Analysis of Knowledge Spillovers in IT clusters

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Abstract. The paper analyses the relation between IT clusters and knowledge spillovers seen as one of the key factors that determine IT companies to locate in the proximity of other companies and thus to generate technology clusters. This research highlights that IT clusters is a particular type of industrial clusters and that knowledge is a valuable resource. The proximity of IT companies generates direct knowledge transfer by R&D cooperation and also a tacit transfer by knowledge spillovers. This flow of knowledge is considered an important factor for the success of IT clusters and a reason for companies to form local agglomerations. The paper analyses and describes a set of indicators used to evaluate knowledge spillovers. Their scope is to emphasize that spillovers generate knowledge transfer and this process occurs inside an IT cluster through a multitude of factors.

Key words: cluster, economic geography, competition, collaboration
JEL Classification: R11

1. IT Clusters

Based on Morosini definition of industrial clusters (Morosini, P. 2004), knowledge-based organizations like many IT companies choose to form geographic proximities because of the advantages of a common market and work pool. For IT companies, every cluster influence factor counts but some categories are more important as they are more related to the particularities of IT activities:

- highly developed communication infrastructure;
- common pool of specialized workforce;
- a developed educational system that generate skilled specialists and that offer a dynamic range of educational and training services;
- a strong R&D network of events, partnerships, laboratories, professionals;
- a framework of universities, technology institutes, research and development centres, financed from both public and private funds.

IT industry is recognized as R&D intense in terms of input but more because its innovative outputs. New and existing companies are pressured by the industry to generate new technologies, to innovate, to offer new services and new products. As an example, in the semiconductor industry the R&D targets have been set by the Moore’s law that has predicted, since 1965, that every two years the number of transistors that can be placed inexpensively on an integrated circuit doubles.

Knowledge is an important factor in the analysis of clusters. In many definitions of clusters (Morosini, P. 2004), (Porter, M. 1998), (Krugman, P. 1991), key determinants of cluster success and evolution are knowledge-based:

- firms strategy;
- competition and concurrency conditions;
- quality and expertise of labour force;
- current technology;
- research & development capabilities.

Extremely few factors, as raw materials, are inexhaustible as knowledge. Knowledge can be quantified based on outputs like number of research papers or maybe innovation patents, but as input it is limitless because it is based on innovative ideas. Knowledge alone, can’t generate innovation. The R&D process must be supported financially and by a strong infrastructure and this is something that can be accomplished by getting funding or by acquiring technology. On the other side, without a knowledge based R&D process, the technology alone can’t generate new knowledge.

Also, along human capital, skilled labour, professional level the most important source for generating new knowledge is the investment in Research and Development (R&D) (Audtresch and Feldman, 2003).

IT clusters have been one of the most success stories that have fuelled the myth of this type of industrial organization. One of the most known cluster myths is the "Valley" one and it was created by the success of the Silicon Valley cluster (Saxenian, 1994), (Gilson, 1999), (Fallick et. al, 2004) and (Rosenthal and Strange, 2003). This success has pushed other governments and public policy makers to establish future IT "Valleys" clusters like Fiber Optic Valley in Sweden or Flanders Multimedia Valley in Belgium.

2 Knowledge-based organizations

Because IT industry is considered by many an intensive R&D field we may conclude that most companies are knowledge-based organizations as research is conducted based on existing knowledge and innovation means new knowledge. This is not entirely true as many IT companies does not conduct activities that are placed inside the accumulate knowledge, use knowledge and generate new knowledge loop.

Knowledge is the sum of insights, experiences and procedures that are considered correct and true and that therefore guide the thoughts, behaviors and communications of people (van der Spek and Spijkevert, 1997) and *organisational knowledge* is the collective sum of human-centred assets, intellectual property assets, infrastructure assets and market assets (Brooking, 1996)

Knowledge management is the explicit control and management of knowledge within an organization aimed at achieving the company's objectives (van der Spek and Spijkevert, 2005).

Knowledge-based organizations (KBO) are economic and scientific entities whose product or service is knowledge-intensive.

Based on previous descriptions, an IT company is considered a knowledge-based organization if its objectives are reached by using, acquiring and generating knowledge. This classification as KBO is important for this study because these companies are more affected by knowledge transfers and spillovers.

3 Knowledge transfer and knowledge spillovers

The proximity between companies that activate in the same industry facilitates knowledge transfer and this has an even more pronounced effect for innovative activities (Krugman, 91).

