Who Benefits from being Co-located in an Industrial District?

A case study of the Leiden Bio Science Park

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Abstract

It is argued since Marshall (1920) that positive externalities such as labor market pooling, input sharing, and knowledge spillovers accrue to firms that are co-located. As a result, these agglomeration economies should be a stimuli for the innovation capabilities of firms that embed themselves within industrial districts or at least favour those firms within one that are best able to appropriate the returns. For firms it is about gaining access to the flow of ideas, people and resources and subsequently the ability to appropriate their returns in order to benefit from co-location in an industrial district. This paper focuses on the Leiden Bio Science Park, an industrial district in the Netherlands that exclusively holds organizations active in or related to life sciences, in order to build a case study and find out which elements are important for firms to benefit from being co-located within an industrial district. In this study, the proxy for benefitting from co-location is the firm's embeddedness in the Leiden Bio Science Park through connections.

The results show that firms that interact with public research institutions are more embedded in the LBSP then do firms that do not interact with these institutions. Also, the firms that balance their external knowledge sourcing, by both using internal and external sources, benefit relatively more compared to choose to focus their knowledge sourcing. Firms that are larger in size are more embedded within the relevant local structures. A small group of LBSP firms command central position in the network of local connections, which puts them in a beneficial position within the informal and formal local social network. This group is also the biggest contributor to revitalizing the local pool of knowledge.

Keywords*: innovation systems, industrial districts, knowledge sourcing, social networks, embeddednes, appropriation capabilities, cognitive proximity*

1. Introduction

Firms within the Leiden Bio Science Park (LBSP) are all part of a knowledge intensive industry that knows a need for creating new knowledge and innovations in order to become and remain successful. These firms have deliberately located themselves within an industrial district, which houses only organizations that are active in or related to the life sciences, in order to develop their business. The agglomeration economies, such as labor market pooling, input sharing, and knowledge spillovers (Marshall, 1920) which arise to those firms co-located with similar and related firms, are claimed by the park management as an important *raison d'être*. Hence, it becomes interesting to unravel the important elements that are theoretically and empirically involved with benefitting from being co-located within an industrial district.

Agglomeration economies alone might suggest that by just being located within an industrial district a firm can benefit from its *milieu*, but it takes more. First of all, an important aspect to benefit from co-location within an industrial district is the embeddedness of a firm within the local social network. Co-location generates potential for the efficient transfer of important news and information (Bathelt et al., 2004) but also of employees with embedded skills (Almeida and Kogut, 1999). Being embedded within a local social network determines whether or not a firm has superior access to these flows of ideas, people and resources. Secondly, whether or not a firm benefits from co-location depends on its incentive and ability to innovate. Thirdly, being able to absorb new knowledge is only relevant when there is enough valuable knowledge, this can not be realised by exclusively looking inwards. Hence the ability to connect with other actors beyond the boundaries of industrial districts is of importance, as the industrial district needs to sustain itself by ensuring a constant flow of new ideas and people. And finally, the effective transfer of knowledge requires an absorptive capacity to identify, interpret and exploit the new knowledge (Cohen and Levinthal, 1990).

It is the coming together of these elements that determines whether a firm is capable of creating the optimal access to and use of resources required in order to benefit from being co-located. These elements are elaborated upon and it is examined whether and how the firms within the LBSP can be differentiated on the extent to which they benefit from being co-located based on these elements. This paper will first explore the different theoretical elements such as industrial districts, social networks, the importance of innovation and knowledge, cross boundary knowledge sourcing and appropriating capabilities. The paper then continues with the data and methodology, followed by the descriptive statistics, the results and a discussion of the findings.

2. Theory

2.1 Industrial Districts: Sectoral and Geographical Concentration of Innovation

Innovation is about generating and applying new knowledge to solve practical problems, i.e. the "carrying out of new combinations" (Schumpeter, 1934). The notion that innovation takes place by the interaction between a set of firms is dubbed innovation systems (Freeman, 1987) and can be differentiated in two dimensions. First of all, there is the sectoral dimension of innovation systems, which revolves around the relevance and effectiveness of interfirm contacts within and between industries. Interfirm contact becomes beneficial when a certain cognitive base is shared, since this is needed to communicate knowledge effectively. Usually, the cognitive base within industries is somewhat similar, since activities of firms within the same industry are to a great extent related. The degree to which the cognitive base between industries is shared will differ greatly across all pairs of industries. Between industries, a shared cognitive base will be based on relatedness created by input- and output relations and labor mobility, i.e. due to frequent flows of resources between industries. The effectiveness of transferring knowledge between industries will differ based on the degree to which a shared cognitive base can be established. Hence, firms are likely to concentrate their interactions based on sectoral relatedness since it is easier to communicate effectively when there is cognitive proximity. The relevance of inter industry contacts will be determined by the activities that a particular firm develops and its need to source knowledge not available within its own industry.

The second, regional, dimension of innovation systems puts innovations in a geographical domain as actors that interact with each other are bound by regimes, policies and norms. Organizing innovation beyond the boundaries of a regional innovation system becomes harder, since bridging the differences between different regional innovations systems results in additional efforts and costs. Furthermore, on a different geographical aggregation level, the production of innovations presents a strong tendency to cluster in geographical locations where key knowledge inputs are available. Such key knowledge inputs are for example skilled workers, industry R&D and university R&D (Audretsch and Feldman, 1996). These geographical delimited locations are often supported by the presence of public research institutions that have the facilities to perform research and development activities. Another factor which concentrates innovation systems in space is strongly related to the characteristics of knowledge, namely that geographical proximity is a prerequisite for the effective transfer of tacit knowledge, as this makes arranging face-to-face contact easier. Hence, the spatial concentration of innovation inputs and facilities creates potential benefit for firms located there, since these firms can benefit from advanced business- and social structures that are in place. These structures allow firms to tap into the local pool of knowledge and labor. Locations where these knowledge inputs are available attract firms, which subsequently attract new firms, which might eventually lead to a beneficial *milieu* for developing a business. Within such a *milieu,* firms have the opportunity to benefit from spillovers that follows from intensive flows of information through the formal and informal channels that are established by actors working in this geographically delimited space. These spillovers are beneficial to firms, as they result in information that can be obtained at less then the original costs.

When combining both the sectoral and geographical concentration of innovations systems, the existence of industrial districts is brought to light, of which the LBSP is an example. The LBSP exclusively houses firms active in the life science sector and is a geographically delimited space in the western part of the Netherlands. The degree of innovative activity within the LBSP is expected to be generally high, due to the knowledge and technology heavy industry in which the firms are active. The geographical location in which these firms operate seems to be chosen because of the availability of the required resources for innovation. The reason why exactly this location has become an industrial district is largely determined by historical developments. These developments shall primarily come down to the existence of large (public) research and educational institutions that initiated the pull and spawning of firms and skilled workers, which led to the growth of the industrial district[1].

In an industrial district such as the LBSP, where inhabitants are all part of one sector, interactions and spillovers that result from co-location can be differentiated along two dimensions, namely the horizontal and the vertical dimension. The horizontal dimension

[1] See the descriptive statistics section for detailed LBSP information, including the development over time.

represents similar firms that are likely to be in competition with each other. These firms have an incentive to monitor the competition in order to keep up with the latest developments. Being in close proximity to the competition makes monitoring others in order to gather information much easier, as one is part of the local *milieu* and has developed systems for tapping into the local pool of information. The vertical dimension represents interactions within the value chain of a certain industry. Value chain interactions are valuable for firms as it delivers insight into supplier- and customer needs, but also offers opportunities for joint product- and process innovations. Hence, the place that a firm holds within the value chain of an industry will largely determine the incentives and potential benefits one has for being co-located in an industrial district. However, the mechanism for achieving this benefit is the same; the local social network.

2.2 Prerequisites to Access Knowledge

Being co-located within an industrial district does not automatically mean that a firm has access to the knowledge that flows and spills over within the boundaries of an industrial district. In order to benefit from co-location, having access is vital. Accessing, for example the pool of knowledge, has some prerequisites, such as being embedded within the relevant social networks that are established within the industrial district. This allows a firm to tap into the flow and spills of knowledge, as well as being able to connect to skilled personnel that already embedded relevant knowledge through prior work in the industrial district. For firms in industrial districts, the embeddednes in local social networks dictates access to information and resources and thus enhance the potential for benefitting from co-location.

Social networks arise from linkages among co-located organizations. Such social networks rely to a great extent on trust and reciprocity, meaning that network structures within an industrial district can only be built and maintained when these two aspects are accounted for. Trust is needed for the willingness to share knowledge and collaborate, whereas reciprocity ensures that the network becomes sustainable. There are both informal networks as well as formal networks. Informal networks arise from connections that find its roots for example in job mobility, co-location in multi-tenant buildings and social activities. These informal networks form a base to establish trust and gauge whether an actor, or someone in the actor's network, has knowledge in which others are interested. Next to informal networks there are formal networks, which are primarily based on joint ventures, co-patenting and other forms of collaborations. Such networks show to which extent firms are doing business with each other, as well as to which degree firms rely on business partners inside or outside an industrial district. But primarily, the position in the formal network represents the degree to which a firm can convert its access to knowledge into innovations.

In general, the position within the social network determines the extent to which a firm can access the knowledge residing inside and beyond the boundaries of the industrial district. It then becomes important for firms within the industrial district to position themselves in a beneficial way, where they can connect with the largest relevant crowd possible. For example, when a firm holds a large portfolio of innovations, one would expect that the firm attracts workers that are best capable of appropriating the returns of this current portfolio, as well as those being capable of building upon this current portfolio in order to create new innovations. Hence, the social network of workers is an important mechanism for firms to benefit from co-location in an industrial district. In this paper, to benefit from co-location can be directly translated into being embedded in the LBSP through connections in the local social network.

2.3 The Importance and Ability to Innovate and Access Knowledge

Although the importance of innovation is widely recognized and it is considered an important source of economic growth (e.g. by Romer, 1986 and Krugman, 1991), the importance of innovation differs per firm. For firms in knowledge and technology intensive industries it functions as a competitive weapon and it is often considered as a routinized activity that covers both internal as well as external research and development. The importance of innovations for such industries is supported by empirical findings that firms in industries such as pharmaceuticals and chemicals have the highest likelihood of patenting[2] (Arundel and Kabla, 1998). Hence, it is the industry in which a firm is active that is often decisive for the importance of innovation.

