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ABSTRACT

University Spillovers: Strategic Location and New Firm Performance*

This study examines the impact of location choice as a firm strategy to access knowledge spillovers from universities. Based on a large dataset of young high-technology start-ups publicly listed in Germany, this Paper tests the propositions that not only geographic proximity to the university matters, but also that the degree to which location choice matters is shaped by the field and type of knowledge spillover. The role of geographic proximity as a location strategy is more important in accessing and absorbing knowledge spillovers from publications in scholarly journals in the social sciences than in the natural sciences. By contrast, geographic proximity is more important in accessing human capital embodied in university graduates in the natural sciences than in the social sciences. The results suggest that location proximity to a university effects firm performance.

JEL Classification: L20, M13 and R30
Keywords: entreprenuership, strategic firm location and university spillover

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1. Introduction

The assets that really count are those accountants can't count

(T. A. Stewart 1995, in Fortune 137 (7), p. 157).

The growing literature on technology management and the economics of innovation has found that knowledge spillovers play an important role in fostering innovative activity (Sorenson/Audia 2000, Baum/Sorenson 2003). In addition, spillovers from universities, as well as from private firms, have been identified as a key source promoting firm innovation and performance (Stuart/Sorenson 2003). However, while the literature has identified the important role played by knowledge spillovers in general, and spillovers from universities in particular (Varga 2000, Stuart/Shane 2002, Anselin et al. 2000, Santoro/Chakrabarti 2002), several key questions surrounding the strategic locational decisions confronting firms remain unexplored.

First, scholars have confirmed that knowledge spills over and that such knowledge spillovers matter in the formation of clusters and agglomerations. But to move beyond this insight much work remains to be done. The concept of knowledge spillovers has been generally treated as being homogeneous. Yet, surely not all knowledge is the same. As concluded in Baum and Sorenson's (2003) volume on *Advances in Strategic Management*: *Geography and Strategy*, it is important to establish a greater taxonomy identifying the rich heterogeneity involved in knowledge and the process by which it spills over. Just as the Eskimos have names for the many different types of snow, scholars must begin the arduous task of identifying and distinguishing among the many types of knowledge spillovers.

Secondly, the mechanisms transmitting knowledge spillovers remain relatively unexplored and unknown. How and why knowledge spills over is more than an academic question. Firms would like to know how spillovers can be accessed and absorbed. Thirdly, while research has identified the important role that universities play in generating knowledge spillovers, their impact on the strategic locational choice by firms remains unknown. Finally, the empirical evidence linking firm location to performance is wrought with ambiguities. This may reflect a failure to distinguish between different industries characterized by different knowledge regimes.

The purpose of this paper is to address these significant holes in the literature linking locational choice as a strategic firm decision to knowledge externalities in general and spillovers from universities in particular. We do this by linking the locational choice of firms in terms of proximity to a university to the research and educational outputs of universities. By distinguishing between natural science and social science research outputs, as well as between student graduates in the natural sciences and social sciences, this paper analyzes a data set consisting of 295 publicly listed firms in German high technology and knowledge industries to identify how locational choice varies over different knowledge-based disciplines.

The remainder of the paper is as follows: The next section reviews the previous studies linking geographic proximity to firm location. Section 3 introduces the four testable hypotheses raised in this paper, the description of the database, and the estimation techniques. The empirical results are presented in section 4. In section 5 a summary and conclusions are presented.

In particular, we find compelling evidence suggesting that firms have a high propensity to locate close to universities. However, the role that geographic proximity plays is shaped by the particular knowledge context or specificity and the communication channel. Locational proximity is less important for scientific knowledge generated by universities where that knowledge is codified through high publication and citation. By contrast, locational proximity is more important where the university generates knowledge in the social sciences that is presumably less codified and less specific.

In addition, fresh graduates serve as a spillover mechanism. However, the role of location to absorb the spillovers of graduates apparently differs between the two knowledge regimes. Location matters more in the natural sciences, which presumably reflects the specialized nature of scientific knowledge. By contrast, the more generic nature of social science renders geographic location less important in absorbing knowledge from social science graduates.

Finally, there is at least some evidence suggesting that location is a strategic choice with an impact on firm performance. Since young and innovative firms often require substantial financial resources to fund speculative development projects and future growth, we focus on the time from firm foundation to IPO (Stuart/Hoang/Hybels 1999, Stuart/Sorenson 2003) as a measure for firm performance for young and high-tech firms. Using a hazard duration model, the empirical evidence indicates that proximity to a university reduces the time needed between firm formation and listing on the stock market.

2. Geographic Proximity to Universities as a Locational Strategy

There are two strands of literature linking locational choice as a strategic decision to access and absorb knowledge spillovers. The first strand in the literature focuses on the existence and geographic distribution of university spillovers. The second set of studies deals with the impact of location on the entrepreneurial choice to start and sustain a new firm. While the first strand of literature establishes that knowledge not only spills over from universities but is also spatially bounded, an implication for the model of entrepreneurial choice is that the prospects for a new firm are greater in locations conducive to accessing and absorbing those knowledge spillovers.

