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Mechanisms of Local Knowledge Spillovers: Evidence from the Software Cluster in Uruguay

Effie Kesidou, Marjolein C.J. Caniëls and Henny A. Romijn

Eindhoven Centre for Innovation Studies, The Netherlands

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Department of Technology Management

Technische Universiteit Eindhoven, The Netherlands

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Abstract
The paper contributes to the understanding of local knowledge spillovers and their importance for innovation in clusters in developing countries. Extensive primary data collected from software firms in Montevideo, Uruguay, are used to bring out the varied nature of knowledge flows that occur in the local cluster. The relative importance of different types of knowledge flow is also highlighted. The most important knowledge flows are not pure spillovers, but rather emanate from intentional action and are associated with commercial transactions with customers.

Keywords
clusters, developing countries, local knowledge spillovers, knowledge flows, Uruguay

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1. Introduction

It has become commonplace to refer to local knowledge spillovers (LKS) as a key ingredient of innovation (e.g. Griliches, 1979; Jaffe et al., 1993; Audretsch and Feldman, 2003, 1996a and 1996b; Baptista and Swann, 1998; Audretsch 1998; Verspagen and Schoenmakers, 2000; Caniëls, 2000). LKS denotes flows in which knowledge is exchanged informally and free of charge. Many theoretical as well as empirical contributions have shown that firms tend to cluster in order to take advantage of the available knowledge that is so to say 'in the air'. The main explanation for this is that knowledge spills over more easily when firms are located in close proximity. Knowledge spillovers might consist for a large part of tacit knowledge, which requires face-to-face interaction in order to diffuse. Co-location of firms in clusters facilitates the development of the kind of personal contacts needed for the intense interaction that gives rise to knowledge spillovers (Saxenian, 1994).

Research on these issues has concentrated on technologically advanced countries. Not much is known about the importance of LKS in developing countries. In the latter, the dominant focus of research on innovation and growth has been on the creation of international linkages between local firms and foreign actors and the knowledge-related advantages this could bring (for a good literature review, see Evenson and Westphal, 1995). Widely used concepts like "international technology transfer" (Enos, 2001), "global value chains" (Gereffi and Kaplinsky, 2001), "catch-up" (Abramovitz, 1986) and "international knowledge spillovers" (Coe et al., 1997) testify to this orientation. The main sources of technological advance for developing countries are seen to lie in the external domain, and the main task is seen to lie in tapping and mastering that foreign knowledge. How such knowledge spreads locally, for instance through knowledge spillovers, has remained obscure. Yet, successful local assimilation requires some degree of diffusion.

In addition, we also have reason to believe that the external orientation of studies about technological change in developing countries is becoming somewhat outdated as far as several newly industrialising countries are concerned. Several developing countries are beginning to make their mark in technologically dynamic modern industries like biotech, ICT and pharmaceuticals, in which local original innovation appears to play a significant role alongside the assimilation of foreign knowledge.

These issues point to the need to gain a better understanding of the nature of LKS and the role they play in developing country clusters, in particular in technologically dynamic industries. This could help in shedding light on the question whether industrial strategies that attempt to harness the benefits of LKS could constitute a viable path towards innovation-based competitiveness and growth in these countries.

The objective of this paper is to shed light on the occurrence and importance of LKS in a developing country cluster in Uruguay. The focus has been on the software industry, as an example of a knowledge-intensive industry, in which it is likely that LKS play an important role. The research is based on a field survey among 98 software firms in Montevideo, of which 97 could be used in the analysis. We first classify LKS into different types. We then trace the mechanisms by which they travel from their sources to their recipients. This results in a detailed typology of local knowledge spillovers as they occur in a particular locality.

Earlier studies in economically advanced countries have shown that LKS can take place in several different ways. For example, they can come about through local labour mobility or by means of local firm spin-offs, in addition to various interactions between staff of different local firms (Breschi and Lissoni, 2001; Saxenian, 1994, Zucker et al., 1998). However, case study evidence (e.g., Schmitz, 1999) suggest that the latter, informal interactions between people employed in local firms, is the leading mechanism through which knowledge spills over within a cluster. Therefore, the focus of this study will be limited to knowledge spillovers that arise from inter-actor interactions. It will not delve into knowledge flows induced by labour mobility or spin-offs.

In Section 2 we address some theoretical insights and concepts used in the study. In Section 3 we elaborate the survey methodology adopted in the research and we briefly introduce the software cluster in Montevideo. In Section 4 we shed light on the mechanisms via which knowledge spillovers take place in that cluster. In Section 5 we address whether different types of knowledge flow are related with specific sources of knowledge. Section 6 contains conclusions and identifies issues for further research.

2. Local Knowledge Spillovers: Theory, concepts and measurement

In the early 1920s Alfred Marshall noticed the resonant diffusion of knowledge within industrial districts, observing that “the mysteries of the trade become no mysteries, but are as it were in the air” (Marshall, 1920, p. 225). Over time, this observation has given rise to a debate on a new set of issues relating to the occurrence of LKS and its significance for innovation. But, what exactly is meant by LKS?

Economists define knowledge spillovers as positive technological externalities, which derive from the inability of actor A to retain the economic returns of its innovative activity. As a consequence, actor B can take advantage of the new knowledge directly and without compensating actor A. Such knowledge spillovers are generated completely spontaneously without intent (Griliches 1979). They arise because it is difficult (sometimes impossible) to prevent others from enjoying the benefits of the use of such knowledge (Arrow, 1962). One of the main arguments for the occurrence of this pure type of knowledge spillovers is the existence of public knowledge (Meade, 1952). Public knowledge is non-rival and non-excludable in consumption. Thus, one may expect that actors that generate public knowledge, including universities and research institutes but also institutions such as conferences, are especially important as sources of these kinds of knowledge spillovers.

