KNOWLEDGE SPILLOVER AND INNOVATION IN TECHNOLOGICAL CLUSTERS

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Abstract: Knowledge spillovers have been used to explain the increased rate of innovation that is found in technological clusters. The last two decades have seen an increasing interest by researchers trying to capture and measure the effects of these spillovers. However, very little is known about the mechanisms of knowledge exchange that take place in clusters. In this paper we draw on the current body of knowledge and use the concepts of tacit and explicit knowledge to understand how knowledge spillovers actually take place. We present a conceptual model of knowledge accessibility as a mean for knowledge transfer, and we distinguish between knowledge transfer and knowledge spillover based on the knowledge holder's intention or lack of it to exchange such knowledge. We then review how tacit knowledge is being accessed in technological clusters and how it affects knowledge creation.

Keywords: Innovation, Knowledge transfer, Tacit knowledge, Spillovers, Clusters, Geographical Concentration

Introduction

The topic of spillovers and innovation in technological clusters has been studied in the literature using two different approaches. The first approach focused on innovative performance of clusters and the role spillovers play in this relationship. The second approach focused on capturing the effects of spillovers that can take place between geographically or technologically close firms and uses innovation outputs to proxy this phenomenon. The first approach, led by Marshall in 1920 and studied more recently by David and Rosenbloom (1990), Krugman (1991) and Kelly and Hageman (1999), showed three advantages of locating in a cluster (known as location externalities). The first advantage is the intensity of a labor pool due to the geographical concentration of firms in the same industry or in closely related ones. The second advantage is the availability of related materials and other inputs at lower cost. These inputs are not always tangible, like raw material and supplies, but also included intangibles like consultations and collaboration. The third advantage is the intensity of knowledge exchange that can lead to knowledge spillovers between nearby firms and institutions in the clusters. Dobkins (1996), Paci and Usai (1999) and Hansen (2002) also studied location externalities and the spatial distribution of innovation. While the first two advantages (location externalities) have an indirect effect on the innovation output of a cluster, the third one has a direct effect on the innovating process of people and firms located in a cluster. Among other researchers, Von Hippel (1988) stated that direct contact with competitors, suppliers and customers is a good source of ideas for innovation. Freeman (1991), and Debresson and Amesse (1991), study networks of innovators and find that they usually tend to be localized. Feldman (1994) points out to how geographical proximity provides the knowledge inputs that contribute to a technological infrastructure supporting innovative activities. Audretsch and Feldman (1996) examine the link between industrial activities and geographic concentration. Baptista and Swann (1998) use regional employment to measure the strength of a cluster and test whether firms located in clusters within the same industry are more likely to innovate than other firms. They conclude that industries that are geographically concentrated and that rely upon sources of basic scientific knowledge in the cluster benefit most from the exchange of knowledge and should therefore grow at a more rapid pace. The spatial distribution of innovative activities has also been studied through detailed case studies by economic geographers like Saxenian (1985 &1994) and Zucker *et al.* (1998). Porter (2003) studied the role of clusters in the US economy and regional economic performance.

The second approach that focuses on measuring the effects of knowledge spillovers was led by Jaffe in (1986), who used a "knowledge production function" to demonstrate that clustering does affect innovation. This type of econometric model was first introduced by Griliches (1979) to measure the effect of R&D investment on knowledge stock and economic growth. Jaffe (1986) built on this model, considering that the total relevant activity of other firms influencing innovation of a particular firm can be represented by a "potential spillover pool" which is the weighted sum of the other firms' R&D investments, with weights proportional to the technological proximity of the firms to the one under consideration. He then used the same model to measure geographical spillovers between neighboring firms and universities using States as units for clusters (1989). Anselin *et al.* (1997, 2000) used the same model in similar studies, but used Metropolitan Statistical Areas (MSAs) as clusters instead. Acs *et al.* (1994, 2002) used the knowledge production function in their studies to compare different measures of innovation output in regional innovation systems. Smith (1999) studied inter-state knowledge spillovers within the United States. Other correlation studies that measured the relationship between firms research efforts and the innovation output of clusters, include Piergiovanni and Santarelli (2001) who evaluated the patent activities of regions in France and how they related to corporate and university expenditures in R&D in those areas. Wallsten (2001) measured the geographical distance between firms and how distance affected their participation in the Small Business Innovation Research (SBIR) program, which provides R&D grants to small firms. Beal and Gimeno (2002) studied the U.S. software industry and found that clustering affected innovative outputs and growth of firms in clusters.