Furthermore, the place a firm occupies within the value chain of an industry determines the importance of innovation. This position within the value chain will determine whether the firm will actively engage in activities to better its access to the required resources for innovation. For example, the degree to which research is among the core activities of a firm will affect the importance of having access to knowledge. Hence, when looking at one particular industry, the importance of research and development within the core activities of a

[2] Patents here serve as a proxy for innovations, as they represent new and technologically feasible devices for which applicants believe in its economic value.

firm will influence the likelihood for being embedded in the LBSP network through connections. Firms that rely more on external knowledge from the LBSP are more likely to try and benefit from that environment, thus:

Hypothesis 1a: *the bigger the importance of being innovative as a firm, the more likely it becomes that a firm is embedded in the network of the LBSP.*

Next to the place within the value chain, the availability of resources plays an important role in the ability to be innovative as a firm. Innovations require new knowledge to be generated and applied, which in turn requires resources such as skilled labor, materials and equipment. The degree to which a firm has access to such resources will largely determine whether a firm has the ability to embed themselves in the LBSP network. Large firms have bigger ability to access resources, as these firms can allocate relatively more resources in the quest to gain access to new resources, hence:

Hypothesis 1b: *larger firms are more likely to be embedded in the network of the LBSP.*

Since knowledge is such an important feature of innovation, its characteristics are explored in order to better understand the ways in which it can be generated and applied to form innovations. Knowledge is often divided across a large set of actors, as specialisation and task partitioning is a common way of organizing production processes (Smith, 1776). It then becomes important for the firm to attract the right specialized knowledge, which is primarily residing in people, in order to build and strengthen its core business. If firms have attracted this specialized knowledge, it will need to manage the internal processes of creating innovations. There are several ways of managing this process, e.g. creating interaction and communication between the researchers of a firm is a great stimulus for combining knowledge, which may eventually lead to innovation. Next to these internal activities, it can be particularly beneficial to construct and manage ways by which a firm can extract the right specialized and complementary knowledge residing outside the boundaries of the firm, since this knowledge can lead to new insight and eventually can be combined in order to create new knowledge. The optimal construction of generating and managing internal and/or external knowledge is dependent on the characteristics of the knowledge that is to be transferred.

For example, the highly contextual and difficult to codify knowledge that technology intensive firms would transfer is more easily transmitted trough face-to-face communication with personal relationships, which prerequisites spatial proximity or the interfirm movement of individuals (Breschi and Lissoni, 2001 and Saxenian, 1994). This highly contextual and difficult to codify knowledge is also referred to as tacit knowledge. The importance of spatial proximity in order to effectively transfer tacit knowledge can be explained by the need for a deep understanding of the knowledge in question. This also explains why the transfer of individuals can result in the effective transfer of tacit knowledge, since an individual has embedded this knowledge within itself. That it is still hard to verbally explain the tacit knowledge now becomes less important, as the individual can demonstrate and put to work its knowledge at the location of the receiving party.

Firms would do good to organize the process of innovation, when it is deemed a vital part of their competitiveness. An important aspect of organizing this process is that firms need to make decisions on how they source new knowledge. Basically the firm has a make, buy or ally decision for generating new knowledge. The optimal way of constructing and managing this decision process will most likely depend on elements such as the life cycle of the firm, as well as its strategy and its available resources. For example, a more narrow research approach improves appropriability, while at the same time it limits the usefulness of external information sources for a firm’s own innovation process (Kamien and Zang, 2000). This might indicate that single product firms, which exist either by strategic choice, limited resources or because it’s in the start-up phase, should benefit from a focus on internal knowledge production. However, the process in which firms generate and apply new knowledge can also be a bilateral one, in which firms do research and development themselves as well as interacting with a wide variety of actors to source knowledge externally. Including external parties into the activity of sourcing knowledge can be organized in different forms, of which co-patenting, joint ventures and acquisitions are the most common formal ways. One might argue that attracting new personnel or firm takeovers are also activities that aim at sourcing knowledge from external parties, but with a side note that now the external source of knowledge is permanently transferred; it becomes internalized.

Since the LBSP is a specialized industrial district that revolves exclusively around the life sciences, innovation is clearly an important driver of developing a business. However, the degree of being innovative will still differ per firm as the importance and ability for generating and applying new knowledge will vary among the inhabitants of the LBSP.

2.4 Prerequisites for Sustainable Access to Knowledge

It is important for firms located in an industrial district to ensure themselves that a beneficial *milieu* is created within the district, where the joint efforts of the inhabitants create enough inflow of knowledge residing outside the boundaries of the district in order to sustain and revitalize the local pool of knowledge. Hence, optimally benefitting from co-location requires a mixture of positions in networks within and beyond the boundaries of the industrial district.

Tapping into knowledge pools residing outside the boundaries of the industrial district is an important feature that can be realized through networks. The resulting connections that reach out of and across industrial districts can provide “key infusions of novelty that spur the development of good ideas” (Burt, 2004). Organizations with better global positions can more easily reach across geographic distance in pursuit of novelty, and these opportunities can prevent local homogeneity or lock-in (Bunker Whittington et al., 2009). Hence the more a firm engages in boundary spanning connections, the more valuable this firm becomes in terms of revitalizing the knowledge pool of the industrial district. But more importantly, the firm with boundary spanning connections can create new combinations of knowledge more easily then do firms that have no boundary spanning focus. These boundary spanning activities to organisations outside the industrial district are also described as pipelines (Bathelt et al., 2004). Being active inside or outside the boundaries of industrial districts in terms of network involvement can not be seen in isolation. It is argued that combining both an inward and outward focus when building and maintaining a firm’s network is more beneficial. For example Cassiman and Veugelers (2004) show that firms that are only engaged in a single innovation activity, either by internal R&D activities or sourcing technology externally, introduced fewer new or substantially improved products compared to firms which combine both internal and external sourcing. Hence, the degree to which a firm is embedded within the LBSP network is determined by the balance it maintains between an LBSP and a boundary spanning focus when sourcing new knowledge.

Hypothesis 2: *A firm’s focus on boundary spanning knowledge sourcing has a positive effect on the embeddedness within the LBSP network.*

2.4 Prerequisites to Understand and Use Knowledge

Being located in an industrial district and having access to a sustainable pool of knowledge is beneficial for the benefit a firm experiences from being co-located on an industrial district, but there is one more element to add to it. A firm needs to understand and use the knowledge, in order to be successful at being innovative. The effectiveness, at which a firm can use the knowledge and benefit from it, will largely be determined by the capacity of a firm to identify, interpret and exploit new knowledge. In order to achieve this, firms need a good absorptive capacity (Cohen and Levinthal, 1990). Identifying new knowledge may primarily run through structures such as being embedded in local social networks, but the ability to interpret and exploit new knowledge requires something else, namely cognitive proximity. It is only when a firm has the cognitive skills to match the new knowledge at hand, that this firm is able to appropriate the returns from the new knowledge. The degree of cognitive proximity will influence the degree of effectiveness of interpreting new knowledge. Boschma and Lambooy (1999) state that the cognitive base of firms should be close enough to the new knowledge in order to communicate, understand and process this knowledge successfully. Then the optimum cognitive base between firms would be one where the distance is not too great nor to proximate, i.e. the relationship will likely show an inverted u-shape. This inverted u-shape exists because the interfirm learning will cease when the cognitive distance becomes either too great or to proximate (Boschma, 2005 and Nooteboom, 2000), hence:

Hypothesis 3a: *the more cognitive proximity a firm has in the LBSP technology map, the more likely it is to be embedded in the LBSP network.*

A firm is not isolated in his efforts to appropriate the returns from new knowledge, for there are institutions such as the government and universities that can help in the quest for innovation. Government often have funds available for ventures that focus on creating innovations, and besides that it is argued that firms benefit from interactions with supporting organizations such as universities. For example, Liebeskind et al. (1996) uncovered that for the biotech sector, companies that were engaged in joint research and publishing with academic institutions were more effective at externally sourcing new scientific knowledge. Hence, interactions with universities are beneficial, as universities function as an intermediary to bridge gaps in cognitive distances between a firm’s pool of knowledge and a targeted piece of new knowledge.

Hypothesis 3b: *Interactions with public research institutions have a positive effect on the embeddedness within the LBSP network.*

It is the coming together of the elements above that should lead to an optimal structure for firms to embed themselves in the LBSP network. In the parts to come, it is examined whether and how these elements determine the differences in embeddedness between firms that are co-located at the LBSP.

3. Method of Research

3.1 Data

The data for this research is derived from three databases. The first database is a 2009 database from Leiden University – faculty Science Based Business, which contains organizational and historical information from 1984 up to 2010 about the organizations that were and are active on the LBSP, together with detailed information of firm's management teams including individual job mobility. This database is complemented with organizational data from the Reach database. Also, various company public websites are used to collect additional data not present in the two above mentioned databases. This results in a dataset that contains 110 LBSP organizations and 163 LBSP managers.

For the construction of a second dataset, there is a third database that is used. This second dataset is derived from the OECD REGPAT database (January 2010)[3] and contains regional codes and IPC codes[4] information about applicants and inventors for each patent. Since this database contains worldwide patents, and the interest for this study lies exclusively in patents that revolve around the LBSP, a thorough selection was made. This selection was made by [1] selecting patents from the Leiden region (NL331), [2] manually filtering the firms located on the LBSP based on the information in dataset one, [3] selecting a list of unique application id's, [4] running a query to add all applicants linked to these application id's and [5] finalising it by search queries to look for any other LBSP patents based on the names of the LBSP firms

[3] The OECD REGPAT database itself is derived from two complementary sources of data: [1] the European Patent Office's (EPO) Worldwide Statistical Patent Database (September 2009) and [2] the EPO's epoline database, which is covering publications up to November 2009.
[4] IPC stands for International Patent Classification and is developed under the 1971 Strasbourg Agreement.

in dataset one[5]. The selection resulted in a dataset that contains a total of 33 LBSP firms that are registered patent applicants, which represents 30% of the LBSP firms in dataset one. These 33 LBSP firms where part of 105 unique (co-)applicants that registered 666 unique patent applications between 1982 and 2010, using a total of 947 unique inventors.

3.2 Research Design

3.2.1 Explanatory Variables

Importance of Sourcing Knowledge (Importance)

To measure the importance of sourcing knowledge the degree to which research is a part of the firm's core business is determined. By categorising the activities conducted in the life science value chain, and assigning a degree to these categories to which research is part of a firm's core business[6], the average degree to which research is part of a firm's core business can be established. The value chain categories and their degrees are presented in table 1 and are accompanied by an intuitive motivation. If a firm has developed multiple value chain activities, then equal shares in size of these activities are assumed (as no data concerning activity size is available). The equation to calculate the firm's average importance of sourcing knowledge becomes:

[1] $$\alpha = \sum_{n=1}^{\infty} \left(\frac{1}{N} * \lambda_{n_1} \right)$$

Where α is the firm's average importance of sourcing knowledge, N is the total number of value chain categories a firm is active in and λ is the degree to which the specific value chain activity (n_1) is focussed on research.

[5] Patents from LBSP firms that were added based on these search queries where mainly from firms that have their headquarters located outside the Leiden region. By only adding patents that used a minimal of one Dutch inventor, I aim to exclusively add patents that have their R&D origin on the LBSP. Besides the public research organization TNO, there are no organizations that have their headquarters elsewhere in the Netherlands. The number patents for TNO that have a LBSP origin where identified by inquiry at the TNO Leiden location.

[6] Although determining these degrees is a somewhat subjective process, the importance lies in the relative distances between the degrees based on the value chain categories and not in the exact degrees.

