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OVERCOMING LOCALIZATION OF KNOWLEDGE

THE ROLE OF PROFESSIONAL SERVICE FIRMS

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Abstract

Overcoming localization of knowledge: The role of professional service firms

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The literature on organizational learning asserts that external learning is often limited geographically and technologically. We scrutinize to what extent organizations acquire external knowledge by accessing external knowledge repositories. We argue that professional service firms (PSFs) grant access to non-localized knowledge repositories and thereby not only facilitate external learning but also help to overcome localization. Focusing on patent law firms, we test our predictions using a unique dataset of 544,820 pairs of EP patent applications. Analyzing patterns of knowledge flows captured in patent citations we find that accessing a PSF's repository facilitates the acquisition of external knowledge. As the effect is more pronounced for knowledge that is distant to a focal organization we conclude that having access to a knowledge repository compensates for localization disadvantages.

Keywords: Learning, knowledge acquisition, localization, patent citations, professional service firm

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Introduction

A common theme in prior literature on organizational learning is the importance of external learning, i.e., the acquisition of knowledge that resides beyond organizational boundaries. External learning can occur through knowledge flows across organizations. Organizations acquire external knowledge when they are affected by other organizations' experience resulting in changes to their knowledge stock (Argote *et al.*, 2000; Huber, 1991). It has been argued that involving external knowledge domains results in a larger variety of ideas to draw from, provides an opportunity for firms to overcome path dependency, and ultimately increases innovative performance (Ingram and Baum, 1997; Miller, Fern and Cardinal, 2007; Lane and Lubatkin, 1998; Liebeskind, *et al.* 1996; Rigby and Zook, 2002). At the same time, there is comprehensive evidence that organizational learning is significantly limited to 'local search'. This implies that organizations are more likely to identify and absorb external knowledge within their geographic and technological proximity, which might again cause path dependency and can ultimately lead to a failure to successfully adapt to changing environments (Cyert and March, 1963; Nelson and Winter, 1973; Dosi, 1988; Cohen and Levinthal, 1989).

In this paper, we focus on the impact of an organization's access to an external knowledge repository on external learning. In particular, we want to highlight the fact that external knowledge repositories are not only a source for the acquisition of external knowledge but they can help organizations to overcome the localization of learning. While our arguments also hold in a more general context we focus in this paper on knowledge repositories that firms can access by contracting professional service firms (PSFs). Prior research has shown that accessing a PSF's knowledge repository facilitates external learning (Hargadon and Sutton, 1997; Zhang and Li, 2010). We aim at adding to this literature by proposing that accessing an external knowledge repository is an effective way to acquire technologically and geographically distant external knowledge. In contrast, previously identified mechanisms of inter-organizational knowledge flows such as strategic alliances, mergers and acquisitions or employee mobility are likely to aggravate the localization of knowledge flows because they are localized, as well (Almeida and Kogut, 1999; Rosenkopf and Almeida, 2003; Stuart and Podolny, 1996).

A unique empirical setting enables us to test this proposition. We focus on situations in which organizations access knowledge repositories that are made provided by patent law firms – a specific type of PSF presumed to be of particular relevance in the context of R&D and innovation. To identify the effect that contracting a PSF has on external organizational learning, we employ a widely used empirical control group design exploiting prior art references contained in patent documents (Jaffe, Trajtenberg and Henderson, 1993; Belenzon and Schankerman, 2010; Corredoira and Rosenkopf, 2010; Rosenkopf and Almeida, 2003; Sorenson and Fleming, 2004; Singh, 2005; Singh, Marx and Fleming, 2010). By exploiting a novel and unique dataset based on 544,820 pairs of European patent applications, we find that contracting a PSF depicts an effective mechanism for organizations to acquire external knowledge. More importantly, our results suggest that having access to the knowledge repository of a PSF can compensate for technological and geographical boundedness.

Our study extends the literature on organizational learning in multiple ways. First, we offer large-scale econometric evidence of how accessing an external knowledge repository facilitates the acquisition of external knowledge. Second, we provide evidence that PSF enables organizations to overcome geographical and technological constraints, thereby facilitating external learning. Finally, the results provide important insights for the development of innovation theory by expanding the understanding of sources of learning to promote innovation.

Theoretical Background & Hypotheses

Organizational learning is generally defined as an organization's acquisition and development of new knowledge that facilitates beneficial organizational changes (Argote, 2012). It is generally agreed that learning can occur in situations in which organizations need to adapt to changing environments. Change often triggers a search for solutions, i.e., search for new knowledge that allows adaptation. While various solutions might be adopted, only the successful ones are recorded for future use. Notions about the detailed mechanisms underlying organizational learning, its processes and its outcomes, however, vary considerable in the related literatures (Fiol and Lyles, 1985).

In this paper, we limit our attention to the identification and acquisition of new knowledge that has been created outside the boundaries of the focal firm. The creation or acquisition of knowledge is

typically considered as a crucial building block of organizational learning and is related to increasing an organization's "stock" of knowledge (Huber, 1991). Organizations can acquire knowledge either internally or externally: Own past experience and experimentation (March and Olsen, 1976; Huber, 1991; Levitt and March, 1988) provide a basis for internal learning while the experience of others (Cohen and Levinthal, 1990; Jensen, 1988; Argote *et al.*, 2000; Denrell, 2003) forms the basis for external learning. This paper focuses on external learning through knowledge flows across organizations.

While it has been noted that knowledge can be tacit and embedded in specific contexts rendering external learning difficult or even impossible (Polanyi, 1958; Kogut and Zander, 1992; Nonaka, 1994), its importance has been emphasized in prior literature. External learning may be less costly than internal learning (though it can lead to less unique outcomes, Barney, 1991). Additionally, external learning has been identified as an opportunity for organizations to overcome limitations of solely internal learning. The latter potentially leads to a failure in adapting to changing environments and impedes innovation (Rosenkopf and Almeida, 2003; Levinthal and March, 1993; March, 1991; Levitt and March, 1988).