Another group of studies in this category have gone further to trace the relationship between spillovers and innovation. Jaffe *et al.* (1993, 2000) compared the geographic location of patent citations with those of the cited patents to show that knowledge spillovers are geographically localized. Maurseth and Verspagen (2002) carried out a similar study for knowledge spillovers between European regions and reached a similar conclusion. By tracking patent citations these studies focused on the exchange of explicit knowledge. Tacit knowledge could also play a significant role in knowledge spillovers and on innovation in clusters. From the current studies one thing is clear, as Griliches (1992) states, "spillovers are present in clusters and their magnitude may be quite large".

Other spillover related studies include Harabi (1997) who investigated the effectiveness of various channels of R&D spillovers at the intra-industry level, surveying 358 Swiss R&D executives representing 127 different lines of business. The study examined R&D activities, reverse engineering, publications, technical meetings, interpersonal communication and patent disclosures as possible channels for knowledge spillovers. The study suggests that a firm's own investment in R&D is the most important channel for spillovers. Kaiser (2002) used data from the innovation survey of European firms to compare five different methods used to measure knowledge spillovers.

In this paper we draw on the existing body of knowledge to provide a framework for understanding the issues of knowledge transfer and spillovers in technological clusters. In section two we will define what a technological cluster is. In section three, we differentiate between knowledge transfer and knowledge spillover by reviewing the different types of knowledge and their accessibilities. We will discuss knowledge spillovers, knowledge externalities, and their underlying processes; and how knowledge spillover is related to appropriability. In section four we show the dynamics of accessing tacit knowledge in clusters and how it affects knowledge creation and innovation. Section five provides our conclusion and research direction.

Technological Clusters

Competing firms often show a tendency to cluster in the same geographic area (Enright 1991; Krugman 1994; Porter 1990, 1998; Pouder and St. John 1996). For instance, in Europe, watch- makers clustered in Switzerland and fashion designers in Paris. In the United States, well known clusters include Detroit for automotives, Hollywood for motion pictures, New York City for financial services, and Silicon Valley for electronics.

What is a Technological Cluster?

Simply put, a technological cluster is a geographical concentration of technology firms. These clusters often form around a scientific research centers, such as universities or national labs. Many researchers have used this definition to study the economics and performance of clusters. Krugman (1991) studied regional specialization based on "advantage of specialized labor pools and intermediate goods, and the presence of knowledge externalities." Porter (1990) also uses this definition acknowledging that clustering provides a mechanism for exchange of information among companies while they maintain their rivalries. Clusters also differ from one another, because of the type of technology, age, and culture. This variation creates problems for researchers who want to compare clusters' economics and performance, Porter (1998), and Padmore and Gibson (1998). Steinle and Schiele (2002) argue that industries respond to clustering differently depending on the inputs and outputs of their value-chains. Some studies of clusters have approached comparison and analysis at a national level (UK Department of

Trade and Industry, 2001). In these studies, "cluster" refers to every technological concentration within the country.

Economic Growth of Technological Clusters and Spillovers:

Economists have long argued that clustering contributes to economic growth. The theory of endogenous economic growth (Romer 1990, 1994, and Grossman and Helpman 1994) is centered on the premise that accumulated knowledge will eventually find its way to productive applications, and hence leads to economic growth. This perspective has renewed interest of researchers to the role that geography plays in knowledge creation, spillovers and product development. Grossman and Helpman (1992) argue that spillovers cause a cumulative process of knowledge creation, and if this process is affected by geography, that may explain why the rate of economic growth varies among regions. Glaeser *et al.* (1992) study growth in cities and the effects of knowledge externalities that result from geographical concentration of industries. Eventually, clusters would decline and may be replaced by new ones formed around new technologies, Brezis and Krugman (1993) and Pouder and St. John (1996). We have also witnessed the relocation of clusters as industries in the US move their manufacturing, software development and services to new clusters in Asia to take advantage of cheaper resources.

Knowledge Transfer and Spillover

As previously presented, most of the knowledge spillover studies try to capture the effect of spillovers on innovation, by measuring the increased innovative output. Innovation, while carried out by organizations, originates from an individual's creativity and the knowledge creation process that goes through multiple iterations between tacit and explicit knowledge, Nonaka (1994). Therefore the effects of spillover and knowledge transfer, need to be examined at the individual level and the mechanisms of such a process need to be understood. In the following section, we will define tacit knowledge and present a model of tacit knowledge accessibility, to show how such knowledge, can be acquired by other people.

What is Tacit Knowledge?

