social capital creation. It is insufficient space in this paper to make reference to the detailed aspects of the structure and dynamics of these knowledge networks.[8] Thus, reference will be only be made to some general characteristics of the networking process when they are useful to understand the processes leading to the definition of social capital.

3. Processes Leading to Knowledge-Based Social Capital Creation

The study of collaborations among academia, firms, and government reveals a complex set of processes proper to the interactive model of knowledge generation and the transfer that constitute the basis of innovation system development. Several processes have been identified by analysing different case studies that become important to define what could be understood as knowledge-based social capital. Among those processes in the cases analysed, the following stand out as the most important: a) creation of co-ordinated actions (knowledge networks) based on informal and formal relationships; b) long-term interactive learning; c) trust development among actors; d) interactive flows of scientific and technological knowledge, and e), the building of regional and/or local knowledge spaces.

Creation of Co-ordinated Actions (Knowledge Networks)

The creation of knowledge networks in the cases analysed has been stimulated by a spontaneous process among actors, institutional policies developed at academic institutions, a set of governmental policy mechanisms applied at regional and local levels[9], and a change of culture among entrepreneurs who are beginning to conceive of the importance of knowledge for their productive processes. This framework favours the participation of several actors in the development and transmission of scientific and technological knowledge. The building of co-ordinated actions among actors to share scientific and technological knowledge is due to important initiatives on the part of the productive sectors, as well as from the participation of public research centres and universities.

From the case studies analysed, it is worth emphasising the role that public research centres in the three geographic regions considered play in development of networks with productive sectors. These centres, as already been documented in other papers (Casas, et al., 2000b), are important repositories of basic and applied research and play a relevant role in the building of knowledge networks and the transfer of knowledge through interaction in

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Saltillo case study, for porosity reduction in lead batteries; 3) Hytemp-Hylsa/UANL/U.de Zacatecas/U. Michoacana case study, to solve an international competition problem of a firm; 4) Peñoles/UANL case study, for the development of building materials from by products with ceramic properties; 5) Univitro/UANL case study, for the training of human resources; 6) a confidential case study, for the improvement of the process for the production of resins for better resistance to water; 7) HYLSA /UANL case study, on steel oxide removal and, 8) Galva/Cinvestav-Saltillo/UANL/I.T. de Saltillo case study, for the production of steel plate for imports substitution.

[8] See Casas, *ed*., 2001 and Luna, *ed*. forthcoming.

[9] These policy mechanisms are analysed in depth in Casas and Luna (2001).

several regions within Mexico. They have accumulated capabilities that are becoming relevant for economic sectors and firms. The contribution of these centres to the creation of regional knowledge spaces by means of the establishment of networks with other research institutions nationally and internationally is fundamental for the creation of knowledge-based social capital for localities or regions (Casas, ed., 2001: 362).
The diverging trajectories of networks found in the cases already analysed share the following characteristics:

a) Networking experiences have an important basis in spontaneous and informal relationships. This clearly occurs in the material sciences field. These experiences represent an advantage for national technological development. However, formalisation of interactions by means of agreements and contracts is a frequent practice in the cases analysed. Nevertheless, from the information gathered it is possible to state that when objectives are accomplished, interactions among members of networks do not end, but subsequently assume different forms and dynamics. This leads to the argument that even when knowledge networks have a strong ingredient of informality based on weak tights (Granoveter, 1973; Luna and Velasco, forthcoming), in the majority of cases analysed these interactions become formalised for the accomplishment of objectives; when the objectives are reached, the interactions lie again on weak and informal tights.

b) Government has shown participation as a player in the building of knowledge spaces to the degree to which it has applied policies that have facilitated the creation of interactions between public research centres and industry. However, this does not demonstrate a clear definition in support of specific regional technological projects. Specifically, in Guanajuato the state government during the end of the 1990s elaborated a Science and Technology Program conceived on the basis of knowledge networking for specific social and economic sectors (PCITEG, 1998), but the program did not include particular programs for priority economic sectors.