Recently, scholars in the field of innovation management have suggested that knowledge spillovers may also be generated through intentional behaviour. This kind of spillover is called a voluntary information spillover by Harhoff et al. (2003, p. 1767). These authors provide several case studies in which actors choose to reveal their innovations to the world rather than to keep them secret. The main idea is that "in a world of self-interested agents with complementary capabilities, free revealing can be profitable" (Harhoff et al., 2003, p. 1767). Informal knowledge sharing among firms in the same business activity has also been discussed by Allen (1983) and Von Hippel (1986). Allen (1983) wrote about a process he called "collective invention". During the nineteenth century in the district of Cleveland in England, firms in the steel and iron industry carried out incremental innovations that resulted in more efficient production. This was aided by firms in the Cleveland district freely sharing information about new

techniques and designs. The channels for the diffusion of information were mainly informal disclosure of information, publications, and conferences. Nuvolari (2004) identifies a similar process of collective invention in the Cornish mining district from 1813 until 1852. The most notable contemporary example of the intentional free sharing of knowledge is found in the case of open source software. In this system, the development of a software product is a collective work of many professionals who are not financially compensated for their contribution. Their main motivation is innovation for its own sake, and the subsequent benefits it brings in terms of reputation, professional success, image (Von Hippel and Von Krogh, 2003). The main idea of these findings is that individuals or enterprises frequently choose to share knowledge freely and widely, bypassing market mechanisms.

A more limited form of free revealing is discussed by Von Hippel (1986) for the steel mini-mill industry in United States. Here, competitive firms engaged in informal know-how trading. Know-how trading takes place between just a few specific parties, in contrast to generalised free revealing that involves parties that may even be unknown to each other. Know-how trading is also different from free revealing à la Linux in the sense that it is based on reciprocity. Thus, such knowledge sharing has elements of a market transaction in it. A similar phenomenon has been noted in the literature about industrial clusters in developing countries. Humphrey and Schmitz (1998) and Nadvi (1996) have emphasised that inter-firm co-operation, based on trust, enables clustered firms to capture economies of scale and knowledge externalities. Schmitz (1999) introduced the concept of 'active collective efficiency', which refers to competitive benefits arising from intentional co-operative joint action. One can also learn from that literature, that collaborative know-how trading takes place predominantly between parties at different stages in a production chain, and between production firms and support institutes. In comparison, horizontal linkages of this type are fairly limited (Schmitz, 1999).

However, free revealing of knowledge can also occur as part of market transactions. This is especially evident in the capital goods sector. The sale of a complex capital good is usually not restricted to a one-off market transaction, but tends to necessitate intensive user-producer interaction to adjust the equipment to the user's requirements and user-environment (Lundvall, 1988; Fransman, 1985). While the relationship begins as a formal transaction between market parties, further collaboration among these parties generates knowledge externalities.

Of course, knowledge transactions that don't give rise to associated spillovers also exist. In particular, firms commonly purchase knowledge services and products from parties like consultants and specialised suppliers, who would be fully rewarded for the value of their inputs. This type of knowledge is purely private. Knowledge transfer through purchase of equipment may enhance the efficiency of the user firm, and may also stimulate imitation through reverse engineering (Dahlman et al., 1987).

Thus, the literature indicates that the nature of the contact between the source of knowledge and its recipient can take different forms. Broadly, one can arrange them on a continuum running from pure spillovers of knowledge on the one extreme, to pure knowledge transactions on the other extreme (Figure 1). Whereas the former concept refers to completely spontaneous circulation of knowledge outside the market, the latter consists of pure market transactions resulting from deliberate actions. In between these extremes are various categories that have characteristics of both to greater or lesser

extent. Thus, when one wants to study LKS adequately, one has to take into account the whole spectrum. To this end, we introduce the concept of 'knowledge flows' which covers this whole range.

INSERT FIGURE 1 ABOUT HERE

INSERT TABLE 1 ABOUT HERE

Table 1 indicates that we have subdivided the spectrum into four more or less distinct categories of knowledge flow. The main distinction is between local knowledge spillovers and local knowledge transactions. This distinction follows the observation by Storper (1995, 1997) and Tödtling and Trippl (2005) that regions or clusters generate so-called traded and untraded interdependencies. Local knowledge spillovers can be further subdivided into pure knowledge spillovers and quasi knowledge spillovers. Under pure knowledge spillovers we group all spontaneous and intentional free revealing of knowledge without demands for reciprocity, and which arise from informal and direct (i.e. outside the market) interaction. Under quasi knowledge spillovers we group all spillovers that originate from knowledge sharing based on (expected) reciprocity, such as would occur in collaborations between firms and their suppliers and customers.

Local knowledge transactions has also been subdivided into two sub-categories. Quasi knowledge transactions refer to those situations in which a market relationship extends beyond the transaction as such, encompassing an informal and free transfer of associated knowledge between the actors involved. These market transactions thus serve as a vehicle for externalities. Pure knowledge transactions refer to relations that terminate after the purchase of a good or service, and in which the price fully covers the value of the knowledge that is transferred.

Table 1 summarises the above discussion. It indicates that different categories of knowledge flows emanate from different types of knowledge sources. Pure spillovers are associated (although not exclusively) with bodies that generate public knowledge. In contrast, pure market transactions tend to originate from private-sector knowledge providers. The other categories lie in between these two extremes, and thus embody elements of both. Thus, we may expect such spillovers to emanate from a variety of sources, including both public and private actors.

3. Methodology and description of the cluster

Following Simmie (2003), we used a social survey method for collecting new primary data that would allow detailed insight into the importance of the various types of knowledge flows discussed above, and their various sources. These primary data were collected by means of interviews in 98 software firms in Montevideo, in Uruguay during 2004. The cluster has been successfully integrated in the global market since the 1990s by providing innovative products. In the interviews we tried to identify the range of different knowledge inputs received by the firms, and the sources from where these emanated, both within the cluster as well as outside it. For the purpose of this paper, the focus is limited to the intra-cluster knowledge sources.