Generally, an organization's search for knowledge has been shown to be bounded or 'localized' with regard to an organization's existing knowledge base. Organizations are more likely to successfully develop technologies in areas in which they are already experienced (Teece, 1988; Teece et al., 1994; Fleming, 2001). Additionally, organizations rely on established routines to drive the search for new knowledge (March and Simon, 1958; Cyert and March, 1963). The results of past learning are the basis for new searches, which induces path dependency in organizational learning (Nelson and Winter, 1982; Dosi, 1988). Furthermore, external learning requires institutional mechanisms such as networks that grant access to other organizations' knowledge (Levitt and March, 1988; Hansen, 1991). However, organizations prefer interacting with other organizations that have similar technological specializations and expertise (von Hippel, 1987; McPherson, Smith-Lovin and Cook, 2001). Empirical studies confirm that organizations tend to search in the proximity of their existing knowledge base (Fleming 2001, Helfat 1994, Martin and Mitchell 1998, Stuart and Podolny 1996). Hence, organizations should be more

likely to identify and absorb (i.e. learn from) external knowledge elements that are in the proximity of their existing knowledge base (Cohen and Levinthal, 1990).

Interestingly, external learning is not only bounded technologically (in the sense that organizations search in the proximity of their existing knowledge base) but also geographically (Jaffe, *et al.*, 1993). Explanations brought forward often argue that knowledge transfer between organizations is fostered by geographic concentration of industrial activity (Marshall, 1920; Saxenian, 1990). Learning processes which absorb information to generate knowledge are collective activities. Hence, the effectiveness of learning, at least in part, depends on interactions (e.g., communication). This is in line with the social theory which suggests that geographical distance aggravates (regular) face-to-face interactions (Stuart and Podolny, 1996). The latter, in turn, increase trust and thereby facilitate knowledge flows between organizations and finally enable or foster external learning (Porter, 1990; Coleman, 1990).

To summarize these arguments, external learning is "insulated by boundaries that makes it challenging, if not even impossible, to locate, acquire, and adopt knowledge across them" (Hwang, Singh and Argote, 2012: 3). This reasoning with regard to technological and geographical distance leads to a first set of baseline hypotheses on how distance affects a focal organization's external learning:

Hypothesis 1a: Geographical distance <u>decreases</u> the likelihood that a focal organization will draw upon the knowledge of another organization.

Hypothesis 1b: Technological distance <u>decreases</u> the likelihood that a focal organization will draw upon the knowledge of another organization.

Research about external learning identifies alliances, acquisitions and employee mobility as channels that provide access to external knowledge (Almeida and Kogut, 1999; Hamel, Doz, and Prahalad, 1989; Mowery, Oxley and Silverman, 1996; Mowery Oxley and Silverman, 1998; Zollo and Singh, 2004; Rosenkopf and Almeida, 2003). PSFs, including consultancies, engineering, design firms, and law firms, have been identified as sources of external knowledge by providing access to a repository of knowledge. Prior literature argues that PSFs provide access to knowledge which cannot be attained otherwise (Hargadon and Sutton 1997; Jewkes, Sawers and Stillerman, 1958; Wolpert, 2002;

Zhang and Li, 2010). It is important to notice, however, that PSFs often also provide access to knowledge (stored in the PSFs knowledge library) which can also be acquired via alternative mechanisms, e.g., through own research, hiring, or forming alliances. However, this may be more difficult or result in higher costs.

Whereas the product development firms analyzed by Hargadon and Sutton (1997) produce knowledge or even products for their clients, we follow another strand of literature which considers PSFs that rarely develop new knowledge but are continuously exposed to new knowledge, accumulate this knowledge, and make it available to their clients (Strumpf, Doh and Clark, 2002; Wolpert, 2002). PSFs typically employ a highly educated workforce of professionals. This workforce accumulates both tacit and explicit knowledge from regular interactions with its clients when working on complex and customized tasks (Greenwood, Li, Prakash and Deephouse, 2005). The knowledge repositories they build from this accumulated knowledge forms the "core competency of [these] PSFs" (Boone *et al.*, 2008). Granting their clients access to this knowledge repository makes PSFs a source of external learning for organizations. Furman and Stern (2011) highlight that independent knowledge repositories (in their study biological resource centers that form repositories of biological materials) validate new knowledge before including it in the repository and making it available to clients. Moreover, since operations of repositories are characterized by economies of scale and scope, the cost of accessing external knowledge should be lower when compared to a situation in which a focal organization engages in its own search (Furman and Stern, 2011). Clients contracting a PSF can thus expect efficient access to pre-validated external knowledge elements contained in the PSF's knowledge repository. It is also worth noting that PSFs' repositories grant access to external knowledge independently of whether the involved parties (the organization that initially created knowledge which was included in the repository and the organization accessing the repository) seek to be connected or not. Accessing a PSF's knowledge repository enables clients to benefit from positive knowledge externalities rather than being connected to another organization.

As a result, we expect that a focal company is more likely to learn from the experience of another organization, if that organization has already interacted with the focal company's PSF. In this case, the PSF's will have acquired knowledge elements created by the other organization and stored it

in its knowledge repository. In subsequent interaction with novel clients, we expect these clients to have access to this knowledge (repository), which increases the likelihood of external learning. Therefore we propose

Hypothesis 2: The likelihood that a focal organization will draw upon the knowledge of another organization increases in cases where the two organizations have contracted the same service firm.

As discussed above, an organization's acquisition of new knowledge is technologically and geographically bounded (Jaffe *et al.*, 1993; Stuart and Podolny, 1996). Having said this, it has been shown that involving more distant knowledge can increase the (innovation) performance of organizations (Miller, Fern and Cardinal, 2007; Lane and Lubatkin 1998, Liebeskind et al. 1996). In such cases, localization is overcome by inter-firm alliances and acquisitions (Hamel *et al.*, 1989; Stuart and Podolny, 1996; Capron, Dussauge and Mitchell, 1998) or employee mobility (Almeida and Kogut, 1999; Marx, Strumsky and Fleming, 2009). However, acquiring distant external knowledge via these channels is difficult because labor markets are highly localized (Almeida and Kogut, 1999) and firms tend to search for alliance partners and acquisition targets predominantly within their technical and geographical proximity (von Hippel, 1987; Saxenian, 1990, Mowery et al., 1998; Stuart and Podolny, 1996).