c) Two different orientations of collaborations are identified in the case studies considered. The first deals with interactions that are basically built on bilateral relationships between academia (public research centres or universities) and large national firms, and those in which government participates in an indirect manner in some of these collaborations through financing research programs. This situation is characteristic of Region 2, which is characterised by a high level of industrial development, such as in Nuevo León and Coahuila, where large firms belonging to different branches of the manufacturing sector are interested in collaborations with academic centres located within the region to support the firms' industrial strategies. In these cases, transference of knowledge by means of interactions between academia and firms does not have a parallel in public industrial or economic policy. The second orientation relates to interactions that involve a set of actors that include not only academia and firms but also government at different levels, entrepreneurs' and producers' associations, and also international organisations. This orientation was found in cases pertaining to Region 1 and 3, where participation of entrepreneurs and producer associations that integrate micro-, small- and medium-size firms is more active when the firms share common problems in their field of specialisation (Tirado and Luna, 2001). In this case, the federal and state governments also assume an important role in building networks and in the creation of mixed organisations in which

public and private sector institutions participate jointly in support of interactions between academia and the productive sectors.

d) It could be argued that networking is preferentially localised in specific states of the country. This implies that local knowledge networks are better built than regional networks. The proximity of public research centres, universities, and firms in the Northeastern and Northwestern Mexican states as well as in those located in the Bajío is contributing to the creation of regional knowledge spaces that could be stimulated by means of co-ordinated policies among local and state governments, firms, and academia to build regional innovation systems in specific productive sectors. However, some cases on which this study is based—particularly the networks built in the field of materials—are not exclusively located in an specific state or region, given that firms also make use of knowledge generated at academic institutions that are distant to them and that contribute to create knowledge networks integrating institutions at a national level.[10]

e) As for the objectives of collaborations, the majority of cases analysed are looking for improvement of processes and products, mainly in the fields of metallurgy, materials, and polymers, where participation of large enterprises is afforded. Other cases seek improvement of organisational procedures, as is the case of telecommunications, giving rise to institutional innovations to stimulate competition in firms by means of interactive process between knowledge and productive sectors. However, it is worth emphasising that another goal that is relevant in the cases analysed, and that is sometimes complementary to other objectives, is the training of human resources, in which academia participates with its infrastructure to orient training of firms' resources and new students at the postgraduate level to fields already identified by firms as strategic for their further industrial development and enhancing the qualifications of their employees. This step has been understood by Lundvall (1999:30) as fundamental for the formulation of a knowledge-oriented technology policy. This orientation of interactions is becoming more important and is formalised in specific contracts, where large national and well-known export firms located in the state of Nuevo León, such as Cemex, Hylsa and Vitro, are stressing their relationships, in this case with public universities, to train their personnel or new students in specific fields of interest for industry. This kind of interaction is stretching knowledge networks, improving the rate of mobility of personnel between academia and firms, contributing to increase the skill level of the labour force, and favours the flow of knowledge among these institutions.

Long-Term Interactive Learning

It is worth emphasising that building knowledge networks is based on interactive and learning processes, mainly in the cases analysed in the fields of material sciences,

[10] A very interesting example of this type is the Resistol Macroproject, developed during the early 1990s as an initiative of the Mexican national firm GIRSA, whose main goal was to integrate and recombine knowledge developed by a set of institutions located in different regions nationwide to create a network in the field of polymers that was of special interest to the firm. Other national firms such as HYLSA and ENERTEC currently apply the same approach. Other examples of networks built at a national level in the field of materials have been documented by De Gortari (2001).

polymers, biotechnology, fisheries, and telecommunications, in which interactions and collaborations were built among different actors. In general, networking between public research centres and local or regional firms or viceversa in Regions 1 and 3 have implied learning, an accumulative and long-term process among the sectors.

The majority of cases analysed have implied interaction among actors during periods longer than 5 years that have been preceded or succeeded by other collaborations seeking different purposes. Few knowledge networks analysed were based on short-lasting relationships in which previous relationships have not taken place, which did not appear to accomplish the specific objectives pursued by the collaboration. These networks were based on less complex process of knowledge interchange, as the main purpose was to mobilise specialised technical services in favour of firms.