Table 1. Value Chain Categories and their Degree of Research being the Core Business

Value Chain Categories & Degrees	Motivation
Services: 50%	Delivering services for the life sciences signals that conducting research is not a core business, however process innovations might be created.
Production: 50%	Running production for the life sciences signals that conducting research is not a core business, however product innovations might be created.
Development: 75%	Development complements research and shall primarily focus on improving and applying product and process innovations.
Research: 100% (functions as base)	Conducting research signals the full importance of sourcing knowledge, primarily to create product and/or process innovations.

This variable is also used to determine whether a LBSP firm is 'at risk' of patenting. Being at risk of patenting, or actually having patents, means that a position within the formal local social network is relevant for a LBSP firm. At risk here is defined by a threshold of 0.75, which needs to be met or exceed in order to be at risk.[7] The threshold signals serious R&D activities for a LBSP firm and hence gives rise to the importance of innovation for that specific firm. This effectively creates a subset of firms that have importance for innovation and hence an incentive to embed themselves in the formal local social network.

Ability to Source Knowledge (Size)

The ability of firms to source knowledge is linked in the theory section with the size of a firm. It is expected that the size of a firm affects the embeddedness of a firm in the LBSP network, as it has better abilities to source knowledge due to the greater resources that can be allocated in this process. This study uses the number of employees as a proxy for the size of the firm.

External Knowledge Sourcing (EKS and EKSsq)

To measure the theorized effect of the degree of external knowledge sourcing on the embeddedness of a firm in the LBSP network, a variable is created by taking the ratio to which non-LBSP organizations are used in a firm's knowledge sourcing activities. This is calculated by taking the patent applications that are shared with a minimum of one non-LBSP organization, as a ratio of the total number of patent applications a LBSP firm holds. This ratio functions as a weighted average, thus dealing with differences in the number of patents

[7] Detailed information regarding the process of determining the threshold for being at risk and additional descriptive statistics can be found in A1.

between LBSP firms. From a benefit perspective, there is likely to be an optimum between LBSP and non-LBSP knowledge sourcing. Both ends of the spectrum result in a narrower view when compared to the centre, where tapping into a balanced mix of both LBSP and non-LBSP sources leads to an optimum in the benefit derived from the amount of knowledge sourced. Hence, the relationship between the embeddedness in the LBSP network and a firm's focus on sourcing non-LBSP knowledge is theorized to show an inverted U-shape. To examine the relationship characteristics the variable is squared. This way, examining whether the relationship shows signs of an inverted U-shape becomes possible.

Cognitive Proximity in Local Technology Map (TechnologyMap)

To analyse the effect of cognitive proximity in the technology map of the industrial district, a variable is constructed using the IPC codes that are registered for every patent application[8]. The cognitive proximity is measured by first constructing a two mode network of the co-occurrences of IPC codes in all LBSP patents. Using UCInet[9], this two mode network is transformed into a one mode affiliation network, where the IPC Codes are lined up against each other to form a valued matrix. Based on this IPC codes affiliation network, the geodesic distances between IPC codes can be calculated. Where a distance of 1 signals a direct link, and higher numbers signal greater distances. These technologies need to be connected to individual patents, in order to then connect these patents back to individual LBSP firms. To do this, the geodesic distances of individual IPC codes that together form a patent are all lined up to the geodesic distances of all other IPC codes, for which weighted averages are taken for each patent[10], creating a degree of cognitive proximity between all LBSP patents. One step further, all patents of a LBSP firm are then individually lined up to the geodesic distances of all other patents, for which weighted averages are taken of the patent portfolio for each firm[11]. Finally, by taking the average geodesic distances of a firm based on the geodesic distances towards all other firms located inside the industrial district, the variable needed for this study is created. During the construction of this variable, the non-patenting firms will be omitted as these do not have observations for this explanatory variable. Also, since calculating the variables based on IPC codes can only be preformed when the technologies are part of the

[8] The LBSP Patents can have up to 35 IPC Codes per patent. Although the IPC coding system entails five different categorized classes to classify technologies, namely section / class / subclass / main group / sub group, only the first four are used as this improves data handling. Although this strengthens the cognitive proximity to some extent, for the purpose of this study it is not harmful as the first four classes entail enough detail.

[9] Borgatti, S.P., Everett, M.G. and Freeman, L.C., 2002, Ucinet for Windows: Software for Social Network Analysis. Harvard, MA: Analytic Technologies.

[10] Weighted averages are taken to account for the number of IPC codes across different patents.

[11] Weighted averages are taken to account for the number of patents across different firms.

main component, four firm observations are lost as a result. For this variable it holds that the higher a firm average geodesic distance, the greater the distance that a firm has towards the LBSP technology map.

Presence of University Collaboration (UniCollab)

By dividing the patenting firms into two groups, based on collaborations with universities on the LBSP (both Leiden University and LUMC), the effect of these collaborations on the embeddedness of a firm in the LBSP network can be analysed. Collaborations with the university are based on shared patent applications between a firm and the university. Hence only patenting firms are taken into account for this explanatory variable.

3.2.2 Dependent Variables

The proxy for benefitting from co-location will be the degree centrality of a firm in either the formal- or informal local social network, since this displays the extent to which a LBSP firm has succeeded in embedding itself into the advanced local business and social structures of the LBSP respectively. Here, the formal local social network constitutes of LBSP firm connected via co-patenting and the informal local social network of social connections between firms based on the LBSP job mobility of management team members. The degree centrality measures the number of ties to others and signals prominence of a LBSP firm in the local social network.

Building a proxy for benefitting from co-location in this study was done by measuring the position of a LBSP firm within the local social networks. The proxy for benefitting from co-location could also be derived from the number of patents that a LBSP firm holds, as this represents a technological feasible devise for which the inventor believes in its economic value. The number of patents can be considered as a step further along the line, as one can argue that patenting depicts a LBSP firm that has made use of its position within the local social networks and transformed its benefits into innovative activity. However, R&D expenditures have very strong empirically links with the number of patents and the data concerning R&D expenditures is not available for a large part of the sample. This is due to the fact that not many LBSP firms are public organizations, resulting in the exclusion of this alternative proxy.

Degree Centrality of a Firm in the Informal Local Social Network (DCInformal)

The informal local social network is constructed based on the job mobility of managers on the LBSP. First, a two mode network is build which includes all 163 managers and all 110 LBSP firms, where subsequently for all managers the number 1 is placed by the LBSP firms where they worked. Then, using UCInet, this two mode network is converted into a one mode affiliation network based on the co-occurrence of all pairs of LBSP firms that have been frequented by the same manager. Using this affiliation network, the degree centrality of LBSP firms can be calculated based on the connections that occur via the informal local social network based on the job mobility of managers. Here it is assumed that the manager is likely to connect the two firms, in which it worked, and that both have the same potential benefit from this connection.

Degree Centrality of a Firm in the Formal Local Social Network (DCFormal)

The formal local social network is constructed based on LBSP firms that either have patents or are at risk of patenting (as described earlier). This creates a subset of firms. Here, a two mode network is build which includes 33 patenting firms and 666 patents, where all LBSP collaborations between LBSP firms were marked with the number one[12]. Then, also using UCInet, this two mode network is converted into a one mode affiliation network based on the co-occurrence of patents between the subset of LBSP firms. The degree centrality of LBSP firms is calculated based on the connections that occur via the formal local social network, which is based on shared patent applications between LBSP organizations.

3.2.3 Control Variables

Time on Park (TimeOnPark)

The time that a firm is present on the park measured in years serves as a control variable in this study, as this represents the time a firm has to learn and embed itself in the local social networks. Hence a greater potential benefit can be expected for firms that have spend more time on the LBSP. This continuous variable thus controls for a duration benefit.

[12] Note that this differs from the variable EKS as this considers the ratio of non-LBSP patent collaborations towards all patent applications. For DCFormal, the interest lies in the number of LBSP patent collaborations.

Presence in Incubation Building (Incubation)

The embeddedness in the LBSP network can potentially be different for firms that had or have their presence in an incubation building, as these buildings offer easy access to co-located firms due to their multi tenant structure. A categorical variable that takes into account any present or historical presence in an incubation building controls for this situation.

Type of Entry

The entry type signals whether the firm has or had significant back-up during their start-up, either by their mother organization or a spin-off origin, which would potentially allow them to embed themselves faster then firms that did not have this kind of back-up. By controlling for the type of entry using the available categories that are assigned to the firms by the park's management, potential head starts are taken into account. This variable is only taken into account during the descriptive statistics, as to provide insights in the LBSP.

3.3 Analytical Strategy

To examine the theorized effects on the degree centrality of both the informal and formal local social network the negative binomial regression is used, as both dependent values show clear signs of excess zeros and over dispersion[13]. The models that are build for both dependent variables are elaborated upon in this paragraph. The models are likely to be subject to reversed causality, for which the data did not allow to control as including time lags of the use of cohorts were not possible with the available data. For the models a significance level of $\alpha \leq 0.05$ (**) is used, but it is also indicated when a significance level of $\alpha \leq 0.01$ (***) or $\alpha \leq 0.10$ (*) is fulfilled. Except for hypothesis 1a, all hypotheses are tested for both dependent variables. Since hypothesis 1a specifically looks at the importance for innovative activity, it would have spurious effects on the degree centrality of a firm in the informal local social network, as all firms have their own incentive to embed themselves in this type of local social network, e.g. to establish potential new business contracts for servicing firms. For the other hypotheses, both dependent variables are likely to be affected by the explanatory variables; hence the hypotheses are tested for both dependent variables.

For the degree centrality of a firm in the informal local social network, there are four different hypotheses to be tested, namely 1b, 2, 3a and 3b. To do this, two base models are used in

[13] Supporting data for fitting the models are presented in appendix A1

which the control variables are inserted. The first base model is used for hypothesis 2, 3a and 3b and uses the control variable TimeOnPark. Since these hypotheses draw on a small sample, only one control variable is used. The second base model is used for hypothesis 1b and uses the control variables TimeOnPark and Incubation. Upon those two base models, the actual models to test the hypotheses are built. These models are tested in isolation when deemed necessary due to relatively small sample sizes. For hypothesis 1b the variable LNSize is inserted in base model 2. For hypothesis 2, first the variable EKS and subsequently the variable EKSsq are inserted in base model 1. For hypothesis 3a the variable TechnologyMap is inserted in base model 1. Finally, for hypothesis 3b the variable UniCollab is inserted in base model 1.

For the degree centrality of a firm in the formal social network, all hypotheses are tested. Again, the same two base models with control variables are created. These models also do not build upon one another, but are tested in isolation, except for hypotheses 1a and 1b. Hypotheses 1a and 1b are inserted in base model 2 and use the same explanatory variables as mentioned above. Hypotheses 2, 3a and 3b are inserted in base model 1 and also use the same explanatory variables as mentioned above. Hence, in total there will be two base models and 5 explanatory models for which all but one are tested for the degree centrality of firms in both the informal and the formal local social network.