Polanyi in 1966 classified knowledge into two types: tacit and explicit. He defined tacit knowledge as the knowledge that "indwells in a comprehensive cognizance of the human mind and body." In other words, tacit knowledge is related to the context in which it is presented and the individual's own interpretation of it. Polanyi argued that this individual interpretation gives tacit knowledge a "personalized quality" that needs to be articulated by the individual in order to be communicated. In contrast, Polanyi defined explicit knowledge as the codified knowledge that is transmitted using orderly formal languages. Nonaka *et al*. (1994), in discussing his model for organizational knowledge creation, called the process of turning tacit knowledge into explicit knowledge: "externalization". He also defined the process of turning explicit knowledge back into tacit knowledge as "internalization". Castillo (2002) attempted to make sense out of the broad spectrum of literature on tacit knowledge by presenting a four-fold typology of the concept. He categorized the various ideas on tacit knowledge into four dimensions (non-epistle, socio-cultural, semantic and sagacious). We will use Castillo's (2002) dimensions of tacit knowledge and Nonaka's (1994) concepts of knowledge creation to help in understanding the mechanisms of knowledge transfer and differentiate between tacit and explicit knowledge.

According to Webster's Dictionary, knowledge is "the body of facts accumulated by mankind". It exists everywhere, in people's heads, in companies and in the surrounding environment. Knowledge is continuously being transmitted from one person (or entity) to another. It is this concept of "knowledge transfer" that classifies knowledge into tacit and explicit. Organizations and people interested in knowledge creation and innovation see value in acquiring tacit and explicit knowledge. We will discuss the concept of tacit knowledge from this angle and examine the demand side of knowledge transfer or knowledge accessibility (see Figure 1). Accessibility is related to an individual's knowledge creation process, and how access to the knowledge of other people and the surrounding environment continuously affects ones own knowledge.

Tacit knowledge is not easily accessible by others. There are different reasons why knowledge can be inaccessible. It could be because the knowledge has not been expressed by the holder (non-epistle), or because the knowledge is dispersed in the surrounding social culture, or is semantic to a particular group, or because it is a personal insight or mental model that enables a person to understand and absorb other knowledge (sagacious). As shown in Figure 1, we consider tacit knowledge to remain "tacit" as long as it has not been accessed. To acquire this knowledge, one needs to understand the type of tacitness and apply appropriate interaction mechanisms to acquire it.

Knowledge Accessibility

For non-epistle tacit knowledge to be accessed and acquired by another person, it needs to go through explicit channels. If an individual is able (and wants) to express this knowledge, it then becomes explicit. The expressed knowledge (no longer tacit) can vary in the degree of clarity, depending on the channel of explicitness and in most cases is best understood through direct interaction. Nonaka (1994) calls this process of tacit knowledge becoming explicit, "externalization". Externalization can go through many iterations until the explicit knowledge becomes clear and easy to communicate. When tacit knowledge first becomes explicit, it usually takes a *non-codified* form, like when one uses body language and tone of voice to express feelings, or in the case where one blurts out thoughts about a particular idea, jumping from one point to another, or when a