2.1 University Spillovers and Geographical Proximity

University spillovers could be defined by externalities towards firms, for which the university is the source of the spillover but not fully compensated (Harris 2001). Such spillovers may arise by personal networks of academic and industrial researchers (Liebeskind et al. 1996, MacPherson 1998), university spin-off firms (Stuart/Shane 2002), participation in conferences and presentations, but also by fresh candidates as an important channel for disseminating the latest knowledge from academia to high technology industry (Varga 2000).

While some models of knowledge diffusion assume that geography plays no role in the cost of adoption (Spence 1984, Cohen/Levinthal, 1990), theories of localization suggest that just because knowledge spills over from universities does not mean that it transmits costlessly across geographic space. In particular, these theories argue that geographic proximity reduces the cost of accessing and absorbing knowledge spillovers.

A prominent example of university spillover is provided by Saxenian (1994). She describes how Silicon Valley began with the students of Stanford Professor *Frederick Terman* who supported his network with both ideas and finances. Jaffe (1989) attributes the main reason for the intellectual atmosphere in Silicon Valley to the prominent and active role played by Stanford University.

Central to the theories of localized knowledge spillovers is the distinction between codified and tacit knowledge (Kogut/Zander 1992). Such elements of know-how and operations cannot be codified easily in a blueprint or a contractual document (Mowery/Ziedonis 2001), or a published article (Audretsch/Feldman 1996). Tacit knowledge needs oral communication and reciprocity which may be ineffective or infeasible over longer distances. Thus, technology transfer or exchange is associated with personnel contacts. The limited geographic reach of such channels for the exchange of information and know-how is one of the leading causes of the impact of geographical proximity. Or, with the words of Alfred Marshall (1890) more than a century ago, "the mysteries of the industry are in the air".

Another explanation why knowledge may be costly to obtain for those not located in geographic proximity to the knowledge source is related to the actual information transfer decision. Many communication processes appear to involve barter of knowledge and ideas (Schrader 1991). Spatial proximity enables the exchange partners to observe and monitor each other's behavior to avoid problems resulting from asymmetric information. Finally, it may be possible to learn certain skills by imitation. This is rather costly without close observation (Harhoff 1999). Thus, geographical location is a strategic element that can generate competitive advantage through accessing and absorbing new knowledge from spillovers at lower costs (Chevassus-Lozza/Galliano, 2000).

Because firms access external knowledge at a cost that is lower than the cost of producing this value internally or of acquiring it externally from a geographic distance (Harhoff 2000), they will exhibit higher expected profits. The cost of transferring such knowledge is a function of geographic distance and gives rise to localized externalities. Thus, the empirical analysis on university spillovers assumes that the geographical dimension is one explanation for the innovative activities of firms.

Most of this research is based on the work of Jaffe (1989) and Griliches (1979). Jaffe (1989) modified the knowledge production function defined by Griliches (1979) by including the geographical dimension and university research as the explanatory variables. In related studies, the endogenous variable - the measure for spillovers - are private investments in R&D, private patents or the number of innovations. Geographical proximity is often expressed by the state level or the Metropolitan Statistical Areas (MSAs) used by the U.S. Bureau of the Census. They are defined to be an integrated economic and social unit with a large population nucleus. Large MSAs are often split into smaller units (SMSAs). Finally, university research is measured by the amount of money spent on R&D, the number of papers published in academic and scientific journals, the number of employees or patents (see Varga 2000, Henderson/Jaffe/Trajtenberg 1998, Hall/Link/Scott 2003).

State-level knowledge spillovers between universities research and product innovation is found in Acs et al. (1992, 1994), Jaffe et al. (1993) and Audretsch/Feldman (1996). Anselin et al. (1997) provide evidence for a significant association between university research and product innovations both at the level of U.S. states and metropolitan areas.

Varga (2000) points to a critical mass of agglomeration to be reached for promoting local academic knowledge transfer at the level of MSAs. Also Mowery/Ziedonis (2001) focus on MSAs and as a measure for geographical proximity but also on the miles between an inviting campus and the licensing or citing MSA. They use the number of patents cited by MSAs to capture spillover effects and confirm the hypothesis of spillover effects. They further provide evidence that knowledge flows through market transactions like licensing are more geographically localized than those operating through non-market spillovers.

Contrary to the approach that knowledge is a public good that is easily accessible and has very few transmission costs (Spence 1984), the empirical evidence provides compelling evidence that accessing knowledge spillovers is costly and rises over geographic distance. For example, view, Audretsch/Feldman (1996) make a distinction between information and knowledge. They point out that although the cost of transmitting information may not change with distance, the cost of transmitting knowledge rises. While information is easy to codify, as it is in the case of academic papers, the transmission of knowledge requires frequent contacts and the interaction of agents. After controlling for the regional concentration of production they provide strong evidence that the clustering of innovative activity increases with the industry's R&D intensity and the employment skill of labor.