4. Results

4.1 Summary Statistics

The summary statistics of the continuous variables used in the analyses are depicted in tables 2, 3, 4 and 5. These tables are sorted based on the two dependent variables: the degree centrality of a firm in the informal and the formal local network respectively[14].

Regarding the informal network, the variables used in the models are presented in table 1. Although there are 110 organizations in the LBSP, 4 of them function as educational organizations and are omitted from the data as these are theorized to be facilitators in the process in which firms benefit from co-location, which explains the 106 observations for the

[14] Detailed summary statistics regarding normality and subsequent adjustments of the (original) variables are included in appendix A1.

degree centrality in the informal network. Furthermore, the external knowledge sourcing and technology map are based upon patent data, which makes for the lower observations[15].

Table 2. Summary statistics Informal Network

variable	N	mean	sd	min	max
Degree Centrality Informal Network	106	0.943	1.511	0	9
LNSize	106	2.297	1.506	0.693	6.897
External Knowledge Sourcing	33	0.049	0.079	0	0.3
Technology Map	29	6.205	6.021	1.083	19.244
Time on Park	106	10.566	6.967	1	28

Using table 3, it can be seen that the variable representing the Technology Map correlates with the degree centrality of the informal network, the size of a firm and the time a firm is active on the park. Also the size of a firm seems to correlate to some extent with the time a firm is active on the park.

Table 3. Correlation statistics Informal Network

Variable	1	2	3	4	5
1 Degree Centrality Informal Network	1.0000				
2 LNSize	0.3453*	1.0000			
3 External knowledge sourcing	0.1592	-0.0211	1.0000		
4 Technology Map	0.5415*	0.5965*	0.2006	1.0000	
5 Time on Park	0.1352	0.4092*	0.4328	0.5656*	1.0000

* = Significant at a 1% level

Regarding the formal network, the variables used are presented in table 4. Here the number of observations is 72, as these represent the firms that either have patents or are at risk of patenting. Again, the external knowledge sourcing and technology map variables are based upon patent data, which makes for the lower observations.

[15] The technology map shows an even lower number of observations, this is due to the way this variable is constructed, for which further details were given in 3.2.1.

Table 4. Summary statistics Formal Network

variable	N	mean	sd	min	max
Degree Centrality Formal Network	72	0.194	0.597	0	3
Importance of Sourcing Knowledge	72	0.844	0.154	0.5	1
External Knowledge Sourcing	30	0.049	0.079	0	0.3
Technology Map	29	6.205	6.021	1.083	19.244
Time On Park	72	9.819	6.951	1	28
LNSize	72	2.418	1.578	0.693	6.897

Correlation statistics concerning the formal network statistics show that the technology map variable correlates with the degree centrality of the formal network, the time a firm is on the park and the size of a firm. The latter two variables also correlate to some extent with each other.

Table 5. Correlation statistics Formal Network

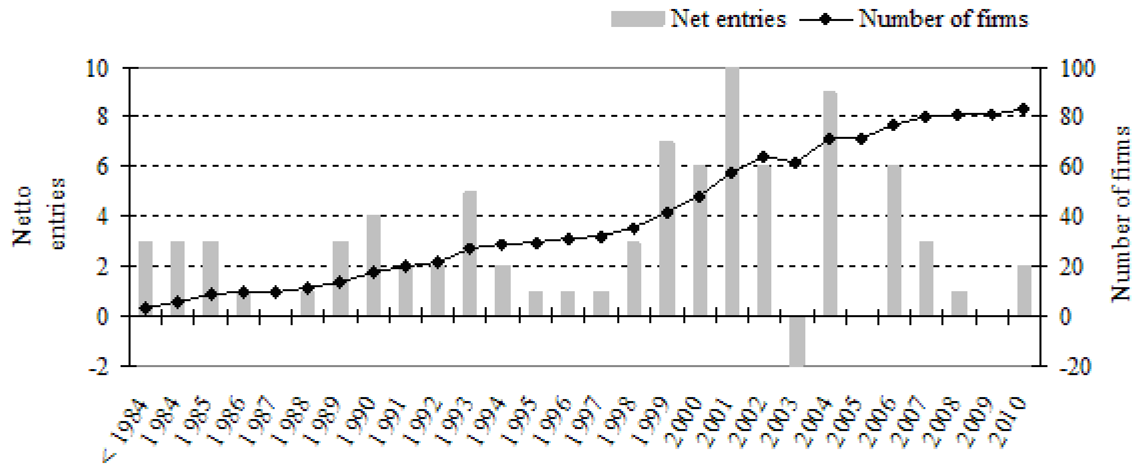
Variable	1	2	3	4	5	6
1 Degree Centrality Formal Network	1.0000					
2 Importance to Source Knowledge	0.0480	1.0000				
3 External knowledge sourcing	0.2205	0.0784	1.0000			
4 Technology Map	0.6134*	0.1351	0.2006	1.0000		
5 Time on Park	0.1920	-0.1618	0.4328	0.5656*	1.0000	
6 LNSize	0.3236*	-0.2011	-0.0211	0.5965*	0.4752*	1.0000

* = Significant at a 1% level

4.2 Descriptive Statistics

By first describing some essentials concerning the LBSP, the characteristics of this industrial district is explored, which allows for a better judgement of part to come. First of all, an industrial district manifests itself over time, showing its importance for a particular sector or region. In 1984, the LBSP officially manifested itself by opening up an incubator facility to attract and help new and existing organizations in the life sciences. Today it still exclusively houses 110 organizations that relate to life sciences, covering an area of approximately 110 hectares in the Leiden region. Over time the LBSP showed a growing number of firms that located themselves on the industrial district. Figure 1 shows the net growth of firms on the LBSP, revealing one primary boost in net entries during the period 1998 up to 2002.

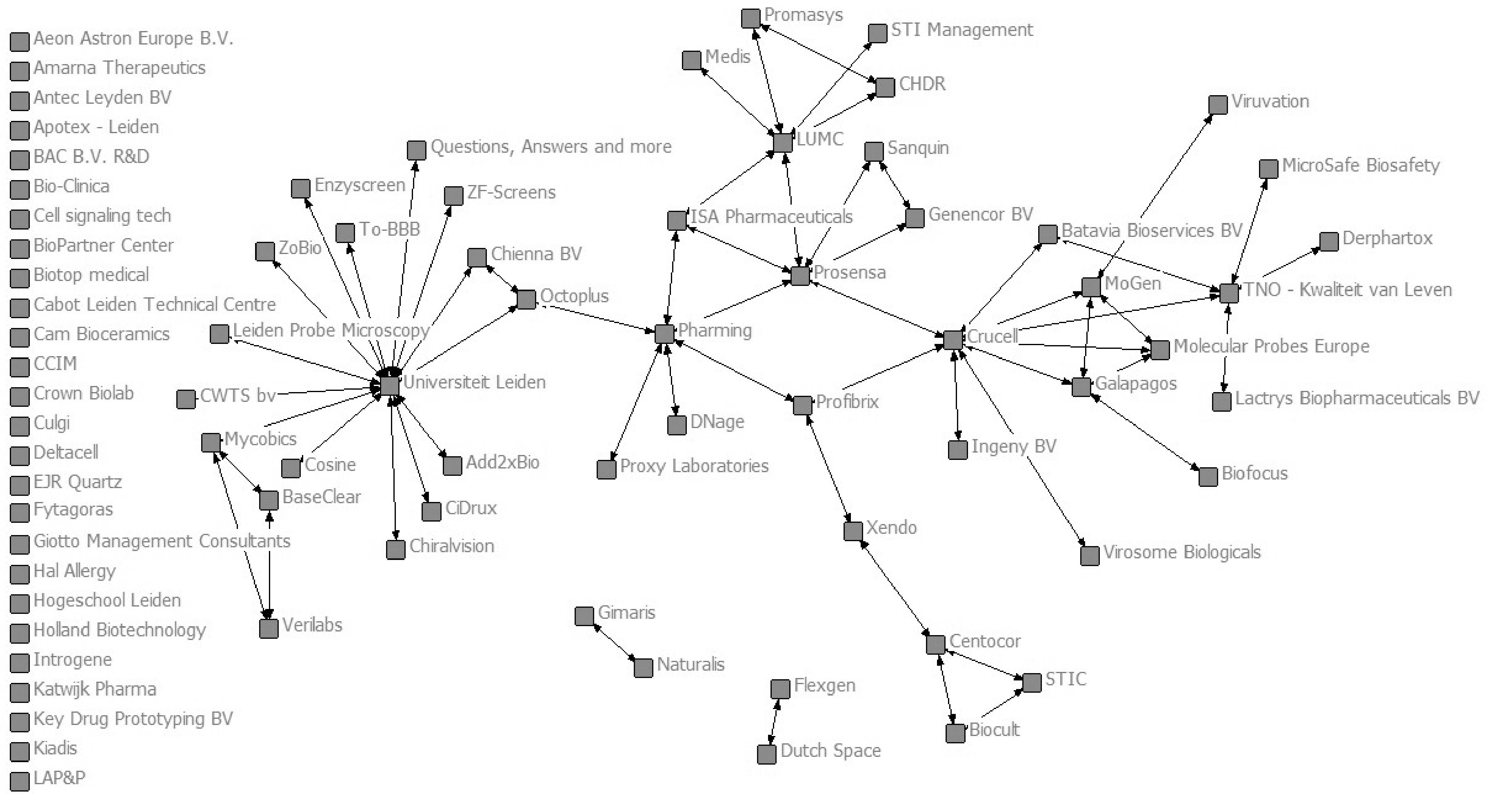
Figure 1. Net growth of firms on the LBSP



The organizations entering the LBSP were start-ups in 40% of the cases, spin-offs in 32% of the cases, division starts in 15% of the cases, relocations in 10% of the cases and for the remainder they were either joint ventures or mergers. Hence, it becomes clear that the primary entry type for the LBSP was the spawning of new firms. In 25% of the cases the LBSP managed to attract firms from elsewhere. Given the fact that 85% of the firms find their origins in the Netherlands, the LBSP is mainly an industrial district of national entities. The organizations are in 62% of the cases aimed at life sciences, 28% provide services related to the life sciences and the remaining 10% is either educational or not-for-profit. More detailed descriptive statistics concerning the LBSP can be found in appendix A2.

The informal social network is build from data concerning the job mobility of managers that are active in the LBSP. Using a total of 163 managers, there are 50 occurrences of job mobility from managers within the LBSP. More then 80% of the 50 job mobile managers switched only once between two LBSP firms. At the upper limit, one manager switched three times and thus worked with four LBSP firms. When constructing a visualization of the affiliation network for LBSP firms, based on their manager's job mobility, figure 1 can be depicted. This figure shows rich mobility of managers within the LBSP and connects large parts of the LBSP firms, resulting in a large main component. This picture clearly shows that both Leiden University and LUMC play important roles in connecting LBSP firms. Also, firms such as Crucell, Pharming, Prosensa and TNO connect many LBSP firms.