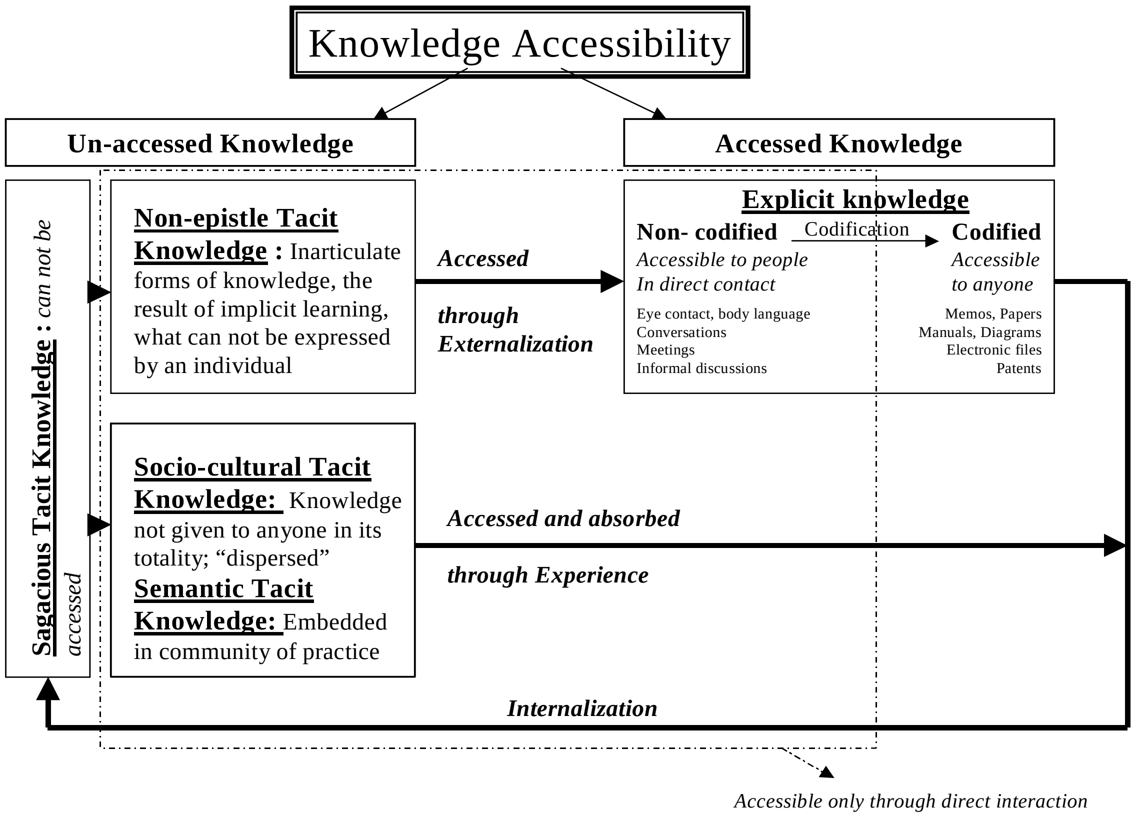

Figure 1 - Knowledge Accessibility and Tacit Knowledge

scientist jots down a formula on a paper napkin, or a group conducts brain storming of an issue on a flip chart. This expressed knowledge, while explicit, can be unclear and misunderstood by someone not directly involved when expressed, and even lost if not recorded immediately. For this knowledge to become easier to communicate, it needs to be *codified.* This happens when someone repeats what he/she said in a more organized fashion and neatly writes down the thoughts in a memo or a document. The more explicitly the knowledge is iterated the clearer and easier to communicate it becomes, until it becomes standard information like in instruction guides, and manuals. Also, well-codified knowledge can be understood away from its origin and can be transferred over long distances and maintained over a long period of time.

Another type of knowledge that is difficult to "access" is knowledge that is dispersed in a particular social or cultural environment or knowledge that is only understood by a particular community. Castillo (2002) refers to these types of tacit knowledge as "socio-culture" and "semantic" types of tacit knowledge. In the case of socio-cultural tacit knowledge, the problem is not in accessing the separate pieces of knowledge that might even be explicit and available to everyone, but rather is in accessing the whole picture or the context that gives sense to the scattered pieces of information. This type of knowledge needs to be "experienced through direct interaction with the surrounding environment, by being in a particular place at a particular time".

For example, to understand the social behaviors of chimpanzees, Jane Goodall (1971, 1986) spent two years in the jungles of Tanzania. According to Castillo (2002), Spender's (1992, 1994) "collective tacit knowledge" and Cook and Brown's (1999) idea of "group tacit knowledge" would fall under this category. The same goes for semantic tacit knowledge. People in a community of practice, for example doctors or lawyers, over time develop their own peculiar jargons, which are not understood by others, unless they become part of the community and interact with others in the community. Unlike non-epistle tacit knowledge, accessing socio-culture and semantic tacit knowledge is not about communication and externalization but rather absorption, where a person accesses tacit knowledge through experience with its piece parts. Sharing the same background and culture helps one internalize such knowledge.

Sagacious tacit knowledge is the unconscious knowledge a person uses to develop new ideas from the existing knowledge. It may involve combining and recombining existing knowledge or discovering linkages between existing knowledge. According to Castillo (2002), "sagacious forms of tacit knowledge are precisely what Polanyi (1966) proposed were the engines of scientific discovery". From an accessibility point of view, sagacious knowledge is internal to the individual and cannot be accessed by others. Each person develops a certain sagacious knowledge or smartness that can help him/her to absorb existing knowledge and do something with it. Many people must have seen an apple falling down from a tree, but only Sir Isaac Newton saw what led him to discover the laws of gravity. However, being exposed to the same set of external factors might trigger similar thoughts between individuals. This is one reason why scientists who are involved in finding solutions to a particular problem do better when they are in close interaction. Nonaka (1994), in his knowledge creation model, called this process of transforming explicit knowledge into tacit knowledge "internalization".