Knowledge transfer in clusters is accomplished by location:

- Inter-firm interaction that takes place inside the cluster through joint research projects, cooperation (Dumont and Meeusen, 2000) and indirectly by the workforce dynamic;
- Inter-firm interaction that takes place outside the cluster at global professional gatherings, conferences, conventions or international trade fairs;

or by duration

- Permanent knowledge transfer networks;
- Temporary inter-firm communications and knowledge transfer networks;
- Arbitrary transfer networks which include knowledge spillovers.

Knowledge spillover is an exchange of ideas among individuals (Carlino, 2001) or a is a non-rival knowledge market externality that has a spillover effect of stimulating technological improvements in a neighbor through one's own innovation, (Carlino, 2001). A more detailed definition was given by Grossman and Helpman (1992). "*By technological spillovers, we mean that (1) firms can acquire information created by others without paying for that information in a market transaction, and (2) the creators (or current owners) of the information have no effective recourse, under prevailing laws, if other firms utilize information so acquired*."

In economic literature have been identified different types of knowledge spillovers:

- **Marshall-Arrow-Romer (MAR) spillover** - the proximity of firms within a common industry often affects how well knowledge travels among firms to facilitate innovation and growth**;**

- **Porter spillover -** knowledge spillovers in specialized, geographically concentrated industries stimulate growth **;**
- **Jacobs spillover -** the proximity of firms from different industries affect how well knowledge travels among firms to facilitate innovation and growth (Carlino, 2001).

One hypothesis that sustains the economic cluster as a real economic identity is that inside the cluster companies are concurring for a larger market share, for better technologies, for less costly resources, for knowledge. The economic and technological environment inside clusters is based on inequality. For IT clusters this reflects in different levels of technology distributed among companies. Some have specialized in niche technologies and markets but others, the most part, share the same customers' pool. For the later the need for better technologies and for knowledge and know-how is the driven force that makes them to evolve and to contribute to the cluster success.

The role of technology and innovation in trade networks and clusters has been recognized by many economic studies on competitive advantages of clusters and of companies in clusters (Porter, 1990), (Grossman, Helpman, 1991), (Porter, 1998), (Branstetter, 1998), (Morosini, 2004), (Baptista and Swann, 1998) and (Andersson and Ejermo, 2006).

The conclusions of these studies, demonstrated over time by the evolution of the IT global markets, show that that comparative advantages are created and maintained by investments in technology, knowledge accumulation, research and development (R&D) and know-how (Andersson and Ejermo, 2006).

Knowledge is a very special resource. It can be controlled and own through international patents but if it used to produce commercial goods or to provide services it can't be fully contained. Knowledge is cumulative, it can be measured in term of patents but if it used to define public technologies becomes something that can be observed, studied and replicated at some extent or with a degree of approximation. Knowledge is a resource that can be traded within a group without losing it, like a standard good. Bernard Shaw describes the concept in an easy to understand manner: "*If you have an apple and I have an apple and we exchange these apples then you and I will still each have one apple. But if you have an idea and I have an idea and we exchange these ideas, then each of us will have two ideas.*"

The effects of international R&D spillovers have been theoretical studied by (Grossman, Helpman, 1991) at a time where IT industry and global markets were limited to few global regions. The two economists predicted that the rate of economic growth is influenced by rate of innovation and have defined a public context in which knowledge is available to developers and innovators without costs. This public context is "the start of the art" and is defined by a deposit of general knowledge. Also, recent studies (Audretsch and Feldman, 2004) have shown that the most innovative industries, like the computer industry, tend to be characterized by considerable investments and outputs in R&D and new economic knowledge.

Knowledge spillovers play an important role for the success of IT clusters, along location and geographic space, because provides access to new economic and innovative knowledge and thus increasing productivity of cluster members. There are economic domains, like chemical industry, where the existing conditions and particularities allow companies to control the access to knowledge in a way that competition can't determine the exact "secret formula" even if they have access to the final product. In IT, the production development, for both hardware and software, is different. For hardware, any competitor can disassembly a product and replicate its structure and components because it's a simple matter of reading an electrical schema. This a reality that has allowed consumers to choose form a large set of available hardware products that provide the same functionality but have different prices and quality levels.