2.2 Geographical Proximity and Entrepreneurship

The prevalent theoretical framework analyzing the decision to start a firm has been the general model of entrepreneurial choice. The model of entrepreneurial choice dates back at least to Knight (1921), but was more recently extended and updated by Kihlstrom and Laffont (1979), Holmes and Schmitz (1990), Jovanovic (1994), Fabel (2002) and Lazear (2002) among others.

In its most basic rendition, individuals are confronted with a choice of earning their income either from wages earned through employment in an incumbent enterprise or else from profits accrued by starting a new firm. The essence of the entrepreneurial choice model is made by comparing the wage an individual expects to earn through employment, W^*, with the profits that are expected to accrue from a new-firm startup, P^*. Thus, the probability of starting a new firm, $Pr(s)$, can be represented as $Pr(s) = f(P^*-W^*)$ and has served as the basis for empirical studies by Evans and Leighton (1989) among others.

None of the above models or studies investigate the role of location in the context of the entrepreneurial choice framework. However, geographic location should influence the entrepreneurial decision by altering the expected return from entrepreneurial activity, P*. The theory of localized knowledge spillovers suggests that P* will tend to be greater in agglomerations and spatial clusters, since access to tacit knowledge is greater.

Although there are several studies providing evidence on spillover effects of university research, there are only few papers which explicitly analyze entrepreneurship and new-firm startups as conduits for knowledge spillovers. The empirical studies focus either on start-up rates in different regional areas or on the specific impact of universities on firm formation, including university spin-offs.

To consider the first part of the literature, Harhoff (1999) supports strong evidence that regional spillover effects enhance new firm formation, especially in regions with high specialization in one industry. However, he did not really include university spillovers. Also Bania, Eberts and Fogarty (1993) analyze the frequency of high-technology start-ups. They find only a small effect of university research funding on the start-up rate in the electrical and electronic equipment sector and no considerable effect in the instruments and related products sector.

Audretsch and Stephan (1996, 1999) show that the spill over of knowledge to a new firm start up facilitates the appropriation of knowledge for the individual scientist but not necessarily for the organization creating that new knowledge in the first place. They use joint papers written together from researchers and practitioners together with IPO data from firms in the biotechnology sector, a predominant industry in the New Economy.

Zucker et al. (1998) use the biotechnology sector to explain how spillover effects in research could improve entrepreneurship and demonstrate that not spillover effects per se but rather the intellectual capital of star-scientists plays a major role of shaping both the location and timing of the entry of new biotechnology firms. They link universities and start ups by articles written jointly between university star scientists and firm scientists.

Based on a patent database from the MIT, Shane (2001a,b) explores the determinants on new firm formation (2001a) and new firm creation (2001b). He assumes that universities create technological spillovers which could be exploited by the formation of new firms. In the first paper he puts on the age of the technological field, the effectiveness of patents and the importance of complementary assets to be exploited through the formation of new firms. Also the importance, radicalness and scope of the patents influence the probability that an invention will be exploited through the creation of new firms. However, he did not control for geographical distance.

Dumais, Ellison and Glaeser (2002) also provide evidence of spillover effects on firm foundation. They use cross-industry patent citations and find that new plants are more likely to locate near industries that are linked intellectually. However, they could not provide evidence for the impact of university spillovers on firm location.

Another kind of university spillovers is identified by Lazear (2002). He analyses the influence of the degree of vocational and experience at universities as measures for either specific skills or alternatively, a more general degree of human capital. He provides evidence that firm start-up activity could not only be explained by the amount of specific human capital but also by the amount of general skills. He tests his theoretical model using data from Stanford University, which is well known for their spillover effects in the Silicon Valley. He shows that students with high specific human capital prefer to work in established firms. By contrast, students with a more general human capital are more likely to create new firms.

Summing up, there is strong evidence that universities generate spillover effects which influence both the innovative activities of private firms and their cost structures. However, there are both theoretical reasons and empirical evidence to believe that such knowledge spillovers generated by universities are not accessed and absorbed at a cost that is invariant to geographic location. Rather, because university spillovers tend to be spatially bounded, the cost of absorbing them increases along with the locational distance from the university. An implication of the geographic distribution of knowledge spillovers is not only that they are spatially clustered around universities, but that the entrepreneurial opportunities to start a new firm are also geographically linked to the spatial distribution of knowledge spillovers.

3. Hypotheses and Methodology

3.1 Geographical Proximity, Spillovers and Firm Formation

As the previous section concludes, a basic tenet in the literature is that university spillovers lower the costs of firms to accessing and absorbing knowledge spillovers. This leads to the formulation of the first hypothesis,

Hypothesis H1: The locational strategy of firm geographic proximity to a university is more important as the research output of the university increases.

Such spillovers could be transmitted through certain conduits across geographic space such as the channels of communication, the social system, or a kind of technology diffusion process. Most of those benefits could not be obtained by markets or ensured by contractual arrangements because much of the tacit knowledge is transferred via communication channels. According to the theory of communication, those channels can be decomposed into two categories: Communication transmitted via articles as a means of mass media in the scientific world, and interpersonal communication. Such interpersonal communications are important influences in determining the speed and thus the costs of the diffusion of knowledge.