While the role of PSFs as sources of external learning has already been discussed, it is important to understand whether the acquisition of knowledge from PSFs is also localized (and therefore enforces local search) or whether accessing a PSF's knowledge repository in fact helps to overcome localization. We argue for the latter. PSFs typically maintain an extensive network of (technologically and geographically) diverse clients (Wolpert, 2002; Zhang and Li, 2010). This means that their knowledge repositories contain knowledge elements from a range of diverse knowledge domains and geographic regions (Hargadon and Sutton, 1997; Wolpert, 2002). Moreover, a PSF's repository is usually stored over a long time since PSF's typically do not discard knowledge once it is acquired (Boone *et al.*, 2008). As a consequence, a PSF's knowledge repository will contain diverse knowledge elements with a low degree of localization.

Organizations that contract PSFs should benefit more from these non-localized knowledge repositories when it comes to technologically and spatially distant knowledge as compared to knowledge in their own "proximity". In particular, knowledge that is close to the focal company can be accessed via a multiplicity of alternative channels which allows for external learning, e.g., by hiring employees from other firms or by striking up collaborations. However, as pointed out above, many of these channels are themselves bounded and could even reinforce localization. In contrast, PSFs' knowledge repositories are not localized. Hence, if a knowledge element stems from a distant knowledge domain or a distant geographic area, a PSF's knowledge repository is likely to create a 'unique' channel through which the focal organization can acquire external knowledge.

As a result, we propose that geographical and technological distance moderate the relation between the likelihood of external learning and the fact as to whether the focal organization and the initial creator of the knowledge element contracted the same professional service firm in a positive way:

Hypothesis 3a: The positive effect of contracting the same service firm on knowledge flows increases with geographical distance.

Hypothesis 3b: The positive effect of contracting the same service firm on knowledge flows increases with technological distance.

To summarize our three hypotheses: geographical and technological distance should decrease the likelihood that a focal organization will draw upon the knowledge of another organization, i.e., reduce the likelihood of external learning (H.1a/b). Contracting the same PSF should increase the likelihood that a focal organization will draw upon the knowledge of another organization, i.e. that it facilitates external learning (H.2). Finally, contracting a law firm should be particularly effective in facilitating the flow of knowledge across geographical and technological boundaries (H.3a/b).

Empirical Setting

Patent law firms and knowledge flows

In our empirical test of the proposed hypotheses, we focus on a particular group of PSFs: patent professionals and patent law firms. As exploratory interviews conducted with patent attorneys indicate, patent law firms offer a broad range of services to their clients that depend heavily on their prior

experience and thus their knowledge repository. These services include the provision of expert knowledge with regard to the technological area in which the clients specialize, support with regard to establishing contacts with potential licensees or licensors through the granting of access to their network, drafting of patent applications, defending infringed patents in court, as well as developing an overall IP strategy (Bessant and Rush, 1995; Knight, 2001, Reitzig and Wagner, 2010).

Each of the tasks outlined above requires intensive communication and knowledge exchange between a law firm and its clients. Typically, continuous interaction occurs during personal meetings between the law firm and its clients. It should be stressed that the information flow between a patent law firm and its clients is bi-directional (cf. Bettencourt et al., 2002). The repeated interaction with clients leads to the accumulation of problem- and client-specific information resulting in a comprehensive knowledge base (Wolpert, 2002; Zhang and Li, 2010). This is the basis for a law firm's knowledge repository. (At this point, we want to stress that we do not allege that law firms willingly transfer confidential information about their clients that would not be published during the patent filing process. Patent attorneys – as other PSFs, too - are subject to basic obligations, which are typically stated in country-specific Patent Attorney Codes.)

Law firms can also act as 'librarians' of these repositories as they validate external knowledge and help to 'find' relevant and distant pieces of knowledge. Due to economies of scope and scale this should enable both local and distant knowledge acquisition at a lower cost as compared to engaging in own knowledge creation (Furman and Stern, 2011). Another important advantage of focusing on patent law firms is the availability of detailed information on a law firm's client base and its clients. Particularly the analysis of comprehensive patent data allows us to identify sources and recipients of knowledge flows and their location in both technology and geographic space, which would hardly be possible in the absence of detailed patent data. Moreover, we rely on European patent data as the fragmentation of Europe in terms of national boundaries, languages and cultures is likely to deepen the problem of accessing distant knowledge when compared to more homogenous economic areas such as North America. Overall, European patents allow us to test our hypotheses regarding the effects of contracting PSFs on organizations' external learning.

Before progressing to a more detailed description of our data, we provide a brief overview of relevant institutional information on the European patent system. According to the European Patent Convention (EPC), there is no general obligation to be represented by a professional representative in proceedings before the European Patent Office (EPO) (Art 133 EPC). However, individuals whose residence or, in the case of organizations, "place of business" is not within one of the EPC contracting states, must be represented by a professional representative during all proceedings before the EPO, except during the filing of the EP patent application. Professional representation can only be assumed by agents or European patent attorneys, who are listed as professional representatives and have passed the European qualifying examination (Art. 134 EPC).

We gathered the names and addresses of patent law firms, as well as the patent applications they were contracted to work on from publicly available patent data using the EPOLINE database. The names of the law firms representing the assignees, listed in electronic filings, were consolidated manually to account for different spellings of the same law firm. Moreover, we ensured that representatives listed in the patent documents were not corporate legal departments. We did this by comparing their names and addresses with the corresponding information on the patent application. These data are enhanced with information from the PATSTAT database (Worldwide Patent Statistical Database), which provides information about a patent's filing date, the identity and address of the applicant, the identity and address of the inventor(s), and the technology classes assigned to a patent. The nomenclature proposed by INPI (French Intellectual Property Institute) and the ISI-Fraunhofer Institute, which categorizes the 70,000 IPC classes according to 30 technology areas (OECD, 1994) has been applied in the assignment of the patent applications to technology areas. PATSTAT further contains detailed information on the references included in patent documents, which are crucial for the research design utilized to test our hypotheses. Finally, the data are supplemented with information from the National Geospatial-Intelligence Agency, which enabled us to calculate the geographical distance between the inventors listed on the patent documents.