The information technology industry in Uruguay consists of four large sub-sectors: (1) software development, (2) consultancy and services, (3) internet and data

transmission and (4) hardware and sales. Since LKS are predominantly present in knowledge intensive sectors (Audretsch and Feldman 1996b) our research concentrated on the two most knowledge intensive sub-sectors of software development and consultancy services, consisting of an estimated 149 firms excluding 1,600 one-person companies (Stolovich, 2003). We obtained an accurate list of these firms from the Uruguayan Chamber of Information Technologies (CUTI). After verifying the accuracy of this list through direct contact with the companies, several were deleted on account of not carrying out the relevant business activities, while several new others, discovered through the local telephone guide, were added to the list. During an initial reconnaissance round, firms also mentioned names of other potentially eligible firms for our survey. This brought the total listed population of firms that develop software and provide consultancy in the Montevideo area to 150.

These 150 firms were approached and asked to participate in the actual survey. Eventually, 98 firms were willing to take part in the survey, of which 97 provided full information. This represents a 65 per cent response rate. This sample includes all the important and biggest software developing and consulting firms in the cluster. The non-participating firms consisted mostly of very small ventures. We administered a structured questionnaire by means of face-to-face interviews with the director or/and the chief engineer of the R&D department in each of the sample companies. The design of the questions was partly based on the EU Community Innovation Survey, with suitable elaborations and adjustments to be able to capture the rich variety of knowledge flows.

The great majority of the firms in the cluster started their operations during the 1990s. In Latin America this period was characterised by a large demand for software products. Due to the presence of well-qualified professionals skilled in diverse fields like informatics, finance, and accountancy, Uruguay was well placed to take advantage of this situation. People with different skills found each other to set up joint software businesses in order to fulfil the increasing local and Latin American demand for enterprise resource planning (ERP) products. These mostly small and medium-sized firms had detailed technological knowledge as well as knowledge of a specific market, or application knowledge, for example in areas like banking and finance, education, health, and construction. Sometimes these might consist of standard products, but they still require highly specific assistance in the form of installation and training. The key to success in supplying this market lies in having hybrid knowledge of informatics on the one hand, and specialised knowledge of specific user-sectors on the other hand. Innovations are usually application-based and tailor made, i.e. satisfying a new need of the customer, while at the same time incorporating new technical trends in informatics in new releases.

During the early 1990s, most firms were developing custom-made software products, often sponsored by their customers. After satisfactory delivery, the product would be sold to other customers as well, on the recommendation of the initial customer. This situation has since changed dramatically; there is a well-developed market and fierce competition among suppliers. A large number of firms create standardised products with multiple applications, while another group of firms has evolved which offers specialised consultancy services. A third group which combines these two activities also still continues to exist. Some basic descriptive characteristics of the sample firms is given in Table 2.

INSERT TABLE 2 ABOUT HERE

4. Pure Knowledge Spillovers in the Montevideo cluster

As mentioned in section 2, knowledge spillovers may occur spontaneously but also intentionally, and they may even come along with market transactions. Thus, in order to unravel local knowledge spillovers, it is important to examine a broader range of knowledge flows, also including flows arising from market transactions. In this and the next three sections we will discuss the findings from the fieldwork pertaining to the four types of knowledge flow listed in Figure 1. For each of the entries in Table 1, we discuss the evidence of its occurrence and importance in the Montevideo cluster, tracing the sources from which the knowledge flows emanate, and the specific mechanisms that were used to get the knowledge from source to receiver. Our analysis in this section is based on qualitative information supplied by the sample firms.

We first examine the occasions in which pure knowledge spillovers occur in our case study and which parties are involved. Moreover, we show the reasons that induce firms to utilize different LKS mechanisms. We structure the discussion using the entries in Table 1, namely: (i) horizontal interactions of the sample firms with other software firms; (ii) interactions with universities and research institutes, and (iii) interactions at exhibitions and conferences.

4.1 Horizontal interactions among software firms

As far as the horizontal interactions are concerned, we observed purely informal interactions among employees of different software firms within the cluster. Informal relations of this type serve various purposes. Firstly, firms' employees initiate and maintain personal contacts with employees from other firms for networking purposes. These relations usually develop among ex-colleagues, professional friends and ex-classmates. The purpose of these contacts is to acquire information regarding the technological or commercial aspects of the software sector. In view of the dynamism of the sector, it is important for competitiveness to regularly access up-to-date information regarding new technologies. In addition, firms network to maintain good relations and develop new contacts that eventually may facilitate their efforts to commercialise their products. For instance, the chief engineer of a local software firm states that "… we communicate informally with other software firms on a permanent basis. Usually these are personal contacts with ex-colleagues, professional friends, people that have studied together, other firms that use the same technology, and friends that work in the university. Through this network we exchange technical and commercial information, which is very important for problem solving and for entering new markets".

In sum, informal exchanges of knowledge take place between colleagues working for various firms in Montevideo and are based on personal contacts. The director/partner of a local software firm claims: "We exchange ideas constantly with colleagues and professionals with whom we have a personal relation. We share information regarding the composition of new technologies and of how to solve precise problems that occur. We consult each other for solving these problems". The president of another local software firm acknowledges: "My engineers are exchanging knowledge with employees of other firms on a daily basis. Usually, they talk and share experiences with employees

of friendly firms. However, I cannot stop them from sharing information with employees of competitor firms".

A second mechanism of horizontal inter-firm interactions are user-communities along the lines discussed by Harhoff et al. (2003) and Von Hippel (2003). Firms that use the same technology often communicate informally amongst themselves in order to exchange information to avoid pitfalls and make the most efficient use of the technology at their disposal. Firms create communities in which they exchange, via e-mail, phone calls and direct contacts, their experiences with using any aspect of a specific technology. In the words of the director of a local software firm, "the general director has an excellent communication with firms that use the same technology; this enables us to solve problems fast".