As shown in Figure 1, tacit knowledge transformation starts out as unarticulated knowledge in someone's head, i.e. "non-epistle". The ability of the person to articulate the knowledge and express it makes that knowledge explicit. This explicit knowledge usually takes a non-codified form when first expressed and then becomes more codified, as it gets refined. Consider a person working alone writing and editing a paper until it becomes clear for someone else to read and understand. In a different case, people may be working closely together to help make a shared knowledge more clear, by repeating another person's idea in different words and by using metaphors. The latter case of knowledge creation includes the externalization and internalization of tacit knowledge from one individual to another. Another example of knowledge transfer can be seen when a person learns a new skill. This process involves both externalization of the knowledge and internalization of it through repeated practice. The externalized knowledge in this case may take a codified form like a set of instructions or a non-codified form like when watching another person carry out that task. For another person to internalize someone's explicit knowledge, he/she uses the sagacious tacit knowledge. This interaction can happen several times for knowledge to become fully absorbed. Nonaka (1994) calls this process "socialization".

The dotted area in Figure 1 identifies the types of knowledge that is best acquired through direct interaction. All inventions and new ideas start as tacit knowledge embedded in someone's or a group of people's head(s). Often, the fastest, easiest, least expensive, accurate and, sometimes, the only way to access that knowledge are through direct interaction. Opportunities for direct interaction among researchers are more easily facilitated when they work and live close together. New information and communications technologies such as video conferencing and Internet are also offering remote interactions among individuals and groups that facilitate to some degree the transfer of tacit knowledge. Effectiveness of such communication technologies needs to be studied and compared to direct interaction.

Knowledge Spillovers

In the previous section we discussed the transfer of knowledge whether tacit or explicit. Spillovers are the unintentional transmission of knowledge to others beyond the intended boundary. At every possible interaction, there is a potential for knowledge exchange. If knowledge is exchanged with the intended people or organizations, it is "knowledge transfer", any knowledge that is exchanged outside the intended boundary is spillover. The unintended "use" of exchanged knowledge is called "Knowledge Externality". When a person makes the decision to share his/her tacit knowledge there is usually a motivation behind this sharing. People share knowledge for different reasons, for example, to get feedback from other people, or to receive acknowledgment of ones ideas, this acknowledgment could be materialistic or simply recognition between peers for the work done. Once this knowledge is out there it can be used in any way to benefit other peoples' work and could lead to other discoveries. Hence sharing knowledge could result in spillovers and other knowledge externalities. Reverse engineering is a good example of knowledge externality. When a company invests in research and development to introduce a new innovative product to the market, the motivation behind that act is to profit from the innovation. However, there is an associated risk that a competitor might reverse engineer that product and make use of the externalized knowledge materialized in the innovative product. Companies guard against spillovers and unintended use for a period of time by patenting their inventions.

It is important to note that *tacit knowledge can be exchanged only at the individual level*, while explicit knowledge can be exchanged at the individual, firm or even at the national level. Companies can exchange knowledge that is explicit in the form of technologies, documents, products or processes. Similarly countries could exchange explicit knowledge through multilateral agreements on technology transfer, education and training as well as direct export and import of products. Exchange of tacit knowledge at the individual level, if it occurs, could be an intended knowledge transfer or an unintended spillover. Spillover of tacit knowledge could help or hinder companies or even countries. For example, when companies locate their R&D centers in a technological cluster, they may benefit from the knowledge of other firms as the result of their employees socializing with others in the cluster, as well as unintentionally facilitating transfer of some of their own corporate knowledge to other companies in the cluster. In this case, although, socialization has been facilitated by the corporate decision, the actual exchange of tacit knowledge is carried out by the employees of these neighboring firms and can only happen through them. Similarly, firms arrange for organizational interactions, seminars, and social outings to promote the exchange of knowledge between their employees. While the exchange of knowledge is intended at the firm level, it can only happen to the extent that individuals get involved in the inter-exchange. In some cases spillovers can occur because the person with the knowledge may not value that knowledge, and hence does not take the time to codify nor want to protect the knowledge.