Figure 1. Affiliation network visualization of the informal local social network



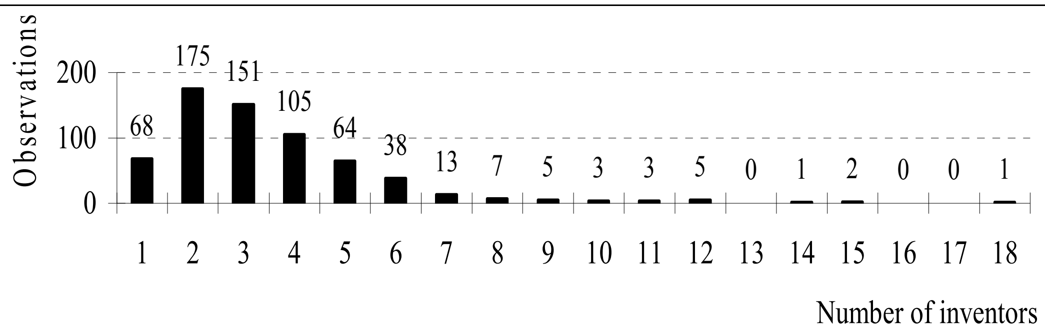
All nodes represent LBSP firms. Data range: 1984-2010

Table 6. Top ten patenting firms at LBSP

#	Name of organisation	Number of patents	Percent
1	Rijksuniversiteit te Leiden	204	32.13%
2	Crucell	149	23.46%
3	Genencor	88	13.86%
4	Centocor	77	12.13%
5	Pharming	29	4.57%
6	OctoPlus	26	4.09%
7	Dutch Space	11	1.73%
8	TNO	7	1.10%
9	BAC	6	0.94%
10	CAM Bioceramics	6	0.94%
Total number of patents		*635*	*95%*

The formal social network is build up from data concerning the patent collaborations between LBSP firms. The patenting firms on the LBSP (33% of total number of LBSP firms) together hold 666 patents. The top ten patenting firms, presented in table 6, hold 95% of all LBSP patents, which includes two organizations that together are responsible for a little over 50% of all LBSP patents[16]. The LBSP firms applied the total of 666 patents in 80.78% of the cases on their own. The remaining 19.22% are cases in which multiple applicants were used. In 17.12% of the cases there were two applicants involved and in 2.10% of the cases between 3 and 6 applicants were used. This sheds light on the way LBSP firms source their knowledge, which is primarily internal. When patenting, the LBSP firms use an average of 3.46 inventors. As can be seen from figure 2, most patents are created with a team consisting of 2 to 4 inventors. The extreme in this picture is where patents are produced with a team of 18 inventors. More descriptive statistics concerning patents on the LBSP are included in appendix A3.

Figure 2. Number of inventors used when patenting

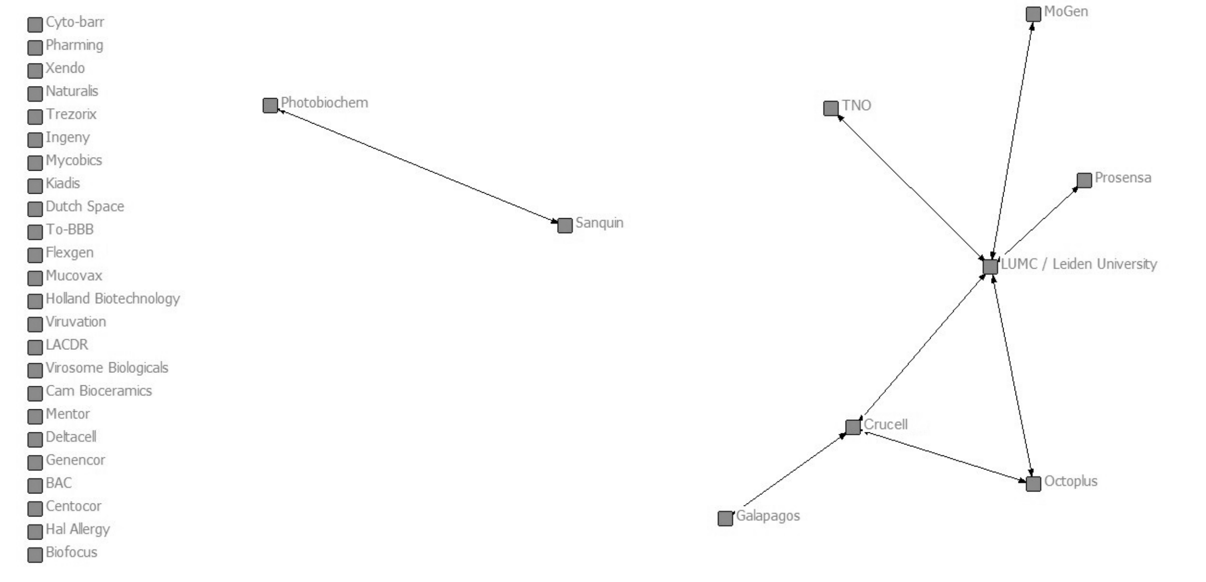


When looking at collaborations between patenting firms, it is interesting to see who the patenting partners are for the LBSP firms. In figure 3, the collaborations between LBSP firms are depicted. It becomes clear that the formal local social network is much thinner, when compared with the informal local social network. Interestingly, most of the key players in the

[16] The Leiden University here consists of LUMC, all Leiden University faculties and all University associated personnel. This clustered information improves data handling and has no effect on the results as educational organizations are left out of the equation.

informal local social network also play an important role in the formal local social network. And when formal local social network activity occurs, it often involves Leiden University / LUMC. Also, a large base of LBSP firms exclusively sources their knowledge internally.

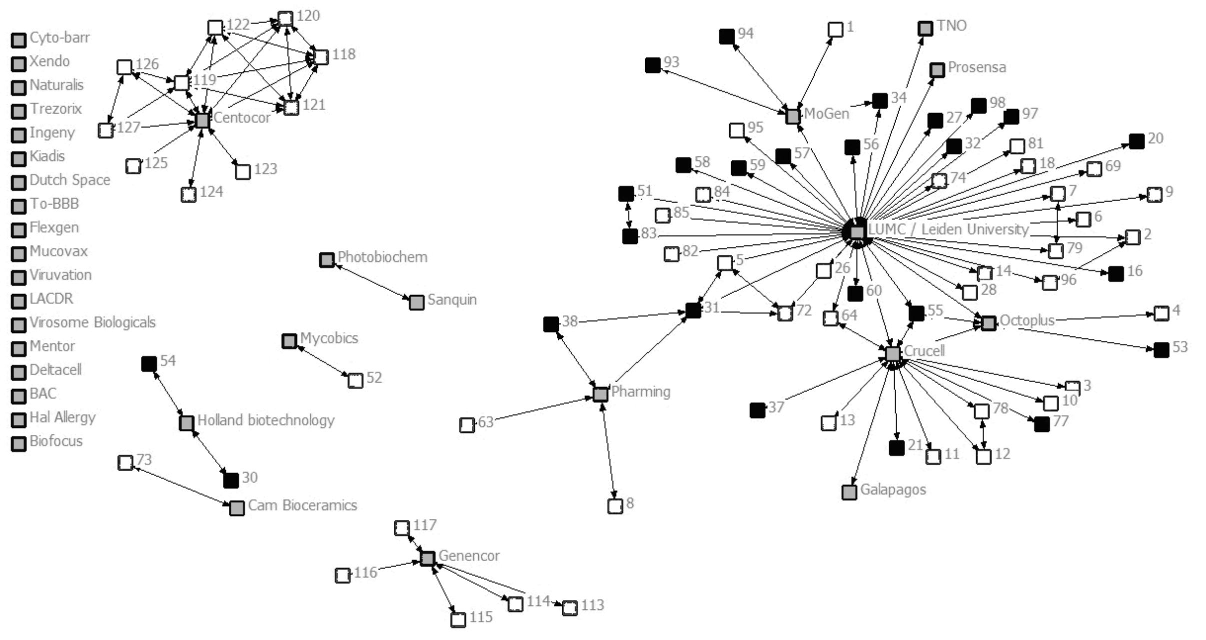
Figure 3. Affiliation network visualization of the formal local social network



All nodes represent LBSP firm. Data range: 1982 - 2010

Although this study focuses on the formal local social network only, the international collaboration partners are also included in the descriptive statistics, since these foreign partners seem to be the predominant patenting partners for the LBSP firms.

Figure 4. Affiliation network visualization of the formal global social network



Gray nodes represent LBSP firms. Black nodes are Dutch- and white nodes are international patenting partners. Data range: 1982 - 2010

In figure 4, less LBSP firms are in isolation, since now they either share patent applications with Dutch (non-Leiden) organizations or with international organizations. Centocor and Genencor, both Leiden based plants with foreign headquarters, focus exclusively on international partners to source their knowledge. Also, it becomes clear that Leiden University and LUMC are great sources of external connections for LBSP firms and form a large main component in the formal local social network. Crucell shows great diversity, as it sources knowledge locally, nationally and also internationally.

When combining the two local social networks, some interesting facts emerge. Although Centocor and Genencor have relatively much external knowledge sources, they are no central players in either the formal or the informal network. Leiden University, LUMC, Crucell and Pharming also have relatively much external knowledge sources and are thereby contributing heavily to the revitalization of the local knowledge pool. These latter organizations are central player in both the formal and the informal network and subsequently re very much at the heart of the LBSP. Also, whereas not much formal local network activity occurs, the informal local social network activity is much more vibrant.

The dependent variables are used as a proxy for benefitting from co-location and it is theorized that the size of a firm in the number of employees has an effect on both dependent variables and importance has an effect on benefit within the formal local social network. Hence, in table 7 the descriptive statistics concerning this theorized effect are presented.