In IT, the advantage of knowledge accumulations and investment in R&D is given by the initial lead that a company can achieve by generating products based on the new technology.

Knowledge spillovers represent a technology driven phenomenon and for IT clusters it represents a key factor as a knowledge transfer process. Taking into consideration the particularities of the computer industry, the high pace of technologies changes, the high wages and adding to that the proximity of IT companies, we get an environment in which experienced workers move quickly and easily between competing firms. Analysis made on IT clusters, like Silicon Valley (Fallick et. al, 2004), have shown that this type of technology cluster has higher rates of *job-hopping* for college-educated men than in other industries. The research also has highlighted another important factor that is responsible for the Silicon Valley high mobility rates. Under California law, non-compete agreements between companies are unenforceable and thus there are no legal measures to reduce mobility costs. Despite the fact this is a source of costly human capital externalities (Gilson, 1999), the Californian approach of this issue is another source of agglomeration economies that was added to the Silicon Valley "culture", along others described by Annalee Saxenian (1994), which contributed the success and fame of this IT cluster. Other factors are specific to the computer industry (Saxenian, 1991), (Fallick et. al, 2004):

- Software development and computer systems manufacture is a modular oriented process that is conducted by a network of independent and specialized suppliers;
- In this industry many professionals are learning from each other and thus creates a tacit movement of technical knowledge by job-hopping between companies;
- Technical innovation is the driving force of the computer industry as technology has a fast rate of becoming obsolete.

Knowledge spillovers and the innovation process are tightly related concepts. Innovation is achieved by generating or gaining new knowledge which then is integrated in the innovation process. Knowledge spillovers are information flows that are taken place between companies. Based on the direction of these flows and their effect, knowledge spillovers are classified as (Cassiman and Veugelers, 1998):

- *incoming spillovers* are flows of information that occur towards the firm; the information can be accessed form public knowledge and information sources, like patents databases, conferences and other events, scientific publications, trade shows and industry seminars or by hiring experienced professionals that have a strong background in the field; also, these flows of information are generated by joint research projects conducted with other companies or with public research centres and universities; incoming spillovers affect positively the company rate of innovation because they increase the firms knowledge base;
- *outgoing knowledge spillovers* are involuntary flows of information that take place from the company towards other firms, competitors or not; other economists like Cassiman and Veugelers (2002) have analysed the outgoing spillovers as a process that affects the company *appropriability*, that is its ability to protect its knowledge gained by innovation and research; it is difficult for a company to fully protect its knowledge base and to block spillovers by restricting movement of its human resource; this can be done by imposing non-disclosure agreements based on existing laws or internal regulations, but is not always possible to implement it or even a feasible action; a study on employees free movement in Silicon Valley (Fallick, Fleischman and Rebitzer, 2004)

Based on these two types of spillovers, companies will try to maximize the incoming spillovers and in the same time to minimize the extent of spillovers to other companies. The Cassiman and Veugelers (2002) has shown that firms benefit more if they are engaged in joint R&D projects. Also, companies that rate incoming spillovers as important sources of information for their R&D process are more likely to engage in cooperative research agreements.

Another classification of R&D spillovers is made by Griliches (1992), who qualifies spillovers as:

- *embodied* if they represent knowledge gained by purchasing better equipment, goods and services;
- *disembodied* spillovers represent the ideas transmitted tacit inside the same industry.

4 Knowledge transfer metrics

Companies that conduct economic activities in the same field are linked between them by same markets, same workforce pool and same sources of information. In order to describe the communication between them and any movement of equipment, technology patents and ideas, researchers have been widely used the concept of *technology transfer* to measure it. In the *knowledge based economy*, this is a subset of the *knowledge transfer* process and it describes the transfer of explicit knowledge, research results, skills and methods from a public or governmental research environment like a research center or university to other institution able to exploit it in a production process or to further develop it.
Knowledge is not a traditional economic commodity that can be easily measured in order to get the stock of available knowledge or to estimate future developments or results in innovation. For example you can measure the production of lumber and you can predict how it will affect the furniture industry. There are several indicators used to measure knowledge but very few to none can be used to measure the impact of knowledge gained by research or transfer on future developments. IT companies that rely on innovation for their competitive advantage have strategies for increasing their knowledge, either by research or by transfer. This can be a risky mission because depending on entrepreneurship, competition and other economic circumstances, the new idea or new technology, if it is obtained can have an impact on the industry that varies from none to breakthrough. Either way, the costs remain and based on that, you can predict their impact on the business future.
A OECD (1996) report on The Knowledge-Based Economy highlights the difficulty to measure knowledge: *The relationship between inputs, knowledge and subsequent outputs are hard to summarise in a standard production function for knowledge because there is no production function, no input-output "recipe" that tells, even approximately, the effect of a "unit" of knowledge on economic performance.* (OECD, 1996).
Based on the assumption that new knowledge is generated through R&D processes and this requires human capital, Audretsch and Feldman (2004) have defined a general model of knowledge production that can be represented as a function of R&D inputs and human capital inputs. This model, even is a generic model, highlights the major importance of these two factors, know-how or knowledge and human resource, for knowledge transfer and especially for knowledge spillovers.