In Montevideo, a unique user-community was formed among the majority of the local software firms around a locally-based supplier (Artech) of a leading platform technology (Genexus). Many software development firms use Genexus to develop a variety of software solutions. Knowledge spills over among the Genexus-using firms which facilitates problem-solving and innovation.

4.2 Interactions with universities and research institutes

With regard to interactions with universities and research institutes, we observed that the software firms access technological *know-why* related knowledge from these actors through various collaborations. Firms in the software cluster in Montevideo have two main reasons for creating links with a university and/or a research institute and cultivating these contacts. The first reason is the possibility to conduct tests for complex software products whose robustness, compatibility, quality and functionality needs to be ascertained. Testing is an essential way to receive feedback on product innovation, and thus serves as an important mechanism for the acquisition of knowledge and learning. The testing sites serve as meeting points where knowledge and ideas flow informally and spontaneously. For example, the Centre for Software Testing (CES) that was established in Montevideo in 2004 serves this purpose.

The second reason why software firms cultivate links with universities and research institutes is because they acquire research inputs from them. This helps to mitigate high risks and speed up development in time-consuming processes. A good illustration of how this mechanism works is provided by the director of a local software firm, who clarified how his firm interacted with the local university and how this gave rise to local knowledge spillovers:

> "We have worked together with the faculty of engineering of the University of the Republic. At one point in the development of our product, we came across a problem that we did not know how to solve. We had a contact in the university and we designed a BSc thesis based on this problem. Three students undertook the challenge and I worked as an external tutor with them. Finally, the students came up with a solution. This solution as such could not be applied. However, their work generated methodological knowledge on how to tackle the problem. This allowed us to create a new component for our product. The interactions between my firm and the university were informal and based on mutual benefit".

The business partner of the above director adds that "… we have informal relations with most of the local universities. Often, we work together in research through the research projects of students. Moreover, we talk with university professors and exchange ideas". These statements illustrate that knowledge flows informally and directly between the firms and the local universities in Montevideo's software cluster.

4.3 Interactions at exhibitions and conferences

Most of the firms recognise the importance of exhibitions, which serve many purposes. Usually, they are the place where firms have the opportunity to make new contacts, become aware of new technologies and practice espionage. Some exhibitions are free of charge, others require the payment of an entrance fee. Even in the latter case, one could say that knowledge spillovers flourish, since the participation fee is just a minimal payment in exchange for technological knowledge and for personal contacts. For example, the manager of a local software firm tells us "you usually pay a fee to participate in an exhibition or a conference, but you get lots of informal knowledge in return".

The director of another firm explains the role of exhibitions and the way in which these are used to acquire knowledge: "We go usually to two big trade fairs in USA and Europe and three or four in Montevideo every year. We sometimes conduct mysterious shopping there: we visit our competitors and we take ideas from them, and of course we collect all the brochures. At the exhibitions we identify the leading competitors and subsequently we regularly follow up by checking what they do through internet".

5. *Quasi* Knowledge Spillovers in the Montevideo cluster

Although some collaborative relations between firms begin formally, they ultimately espouse an informality that flourishes mainly on the basis of trust. Trust depends on reputation, which in the software cluster in Uruguay is based on firm performance, rather than social status. The main reason for this is that from its genesis, the cluster has been export-oriented, facing severe competition and pressure from international players. In this context, relations with other enterprises are influenced less by the local identity of firms than by their actual performance. We found evidence of three types of informal trust-based collaboration that give rise to quasi knowledge spillovers:

5.1 Vertical interactions -- backward linkages

Software firms in Montevideo develop close relations with their suppliers. The latter constitute the main providers of technological progress for software firms. One local firm (Artech) and two multinational companies (IBM and Microsoft) constitute the main local suppliers of tools and knowledge. Informal sharing of know-how is the main mechanism by which knowledge is transferred from suppliers to local firms. Suppliers share their knowledge with local software firms for two main reasons. Firstly, suppliers such as Artech use local software firms as B-testers. Selected software firms test the technological tools, detect errors and offer ideas for further improvement. For example, the marketing manager of a software firm within the Montevideo cluster claims why the co-operation that his firm has established with Artech is informal: "Genexus, a tool developed by Artech, is the most innovative technology at this moment in Uruguay, and

we can use it freely. We were the second software firm that started using it. Ever since, our firm has been the biggest B-tester of Genexus, helping Artech with error detection. There is no contract or money involved in this collaboration because both partners get something out of it, and it is based on trust. Our employees are talking and exchanging ideas on a daily basis with the employees of Artech, which is located next door. Face-to-face informal communication with the employees of Artech constitutes one of the most important ways of acquisition of technological knowledge and learning from one of the most successful companies in the cluster".

Secondly, suppliers of application platforms such as Microsoft are interested in entering specific application markets such as finance and telecommunications. They achieve this through close trust-based collaboration with software firms. Thus, when a software firm sells its products (which are developed using Microsoft) then Microsoft automatically increases its sales as well. For instance, the director/engineer of a local firm explains the nature of his dealings with a TNC. "The interactions with the TNC do not involve monetary transactions. The TNC provides most of the licences for their products free of charge, as they want us to use their products. TNCs like Oracle, IBM and Microsoft compete for market share, so they provide their products for free to the software firms".