Overall, we utilized information on approximately 1.5 million patent applications filed at the European Patent Office (EPO) between 1990 and 2006. Over this period, more than 1.1 million applications (approximately 75%) have been represented by patent law firms. This shows the importance of patent

law firms within the patent system. European applicants filed 734,771 patent applications during the same time period. The share of applications that were outsourced by European applicants (approximately 62%) is lower than the overall average because European applicants are not required to have representation at the EPO if their "principal place of business" is not in one of the contracting states of the EPC (Art 133, EPC). Since the late 1990s, the share of European (EP) patent applications filed by law firms has slightly decreased. A possible explanation for this is that, since the late 1990s, the European patent system has experienced a so-called patent explosion (i.e., an above-average growth in patent applications for primarily strategic reasons, cf. Hall, 2005). This growth in patent applications has generally been driven by large organizations that often maintain an in-house patent department responsible for filing patents.

In total, we noted 3,801 law firms which acted as representatives between 1990 and 2007. Within this period, a patent law firm filed on average about 307 patent applications for approximately 95 different clients in about 13 areas of technology (see Table 1). The overall distribution of patent applications filed among law firms is skewed. Table 1 demonstrates that the average number of filings is about 9 times higher than the median and that the upper quartile of all patent law firms represents more than 90% of all outsourced filings in our sample. It should be noted that it is common for patent law firms, independent of their size, to serve different clients (see Table 1).

INCLUDE TABLE 1 ABOUT HERE

The descriptive statistics clearly show that for the majority of their patent filings, applicants turn to external patent law firms. Consequently, patent law firms serve a number of other clients both in the same and in different technology fields. This forms a precondition for the hypotheses we want to test empirically.

Identification of knowledge flows and sample construction

The empirical setting of patent law firms allows us to identify the knowledge acquisition patterns of organizations and the role PSFs play in facilitating a focal organization's access to distant knowledge. In particular, we analyze references that are included in a patent application in order to identify

knowledge flows. This approach was pioneered by Jaffe *et al.* (JTH) (1993) and has since been widely employed in management and economics literature. Every patent document contains a description of the existing prior art to establish the underlying invention's novelty (which is a prerequisite of patentability). This description contains references to existing patents and the related non-patent literature (predominantly scientific publications). Based on this information, it is generally assumed that if patent A contains a reference to a (preceding) patent P as prior art, the knowledge documented in patent P was identified by the inventor/applicant of patent A. The determinants of knowledge acquisition can then be identified as follows: 1) A control group is created by replacing citing patens (A) with patents that are similar but that do not cite the cited patent (P) in a citing/cited pair. 2) The treatment group is compared with the control group. In addition to the analysis of knowledge localization (Jaffe et al., 1993; Singh, et al., 2010), the JTH method was employed in more general regression frameworks to identify various alternative determinants of knowledge acquisition, such as inventor mobility (Correida and Rosenkopf, 2010; Almeida and Kogut, 1999; Rosenkopf and Almeida, 2003; Song, Almeida and Wu, 2003) or interpersonal networks (Singh, 2005).

For the scope of this study, we analyzed knowledge flows among European firms and focus on EPO patent applications filed by European patent applicants that list at least one inventor with a European address of residence at the time of invention. Additionally, self-references, i.e., references to the applicants' prior patents, are excluded from the study. Based on all applications filed at the EPO between 1990 and 2007 that satisfy these two criteria, we construct the sample of cited/citing and matched cited/non-citing patent pairs according to the following procedure: First, we identified all patent applications with filing years from 1990 to 1995 that have been cited 12 years after application by at least one EPO patent application that lists at least one inventor and applicant with an address in Europe. We restrict the time-window for citations to 12 years to ensure that patents from different application years have the same chance of being cited by subsequent filings. Information on all cited patents is matched with information on the citing patents. In total, we identified 98,612 patent applications that met these criteria. Because some of these patents have been cited by more than one patent, our treatment group consists of 136,706 pairs of cited/citing patent applications. For these pairs, it is assumed that the applicant of the citing information was aware of the invention protected by the

cited patent. Second, for these cited/citing patent pairs, we constructed (i) an equally large set of patent pairs consisting of pairs of initially cited patents with randomly drawn non-citing patents that are characterized by the same application year and the same technology classification (IPC 4-digit classification). We then constructed (ii) a set of twice as many pairs, again consisting of pairings of the initially cited patents with randomly drawn non-citing patents from the same application year but of a different IPC4 technology class. Taking non-citing patents from the same IPC4 class as the initial citing patent does not constitute a random draw from the population of potentially referring patents from the same application year. Therefore, we enlarge our control group with additional pairs formed by the cited patents from the group of initial cited/citing pairs and non-citing patents that had been filed in the same year but in a different IPC4 class than the initial citing patent (see Singh, et al. (2010) for a discussion). Using 1 : 1 : 2 as the relative shares of the three sub-samples is an arbitrary choice. As the choice-based regression framework, described in the following section, reflects relative weights, different relative shares were employed. The results remain qualitatively unchanged.

Overall, our sample, comprising the treatment and the two control groups, consists of 546,145 paired patents. 1,325 of the patent pairs were excluded from the multivariate analyses as we do not have the full set of variables for these cases.

INCLUDE TABLE 2 ABOUT HERE

We report important descriptive statistics in Table 2. It is no surprise that we find strong evidence of the localization of knowledge flows. The geographical distance measured in kilometers between two inventors (based on the place of residence listed in the patent document) listed on a cited/citing patent pair is significantly smaller than the average distance of two inventors listed on cited/non-citing patent pairs. Note that if more than one inventor is listed on a patent application, we use the distance between the two inventors on the separate applications that are closest to each other. Regarding technological distance, we find that in approximately 42.4% of cases, citations originate from patents that are technologically distant (assigned to a different IPC4 technology class as the cited patent, see Table 2). By definition, control group (i) contains patent pairs with a similar share of distant patents because matched non-citing patents have been selected based on their application year and IPC4

class. For control group (ii), where patents were matched according to the year of application regardless of their IPC classification, the share of paired patents that are assigned to the same IPC4 classification amounts to less than 1%. Over time, the geographic and the technological distance between citing and cited patents increase only slightly. The average geographic distance between inventors listed on two citing patents increased from approx. 430 km in 1992 to approx. 470 km in 2007 while the of citations coming from a different technological area increased from 38% to 40% over the same period. These increases can be interpreted as a small overall decrease in the localization of knowledge. The increased use of modern communication technologies – most notably the internet – might explain this finding as it renders distant knowledge more accessible.