The primary conduit to achieve and absorb the spillover effects is through strategic location yielding geographical proximity to the knowledge source. Thus, the firm locational decision should be influenced by the activities of the local universities. In particular, the role that geographic proximity to the university plays in accessing spillovers should be shaped by the relative importance of the transmission of codified knowledge through the mass media (in the scientific context) versus the relative importance of tacit knowledge.

The relative importance of codified knowledge is reflected by the predominance of articles published in high quality scientific journals - the mass media channel. By contrast, the relative importance of tacit knowledge is reflected by the number of fresh graduates from the university, which serves as a measure for the intense demand for labor and interpersonal communication.

The second hypothesis is therefore based on the anticipated impact of the relative importance of tacit knowledge versus codified knowledge on the locational benefits of geographic proximity to a university:

Hypothesis H2: The strategic advantage bestowed by firm geographic proximity to a university will be greater where the university generates research output with a high tacit knowledge content. By contrast, universities generating research output with a low tacit knowledge content offer less of a strategic advantage to firm locational proximity.

Strict adherence to the scientific method assures that academic publications embody a high component of codified and specific knowledge in the natural sciences (Stephan 1996). By contrast, with a more limited applicability of the scientific method, publications in the social sciences embodied less codified knowledge (Stephan 1996). However, only a small field in the social science, like economics and econometric theory, contain specific and codified articles. The distinction between codified and less codified research articles also reflects the degree of specific knowledge. Research fields in the natural science are to a greater extend specific to certain industries as fields in social science. As an example, the role of social and human capital is not only specific to one industry as it is in the case of biochemistry or medicine.

In contrast to other studies, we are able to decompose the output of academic research into natural science and social science. Prominent examples of research spillover effects in science are demonstrated in the case of biotechnology by Audretsch/Stephan (1996, 1999), Zucker et al. (1998) or, more general in the case of patents or investments in R&D (Jaffe 1989). To our understanding, there is no empirical study which primarily focuses on research spillover effects in social science. We assume that such effects are less special and firm specific than those in science. For example, seminars, presentations and conferences in accounting, finance or management are valuable for every firm, independently from the type of production or the industry classification. Those effects could be measured by the number of articles published in this field. Since spillover effects in social science are relevant for all firms we expect no differences across industries, compared to research spillover effects in science.

Hypothesis H3: In the natural sciences codification inherent in published articles enables absorption over a longer geographic distance. In the social sciences geographic proximity is required to absorb knowledge spillovers.

Spatial proximity to universities can also generate positive externalities that can be accessed by the firm through hiring fresh graduates. First, fresh graduates may be important channels for disseminating knowledge from academia to the local high technology industry (Varga 2000). Other externalities may rise through the close location per se. Local proximity lowers the search costs for both firms and graduates. This may lead to some competitive advantage over similar firms which are not located close to universities, especially when high skilled labor is a scarce resource and there is intense competition about high potentials.[1]

Hypothesis H4: The greater the output of student graduates, the lower is the distance between the firm and the closest university.

A similar logic as for research activities holds for the relative components of tacit and specific knowledge embodied in graduates. Graduates in the natural sciences presumably embody a higher component of human capital specific to a particular science and technology. The knowledge of biologists, information engineers, physics or chemists is more specific to a particular firm and industry compared to the knowledge of economists, sociologists and graduates in business. Graduates embody specific knowledge in the natural sciences, leading them to locate within geographic proximity to the university.

However, since we focus on young and innovative firms, there are some restrictions compared to past research. Since those firms are small and constraint in their financial resources, they are less able to act as research partners in natural or physical science for universities by providing funds or physical assets. Also academic research in those areas are not always a kind of public good if academic researchers compete with researchers

[1] See also Stephan et al. (2002), analyzing the firm's placement of Ph.D students.

from firms which are not included in the research relationship. Thus, research spillover cannot easily be exploited. The main channel to participate from the academic research is to employ graduates from local universities. By contrast, graduates embody general knowledge in the social sciences, leading them to more diffused locations. Thus, the 5th hypothesis predicts that the ability of firms to access and absorb social science graduates is less dependent upon specific location than is the case for natural science graduates.

Hypothesis H5: A firm's ability to access and absorb graduates is less dependent upon geographic space in the social sciences than in the natural sciences.