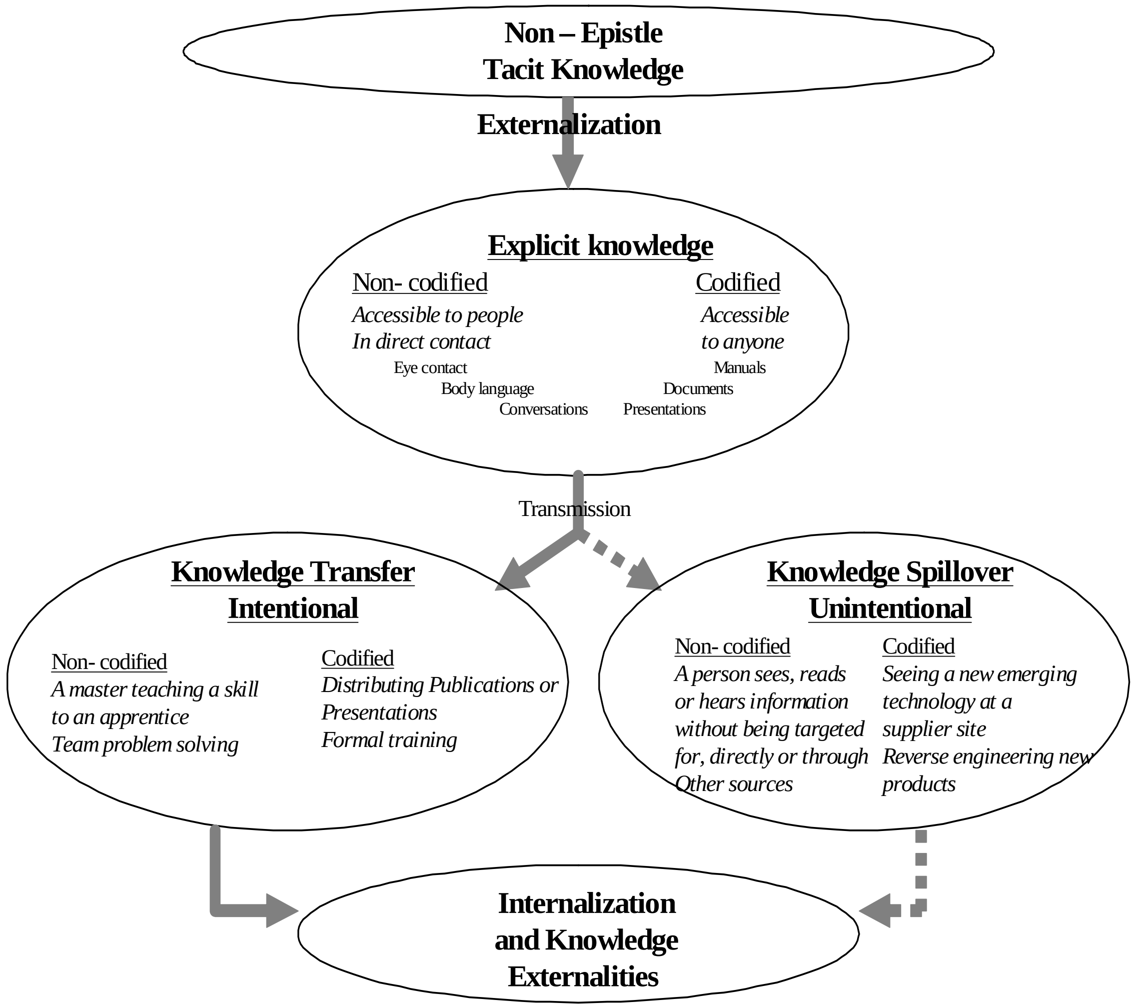

Figure 2 - Knowledge Transfer versus Spillover

Figure 2, depicts the flow of knowledge from the holder to receivers. For tacit knowledge to be transmitted, a person first needs to articulate and make that knowledge explicit (externalization). Next, the person makes a decision as to who this knowledge is to be shared with. That is knowledge transfer. The knowledge could also be shared with others unintentionally, or spills over to others. It is important to note that there are situations where a person does not have control over this sharing process. Generally speaking, the more the knowledge is codified, the less control a person has over who receives this knowledge, as the transfer can be facilitated by others. This does not mean that non-codified knowledge does not spillover; it does but may not as frequently and as easily as codified knowledge. For example, it might happen that someone visiting a person's workplace watches this person do his/her job and learns from what was observed, just because he/she happened to be there. This learning also depends on the recipient's ability to absorb this knowledge. This ability is what Cohen & Levinthal

(1990) and Caloghirou's *et al*. (2002) defined as "absorptive capacity", where a firm's ability to absorb knowledge depends on the experience and training of its people. This can also explain why Harabi's (1997) survey of 358 Swiss R&D executives concluded that a firm's own independent R&D investment, which determines a firms ability to understand and absorb other firms innovations, was considered the most effective channel for knowledge spillover. The absorptive capacity at the individual level corresponds to the person's sagacious knowledge. For example, two different people could stumble over the same piece of information. One person can link this information to other information he/she has and make use of it in an innovative way, while the other person does not and overlooks the available knowledge. The sagacious aspect of tacit knowledge affects the way knowledge is acquired and internalized, in the sense that people react differently to external factors, and given the same set of data different people may reach different conclusions. It is also what leads to knowledge externalities where a person uses the acquired knowledge for a different purpose than the original one set to externalize it.