Finally, Table 2 presents summary statistics regarding the involvement of patent attorneys. We find significant differences regarding the share of patent pairs where the applicant of the citing patent was represented by a patent law firm that has been exposed to the cited knowledge as it was also contracted by the applicant of the cited patent. The share amounts to 2.4% for citing/cited pairs, and it is significantly smaller for the cited/non-citing pairs, i.e., it amounts to 0.51% for control group (i) and to 0.08% for control group (ii). We interpret this finding as evidence that patent attorneys accumulate knowledge from interaction with previous applicants (of the cited patents) and make this knowledge available (almost like a library) when interacting with subsequent clients (applicants of citing patents). Hence, they support their clients in getting access to external (and potentially distant) knowledge, which would otherwise be more difficult to reach and thereby make external learning possible.

As we clearly demonstrate in Table 2, this important result might be confounded by the localization of knowledge flows: applicants appear to prefer law firms that are in geographical proximity over law firms that are geographically distant. Consequently, knowledge flows could be driven by proximity rather than by contracting the same law firm. Another confounding effect might be driven by technological proximity: applicants that are technologically close (in terms of being active in the same technology area at the level of IPC4 classifications) tend to choose the same law firm (perhaps because of the latter's specialization or reputation in the field). Therefore, an increased likelihood of knowledge flows might be caused by either technological proximity or access to a common law firm's

knowledge. To disentangle these effects, we conduct a multivariate analysis of the likelihood of knowledge flows that allows us to control for additional covariates.

Multivariate Analysis of Knowledge Flows

Econometric model

In our analysis, we utilized a regression approach that expands upon Jaffe et al. (1993) and is similar to the approach previously used by Sorenson and Fleming (2004), Singh (2005) and Singh et al. (2010). The likelihood of a citation occurring between "any" two patents (0/1) is modeled in a generalized probit regression framework. A generalized framework – as opposed to standard discrete choice models – is chosen to reflect that citations between entirely randomly matched pairs of patents occur only to a very limited extent. Therefore, our sampling strategy, as described above, deliberately overweighs pairs of cited/citing pairs (i.e., patent pairs for which an actual citation occurred) relative to randomly matched cited/non-citing pairs (see also Singh et al. (2010) for a discussion). The probability of a citation occurring is a function *f(.)* of the independent variables *X* and parameters *b* with *Pr(citation = 1) = f(Xb)*. For representative samples, a natural choice for *f(.)* is the logit function or the cumulative normal distribution (probit model) (Wooldridge, 2010). Because our sample is not representative of the underlying population of all patent citations (actual and potential) but rather the result of a choice-based sampling approach that overweighs actual citations relative to the number of potential citations that might have occurred, standard logit or probit models would lead to biased estimates of *b* (Manski and McFadden, 1981; Greene, 2003). Manski and Lerman's (1977) weighted exogenous sampling maximum likelihood (WESML) estimator is a suitable approach to correcting the choice-based nature of our data by weighing each observation according to the inverse of its probability of occurring in the final sample (Manski and Lerman, 1977). Given the weights *w(i) = Q(i)/H(i)* for each group *i* of the choice-based sampling, with *Q(i)* being the population shares and *H(i)* the sample shares, an unbiased estimator of *b* can be obtained by maximizing the weighted exogenous sampling likelihood function with respect to *b*. The estimator is the solution to maximizing the weighted log-likelihood function with respect to *b* and $max_b \sum_{n=1}^{N} w(i) log P(i, x, b)$.

To answer our research question whether law firms facilitate the acquisition of external and external distant knowledge, an explanatory variable will be included in the regression that indicates whether cited/(non-) citing patent pairs have been processed by the same patent law firm. If PSFs provide access to external knowledge, as we hypothesize in H2, the regression coefficient of this variable should be significantly different from zero and positive. To control for the localization of search (H1), we include geographical distance (log of the km-distance between the inventors on paired patents) as well as technological distance between the focal and the citing patent (different IPC4 classification on paired cited and (non-)citing patent or not). We test the moderating influence of both geographical and technological distance (H3) on the effect of contracting the same patent law firms on the likelihood of knowledge flows by interacting the two distance measures with the same law firm indicator. In all our regressions we control for inventor mobility by including a dummy variable indicating whether there is a common inventor on the cited and the citing patent. Finally, we compute the annual number of patent filings, the annual number of technology areas, and the cumulated number of clients of the law firm that processed the citing patent application to control for law firm characteristics. Note that a dummy variable indicates whether the applicant of the citing patent was represented by a law firm. All regressions include dummy variables for different technology areas (at the level of the 30 OECD technology classes, OECD 1994), the year of application of the cited, as well as the citing patent and the citation lag in years to control for time or technology effects otherwise not captured by our set of variables. For reasons of brevity, we do not report the coefficients of these variables. The full set of coefficient estimates can be obtained from the authors upon request.

The identification assumption made within this paper is that the key explanatory variables, particularly the service company's choice, are exogenous with regard to observed knowledge flows (dependent variable), i.e., unrelated to the error term. The primary concern regarding exogeneity is unobserved quality of the service companies which may affect both the probability that a patent receives a citation (e.g., because the service company has more experience in filing patent applications, which may result in higher patent quality) and the decision to employ a particular service provider. This factor would lead to a positive bias in our law firm coefficient. To address the possible endogeneity problem caused by the quality of the service firm, we add a number of control variables to our

regression, including the number of patents filed by a law firm, the number of technical areas in which the law firm is active, and the number of clients the law firms served during the year under consideration. Consistent with Belenzon and Schankerman (2010), another important issue to be discussed is the possible endogeneity of location. Again, in our analysis, it is assumed that the distance between the applicants listed on the citing and the cited patent is exogenous, i.e., the quantity of applicant learning decreases as the distance between the two parties increases. However, the effect could also be caused by an endogenous spatial distribution of inventors or applicant exploitation of knowledge flows, in other words, through a matching mechanism. In accordance with Belenzon and Schankerman (2010), we attempt to disentangle the two scenarios by using fine-grained controls for technological areas, i.e., the 30 technical areas proposed by the OECD (1994) that are included in the regression analysis.