Other studies have measured the impact of knowledge transfer from public research organizations (Gardner et al., 2010) and also have analyzed metrics used worldwide by technology transfer industry association. The number of transferred patents remains the most used metric. It is easy to follow and to determine but its value reflects only a part of the knowledge transfer process.
Some conclusions commonly found in these related studies highlight both the difficulty and importance of measuring knowledge transfer and its effectiveness. Many companies use inconsistent internal procedures that don't allow a direct comparison of results (OECD, 1996). Most metrics are used to measure the results of the post knowledge transfer, like patents, because it is difficult to predict the effects
The Organization for Economic Co-operation and Development – OECD has established four key aspects that must be taken into consideration when measuring the effectiveness of knowledge transfer (OECD, 2006):

- Timing
- Attribution
- Appropriability
- Inequality

In order to analyze knowledge transfer inside an IT cluster, this research takes into consideration set of metrics that are based on the direct and indirect cooperation between cluster companies, the private sector and the academia which is an important factor for innovation and knowledge transfer. This assumes that the IT cluster companies only benefit from knowledge generated by other firms in their cluster, and that all such entities are weighted equally in the construction of the knowledge spillover pool. Other economists like Jaffe (1989), proposed methods to determine the R&D position of the company inside its industry or cluster in order to measure their magnitude of spillovers.

The quantitative metrics are used to measure the knowledge transfer at three levels: labour force, company and cluster. Each level has factors that directly influence how the knowledge transfer process is taking place. More, the knowledge transfer process must be a function that takes into account the knowledge inputs, flows and outputs.

At labor force level, measurable factors are used to analyze the impact of the skilled workers movement between companies inside the cluster:

- Educational level;
- Field of activity;
- Experience in their field of activity;
- Experience in R&D activities;
- Position in the business hierarchy.

Measurable factors at company level (Holi, 2008):

- Company position in terms of market share;
- The domain of activity; even in the IT industry there are domains and activities which are less dependable on R&D;
- Number of developed patents (Andersson and Ejermo, 2006).
- Number of acquired patents;
- Number of collaborative research projects;
- Number of research contracts;
- Income of research funding;
- Number of employees in R&D departments;
- Number of Continuing Professional Development (CDP) programs offered to employees;
- Technology transfers;
- Investments in R&D projects;
- Investments in Spin-Outs projects;
- Number of publications regarding proprietary technologies;
- Average number of new employees that have an industry background;

Measurable factors at cluster level:

- Number of joint ventures;
- Number of start-up companies;
- Number of scientific and industry events;
- Number of networks;
- Average number of personnel transfers inside the cluster;

Knowledge spillovers are tacit knowledge transfers processes and that makes more difficult the task to measure them. Even in the earlier studies on clusters and their externalities, Krugman (1991) warned about the impossibility to measure knowledge spillovers because "*knowledge flows are invisible, they leave no paper trail by which they may be measured and tracked*", (pp. 153). Despite this, other researchers (Branstetter, 1998) have tried to quantify their impact based on firm' labor and knowledge capital levels (Jaffe, 1989), (Griliches, 1992) or based on patents numbers and references (Jaffe et al., 1993), (Lukach and Plasmans, 2002).

5 Conclusions

Knowledge transfer between companies affects organizations which conduct intensive R&D activities. Knowledge transfer is a process determined directly by the interaction between companies and also as side-effect by knowledge spillovers. The latter is related to events and activities that aren't under total control of companies. A framework of metrics used to measure the effects of knowledge-spillovers helps economists, policy makers and industry to acknowledge the importance of advantages provided by a cluster.

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