The preceding five hypotheses focus on the strategic locational decision confronting the firm and how it will vary according to different knowledge conditions, types of university research output, and the relative importance of tacit and codified knowledge. Firm performance should also be influenced by location. In particular, access to knowledge spillovers should generate a superior performance. Measuring performance in early stage knowledge based technology firms is well known to be difficult, since traditional performance measures, such as profits, do not apply (see Audretsch/Lehmann 2002b). Thus, we take the duration from firm foundation until the listing on the stock market as a performance measure (see also Stuart/Hoang/Hybels 1999, Stuart/Sorenson 2003). The availability of external equity is an important resource for high-tech firms. Because new firms lack existing cash flow to finance investment and future growth, the time window from foundation to the listing on the stock market is important for the efforts of the firms to exploit new technologies. Since high-tech firms are associated with a high risk of default and asymmetric information, they suffer from credit restrictions by banks (Audretsch/Lehmann 2002a). The only way to receive financial resources to grow is equity, provided by venture capitalists or large firms. The vast amount of capital, however, is reached when the firms are able to go public and disseminate their shares on the stock market. This leads to the final hypothesis:

Hypothesis H6: The greater the geographic proximity of the firm to the university, the lower should be the time window from firm foundation to the stock market listing.

3.2 Methodology

Sample

To test the hypotheses that firm foundation depends on geographical proximity and university spillovers we use a unique dataset of all of the German firms listed on the *Neuer Markt*. The total population of firms listed on the *Neuer Markt*, Germany's counterpart of the *NASDAQ*, between 1997 and 2002 was 295. This dataset consists of all 295 publicly listed German firms, and was collected combining individual data from IPO prospectuses, along with publicly available information from on-line datasources including the *Deutsche Boerse AG* www.deutsche-boerse.com. We use this database for several reasons. First, the included firms include highly innovative industries, like biotechnology, medical devices, life sciences, e-commerce and other high-technology industries which represent the knowledge-based economy. Secondly, studies from the U.S. provide strong evidence for the growth effect of clusters influenced by the presence of research active university (Feldman 2000). This dataset enables us to follow this line of research. Thirdly, this data set represents the technological change in the German Business sector from the predominance of medium sized firms in the production and manufacturing towards the high-technology and service sector. We complete this dataset by adding university-specific variables, which are individually collected from the universities and the research database from the ISI (Information Sciences Institutes). We did not include research institutes since they only have a few graduates.

Variables and Measurement

To test the six hypotheses posed in the previous section, we use two different dependent variables. First, we take the *DISTANCE* to the closest university. Since universities in Germany are more geographically concentrated compared to the U.S., we need a measure which is sensible enough for small variations. The distance is measured in kilometers using the online database of the *German Automobile Club* (www.adac.de). All firms located within a radius of 1.5 kilometers are classified as belonging in the distance category of 1 kilometer.

The second endogenous variable is *CLUSTER*. This ordinal variable captures geographic proximity by focusing on the location closest to the university, within the same city and outside this area. This measurement is analogous to SMSAs and similar measures indicating locational proximity. The variable *CLUSTER* takes the value of one if the firm is located within a close radius of 8 kilometers (the median value) around the university. If the firm is located within a radius of 20 kilometers the variable takes on the value of 2, or 3 if the location is outside the radius of 20 kilometers.

We include the *DURATION* or time-to-IPO as the third endogenous variable. Since we have no exact information about the month of firm formation, we used the number of years to measure the time dimension.

The independent and predictor variables are as follows. To measure research output of universities we include the number of articles published in high quality journals (see

Zucker et al. 1998, Audretsch/Stephan 1996) and the number of graduates in 1997. Since university spillovers are not restricted to patented inventions and occur solely in the natural sciences, we include measures for social science research output as well as natural science output. This enables us to discriminate between the sources of spillover effects. Since knowledge-based industries include services such as media and entertainment, service, or e-commerce, spillovers can also be generated by fields without high patent activities. Articles published in social science (*SSCI*) are measured by the ISI-database *SSCI* (Social Science Citation Index). Articles in natural sciences (*SCI*) are taken from the *SCI* (Science Citation Index). We included the number of listed papers for each university published from 1993 until 2000.[2]

Although a number of studies provide strong evidence that the number and quality of articles published in high quality journals influences the location of innovative activity, Varga (2000) points to the effects of new graduates as an important mechanism for transmitting the latest knowledge from academia to firms located in the same geographic area. However, spillover effects may not only arise by the knowledge transmission of students but also by their employment effects. The nearby location enables firms to attract high skilled employees with lower costs. Recent graduates also have the possibility to work at local companies without leaving the their social network. We further control for graduates from science (*SCIGRADS*) and from social science (*SSCIGRADS*). Both measures are from the year 1997.

Previous research has shown that spillover effects differ between industries in their necessity and capability to absorb spillover effects (Jaffe 1989, Cohen/Levinthal 1990, Henderson/Cockburn 1994). To control for specific industry effects, we include dummy

[2] The publications in social science and natural science did not vary across the universities during time.

variables for the following industries: Software, E-Services, E-Commerce, Computer & Hardware, Telecommunication, Biotechnology, Medicine & Life science, Media & Entertainment, and High-Technology. In addition, to control for the impact of the life cycle of the firm (Agarwal et al. 2002), we include firm age.

3.3 Analysis and Methodology

To test the six hypotheses raised in section 3.1, we employ three different empirical estimation methods: negative binomial regressions, ordered probit, and hazard models.