For instance, multidisciplinary networks built in Region 3 for shrimp aquaculture implied a long-term learning process beginning in the early 1970s when CIBNOR was built in La Paz, Baja California. However, formal shrimp research work at CIBNOR began in the mid-1980s and aimed at developing the biological basis for technological development of this crop in the Northwest region. Since that time, this public research centre has built important interactions with different firms interested in several production stages of shrimp, ranging from the reproductive stage to genetics and nutrition. Networks have also been built between CIBNOR and federal and local governments, causing a learning process among academia, government, and firms. This centre has played a very active role in the consolidation of a regional network on shrimp aquaculture formalised by the National Science and Technology Council (CONACYT) in 2001. This implies that the building of this knowledge network has lasted more than 15 years, alternating from formal to informal networking and viceversa.

Trust Development Among Actors

This factor explains why it is possible to build knowledge networks among actors. Geographic or physical proximity is a condition for trust building, but also the existence of mature research institutions and the demonstration that knowledge could be used to aid solving specific problems of productive sectors are elements contributing to the generation of trust.

In some cases analysed, particularly those located in Regions 1 and 3, the processes of learning have passed through different stages and difficulties in the confidence generated among actors. Trust building is mainly based on the development of what can be called technical trust or technical confidence, which arises once the actors agree on a common goal: they demonstrate that the problem is identified and shared by actors belonging to different cultures, they interchange knowledge, information, and values and then adequate solutions are found.

Processes of this sort are particularly relevant in Region 2, as large Mexican firms located in the State of Nuevo León have been involved in collaboration activities with state universities during the past several decades and achieving trust building because they have

been involved in collaborative actions having different purposes such as technical assistance, human resource training in specific fields of interest for firms, and in some cases collaboration in basic research projects. Personal and informal meetings between university and firm personnel and mobility of personnel among these institutions have allowed generation of trust and the conviction of joint collaboration. In this context, it is worth mentioning that knowledge networks built for human resources training, particularly those established between Cemex and Peñoles firms with the State University of Nuevo León. The training of students in collaboration with firms allows students to acquire additional practical experience by means of direct participation in projects for the solution of specific technical problems of firms (case study related to quality improvement in the paint industry). This process has important effects in the orientation of research interest of new human resources, acquiring a strong incentive for applied research and technological development, an orientation that has to date merited very little attention in Mexico. To some extent, academia attempted to initiate relationships with the productive sector and to build trust by offering it programs or courses for training of adequate human resources and the solution of technical problems by means of services.

Interactive Flows of Scientific and Technological Knowledge

In research conducted previously (Casas, coord., 2001), the importance was documented that existing knowledge based in universities and public research centres has for improving productive process in firms, such as in the cases of -shrimp improvement, virus-resistant strawberry plants, the manufacture of specific parts for the sugar cane industry, and the achieving of the ISO 9000 quality norm. In case studies analysed, accumulated knowledge showed to be relevant to solve important and timely problems and firms in the productive sectors. However, these cases are useful to document the fact that the creation of networks among different actors also leads to development of new knowledge, the recombination of knowledge, and in some cases to generation of knowledge at the forefront that becomes significant for the productive sectors. Examples of this sort include development of research in optic characteristics of paints, investigation on reactive extrusion in the field of polymers, and development of genetic engineering of shrimp and agave, among others.
This process implies different flows of knowledge, the training of human resources, particularly at the postgraduate level, and less frequently interactions that imply technological development. It should be noted that associations of farmers play an important role in the building of knowledge networks in the Bajío region. These farmers are in the process of understanding the importance of knowledge in improving crop production.

The nature of knowledge that flows and is shared in the creation of networks has a strong relationship with the type of objectives of these interactions. The most common objectives in the cases analysed are services, use of infrastructure, and human resource training. In the light of the case studies, it can be stated that three different sets of flows were identified: information; knowledge, and values. From the evidence gathered, it is possible to argue that the most common inputs exchanged between academia and firms are ideas, technical skills, experiences, methods and procedures, and values. This means that networks are

strongly sustained in knowledge flows even when certain information inputs, such as data and marketing information, are also in circulation.

Codified knowledge is being exchanged into an important degree, but not in the classic ways found in developed countries (Senker and Faulkner, 1996; Vithlani, 1996), i.e., by means of joint publications or patents[11], but rather by means of other mechanisms such as technical reports that reflect the advancement of collaboration and that was a means indicated by various case studies analysed. These reports imply the codification of knowledge acquired in the experimental process and in observation activities in firms and is has been published (Gibbons, et al., 1994). The joint generation of patents between academia and firms is a process of importance for firms but not for academia. In the cases analysed, only one joint patent was registered, i.e., in the case of the design of machinery to solve a specific problem of a firm in the metal-mechanic industry. Publications are not a means to diffuse results of collaboration projects, given that confidentiality is a norm that should be observed in these interactions.