Results

Marginal effects from weighted probit regressions are reported in Table 3 (robust standard errors are in brackets). We present the regression results from five different model specifications. The first specification in Table 3 contains exclusively geographical and technological distance as key independent variables. With these estimations, we attempt to replicate the stylized finding of localized knowledge acquisition and at the same time test H1. Our findings suggest that, to a significant extent, both geographical and technological distance determine the likelihood of knowledge acquisition. We find that increasing the distance between two inventors significantly reduces the likelihood of knowledge flow (see column 1 of Tables 3). Additionally, we find that technological distance significantly decreases the likelihood of knowledge flow as the coefficient is negative and highly significant.

Furthermore, hypothesis H2 proposes that knowledge which is incorporated in a PSF's knowledge repository is more likely to be acquired by the focal organization. Column 2 of Table 3 additionally includes the dummy variable which shows whether the two applicants listed on the paired patents were clients of the same law firm, indicating that the focal firm has access to knowledge that was incorporated in this law firm's repository. The coefficient of this dummy variable is positive and highly significant. Patent applicants are 7.21% more likely to acquire external knowledge that has been

included in a law firm's repository as opposed to other external knowledge. Based on this finding, we cannot reject hypothesis H2 that having access to a patent law firm's knowledge repository in fact facilitates external knowledge acquisition, i.e. external learning.

In columns 3, 4 and 5 of Table 3, we finally test our hypotheses regarding the moderating effects of geographical and technological distance. With regard to the effect of geographical distance (column 3), we find that the interaction between the indicator for a common law firm and the geographical distance is positive and highly significant.

INCLUDE FIGRUE 1 ABOUT HERE

In Figure 1 we include a graphical representation of the marginal effect of the same law firm dummy over the range of the observed km distance as well as technological distance to visualize the moderating effect of distance on the same law firm effect. The left panel of Figure 1 shows that the likelihood of a citation between paired patents decreases with increasing geographical distance. More importantly, Figure 1 also shows that the likelihood of a citation between two paired patents is not diminished by increasing distance if the same law firm was involved in both patents. Having access to a law firm's non-localized knowledge repository therefore effectively helps to overcome the disadvantage of being geographically distant from the source of knowledge.

Our findings with regard to technological distance point in the same direction (see column 4 of Table 3 as well as the right panel of Figure 1): Organizations benefit more from contracting law firms when knowledge is transferred from IPC4 areas that are different from those in which the organizations are active. The right panel of Figure 1 implies that accessing a law firm's knowledge repository not only helps to effectively overcome localization disadvantages. As our estimations and Figure 1 show, the likelihood of acquiring knowledge via a law firm's repository is not diminished by for distant knowledge but in fact even increases. It can therefore be argued that PSFs stimulate distant search and broaden their clients' search so that they acquire knowledge that resides beyond their existing knowledge base. Accessing external knowledge repositories provided by PSFs seems to be even more effective to acquire technologically distant knowledge as opposed to geographically distant knowledge.

In sum, these findings support hypotheses H3a and H3b in that contracting a law firm is effectively facilitates external learning across geographical and technological boundaries. So the more distant an organization is from knowledge, the more it benefits from contracting a law firm whose knowledge repository contains this knowledge.

Extension

The organizational learning literature generally stipulates that learning is the recording of successful solutions to make them available for future actions (Levitt and March 1988, Huber 1991). Our results above indicate that PSFs facilitate access to and the acquisition of external knowledge – in particular for knowledge that is distant from the focal firm. In order to strengthen this key result of our empirical analysis, we further analyze to what extent knowledge that has been made available by a PSF is actually recorded (incorporated into the focal firm's knowledge pool) and be used in future actions. If the interaction with a PSF indeed enables external learning, the knowledge made available by a PSF should remain within the learning organization's knowledge pool and used in the future.

In order to test this proposition, we analyze a focal organization's patent applications subsequent to the patents that are included in our original sample and which were actually citing relevant knowledge contained in the cited patents. The prior art cited in these patents is relevant for an organization's broader innovative activities and the organization's subsequent patents should therefore be more likely to cite the same prior knowledge than random patents from other companies. As some of the originally cited knowledge was made available by a PSF and some of it was not, we can exploit this setting to test whether knowledge made available by a PSF is used differently compared to knowledge acquired by other means or not. We include an interaction effect whether initially cited prior art stems from collaboration with a patent law firm or not (1/0). If knowledge made available by a PSF remains within a firm, its subsequent patent filings should no less or more likely refer to this prior art and the interaction effect should be insignificant. If, however, knowledge made available by a PSF does not remain within a firm, its subsequent patent filings should be less likely to refer to knowledge that was acquired from a PSF and the interaction effect would be significant and negative.

For this robustness test, for each of the patents that represent knowledge acquisition (actual citations) in our sample, we identify the subsequent patent filing of the same applicant in the same technology area. Note that for initially citing patents that refer to relevant knowledge made available by a PSF we identify a company's first subsequent patent that was filed without the help of this PSF. For some patents, we have not been able to identify subsequent filings because of the truncation of our data or because an applicant had not contracted a different law firm. If acquired knowledge remains within the receiving organizations, these subsequent patents should be more likely to refer to the initially cited knowledge than a patent from a randomized control group. Therefore, we construct a control group of randomly sampled patents characterized by the same technology areas and filing years as the subsequent patents we identified. A variable is included to indicate whether a focal patent is a subsequent filing to a patent in our original sample that represented knowledge acquisition or whether it belongs to the matched control group of patents that are unrelated to the primary sample.

Further, we include an interaction variable that indicates whether a focal patent is a subsequent filing to an application that (i) represents knowledge acquisition in our primary sample and (ii) was filed with the help of a PSF (0/1). This interaction allows us to test whether knowledge acquired from a PSF's repository remains within an organization or not. If knowledge from a PSF's repository remains within an organization, this interaction term should have no significant effect on the likelihood that patents refer to the initially cited patents.