First, we employ the negative binomial regression model as the analytical technique for estimating the impact of university research output on the strategic locational choice of firms. The underlying assumption is that distance as measured in kilometers could be interpreted as count data. Since ordinary least squares regression is inappropriate for the count dependent variables that have large numbers of the smallest observation and remaining observations taking the form of small positive numbers, this estimation method seems to be more appropriate (Greene 2003). Also, this statistical technique is designed for maximum likelihood estimation of the number of occurrence of nonnegative counts like the event of location.

Secondly, we apply ordered probit estimation as a robust test for the negative binomial regression. According to studies which takes SMSAs, or related areas, as the measure for geographic proximity, we use the ordinal variable *CLUSTER* as the dependent variable. The regression is then based on the maximum-likelihood method. In place of the traditional calculation we estimate the regression with the Huber/White/sandwich estimator of variance.

Finally, to make an inference about the impact of locational strategy on firm performance, we estimate a simple Cox proportional hazard approach to measure the duration effect from firm foundation to the listing on the stock market. The probability for being listed within an interval $(0,t)$ is given by the distribution function $F(t)$. The derivation is called density of T and named by $f(t)$. The complement of the distribution function is called survivor function $S(t)=1-F(t)$ and indicates the probability for not being listed on the stock market at time t. A central element in the analysis of duration data is the concept of the hazard function. It is defined as the conditional probability for being listed on the market within the interval $t+\Delta t$ given the firm has not been listed on the market at time t (see Kiefer 1988).

4. Empirical Results

4.1 Descriptive Statistics

Table 1 presents some descriptive statistics of both dependent and independent variables. The closest location is one kilometer and the maximum distance is 177 kilometers away from the nearest university. The skewed distribution of the data is reflected by the difference between the mean and median values. While the arithmetic mean distance is about 17 kilometers, the median shows that 50% of the firms are located within an area with the radius of 7 kilometers. The 25% (75%) Centile demonstrates that 25% (75%) of the firms are located within a small radius of 1 (21) kilometer. Thus, locational proximity to a university for the 295 firms in the data set is a first hint that university spillover effects may influence the strategic location decision.

The descriptive statistics also show that the data is overdispersed and thus that the alternative regression, the Poissson regression, is inappropriate.[3]

Table 1: Descriptive Statistics

	Mean	Std. Dev.	Min	Max	25%Cent	Median	75%Cent
Distance	16.69	23.457	1	177	1	7	21
SCI	10,689.17	11,947.55	8	34,148	169	6,357	13,742
SSCI	596.41	607.06	0	1,694	98	491	816
SCI-Grads	20,494	15,292.45	0	47,112	4936	7,725	9,395
SSCI-Grads	7,270	3,921.09	0	20,570	6993	15,831	30,290
Age	10.27	11.11	0.1	107	3	8	14.25

Table 1 indicates that research activities and the number of graduated students vary considerably across the universities. A comparison between the mean and median exhibits the skewed number of papers in both the social sciences and natural sciences. On average, each university published about 600 papers in social science and more than 10,000 articles in natural science. However, the number of articles published by 50% of the universities is much lower. Also the number of graduates differs across universities.[4]

Interestingly, the number of articles and graduate students varies not only across universities but also across the two fields. While the mean university publishes twice as many articles in the natural sciences compared to the social sciences, this difference increases with the number of published papers. While 50% of the universities publish about 500 articles in social science, there are more than 6,300 papers in science. The opposite trends can be found for the number of graduates.

[3] However, the results did not vary according the assumption of the underlying distribution of the variables.

[4] The University of Ulm (University of Erfurt) has no students in social science (natural sciences).

The data presented in table 1 show that most of the firms are strikingly young. Half of the firms in our sample are eight years old or less. Also 25% of the firms are younger than 3 years.

Table 2: Correlation Matrix

	KM	SCI	SSCI	SCI-Grads	SSCI-Grads
SCI	0.0119	1			
SSCI	-0.0200	0.9585	1		
SCI-Grads	-0.0408	0.1621	0.0446	1	
SSCI-Grads	-0.0486	0.7620	0.7986	0.0717	1
Age	0.1057	0.0066	0.0101	0.0784	-0.0435

Table 2 provides the correlation between the included variables. The high correlation between the articles published in SCI and SSCI demonstrates that universities are either research active - or not - independent from the discipline. Interestingly, there is a high correlation between the articles published in social science and the number of graduates in these fields. This may be due to size effects. Such effects, however, could not explain the rather low correlation between the number of graduates in the natural sciences and the number of articles published in this field.

4.2 Firm Proximity and Research Output

Table 3 utilizes two different methods to estimate the distance from the location of the firm and the closest university as a function of the set of independent variables discussed above, which include the age of the firm, the social science and natural science research activities by the universities and their output of graduate students. To correct for a miss-specification of the independent variable, we estimate both, negative binomial and ordered probit regression models. The results for both estimations are listed in table 3.