As noted before, knowledge transfer can happen at every possible boundary of knowledge exchange. According to these boundaries, we can identify three levels of knowledge spillovers as discussed in the following section.

Levels of Knowledge Spillovers:

a) Individual Level (across people) - This is a case where knowledge is unintentionally exchanged between people. Individuals have control over their tacit knowledge and can share them with whomever they want or need to. Spillover can happen due to ignorance, or when the tacit knowledge is externalized to put to use. A person can use patent or copyright to protect his or her individual knowledge, but once the knowledge is explicit it could be spilled over to others. Members of a team working together, whether from within the same organization or from different organizations like in customer – supplier relationships, exchange knowledge. That knowledge is not considered a spillover as long as they intended to share this knowledge. However, sharing knowledge that is not intended for the group or sharing the group knowledge with people outside the group or outside the organizations who are not intended to have such information is a spillover.

b) Enterprise Level (across firms) - Knowledge could be exchanged between companies. This can happen between neighboring companies (sometimes located in close proximity) or can happen as a result of these companies doing business together. If the information exchanged is intended for the other organization that is knowledge sharing or knowledge transfers. Any information exchanged that is not intended is spillover. *Intra-industry*, knowledge spillovers happen as a result of industry specialization, as shown in the early work of Marshall (1920) and Arrow (1962) and reaffirmed by Romer (1986, 1990). It is referred to in the literature as MAR, Marshall–Arrow–Romer, externalities, where knowledge accumulated by one firm tends to help the development of technologically close firms (Jaffe, 1986). Industries that are geographically concentrated benefit most from exchange of knowledge within the industry and should, therefore, grow at a more rapid pace. *Inter-industry* knowledge spillovers happen as a result of the diversity and variety of knowledge between complementary industries or customers and suppliers that service each other. According to Bairoch (1988), diversity of industries in an urban area may lead one sector to adopt a technological solution that has worked for another.

c) Global Level (across nations) - This is the case where knowledge is unintentionally exchanged between countries. This can happen between neighboring countries like in Bernstein's (2002) study of United States spillover to Canadian manufacturing firms, or it can accompany the process of technology transfer that happens when countries trade with one another, as shown by Coe and Helpman (1995), Walter (1995), Xu and Wang (1999) and Madden and Savage (2000). The unintentional knowledge transfer in this case is international spillover. For example, when a country imports a product from another and does reverse engineering to that product, even if the product is not copied the insight gained is still a spillover, since it was not the intention of the exporting country (or company) to transfer the knowledge of how to make the product. However when a US company sets up an R&D lab in a developing country for the purpose of transferring knowledge to local engineers and scientists, that is a case of technology transfer and not a spillover.

Knowledge Spillovers and Appropriability

Levin and Reiss (1988) and De Bondt, (1996) define spillover as the side effects of a firm's strategies to invest in R&D. Bernstein and Nadiri (1988) differentiate between the social and private rates of return on R&D capital by studying five high-tech industries, and treating each one at a time as a separate spillover source. According to Kaiser (2000), "economists have demonstrated that the social returns to innovation exceed the private returns to innovation if the knowledge produced in an innovation process is not fully appropriable by the innovating firm". As a consequence, spillovers benefit other firms with their innovations. Many researchers (Mowery and Rosenberg 1989; Kamien *et al.* 1992, and Suzumura 1992) have observed that smaller firms that don't invest as much in R&D as large ones are still as innovative. This observation indicates that enterprise knowledge spillovers (across firms) happen as a result of a firm's own investment in R&D, and if it were up to the firms, they would want to appropriate all knowledge generated as the result of their innovation efforts. However, such protection may not always be possible. Knowledge spillovers arise due to failures in the protection mechanisms of knowledge generating firms. A typical protection mechanism we discussed earlier is application of patents. Patents provide full legal protection for a firm's research outputs for a limited time period, at least in theory. Other protection mechanisms include copyright, trademarks and trade secrets.