Tacit knowledge is also an important input that is transferred in the cases analysed. This mainly consists of ideas, abilities, and experiences that reflect capacities incorporated in personnel that are acquired in formal and informal training. It is mainly shared by means of personnel mobility and face-to-face relationships. Informal relationships are basic to allow transfer of knowledge and this is possible when technical trust has been established among the actors participating in these networks.

From the latter, it is possible to argue that tacit knowledge and the learning process developed among different institutional actors play an important role in network building. Evidence documented is also useful to argue as other authors have done (Bonaccorsi and Piccaluga, 1994:245), that "the propensity of firms to enter into university-industry relationships is positively related to the level of tacitness of the knowledge involved in the relationship" and that "the higher the level of tacitness of the knowledge involved in the relationship, the higher the frequency and intensity of information exchange and personnel exchange and the richness of information exchange through personnel channels".

It is worth noting that the creation of networks implies the sharing and transfer of multidisciplinary or interdisciplinary knowledge. Several case studies analysed are based on this practice, giving rise to increasing of horizontal relationships among researchers. This is explained by the fact that the solution of specific problems requires the intercourse of different disciplines. This leads to new organisational forms in the production of knowledge closer to Mode 2 and new organisational forms of research centres. Of particular importance are the projects on shrimp aqua-culture, agave-tequila, and optic fibers for medical use as well as other projects related to development of new materials,

[11] Proposals are made in a recent paper (Breschi and Lissoni, 2001) with regard to the fact that there is a need to advance toward richer quantitative analysis of indicators of knowledge interchanges, using those that are proving to play an important role such as patents and the counting of innovations. However, they resulted in weak significance for the findings of this investigation. Our view is that there is a need for more qualitative rather than quantitative indicators, as pointed out by Senker and Faulkner in previous papers.

which generates new horizontal collaborative forms among researchers who previously worked in isolation from each other.

Building Regional and/or Local Knowledge Spaces

The existence of accumulated knowledge, incipient networking, and interactive learning process in specific regions or localities within Mexico is giving rise to the creation of what we call knowledge spaces. We use this concept to designate regional spaces that have accumulated under-utilised knowledge—in specific fields relevant to social or economic development—and emergent knowledge flows among actors, giving rise to the building of knowledge networks. This process leads to the recombination of knowledge among public research centres and universities and by means of inter-firm relationships, facilitates the creation of social capital in specific and specialised research and technological fields. The creation of knowledge spaces reflects a situation that is characteristic of Mexico and probably of other developing regions that present a limited process of innovation.

Some important characteristics that allow the building of knowledge spaces, at the regional level include: a) Universities and public research centres that have accumulated experience in different knowledge fields over a long period of time and that have oriented their activities toward specific problems of the region; b) entrepreneurs and technicians in firms, as well as entrepreneurs organisations at regional and local levels, who have professional training that allows them to understand the role of knowledge in the solution of production problems—organisational or technological—and who search for interactions with knowledge-producer institutions; c) previous existence of informal relationships based on face-to-face interactions that have permitted learning processes among actors belonging to different sectors and cultures, and that have led to generation of technical trust among them; d) interactive knowledge flows that benefit both firms and academic institutions. This interchange of knowledge contributes to both the solution of specific technical problems of firms and to development of basic and applied research in academia in specific fields; e) local government participation in the creation of capabilities and facilitating interactions by means of programs and mechanisms, and f), the shared challenge of desire of actors (academia, firms, local governments, and farmers' associations) to join together to identify opportunities, and by means of the solution of specific problems of production to improve the performance of economic sectors contributing to local or regional development.

Such aspects do not yet define a regional innovation system, but they constitute a step forward in the development of innovations systems based on interactive experiences.
From the case studies analysed, different levels of consolidation of regional or local knowledge spaces were identified; the most consolidated were found in Region 1 and 3. In the former case, knowledge networks built in the metal mechanic industry in Querétaro and in the latter case, the shrimp aqua-culture network of the Northwest of the country, which integrate the capabilities and learning process of several states in that region. Less consolidated spaces were found in Region 2 (Northeast), given that networks were created by bilateral interactions between academia and large Mexican firms, but non-direct governmental participation was found.