If geographic proximity is important to access and absorb knowledge spillovers, we expect a negative sign on the estimated regression coefficients, which would indicate that research and education outputs induce the founder to pursue a strategy of locate within close geographic proximity of a university. A positive sign on the estimated regression coefficient would indicate that accessing the university output is not important to the firm, or else geographic proximity is not essential to access knowledge spillovers.

As the empirical results in Table 3 suggest, both estimation methods provide evidence that the distance between firm location and the closest university is positively related to the university outputs of research and human capital. Both the number of articles published in social sciences, as well as the number of graduates influences the strategic decision to locate with a geographic proximity to a university. These results confirms hypothesis *H1*. In contrast, we find a significant and positive sign of the coefficient of the research output in the natural sciences, which confirms the finding in Audretsch/Stephan (1996) that geographic proximity is not important where codified knowledge plays an important role. Thus, our results confirms hypothesis *H1* only for social science but not science.

Although both the negative binomial and ordered probit estimation methods provide similar results for the cardinal variables, the results differ for the coefficients on the industry dummies. These differences can be attributed to the well known result that ordered probit estimations are not the ideal estimation procedure for evaluating the effect of dummy variables (Greene 2003, 740).

Table 3: Negative Binomial and Ordered Probit Regressions Estimating Geographic Proximity to a University

The coefficients of SSCI, SCI and SSCI-Grads and SCI-Grads are multiplied with e-06. T-values are in brackets. The baseline are firms which could not be classified in one of the nine industries.

	Negative Binomial Regression	Ordered Probit
Age	0.0094 (1.37)	.01190 (1.89)*
SSCI	-2532.2 (2.10)**	-1700,19 (3.29)***
SCI	129.3 (2.34)**	72.61 (2.96)***
SCI-Grads	-31.5 (1.40)	-34.3 (1.74)*
SSCI-Grads	-3.22 (0.43)	-.1.37 (1.78)*
Software	-0.0323 (0.39)	-.0051 (.05)
Service	-0.2170 (0.97)	-.3904 (1.67)*
e-commerce	0.2012 (0.61)	.0384 (.11)
Hardware	0.1529 (0.49)	-.2002 (.64)
Telecom	-0.2734 (0.91)	-.0273 (.10)
Biotech	-0.1094 (0.31)	.0082 (.03)
Medtec	-0.9012 (2.17)**	-.7903 (2.00)**
Media	-1.1733 (4.35)***	-1.007 (3.58)***
Technology	0.1980 (0.73)	.4182 (1.49)
Constant	3.1381 (12.30)***	-
Pseudo R2	0.0192	.0783

Estimation of the models in Table 3 assumes that the relationships between each of the independent variables and the dependent variable is homogeneous across industries. To identify whether this assumption is true, in Table 4 the negative binomial model is estimated separately for each industry.

The negative coefficients in most the industries of the measure of social science research output suggests that greater research output increases the importance of geographic proximity to the university.

By contrast, in the natural sciences, the positive coefficient in most industries indicates exactly the opposite – geographic proximity to a university becomes less important as research output increases. This would suggest that accessing and absorbing knowledge spillovers requires close geographic proximity in the social sciences but not in the sciences. As Stephan (1996) suggests, this may reflect a greater propensity for the scientific method to result in codified knowledge in the natural sciences than in the social sciences, where no common methodological approach has been adopted.

Table 4: Negative Binomial Regressions estimating Geographic Proximity to a University

Branche (N)	Age	SSCI	SCI	SCI-Grads	SSCI-Grads	Constant	P-R2
Software (55)	0.0272 (1.21)	2427.4 (0.89)	-113.4 (0.84)	-84.4 (1.77)*	2.50 (0.14)	3.0682 (5.87)***	0.0161
E-Services (72)	0.0242 (1.27)	-646.90 (0.25)	7.86 (0.06)	80.4 (1.32)	-11.9 (0.86)	2.1618 (4.09)***	0.0179
E-Commerce (18)	0.1471 (2.53)**	-14589.9 (3.38)***	678.1 (3.57)***	-288.5 (0.89)	33.2 (0.67)	3.5530 (4.37)***	0.0887
Computer & Hardware (22)	-0.0101 (0.51)	-18026.9 (2.24)**	794.1 (2.16)**	-184.4 (3.07)***	63.8 (1.47)	3.4966 (4.39)***	0.0986
Telecommunication (23)	0.0262 (0.92)	-3529.4 (0.79)	158.2 (0.78)	23.9 (0.41)	-15.9 (0.75)	2.6109 (3.39)***	0.0381
Biotechnology (15)	0.0090 (0.21)	-34768 (4.36)***	1200.3 (4.00)***	-7.56 (0.14)	162.9 (3.77)***	2.3784 (5.02)	0.1294
Medicine & Life Science (38)	-0.1666 (2.15)**	-3927.3 (0.47)	-87.3 (0.25)	-478.3 (1.68)*	186.8 (2.96)***	3.2665 (2.39)**	0.2105
Media & Entertainment (38)	-0.0389 (1.32)	-1176.1 (0.40)	13.6 (0.11)	-35.1 (0.62)	12.2 (0.59)	2.1143 (3.02)***	0.0168
High-Technology (30)	-0.0026 (0.35)	2172.5 (0.60)	-97.2 (0.58)	4.09 (0.06)	1.28 (0.05)	3.1120 (5.59)***	0.0024

The coefficients SSCI, SCI, SSCI-Grads and SCI-Grads are multiplied with e-06. z-values are in brackets. P-R2 is the pseudo R2.