Table 4 reports the results from a probit analysis estimating the likelihood that a patent refers to an initially cited patent. We find that firms that were initially citing prior art contained in a patent are significantly more likely to refer to this knowledge in subsequent applications than random applicants based on our matching (see Table 4, column 1). We interpret this result as an indication that knowledge cited in a patent application is in fact relevant to a firm's ongoing innovation activities and is incorporated in its own knowledge pool. Moreover, and more importantly, the interaction effect for subsequent filings to patents that represent knowledge acquisition via the repository of a PSF is insignificant. This implies that knowledge made available by the focal organization's patent law firm is not significantly different from knowledge acquired internally, in terms of the likelihood that a company is using this knowledge in its future activities (see Table 4, column 2) . Based on this finding,

we conclude that PSFs do not only call their clients' attention to external knowledge, but the knowledge is in fact incorporated in the clients' own knowledge pool. This finding strengthens our key result presented above: When organizations interact with PSFs – who have a knowledge repository at their disposal created during prior interactions with their clients – then these organizations gain access to external and possibly distant knowledge, and, as highlighted in our robustness test, actually learn.

INCLUDE TABLE 4 ABOUT HERE

Discussion

There are limitations to our study, which we briefly discuss, below. First, there is an ongoing debate whether patent citations are a reliable indicator of knowledge flows. At the heart of this debate is the fact that patent citations do not necessarily originate from the patent applicant. The inventor/patent applicant only adds citations to the patent application originally filed, whereas the patent examiner usually adds citations to the final patent document as it is eventually granted or refused. For US patents, survey-based evidence indicates that inventors may not always be fully aware of examiner-added citations that are contained in patents (Jaffe, Trajtenberg, and Fogarty, 2000). On the other hand, Lampe (2012) demonstrates – again, in the US context – that applicants strategically withhold relevant prior art from the examiner. As a consequence, examiner-added as well as inventor-added citations will be only a noisy measure of knowledge flows. Alleviating some of the concerns related to the origin of patent citations, Alcácer and Gittelmann (2006), as well as Thompson (2006), state that the patterns created by citations added by patent examiners are similar to inventor-added citation patterns. Contrary to the US patent system, applicants at the EPO are not required to refer to any relevant prior art in their patent applications. Applicants in the European patent system have the right but not the obligation to suggest references to the examiner. Duguet and MacGarvie (2005) combine European patent data with survey-based information on knowledge flows obtained from the Community Innovation Survey (CIS) in order to scrutinize the use of patent citations as indicators of knowledge flows, and they conclude that European patent citations are suitable, though noisy, for tracing knowledge flows. In unreported regressions we test the robustness of our findings by constructing two separate treatment/control

datasets – one containing exclusively inventor-added citation pairs in the treatment group, and the other containing exclusively examiner-added pairs in the treatment group. Running the same matching routine to replace the citing patents and the same regression specifications used for our primary sample, we find that our results remain qualitatively unchanged for both datasets. In particular, exclusively relying both on inventor-added citations only or on examiner-added citations only, we find that two applicants who contracted the same law firm are significantly more likely to experience knowledge flows than other patent applicants.

Finally, another critique of using a treatment/control-group approach to identify the determinants of knowledge flows has been brought forward by Thompson and Fox-Kean (2005). They emphasized that matching citing patents with technologically 'similar' patents requires assumptions with regard to the technological distance between patents. This might impact the results in cases where the distance is too coarse to effectively control for a pre-existing geographic concentration of production in similar technologies. However, comparing classifications of differing granularities, Jaffe et al.'s (1993) finding that knowledge flows are geographically localized remained robust (Thompson and Fox-Kean, 2005). The matching routine we applied is based on the 4-digit level of the IPC classification scheme, which is more detailed than the 3-digit USCS classification typically used in comparable studies of US patent data. Moreover, it should be kept in mind that Thompson and Fox-Kean's (2005) critique is primarily focused on potentially spurious effects with regard to the identification of the geographical localization of knowledge flows but not necessarily other determinants of knowledge flows such as access to a law firm's knowledge repository.

Conclusion and Further Research

In this study, we investigated the impact of accessing an external knowledge repository on external learning. We did this in the context of PSFs by analyzing a data set capturing 544,820 pairs of EP patent applications as well as the names of PSFs. In line with previous research, we argued that the knowledge PSFs accumulate during interactions with their clients is stored in a knowledge repository and that accessing this repository enables external learning. Our study has produced two primary findings: First, organizations are significantly more likely to acquire external knowledge from another organization if knowledge produced by the latter has been included to a (PSF's) knowledge repository.

Additionally, we find that a focal organization's distance to the external knowledge (both technologically and geographically) moderates the likelihood of acquiring external knowledge via a repository. In particular, the positive effect of accessing a PSF's knowledge repository including relevant knowledge increases with geographical and technical distance. An extended analysis further revealed that interactions with PSFs do not only enable the acquisition but also the storage of knowledge in a client's knowledge pool, i.e. PSFs, indeed enable external learning.

The findings presented in this paper have a number of important theoretical and practical implications. Most existing research has considered a direct link between the knowledge-generating and the knowledge-seeking entities. External learning has either been enabled by a knowledge broker or through fully outsourcing the generation of distant knowledge (Hargadon and Sutton, 1997). Our study contributes to the literature on organizational learning by shedding light on a so far largely disregarded source of external learning, knowledge repositories, which enables knowledge acquisition without direct interaction between the knowledge-generating and the knowledge-seeking entities. Furthermore, research on innovation in organizations perceives innovation as a process of knowledge recombination (Schumpeter, 1934). Rosenkopf and Nerkar (2001), for instance, suggest that firms have to establish the ability to create new knowledge across technological boundaries. By showing that accessing a knowledge repository – in our example by contracting a PSF – can help organizations to overcome localization of knowledge and to allow the acquisition of knowledge outside their boundaries, the results of the present study provide insights that may facilitate knowledge recombination across technological and geographical boundaries. In other words, accessing external knowledge repositories can help organizations to search for distant knowledge, to broaden their search and possibly ultimately improve their innovative performance.

Additionally, our results provide an important implication for the economics of the patent system. The rationale of the patent system is to foster innovation by allowing firms to appropriate returns from R&D investment by granting a temporary exclusion right and to promote the diffusion of knowledge in order to speed up innovation and to avoid duplication of R&D efforts (Scotchmer, 2004). As prior research and our own results indicate users of the patent system might have difficulties in acquiring existing knowledge, in particular when it is distant. From an economic perspective, patent law

firms not only increase private benefits of their clients but at the same time contribute to a faster diffusion of knowledge and ultimately to an increase in overall welfare.