5.2 Vertical interactions -- forward linkages

Local software firms commonly form commercial collaborations with distributors, 'Socios de negocio', who implement their software and offer consultancy services. These distributors are business partners who commercialise software products on behalf of developers. They integrate software products into the systems of customers and tailor them to their needs. In other words, these firms sell, install, maintain and offer training to the final customer. Tying up with distributors serves two purposes. Firstly, software firms can focus on a specific business strategy and leave the marketing and commercialisation to another firm. Secondly, this is a path that many software firms have followed in order to enter foreign markets. The strategy begins by identifying software firms specialising in services in growing markets. The second step is to demonstrate the product and its credentials and to allow the potential user firm to try it. If the potential user firm likes the product, the software firm continues to offer the new versions and training for free, in order to enable the user firm to understand the full capacity of the program. From this point onwards, the software firm takes the role of the provider of free technology, and the distributing firm takes the role of receiving this technology, learning how to use it, promoting it and eventually selling it.

Generally, we would expect this type of relationship to involve contracts and sales. However, our fieldwork results indicate that many of these collaborations are informal and based on trust. According to the director of a local software firm, "we have a commercial collaboration with a firm in Ecuador. This firm has in-depth knowledge and they use our tool in their work. They sell our tool to their customers. It is an indirect way of selling. Through this co-operation we acquire information about the specific requirements of the customers, and we proceed by adapting the product to the need of the market".

Similar arrangements exist with local software-distributing firms. In that case, these firms offer consulting services to the final customer. These distributors provide feedback

about their customers to the software development firms, which facilitates the incremental improvement of software.

5.3 Interactions with support institutes

The Montevideo software cluster exhibits institutional relations that are multilateral agreements of actors with common aims. There are two main institutions that are active locally, CUTI and Integro. CUTI functions as a link between the software firms and national and multinational funding organisations. In addition, CUTI organises trade fairs and exhibitions in order to promote Uruguayan software abroad and to improve the image of the country as a technology centre. Integro, on the other hand, represents the effort of local firms to share costs and acquire training in relation to quality certifications and marketing strategies for exports.

The director of a local software firm that actively participates in CUTI explains its role: "CUTI is a political actor that gains its relevance above the needs of every single firm. CUTI is the interlocutor which searches, and connects the different political segments nationally. In addition, the CUTI puts strategic goals above the individual goals of the firms. The concept of the mission of CUTI is to take overall action that the firms cannot take individually. The benefits of these actions will be seen in two or three years. However most of the firms in Montevideo do not perceive the role of CUTI in the same way. They fail to see the importance of CUTI for the development of the software business".

Integro is perceived to be more significant for knowledge spillovers between the software firms in the cluster. The director of a local software firm explains the reasons for its participation in Integro: “Integro is an alliance which enables us to better commercialise our product abroad. In addition, we receive training in marketing, sales and negotiation all together. It is our intention to work together to achieve synergy". This opinion is supported by the directors of several other firms. For example, the director of another software firm elucidates the activities of Integro:

> "Eight companies that participate in the Integro group decided to undertake the CMMI (Capability Maturity Model Integration) project together. CMMI evaluates the quality of the process by which each firm produces software. It is difficult for a small firm to go through such a process due to financial and time constrains on its own. Co-operation generates synergies in terms of access to credit and sharing of experiences. Firstly, firms may gain easier access to finance because they provide guarantees to one another. Secondly, they exchange new knowledge and experiences. There are no earlier experiences with CMMI in Uruguay, so there is no local benchmark against which firms can assess how they are doing. Being part of a group of firms that follow the same trajectory is important because it enables us to compare experiences, avoid reappearance of mistakes and promotes the application of best practice, etc".

5.4 Horizontal interactions -- technological collaborations

Firms also frequently develop informal relations with fellow software enterprises in order to undertake big projects together and to overcome the size problems they are facing. This networking takes the form of technological alliances. The director of an Uruguayan software firm states: "For a small firm, the network of personal contacts with other actors

of the software market is crucial and more important than the formal relations. For example, we undertook our most recent project for a medical lab together with another software firm. If you have an informal network of contacts, it is easier to form a formal alliance when you need it". Similarly, another local software firm observes: "We undertake large projects with other software firms. There is not a written formal contract which governs these collaborations. There is a spoken agreement based on trust."

6. Quasi Knowledge Transactions in the Montevideo cluster

Quasi knowledge transactions refer to the acquisition of knowledge through the extension of relationships which are based on market transaction. In the Montevideo software cluster, these types of flows were found to occur in the interaction between software developing firms and their customers.

6.1 Interactions with customers

Customers have contributed a lot to the emergence of software firms in the Montevideo cluster. In particular, they have provided the financial capital for the research and development of the first product of many of these firms. Capital markets are highly imperfect in most developing countries. Moreover, the financial market of Uruguay weakened as a result of the Argentinean crisis of 2001. The bulk of the software firms started off by providing a software development service to a specific large customer in need of automating its production or distribution systems, or its human resource management. According to the director of a local software firm "the first client had the role of a godfather; he financed our first project which implies that he carried the financial risk and gave us time to learn".

Customers bring application know-how with respect to specific lines of business (finance, health, education, etc.). They transfer this know-how to the software firms initially by setting the requirements for the product and subsequently by giving feedback concerning its performance, reporting problems and/or expressing the need for additional functions. There is no financial compensation on the part of the software firms for the knowledge they gain as a result of the interaction with the customers. However, the relationship between customer and the software firm is primarily a market relationship. The free transfer of knowledge is a by-product of this relationship. As a result, the know-how gains acquired by a software firm depend on the success of this market relationship. In particular, two features of the relation are crucial: the capabilities of the customer and the type of interaction.

Research about the software industry has shown that innovative customers are the most important as sources of knowledge for software firms (Veloso et al., 2003). They are responsible for establishing the problem, calling for a solution and providing feedback. In the words of the director of a local software firm "customers are faced with practical problems; their knowledge concerns the definition of the problem. Then we proceed by searching the solution". The more innovative a customer, the more sophisticated products he will demand from his suppliers. Software firms that provide products to innovative sectors (banking, telecommunications, etc.) are stimulated more than firms that provide products to sectors that are less technologically dynamic (timber industry, construction industry, etc.). The director of a local software firm illustrates this well: "We created a software product for the timber industry but it was not successful.