The negative coefficients of the number of graduates in the natural sciences (*SCIGRADS*) in six of the nine knowledge-based industries suggests that, at least in most of the high-tech industries, firms choose to locate close to universities with a high yield of natural science graduates. By contrast, this holds for only two industries in the social sciences. The different impact of human capital output by the universities on the locational choice of firms presumably reflects the high component of specific skills embodied in the natural sciences but more general skills in the social sciences. For example, students in economics, business or sociology do not really differ systematically across universities in Germany, although the research intensity in those fields are different. In contrast, students in natural science differ extremely in their specialization. As an example, in Biology graduates in botanic are no close substitutes for graduates in biotechnology. This may not hold for students in business with a specialization in either finance or accounting. Thus, the heterogeneity of the students may lead founders to locate close to the university with the expected students while students in social science are more easy available on the labor market.

4.3 Geographic Proximity and Firm Performance

To test the final hypothesis that the locational decision impacts firm performance, we estimate a hazard model. The results are shown in Table 5. The sign of the estimated coefficient indicates the direction of the effect of the explanatory variable – distance – on the conditional probability of becoming listed publicly on the stock market. A positive estimated coefficient would indicate a higher value of the hazard rate and therefore a positive impact on the likelihood of the firm going public at that point in time. Because the geographic measure reflects firm proximity to a university, we expect a negative sign, which would indicate that firms locating closer to a university should endure a shorter duration between formation and the IPO. According to Table 5, the negative coefficient on the distance between the firm and the nearest university confirms Hypothesis 6.

Table 5: Results from the semiparametric COX regression

	Cox-Regression
Distance	-.0058 (1.93)**
SSCI	-.0058(1.42)
SCI	.0000258 (1.31)
SCI-Grads	.0000030 (1.81)**
SSCI-Grads	.0000002 (.30)
Software	-.0658 (.52)
Service	-.09834 (.52)
e-commerce	1.14659 (3.99)***
Hardware	-.34467 (1.30)
Telekom	.13590 (.53)
Biotech	.2883 (.96)
Medtec	-.08932 (.25)
Media	.4471 (1.94)**
Technology	-.5249 (2.15)**
Pseudo R2	.015
LL	-1377.9595***

In addition, the duration to IPO is lower when the firm is located close to universities with a high number of graduates in the natural sciences. This would again suggest that accessing the tacit knowledge embodied in human capital requires geographic proximity in the natural sciences but not in the social sciences.

5. Conclusions

A recent literature has emerged suggesting that not only are the spillovers of knowledge important in generating innovative output, but that universities provide an important source of such knowledge spillovers. However, this literature has generally ignored the impact that such university spillovers exert in shaping the strategic locational decisions of firms. The results of this study not only confirm that university spillovers play an important role, but also that they have a strong influence in the strategic locational decisions of firms. In particular, the empirical evidence suggests that geographic proximity is a key element of firm strategy . However, the locational decision is shaped not only by the output of universities, but also by the nature of that output. In this paper, we consider two specific university outputs – research and education, which generates human capital – in two different fields, the natural sciences and the social sciences. To access knowledge transmitted by published articles in the natural sciences, geographic proximity is not particularly important. This is consistent with the findings of Audretsch/Stephan (1996) that geographic proximity is not a prerequisite to access and absorb codified knowledge. By contrast, in the social sciences, geographic proximity to the universities is apparently more important, which may reflect a higher tacit knowledge content in social science research which reflects the lack of a unified scientific methodology.

These results are actually reversed in accessing the educational output of universities, in the form of graduated students. Firms tend to locate in geographic proximity to universities with a high number of graduates in the natural sciences, which presumably indicates the limited geographic options for students with human capital specific to particular technologies. By contrast, firms are less geographically restricted with respect to universities with a high number of graduates in the social sciences, which reflects the more general skills and human capital rendering the student more mobile.

This paper also provides at least some evidence that the strategic locational choice shapes firm performance. In particular, we find that the duration between startup and going public is less when the firm is located within geographic proximity to the university.

These results confirm the resource-based view of the firm, in that research and human capital are important resources shaping not just the locational decision but also the performance of new and young firms. These resources can be obtained through accessing spillovers of knowledge from sources that are external to the firm, in this case from the university. However, as the results of this paper suggest, the strategic locational decision of the firm and the role of geographic proximity will be shaped not only by the existence of knowledge spillovers but also the particular type of knowledge spillover. The locational decision to access knowledge in the natural sciences clearly has different strategic implications than to absorb knowledge emanating from the social sciences. In both cases, geography plays a role, albeit a decidedly different one.

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