Table 7. Descriptive statistics of firm size and importance

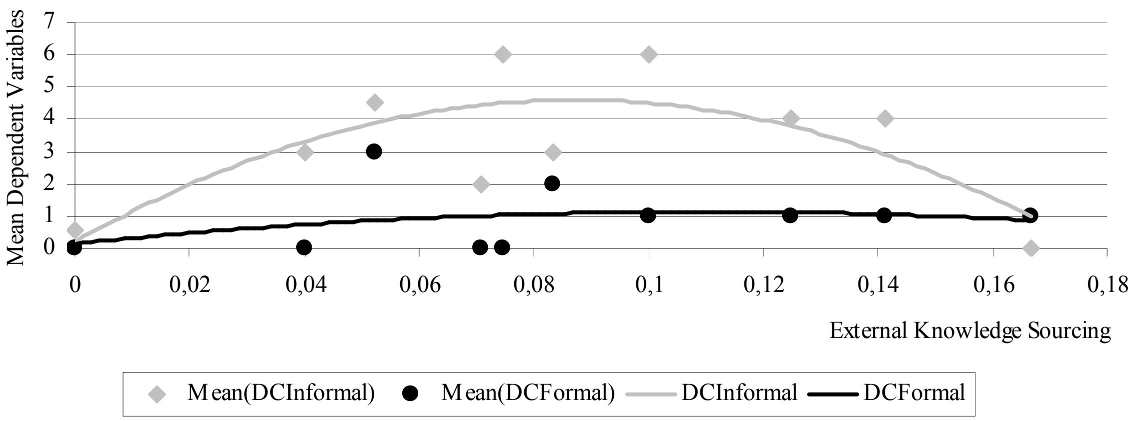
LNSize (Categorical)	**Obs.**	**Mean(DCFormal)**	**sd(DCFormal)**	**Obs.**	**Mean(DCInformal)**	**sd(DCInformal)**
1	25	0	0	25	0.31999999	0.5567765
2	30	0.04545455	0.2132007	30	0.89999998	0.9595258
3	27	0.29411766	0.7717437	27	0.74074072	1.095185
4	24	0.44444445	0.8555853	24	1.875	2.490198

Importance (Categorical)	**Obs.**	**Mean(DCFormal)**	**sd(DCFormal)**
1	41	0	0
2	19	0.31578946	0.8200699
3	22	0.13636364	0.3512501
4	24	0.20833333	0.6580054

By comparing the means of the explanatory variables LNSize and Importance with the two dependent variables, the relations are examined for the first time[17]. It shows that the importance does not show a clear effect on the degree centrality in the informal local social network. However, a bigger firm size results in more centrality in both the informal and formal local social networks.

To examine the relationship between the ratio of external knowledge sourcing and the degree centrality of both the informal and the formal local social network, figure 5 is presented. Here a scattorplot of the observed means is depicted, together with a trendline. As can be seen, the relation between the ratio of external knowledge sourcing and the informal local social network shows signs of an inverted U-shape. This signals that firms that combine both LBSP and non-LBSP sources are more embedded in the LBSP network. The relationship with the degree centrality in the formal local social network is more spurious, as no clear results can be derived from the scatterplot.

Figure 5. Relation between External Knowledge Sourcing and the two dependent variables



Whether the presence in an incubation building resulted in more embeddedness in the LBSP network is first explored by comparing the differences in mean. Table 8 presents the descriptive statistics regarding the differences in mean, where 0 stands for no presence in an incubation building and 1 stands for presence in an incubation building. As the results show,

[17] This meant categorizing the explanatory variables in order to compare the means of these groups with. The first group of importance shows zero values, since the observations in this first group are below the threshold of being taken into account for the formal network. However, the first group of importance in the informal network also shows zero values, these zeros are actual data which gives rise to the isolated position of the smallest LBSP firms.

the mean for both the informal and formal network is lower for LBSP firms that were present in an incubation building, which contradicts theory[18].

Table 8. Presence in Incubation Building

	N	Mean(DCInformal)	sd(DCInformal)	Mean(DCFormal)	sd(DCFormal)
0	74	1.0675676	1.649666	0.25	0.699544
1	32	0.65625	1.095721	0.08333334	0.2823299

4.3 Results

To analyze whether LBSP firms benefit from co-location, a negative binomial regression is performed on which the hypotheses are tested for the degree centrality of a firm in the informal local social network. The result of this analysis is presented in table 9.

Table 9. Benefitting from Co-location via DCInformal

Negative Binomial	Base Models		Size	External Knowledge Sourcing		Technology Map	University Collaboration
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Control Variables							
TimeOnPark	0.0289	0.0216	-0.0093	0.0273	-0.013	-0.0172	0.0186
	(0.0209)	(0.0219)	(0.0230)	(0.0423)	(0.0284)	(0.0361)	(0.0265)
Incubation (presence)		-0.3709	-0.2083				
		(0.3597)	(0.3470)				
Explanatory Variables							
LNSize			0.3151***				
			(0.1012)				
EKS				4.2588	52.9191***		
				(5.3941)	(11.1383)		
EKSsq					-298.8431***		
					(77.0392)		
TechnologyMap						0.1178**	
						(0.0476)	
UniCollab							1.3164***
							(0.4427)
Constant	-0.3841	-0.2079	-0.749**	-0.137	-0.4621	-0.1131	-0.1075
	(0.2775)	(0.3243)	(0.3535)	(0.5459)	(0.4083)	(0.4488)	(0.3840)
Log Likelihood	-141.3181	-140.788	-136.0145	-50.2263	-38.885	-49.1917	-54.3501
Alpha	1.2772	1.2421	0.9271	1.3307	0.1223	0.7593	0.5567
Pseudo R-Square	0.0067	0.0104	0.044	0.0179	0.2397	0.0724	0.0797
Number of Obs.	106	106	106	30	30	29	33

[18] The differences in means however, are not significant, as t-test statistics reveal. These statistics are added in appendix A4. This is likely caused by the small sample size.

In model (1) the first base model is introduced, which includes the variable TimeOnPark. In Model (2) the second base model is presented, which also includes the presence in an incubation building[19]. Both base models include control variables that are not significant. The alpha value is clearly greater than zero, which indicates over dispersed data and signals that indeed the negative binomial model is a better estimated then when using a Poisson model. The alpha values are greater then zero during all models concerning the degree centrality of firms in the informal local social network. Also, the control variables exert no significant effect in all models presented in table 9. When examining model (3), which looks at the effect of the size of a firm on the embeddedness in the LBSP network, then it becomes clear that the variable LNSize has a significant effect at a one percent level. If a LBSP firm becomes one unit more central in the informal local social network, then the difference in the logs of expected counts of LNSize is expected to change by 0.3151, given that the control variables are held constant. This provides support for hypothesis 1b for the informal local social network, the size of a firm has a positive effect. Models (4) and (5) explore the relationship and effect of the ratio of external knowledge sourcing. Model (4) only includes the original ratio variable, which puts forth no significant effect. Model (5) also includes the squared variable to examine any quadratic relation. Now both the original and the squared ratio of external knowledge sourcing have a significant effect at a one percent level. However, the coefficient and subsequently the standard deviations are considered high, which results in caution when interpreting this result. Nonetheless, hypothesis 2 is supported for the informal local social network, since the ratio of external knowledge sourcing shows a significant effect. In addition, and in line with the theory presented, the relation follows an inverted U-shape. Model (6) is concerned about exploring the effect of a firm's centrality in the technology map of the LBSP on the embeddedness in the LBSP network. Here, at a five percent level, the variable shows a significant effect, hence giving support for hypothesis 3a within the informal local social network. In model (7), which is the last model to explore the informal local social network, the effect of interacting with public research institutions is explored. Here, the model shows that for the variable UniCollab[20] the coefficient is significant at a one percent level, meaning that firms that interact with a Leiden public research institution have a higher degree centrality in the informal local social network. More specific, the difference in the logs of expected counts is expected to be 1.3164 unit higher for LBSP firms that interact with public

[19] For this control variable, the category where firms did have a presence in an incubation building is presented.
[20] For this explanatory variable, the category where firms do interact with public research institutions are presented. Here the public research institutions consist of both LUMC and Leiden University.

research institutions compared to LBSP firms that do not interact with these institutions. This model thus shows that hypothesis 3b is supported for the informal local social network. When comparing models (3) to (7) it becomes clear that the effect of the explanatory variables on the embeddedness in the LBSP network is weakest for the variable TechnologyMap in model (6) and for the variable LNSize in model (3). Although the strongest effect is seen in model (5), its interpretation is less clear as the coefficient is high. For the UniCollab variable, presented in model (7), the effect is strong.

Besides the informal local social network, benefits from co-location can also manifest itself via the formal local social network. Table 10 analyzes the effects of the explanatory variables on the degree centrality of a LBSP firm within the formal local social network. In addition to the results in table 9, the importance of being innovative is now also taken into account.

Table 10. Benefitting from Co-location via DCFormal

Negative Binomial	**Base Models**		**Size**	**Importance**	**External Knowledge Sourcing**		**Technology Map**	**University Collaboration**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Control Variables								
TimeOnPark	0.0875	0.0713	0.0344	0.0121	0.0213	-0.0457	-0.0417	-0.0387
	(0.0576)	(0.0587)	(0.0573)	(0.0568)	(0.0765)	(0.0632)	(0.0471)	(0.0398)
Incubation (presence)		-0.6879	-0.0306	-0.02983				
		(0.9727)	(0.2828)	(1.0636)				
Explanatory Variables								
LNSize			0.6029**	0.784**				
			(0.2828)	(0.3209)				
Importance				5.0411				
				(3.5555)				
EKS					9.5522	83.4015***		
					(8.9018)	(30.4155)		
EKSsq						-413.9346**		
						(167.8613)		
TechnologyMap							0.1664***	
							(0.0433)	
UniCollab								3.0552***
								(0.6988)
Constant	-2.6606***	-2.3149***	-3.9693***	-8.6065**	-1.8004*	-2.8008**	-1.8030**	-1.8231***
	(0.7671)	(0.8663)	(1.2686)	(3.6707)	(1.0944)	(1.2540)	(0.7521)	(0.6768)
Log Likelihood	-35.0522	-34.7967	-32.1784	-31.0162	-23.5117	-16.182	-20.2113	-17.7021
Alpha	3.8447	2.6081	3.6586	1.9157	2.5647	0.3536	4.73e-75	7.29e-08
Pseudo R-Square	0.0349	0.0419	0.114	0.146	0.0427	0.3411	0.2163	0.3785
Number of Obs.	72	72	72	72	30	30	29	33

Again, table 10 shows that the first two models are used to introduce the control variables. These variables are the same with respect to table 9, but now the number of observations is decreased, since the subset of LBSP firm that have patents or are at risk of patenting is used. Model (1) starts with TimeOnPark, which is not significant. The constant term for model (1) is significant and negative; this constant remains significant and negative throughout all models. In model (2) the incubation variable[21] is inserted, which also shows no significant effect. Throughout models (1) to (6) the alpha value is greater then zero, which indicates that the negative binomial regressions result in better estimates than a Poisson model. However, for models (7) and (8) the alpha value approximates zero, which reduces both models to the Poisson model. When examining the effect of the size of a LBSP firm on the degree centrality in the formal local social network, it becomes clear that there is a positive significant effect on a five percent level. If a LBSP firm becomes one unit more central in the formal local social network, then the difference in the logs of expected counts of LNSize is expected to change by 0.6029, given that the control variables are held constant. Hence, hypothesis 1b is also supported for the formal local social network. Model (4) examines whether the benefit that a LBSP firm experiences via the formal local social network is affected by the importance of being innovative as a firm. The results show that, when adding the variable Importance to the negative binomial regression from model (3), no significant effect is observed. Hence, no support can be found for hypothesis 1a. In table 10, models (5) and (6) explore the relationship and effect of the ratio of external knowledge sourcing. Model (5) only includes the original ratio variable, which again has no significant effect. Model (6) then includes the squared variable and reveals that now both the original and the squared ratio of external knowledge sourcing have a significant effect. The original variable shows this significant effect on a one percent level, whereas the squared variable is significant at a five percent level. However, the coefficient and subsequently the standard deviations are again considered high, which requires caution when interpreting this result. Hypothesis 2 can also be supported for the formal local social network and again the relation follows an inverted U-shape. To test hypothesis 3a for the formal local social network, the variable TechnologyMap is inserted in model (7) together with the control variable TimeOnPark. Here the results show a significant effect, hence supporting hypothesis 3a. Although the coefficient shows a positive effect, the interpretation is counterintuitive, since a greater centrality in the technology map requires a

[21] Again, for this variable, the category where firms did have a presence in an incubation building is presented

lower value in the Technology Map. More specific, if a LBSP firm were to increase the centrality in the Technology Map, it lowers its value in the TechnologyMap variable; hence the difference in the logs of expected counts would be expected to decrease by 0.1664 unit, while holding the other variables constant. Model (8) explores the effect of interacting with public research institutions on a LBSP firm's degree centrality the formal local social network. Here, the model shows that again the variable UniCollab[22] has a positive significant effect at a one percent level. This provides support for hypothesis 3b. Comparing the results of all models in table 10 gives the same picture compared to the results in table 9; the effect of the explanatory variables on the embeddedness in the LBSP network is weakest for the variable TechnologyMap and for the variable LNSize. The variable UniCollab shows a strong effect.