We tried to improve it and sell it to other customers without any success. The problem derives form the fact that the timber industry does not invest in information technology in general, particularly in Uruguay. It represents a niche market that we managed to enter, but it is not an innovative sector."

The feedback coming from customers, in the form of additional requirements or the discovery of defects, has enabled the firms in Montevideo to 'learn-by-interacting' Lundvall, 1988). The director of a local software firm claims: "Face-to-face communication with the customer enables us to detect the problem in reality". This is very important, because it allows firms to monitor the needs of the market. Finally, problem-solving activities are more successful when a good definition of the problem is provided by a customer.

7. Pure Knowledge Transactions in the Montevideo cluster

Knowledge flows involving pure market transactions are of two types: the purchasing of *knowledge services* from specialists (i.e. consultants), and the purchasing of *knowledge products* (equipment- or machinery-embodied technology) from suppliers.

7.1 Purchase of knowledge services from consultants

Consultants can complement the knowledge base of the firm by providing information about the way in which software is to be applied in specific business fields. This knowledge is tacit in nature and embedded in humans because it concerns the application of specific knowledge in a local business context. This point is illustrated by a transnational company that attempted to enter the Uruguayan market. The firm initially faced many difficulties in understanding the Latin American market, despite its international experience. It became essential for this firm to gain a sound understanding of local application sectors. As the president of the Uruguayan branch explains: "Ten percent of our innovative projects failed because we could not understand the local business culture. Even though this company has 35 years experience, we could not comprehend the needs of the local customers." In the end the firm acquired this type of knowledge by using the services of local consultants. This type of knowledge is vital, especially for software firms that provide services and/or customised products to a broad spectrum of application sectors.

7.2 Purchase of knowledge products from suppliers

Software firms also buy knowledge from suppliers through commercial contracts. The latter usually sell technological knowledge in the form of artefacts that incorporate scientific principles. The relationship between software firms and their equipment suppliers is formal, based on licenses or formal partner contracts.

8. Quantitative importance of different types of knowledge flow

The foregoing analysis provided in-depth insight into the different mechanisms by which the sample firms tapped into their local knowledge base. The purpose of this section is to provide some insight into the relative and absolute importance of these different types of knowledge flow discussed above, according to the responses given by the sample firms. For each mechanism of knowledge flow, Figure 2 ranks the number of sample firms that reported to utilise it.

The most-used knowledge flow is a quasi knowledge transaction associated with interaction with customers. No less than 85 out of 97 firms (87.6% of the total number of firms) reportedly benefited from this knowledge flow mechanism. Additional interactions with customers take the form of quasi knowledge spillovers. These are found under the heading of backward and forward linkages, mentioned by 55 firms (56.7%). The second-most important type consists of flows emanating from visiting exhibitions and conferences, mentioned by 66 firms (68.0%). These take two distinct forms - pure knowledge spillovers (in the case of free events) and quasi knowledge transactions (in the case of fee-paying events). A third important type consists of collaborative relations with actors at the same stage of the value chain, which are reported by 54 firms (55.7%). These relations consist entirely of pure and quasi knowledge spillovers. The least-used knowledge links in the sample concern the quasi knowledge spillovers arising from interactions with support institutes, which is used by just 19 firms (19.6%), and linkages with universities and research institutes, which are pure knowledge spillovers used by 20 firms (20.6%). This is a common pattern in developing countries, where the great majority of firms -especially small and medium ones- are not in contact with the state, universities or collective organisations. The two remaining knowledge mechanisms listed in the figure are of intermediate importance. They emanate from pure knowledge transactions with consultants (25.8%) and equipment suppliers (40.2%).

INSERT FIGURE 2 ABOUT HERE

Figure 3 shows average importance scores for the relationships presented in Figure 2. Each firm was asked to rate the importance of each local knowledge link for its innovation processes on a scale ranging from 0 to 4. Score 0 indicates that a firm does not use a particular mechanism; score 1 signifies "limited importance"; score 2 represents "somewhat important", while score 3 represents "important" and score 4 "crucial". Figure 3 shows that only one category has an average value above the mid-point in the scale (2), namely local quasi knowledge transactions with customers. With a rating of 3.4, this knowledge flow category is by far the most important mechanism for the innovation processes undertaken by the firms. In fact, it is the only truly important category. The scores assigned to the other categories are all below 2, with the forward and backward linkages and horizontal interactions with other firms attracting the highest scores (1.8 and 1.6, respectively). The highest average ranking for interactions involving efforts by public, collective and other non-profit sector-promoting institutions is a mere 1.1 for fee-paying conferences. In this respect, the Montevideo software cluster is still no different from other developing country clusters, which tend to be characterised by tenuous and ill-developed linkages with promoting organisations and weak regional innovation systems in general (Arocena and Sutz, 2001).

The overall picture emerging from Figure 3 is one in which local quasi transaction-based flows are the dominant knowledge transfer mechanism, more important than local knowledge spillovers. We conclude that geographical proximity clearly matters, but the idea that all the crucial knowledge is "in the air" in the way that Marshall (1920) suggested and many others have adopted, is not clearly confirmed by our findings. Local knowledge acquisition for innovation is more strongly bound up with local market transactions.

INSERT FIGURE 3 ABOUT HERE

9. Conclusions

The empirical material presented in this paper supports the idea that firms in the software cluster in Montevideo utilise a whole range of different knowledge flows for their innovation process. Only some of these can be adequately described by the conventional economic concept of pure local knowledge spillovers -- free unintentional knowledge flows that are in Marshall's words, "in the air". We were able to show a much richer picture by adopting a framework that includes additional categories of knowledge flow involving some degree of intention and/or transaction-based elements, drawing together insights from a variety of studies which have already provided some scattered evidence of the existence of these different types of knowledge flows.