The consolidation of knowledge spaces lies at the level of articulation of resources and capabilities and the disposition, the learning, and the active participation of actors. In sum, this consolidation depends on co-ordination arrangements among actors.

3. Final Remarks: From Knowledge Networks to Knowledge-Based Social Capital

Research conducted to date has revealed the importance of the complementarity that is being built between knowledge produced at public research centres and universities, which has accumulated in productive sectors and governmental actions oriented toward stimulating scientific and technological development.

The study herein presented highlights of the importance that interactive and learning processes have in the creation and transference of knowledge between producers and users of knowledge. These facts become relevant to support science, technology, and innovation policies, considering a focus on the interactive relationships, a feature envisaged in current approaches of public policy-making.

The building of knowledge networks based on formal and informal relationships, the interactive learning process, development of technical trust, and reciprocity norms and values based on interactive flows of scientific and technological knowledge constitute relevant aspects for building regional and/or local innovations systems.

Several such characteristics could be understood as social capital in agreement with literature already reviewed. Given that this concept is not well defined in the innovation theory and to avoid misunderstanding with other uses, this paper proposes the use of knowledge-based social capital to define what this investigation has found when analysing interactions among academia, firms, and government. Such capital has relevance to support knowledge-based regional or local development, but from our position it could not be reduced only to innovation activities.

Some authors have argued that the sole existence of social capital lies in its "collective capacity of key socioeconomic players in the region to form and effectively use networks or other forms of cooperation on the basis of shared value system, norms, and institutions (e.g. trust and reciprocity) in order to enable and accelerate the process of regional learning ... (means) creating an efficient regional innovation system which facilitates the generation, diffusion, and economic exploitation of knowledge in the form of new or improved economic activities (products, processes, and services) in a region" (Landabaso, et al., 2003).

However, from our perspective the mere existence of social capital based on knowledge generation, diffusion, and exploitation at the regional level is not the equivalent of regional innovation systems. This is so because such characteristics do not necessary lead to innovation activities, but are relevant to improving production problems, competition in firms, and social development. The exchange and creation of knowledge does not necessarily lead to innovation in the cases analysed in this paper. In fact, Landabaso et al. (2003) found that when looking at pilot experiences in the European Union, "when

regional innovation strategy was less successful, weak regional partnerships between public and private actors appear to be the main failure factor. A limited social capital tended to have a negative impact on the success of regional innovation policies"

Previous statements could lead to explain why the knowledge-based social capital found in the case studies considered in this paper have not lead to the creation of regional innovation systems. We can argue that when social capital is limited, it could contribute to the creation of regional knowledge spaces, a condition that could lead to regional innovations systems if adequately supported by a strong regional innovation strategy.

These findings are particularly suggestive from a public-policy perspective. Long-term policies should consider the complementary relationship between the public and private sectors in the generation and transfer of knowledge, and on this basis seek social and economic development objectives at regional and local levels.

Several governmental and private programs in Mexico put into practice during the 1990s and the early twenty-first century in Mexico created conditions and support to build networks and regional knowledge spaces (Casas, et al., 2000a). However, such actions have been applied without considering a diagnosis of the knowledge based social capital already built. From the results of this investigation, it becomes relevant that a process of knowledge-network creation is already taking place in several regions within the country. These networks constitute the basic element for knowledge-based social capital building because they involve collaboration and common actions among public and private regional actors to exploit knowledge.

From an analytic and theoretic perspective, it becomes relevant to analyse separately the set of characteristics that could be understood as social capital to preserve their richness. There is a trend in social and economic studies to sum up a large set of elements within the concept of social capital. In this regard, this paper follows some critiques already presented concerning the social capital concept (Vargas, 2001) as general, vague, and problematic because it is difficult to analyse, capture, and measure the social capital concept, even when it is applied to innovations studies. Further efforts in this direction are needed[12], and this paper aimed at contributing to a better understanding of social capital, introducing some characteristics that could lead to the definition of knowledge-based social capital.

[12] Landabaso *et al.* (2003) argue that there is no widely accepted methodology or set of indicators to measure and evaluate social capital to date. Therefore, methodology issues are additionally of utmost importance for the policy dimension of the problem.

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