5. Limitations and Further Research

5.1 Limitations

This study draws exclusively on data gathered for the LBSP, which constitutes both strengthening and limiting factors. As this particular industrial district is relatively small in the number of organizations, only a small sample size can be tested. This small sample size results is thin regression models and makes drawing conclusions a process that has to be done with even more precaution, since the models are tested in isolation and with few control variables. The up side is that the relative small number of organizations enabled the gathering of detailed information regarding a broad number of subjects, hence enabling the exploration of a wide variety of mechanisms that are theoretically involved with being embedded in the LBSP network.

Although the dataset with information about the LBSP organizations includes some data over time, e.g. for the number of employees and the job mobility of managers, to little was known for this study to take the development over time into consideration. However, using cohorts could prove insightful for the effect of time on the embeddedness of a firm in the LBSP network. Then, variables such as the time a firm is active on the park could be analyzed in more detail, giving a more dynamic image of the roles, positions and interactions of the LBSP firms.

[22] Again, for this variable, the category where firms do interact with public research institutions are presented. Here the public research institutions consist of both LUMC and Leiden University.

5.2 Further Research

For future research, it would be interesting to include not only local connections within the social networks, but expand the scope by also looking at non-local connections in both the informal and formal social network. By expanding the scope, a greater part of the actual social network connections from LBSP firms is captured and hence a more realistic and dynamic picture is to be expected regarding the benefits LBSP firms exert from being co-located. Figure 4 in this study hints towards the added power of the non-local connections, which shows the external focus of LBSP organizations for the formal social network. However, adding the non-local connections would imply that now the benefit lies beyond the boundaries of the industrial district, thus exceeding the focus of this study, therefore this scope was not adopted for this study. Nonetheless, non-local connections are theorized to be vital for the revitalization of the local knowledge pool and these connections can track important pools of resources that are essential for a particular industrial district.

Benefitting from co-location in an industrial district has a prerequisite that a firm locates itself in such a geographical delimited space in the first place. This brings up the question why a firm would do such a thing. Certainly, this study explores important benefits from co-location de facto, but it is also interesting to examine whether there is a social precedent to its chosen location. Thus, for example exploring, in a game theory setting, where an entrepreneur roots its business given its current social network and need for resources. This examines the importance of social networks in the beginning of a firm's life. The mode in which a firm enters an industrial district is also explored to some extent within this study, aiming to give insights in the LBSP itself, but further research which focuses on the start of a firm might shed light on the importance of social precedents and their effect over time for the experienced benefit from co-location in a later stage of the firm's life.

As mentioned in the limitations, including a time perspective to examine the evolutionary developments might prove insightful for studying the benefit a firm exerts from being co-located in an industrial district. This additional layer explores whether and how the historical development drives future benefits from co-location.

The LBSP holds relatively few organizations; hence it would be interesting to conduct further research at bigger industrial districts. Testing the mechanisms addressed in this study for other industrial districts would strengthen the understanding of why certain firms benefit from co-location.

By exploring the mechanisms for benefitting from co-location for other sectors, which are either homogeneous of heterogeneous in the types of organizations that inhabit the industrial district, the differences between sectors can be established. As the life science sector, in which all LBSP firm are active, is a highly innovative and publicly supported sector, the benefits from co-location are likely to be different. A different degree of public support, a less technology intensive sector or a different common way of organizing the process of sourcing knowledge can influence the effects and importance of the elements explored in this study. Therefore, conducting this study for other sectors should broaden the understanding of why and how firms benefit from co-location in an industrial district.

6. Conclusions and Discussion

By examining different elements that are theoretically involved with benefitting from being co-located in an industrial district, this study aims to determine who benefits and why. It is explored whether and how firms can be differentiated on the extent to which they benefit from co-location in an industrial district. The elements: the importance to be innovative, the ability to access resources, the balance between internal and external knowledge sourcing, the cognitive embeddedness in the local technology map and the interactions with public research institutions are analyzed on their effects on the embeddedness in the LBSP network, which functions as the proxy for benefitting from being co-located.

For the importance of being innovative as a firm and its effect on the embeddendness of a firm in the LBSP network, no support can be provided based on the results of both the informal and formal local social network. However, the variable introduced to measure the importance certainly had its purpose, since it functioned as a selector for firms that are at risk of patenting. Based on a threshold for being at risk of patenting, the subset of LBSP firms could be filtered which were included in the regressions for the formal local social network. This enriched the data that was built based on patents by only including the relevant firms.

The study found strong evidence that the size of a firm affects the embeddedness in the LBSP network, the results showed that this holds for both informal and formal local social networks. The bigger the size of a firm, the bigger the benefit it experiences by means of degree centrality in both the informal and formal local social network. Basically, this boils down to a mechanism that works the same as with R&D expenditures and patents; the bigger the input in the process to access sources, the bigger the output in term of degree centrality in the local social network. As can be seen from the results, the effect of firm size is bigger for the formal local social network then for the informal local social network.

When examining the effect of maintaining a balance between LBSP and non-LBSP knowledge sourcing on the experienced embeddedness in the LBSP firm, it becomes clear that there is support for the quadratic relationship for both the informal and formal local social network. Hence, as theorized, both a solely LBSP as well as a solely non-LBSP knowledge sourcing focus is less beneficial then a balanced focus on both sources. On the subject of knowledge sourcing and revitalizing the local knowledge pool it becomes clear that only a few key players source substantial non-LBSP knowledge, but not many LBSP firms benefit from being connected with these key players through the formal local social network. Within the informal local social network, these key players command central positions in which they connect with a large main component, hence giving them a beneficial position which results in superior access to resources.

The degree of centrality of a firm in the local technology map and its effect on the embeddedness in the LBSP network is supported for both the informal and the formal local social network. Here, a lower value of the variable results in a higher centrality, i.e. the results show a negative effect of cognitive centrality on the benefit a firm exerts from being co-located. This effect is counterintuitive and requires caution, as the sample size is small and the variable showed correlation with both dependent variables. The effect might give rise to the degree of competition or diversity on the LBSP, which would result in a shielded and/or a fragmented LBSP technology map. These effects are likely, as the number of LBSP collaborations are also relatively low. The effect of having cognitive proximity, however, is the lowest when compared to the other explanatory variables, this holds in both the informal and formal local social network.

The last element examined in this study is the effect of interaction with public research institutions on the embeddedness in the LBSP network. This theorized effect, where such institutions function as intermediaries, is supported for both the informal and the formal local social network. The results show that the effect is biggest within the formal local social network, which means that the biggest benefit from interactions with public research institutions is experienced through an improved embeddedness within the formal network. This, certainly in combination with the findings of the LBSP technology map, signals the important role of the public research institutions for the LBSP firms. Furthermore, these interactions result in relatively big benefits when compared with the other examined elements.

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Appendices

Appendix A1

If necessary, more detailed summary statistics regarding the used variables are depicted here; this includes non-normality statistics and additional information about the construction of variables. First, the variables for the informal network are discussed based on Table A1.1. If new or different information regarding the variables comes up for the formal network, then it is subsequently discussed in the section following Table A1.4.

Table A1.1. Summary statistics Informal Network

variable	N	mean	sd	min	max	variance	skewness	kurtosis
Degree Centrality Informal Network	106	0.943	1.511	0	9	2.282	2.561	11.317
Ability to Source Knowledge	106	38.075	107.420	2	989	11538.970	6.981	59.853
LNAbility	106	2.297	1.506	0.693	6.897	2.268	0.731	2.631
External Knowledge Sourcing	30	0.049	0.079	0	0.300	0.006	1.805	5.622
Technology Map	29	6.205	6.021	1.083	19.244	36.255	1.155	2.831
Time on Park	106	10.566	6.967	1	28	48.534	0.677	2.604

Degree Centrality Informal Network

Table A1.2. Degree Centrality Informal Network

Degree Centrality Informal Network	Freq.	Percent	Cum.
0	57	53.77	53.77
1	26	24.53	78.3
2	11	10.38	88.68
3	6	5.66	94.34
4	2	1.89	96.23
5	1	0.94	97.17
6	2	1.89	99.06
9	1	0.94	100
Total	**106**	**100**	

The first dependent variable shows signs of over dispersion, as the variance exceed the mean. This variable has excess zeros, since 53.77% of the observations have 0 degree centrality in the informal network, as can be seen from table A1.2. No adjustments were made for this variable, despite of the high values for non-normality, as the negative binomial regression does not assume a normal distribution for the data and account for the over dispersion by using an additional error term.

Ability to Source Knowledge

The number of employees, used to construct the ability variable, is based on the Reach database which selects data from the last available year. The original variable shows heavy signs of non-normality, given the values of 6,981 and 59,853 respectively for skewness and kurtosis. Hence, the variable is adjusted based on non-normality by log transforming it. The log transformed variable (LNAbility) is used in regression and shows no sign of non-normality.

External Knowledge Sourcing

The variable to account for the ratio of external knowledge sourcing draws on patent data for its construction, hence a smaller sample remains. This variable shows excess counts of zeros in 51.43% of the cases. Three observations were dropped as they were labelled as outliers at the far right side of the distribution. To examine the relationship characteristics of this variable, more specifically the potential quadratic one, two additional adjustments are made for this variable. First, the variable is categorized in order to examine its characteristics in the descriptive statistics. Second, a new variable is constructed by squaring the original term in order to examine the characteristics in the regression model.