By combining these insights into a coherent framework, and applying it to an empirical case, we are able to establish evidence of knowledge flows involving pure spontaneous spillovers, quasi spillovers that require some purposive knowledge-sharing action, quasi market transactions, and pure market transactions. Moreover, we were able to identify the role played by different actors in the local innovation system in bringing about these different types of knowledge flow. We were also able to give some indication of the relative importance of each category, based on a survey-based assessment by 97 entrepreneurs.

Our results indicate that pure knowledge spillovers mechanisms, which have often been singled out in the economics literature on the subject, are only a subset of a much larger array of local mechanisms used by clustered firms to augment their internal innovation activities. In fact, the single-most important mechanism found in the Montevideo software cluster consists of quasi knowledge *transactions* with customers.

One limitation of our research is that our field data were confined to one (albeit important) category of spillovers, namely spillovers through interaction of the sample firms with other parties in the local innovation system. Spillovers may also occur through labour market mobility and firm spin-offs. Taking these mechanisms into account could lead to an even more complex and complete view of how knowledge flows occur in clusters, and how they affect innovation.

A second limitation of our study concerns the generalisability of our findings, which pertain to one developing-country cluster and are also bound to reflect local, national and sectoral conditions. For example, the survey data indicate that customers are the principal source of knowledge for innovation in the Montevideo cluster. It is true that this result is in line with findings from earlier literature regarding the key role of customers in software sector innovation (Pavitt, 1984; Veloso et al. 2003; Malerba, 2005) in other countries as well, including more developed ones. This findings suggests that there could be important sectoral similarities in clusters across countries world wide. More research needs to be undertaken to establish whether similar or different patterns hold in other sectors of economic activity.

Moreover, the similarity in findings from our study and existing literature - which pertains to more developed countries - raises the question to what extent our findings reflect typical conditions in developing countries, or are part of a much more world-wide model that has not yet emerged due to lack of detailed firm-level research. Our study

should be seen as a first attempt to identify possible patterns for less developed countries. Thus, more research at firm level is needed, both in developing and developed countries, in order to establish whether our findings are part of a more general picture, and to what extent this picture is similar across countries at different stages of development.

In view of the questions about generalisability, it would be presumptuous to try to draw out detailed policy implications from our work, beyond some cautious pointers for the specific cluster under investigation. The findings do point towards the relevance of cluster-based policies to promote innovation in a less developed country context. They also point to the importance of knowledge flows caused by intentional behaviour, and at the same time point up the limited importance of support bodies such as universities, research institutes, and conferences. This points to possibilities for improvement of linking the knowledge needs of firms, and the role played by support institutions in meeting these needs. This suggests that gains could be made by increasing the effectiveness of their knowledge distribution function, and by making sure that the knowledge which is being offered is relevant to the firms. Another activity which is likely to have a high pay-off is the stimulation of inter-firm collaborations for innovation, for example through financing joint research and development.

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Figure 1: Conceptual framework

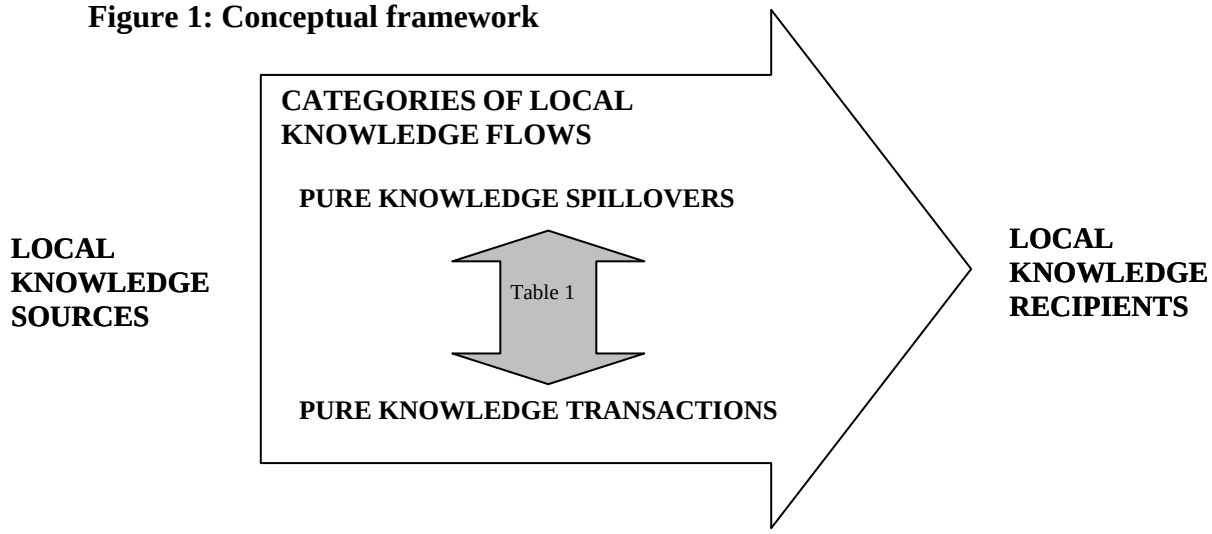
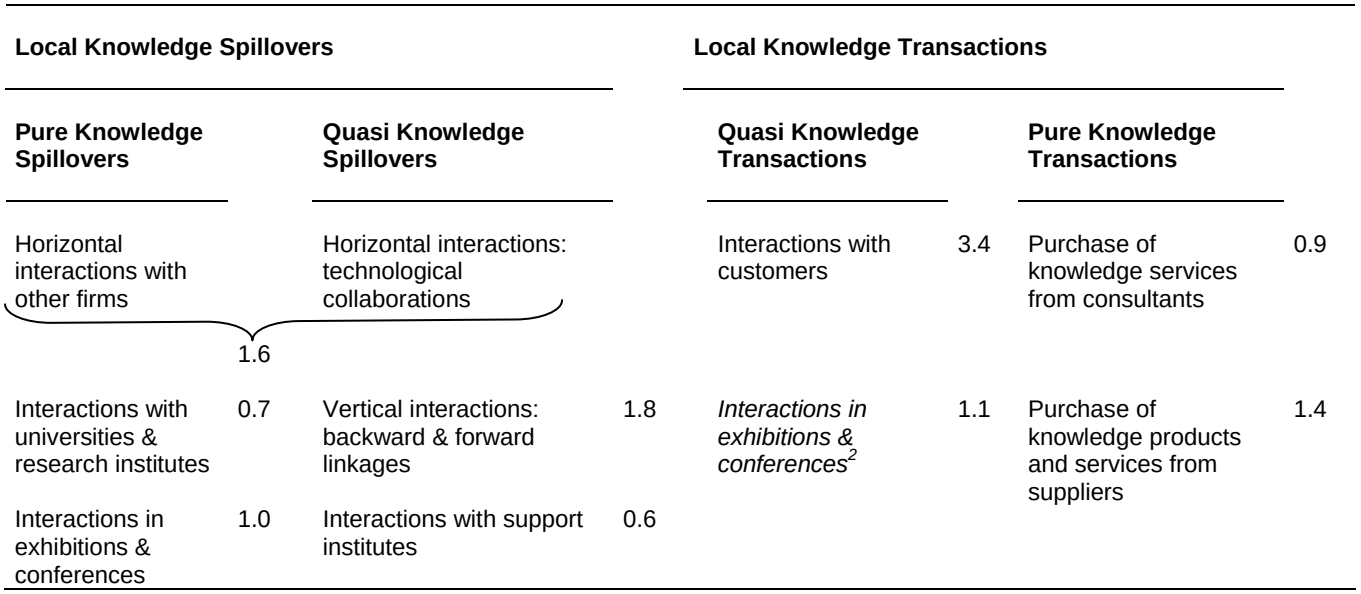