Technological Cluster and Knowledge Creation

Inventions and innovations are the output of the knowledge creation process and embody tacit and explicit knowledge. According to Babtista and Swann (1998), "so long as much technological knowledge has a tacit nature and cannot be codified through plans, instructions or scientific articles, it seems reasonable to expect a greater geographic concentration of innovators". They argue that learning from new technologies can only happen through repeated use and informal personal contacts with the innovators, particularly when a technology is in the early stages of development. This may be one of the reasons underlying formation of technological clusters. This argument also supports Pavitt (1987) notion that informal, un-codified new technological knowledge should flow more easily locally than over great distances. Corno *et al*. (1999) also referred to technological clusters and transfer of tacit knowledge when they studied industrial districts; they characterize as "complex networks between firms". They analyze these systems from a geographic perspective they call "ba" (Japanese for place). Nonaka and Konno (1998) adapted the concept of "ba" to elaborate on their model of knowledge creation. According to them, "ba provides a platform for advancing individual and/or collective knowledge; it is the place where different subjects participate in the process of knowledge creation and the exchange of tacit knowledge.

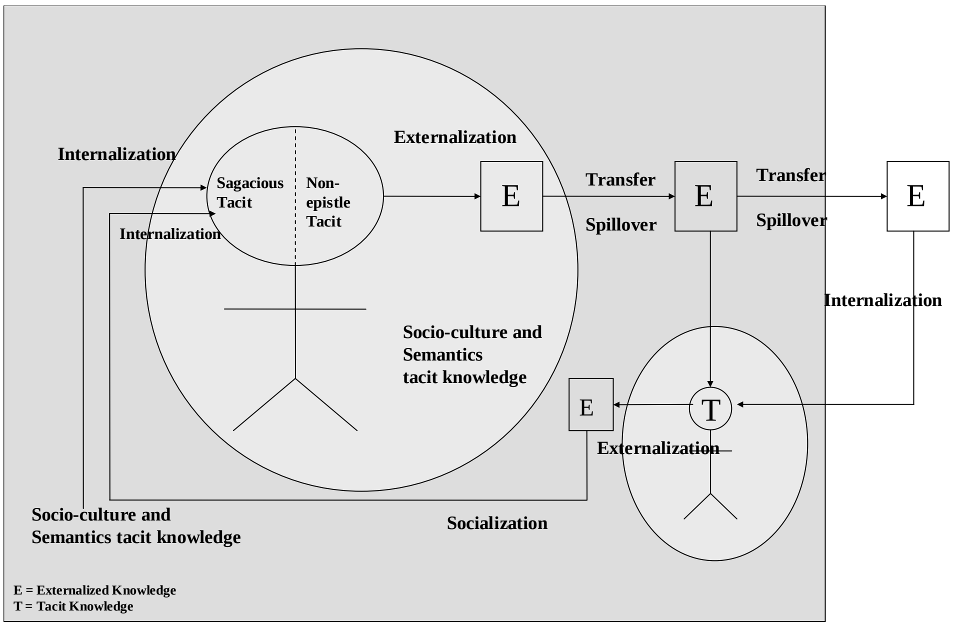

Figure 3 – Technological clusters and knowledge transmission

Figure 3, illustrates transfer of knowledge between individuals in different companies within a cluster (socialization). The geographical proximity allows for direct interaction with customers, suppliers, partners, competitors as well as educational and research institutions. Direct interaction helps an individual acquire the externalized knowledge, where in some cases that knowledge is still "non-codified". Technological clusters also allow for an individual to *absorb* the collective tacit knowledge embedded in the socio-culture of the cluster. Being in technological clusters also enhances a person's tacit knowledge by monitoring the emerging technologies closely, identifying general problems and solutions in an industry, and working in an environment that appreciates and encourages new ideas. Hence one can expect more innovations and shorter innovation cycle from researchers within a cluster than those outside the cluster.

Conclusions and Research Direction

In this paper, we have built on the existing body of literature to explore the effect of knowledge spillovers within technological clusters on innovation. We classified knowledge from an accessibility perspective and showed how accessibility mechanisms differ with respect to tacit and explicit knowledge. The socialization process and the exchange of non-codified knowledge need direct interaction to be transmitted, and therefore is more prevalent in technological clusters. We also distinguished between knowledge transfer, knowledge spillovers and knowledge externalities. Spillovers and externalities can happen at individual, enterprise or national levels. Non- codified knowledge is not the only source of knowledge that is unique to technological clustering, tacit knowledge embedded in the cluster itself like socio-culture and semantics are another source of knowledge that can be best acquired by locating in the cluster itself.

We discussed earlier research that shows clustering does have an effect on innovation, and that spillovers are considered an important location externality affecting innovative capacity of clusters. However, little is known on the mechanisms that influence creativity and contribute to the increased innovative output of technological clusters. We are in the process of identifying and classifying these influences, and assessing whether and to what extent locating in a cluster affects these mechanisms. Our research is a work in progress and will be reported further in the future.

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