Table A1.3. External knowledge Sourcing Ratio

EKS	Freq.	Percent	Cum.
0	18	60.00	60.00
.0400	1	3.33	63.33
.0522	2	6.67	70.00
.0707	1	3.33	73.33
.0747	1	3.33	76.67
.0833	1	3.33	80.00
.1	1	3.33	83.33
.125	1	3.33	86.67
.1414	1	3.33	90.00
.1667	1	3.33	93.33
.25	1	3.33	96.67
.3	1	3.33	100.00
Total	**30**	**100.00**	

Time on Park

The control variable runs up to a maximum of 28 years. Although three organizations where located on the same geographical space for longer then those 28 years, the maximum is set to 28 as this marked the beginning of starting up the industrial district. 26 years ago the official start occurred, as more organizations located themselves on what was then named the LBSP. So setting the maximum to 28 is a margin for the original organizations, which depicts the head start they had and also recognizes them as the originators.

Incubation

The LBSP currently has two incubation buildings for which a total of 32 (former) inhabitants are recorded, namely the BioPartner 1 and BioPartner 2. The latter was originally named Academic Business Centre and signalled the start of the LBSP in 1984.

Table A1.4. Summary statistics Formal Network

variable	N	mean	sd	min	max	variance	skewness	kurtosis
Degree Centrality Formal Network	72	0.194	0.597	0	3	0.356	3.520	15.455
Importance of Sourcing Knowledge	72	0.844	0.154	0.5	1	0.024	-0.885	3.010
External Knowledge Sourcing	30	0.049	0.079	0	0.3	0.006	1.805	5.622
Technology Map	29	6.205	6.021	1.083	19.244	36.255	1.155	2.831
Time On Park	72	9.819	6.951	1	28	48.319	1.010	3.293
Ability to Source Knowledge	72	46.847	127.752	2	989	16320.470	5.935	42.761
LNAbility	72	2.418	1.578	0.693	6.897	2.490	0.707	2.545

Although the sample size differs for the formal network, only two variables are noteworthy since they are newly added. The other variables were given no different treatment based on the difference in sample size.

Degree Centrality Formal Network

The second dependent variable also shows sign of over dispersion, as the variance exceed the mean. This variable also suffers from excess zeros, which shows in table A4, since 87,5% have 0 degree centrality in the formal network. Again, no adjustments were made for this variable, despite of the high values for non-normality, as the negative binomial regression does not assume a normal distribution for the data and account for the over dispersion by using an additional error term.

Table A1.5. Degree Centrality Formal Network

Degree Centrality Formal Network	Freq.	Percent	Cum.
0	63	87.5	87.5
1	6	8.33	95.83
2	1	1.39	97.22
3	2	2.78	100
Total	**72**	**100**	

Importance

The continuous variable has a range between 0.5 and 1.0, which are the direct result of the chosen categories of table 1 in the main body. The importance variable has a double function, where first of all it sets the threshold for firm to be ‘at risk’ of patenting and second of all it is created to examine its relationship with the embeddedness in the LBSP network. It sets this threshold in order to select a subset of LBSP firms that theoretically have, to different degrees, an important place for innovation within it core activities. For this subset, the degree centrality in the formal network is calculated, as it is theorized that for them it is important to embed themselves in the formal network.

Table A1.6. Importance of innovation

Importance	Freq.	Percent	Cum.
0.5	42	38.18	38.18
0.625	2	1.82	40
0.75	20	18.18	58.18
0.875	22	20	78.18
1	24	21.82	100
Total	**110**	**100**	

Appendix A2

Additional descriptive statistics concerning the LBSP are given in table A2.1.

Table A2.1 Characteristics of organizations located on the LBSP (2010)

Entry/Exit	Observations	Percent
Entries	110	100%
Exits	26	24%
Netto	*84*	*76%*

Point of origin	Observations	Percent
Local	93	85%
National	9	8%
International	8	7%
Total	*110*	*100%*

Firms that:	Observations	Percent
Holds patents	33	30%
use(d) incubator	32	29%
Total	*110*	*100%*

Type of entry	Observations	Percent
Start-up	44	40%
Spin-off	35	32%
Division start	17	15%
Relocation	11	10%
Joint venture	2	2%
Merger	1	1%
Total	*110*	*100%*

Business	Observations	Percent
Life sciences	68	62%
Services	31	28%
Not for profit	7	6%
Education	4	4%
Total	*110*	*100%*

Descriptive statistics	Mean	SD	Min	Max	N
Age of organisation*	15.538	18.963	2	128	106
Years on LBSP*	10.566	6.967	1	28	106
Age on entering LBSP*	4.972	17.225	0	108	106
Number of employees*	38.075	107.420	2	989	106

* Excluding educational organisations

Appendix A3

Additional descriptive statistics concerning the LBSP patent are presented here.

The number of patents that LBSP firms have records up to 204 patents, as can be seen from figure A3.1. Most LBSP firms have not more then 8 patents, which can be seen from figure A3.2. This figure zooms in to give a clearer picture of the number of patents for LBSP firms.

Figure A3.1 Number of patents observed within the patenting firms

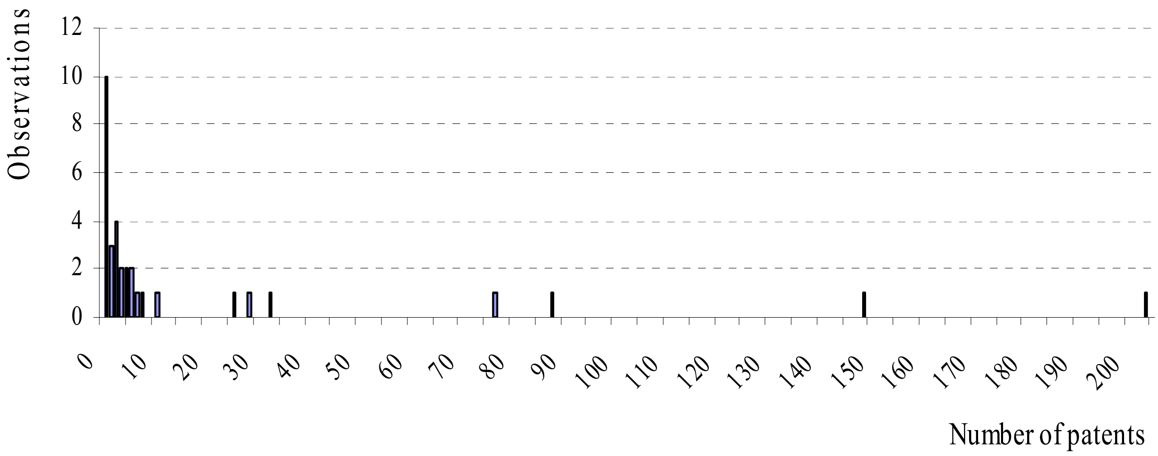
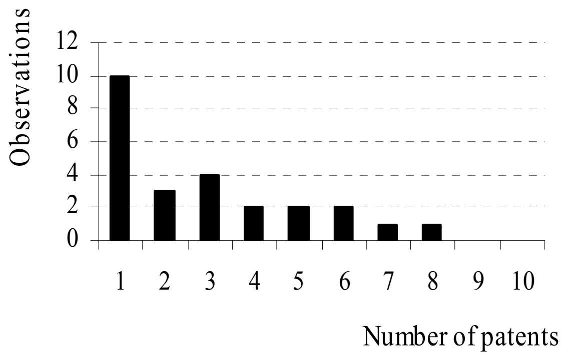
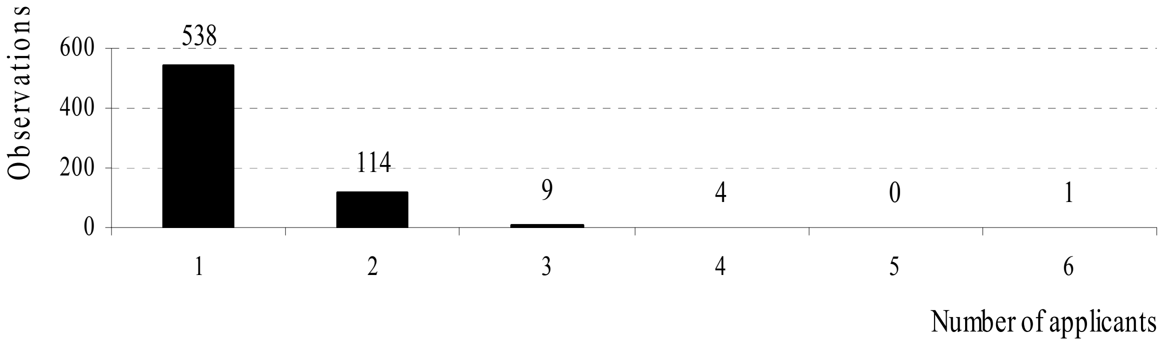


Figure A3.2 Zoomed in on number of patents observed



The number of applicants per patent depicted in figure A3.3 shows that, by far, most LBSP firms are the only applicant for their patent. This means that LBSP firms prefer to source their knowledge internally. When LBSP firms do apply their patents with more applicants, then the predominant number of partners is one. Just a few LBSP firms use more then one patenting partner, namely two partners in 9 cases, three partners in 4 cases and five partners in 1 case. shows this information.

Figure A3.3 Number of applicant per patent



Where in the main body the top ten patenting LBSP firms was presented, here, in addition, the top ten patenting inventors at LBSP are presented. The LBSP shows some frequent inventors, such as A. Bout with a total of 35 patents, M.J.E. Havenga with 32 patents and R. Vogels with 27 patents. The top ten patenting inventors are involved with one third of all LBSP patents, showing that, combined with the above patent information, just a hand full of inventors have a large degree of innovative LBSP activity registered on their name.

Table A3.1 Top ten patenting inventors at LBSP

#	Name of inventor	Number of patents	Percent
1	A. Bout	35	5.51%
2	M.J.E. Havenga	32	5.04%
3	R. Vogels	27	4.25%
4	W.J. Quax	19	2.99%
5	B.E. Jones	18	2.83%
6	A.P. Otte	17	2.68%
7	C.A. de Kruif	16	2.52%
8	C.J.M. Melief	16	2.52%
9	J. Giles-Komar	15	2.36%
10	P.J.J. Hooykaas	15	2.36%
Total number of patents		*635*	*33%*

Appendix A4

T-tests for differences in mean between both the formal and informal local social network variables and their presence in an incubation building are presented here.

Table A4.1 Two Sample T-Test (differences in DCInformal means by Incubation)

Incubation building	Obs	Mean	Std. Err.	Std. Dev.
0	74	1.0676	0.1918	1.6497
1	32	0.6563	0.1937	1.0957
combined	109	0.9434	0.1467	1.5108
Ho: Mean (1) = Mean (0)	**Ha: Mean (1) != Mean (0)**		**T = 1.2909**	**P = 0.1996**

Table A4.2 Two Sample T-Test (differences in DCFormal means by Incubation)

Incubation Building	Obs	Mean	Std. Err.	Std. Dev.
0	48	0.25	0.101	0.6995
1	24	0.0833	0.0576	0.2823
combined	72	0.1944	0.0703	0.5967
Ho: Mean (1) = Mean (0)	**Ha: Mean (1) != Mean (0)**		**T = 1.1193**	**0.2668**