Figure 2: Number of firms benefiting from different local knowledge flows[1]

Local Knowledge Spillovers				Local Knowledge Transactions			
Pure Knowledge Spillovers		**Quasi Knowledge Spillovers**		**Quasi Knowledge Transactions**		**Pure Knowledge Transactions**	
Horizontal interactions with other firms	54	Horizontal interactions: technological collaborations		Interactions with customers	85	Purchase of knowledge services from consultants	25
Interactions with universities & research institutes	20	Vertical interactions: backward & forward linkages	55	*Interactions in exhibitions & conferences*[2]	36	Purchase of knowledge products and services from suppliers	39
Interactions in exhibitions & conferences	30	Interactions with support institutes	19				

Note 1: To construct this figure, we have given the value of 1 if a local source of knowledge is used by a firm (irrespective of its importance), and 0 if the source is not used.
Note 2: The "Interactions in exhibitions and conferences" under Quasi Knowledge Transactions were added as a separate category, distinct from the same type of interactions under Pure Knowledge Spillovers, because they were reported quite often. No such distinction was made in the text in the preceding sections.

Figure 3: Importance attached to different local knowledge flows by the sample firms[1]



Note 1: Firms were asked to rank the importance of each mechanism of local knowledge flow on a scale ranging from 0 (unimportant) to 4 (crucial). The figures in the figure represent the average rankings per knowledge flow.
Note 2: See note 2 under Figure 2.

Table 1: Classification of local knowledge flows

Local Knowledge Spillovers "Untraded interdependencies" (Storper, 1995, 1997; Tödtling and Trippl, 2005)		**Local Knowledge Transactions**	
Pure Knowledge Spillovers (Griliches, 1979; Harhoff et al., 2003; Allen, 1983)	**Quasi Knowledge Spillovers** (Von Hippel, 1986; Schmitz, 1999; Humphrey and Schmitz, 1998)	**Quasi Knowledge Transactions** (Lundvall, 1988; Fransman, 1985)	**Pure Knowledge Transactions**
Horizontal interactions with other firms	Vertical interactions: backward linkages	Interactions with customers	Purchase of knowledge services from consultants
Interactions with universities & research institutes	Vertical interactions: forward linkages		Purchase of knowledge products and services from suppliers
Interactions in exhibitions & conferences	Interactions with support institutes		
	Horizontal interactions: technological collaborations		

Table 2: Key descriptive characteristics of the sample

Characteristics	Firms	Employees		Sales		Exports	
	Number	Average number	%	Average sales in US dollars (000)	%	Average sales in US dollars (000)	%
Principal activity of the firm							
Software Development	47	19	38	2 186	58	785	47
Consultancy and Services	19	45	37	3 070	33	1 939	48
Both (Soft. Dev. & Consult.)	26	18	20	435	6	74	3
Other related business activity	5	21	5	967	3	640	4
Type of firm							
National	73	15	47	1 155	61	355	33
Domestic multinational	20	44	38	1 852	21	1 059	27
Foreign multinational	3	113	15	10 900	19	10 580	40
Non-profit organisation	1	7	1	N.A.	N.A.		0
Year firm started							
< 1970	4	40	7	3 517	8	975	5
1971 - 1980	6	77	20	2 691	9	2 032	15
1981 - 1990	28	24	28	3 475	55	971	35
1991 - 1999	41	15	27	428	10	95	5
2000 - 2004	18	23	18	1 784	18	1 759	40
Size of the firm in employees							
1 - 10	50	6	12	115	3	15	1
11 - 49	35	25	38	2 629	52	578	26
50 - 250	10	67	29	4 140	23	2 290	28
> 251	2	256	22	19 000	22	17 800	45
Total	97		100		100		100

Source: Kesidou (2007)