For R&D managers, relying on knowledge repositories can reduce the costs, time and risks of external learning. For instance, PSFs accumulate, store, and validate external knowledge and thereby help to 'find' relevant and distant pieces of knowledge. This enables rapid technological advances at a lower risk. Furthermore, the fact that PSFs can accommodate for localization disadvantage puts less pressure on location decisions. For instance, organizations located outside technology clusters can benefit from contracting a PSF that has worked with organizations located inside a cluster. The knowledge repositories of these PSFs are likely to contain knowledge created by organization in the cluster and thus enable organizations located outside the cluster to benefit from positive knowledge externalities, even over a distance. Hence, choosing a professional service firm (or, as in our setting, a patent law firm) appears to be a strategic decision for organizations.

Our results also open up important questions that can be addressed in future research: The most promising avenue of further research may be a detailed analysis of the fit between an organizations existing knowledge pool and the knowledge contained in external knowledge repositories. In our paper we were agnostic about this fit. One might expect that repositories containing knowledge that is neither too similar nor too different from an organization's own knowledge are most beneficial for external learning. To overcome knowledge localization, the knowledge contained in the repository has to be sufficiently different to the company's own knowledge - thus not too similar. However, a firm needs to have at least a minimum level of familiarity with the external knowledge in order to be able to 'absorb' it (Cohen and Levinthal, 1989). Or, as Kogut and Zander (1992) argue, organizations need to develop 'combinative capability' to link existing with newly acquired knowledge. Another very fruitful path of future investigation is the relationship between contracting PSFs and firm performance. The fact that PSFs grant access to distant knowledge and enable external learning may well lead to more radical innovations, which, in turn, could result in higher performance of the firm.

Additionally, as mentioned earlier, external learning through contracting PSFs differs from external knowledge acquisition though knowledge brokers (Hargadon and Sutton, 1997). Existing studies analyze brokers that actively connect two parties and examine their characteristics, activities

(Burt, 2005; Gould and Fernandez, 1989), the performance effect of their position in a network of actors (Stuart and Podolny, 1999; Burt 2004), and how they ultimately generate returns from linking supply and demand in markets (Bidwell and Fernandez-Mateo, 2010; Fernandez-Mateo, 2007). The PSFs analyzed in the underlying paper transfer knowledge – acquired from interacting with one client – to another client. They do not directly link them, which is probably also not desired by their clients. Furthermore, the 'brokering' activity of PSFs is tied to the provision of a core service. Future research may want to address to what extent the insights from studies of knowledge brokers that directly link supply and demand can be transferred to situations of 'indirect' brokerage like the one between PSFs and their clients.

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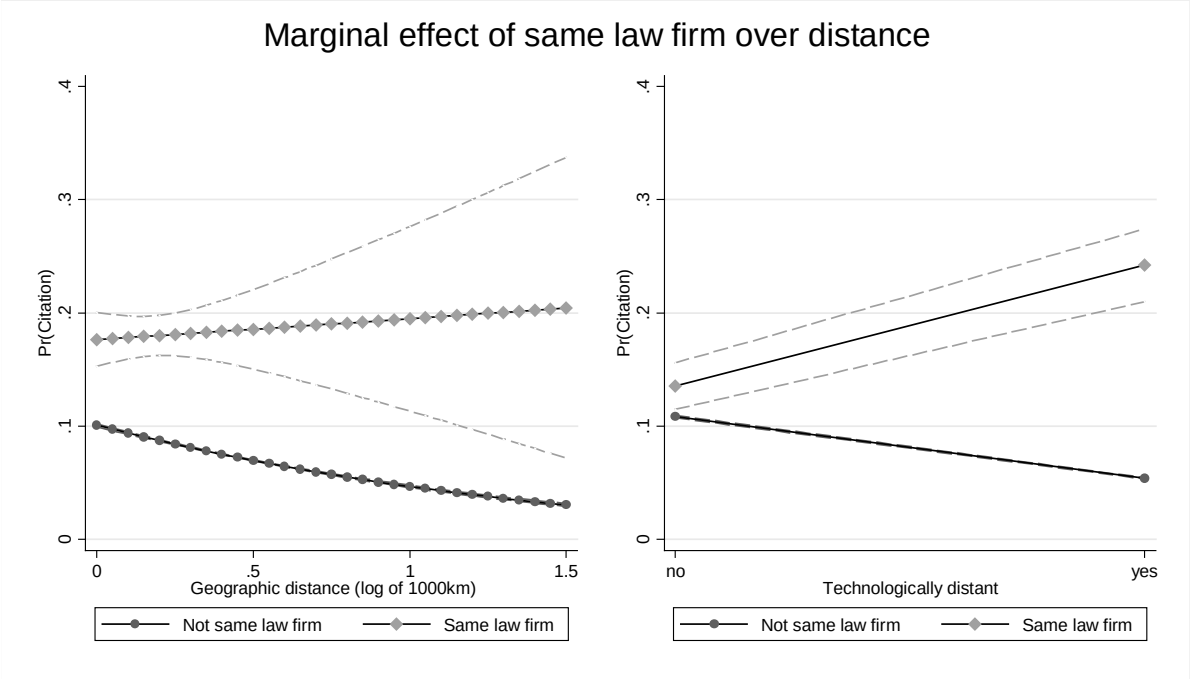

Figure 1: Moderating of effect of distance on the effect of the same law firm dummy. The left part of the figure (geographical distance) is based on Column 3 of Table 3. The right part of the figure is (technological distance) is based on Column 4 of Table 3. Note: Dashed lines represent 95% confidence intervals.

Table 1: Summary statistics for patent law firms for the period 1990 to 2006 by quartile (in terms of number of applications filed at the EPO). We report the number of patent applicants served by a law firm based on the consolidated applicant information contained in PATSTAT. The number of technology areas is equal to the count of the updated OECD (1994) technology classes, to which at least one patent application represented by a law firm was assigned.

Quartiles (based on number of applications filed)	Number of law firms	Number of filings (mean)	Share of all applications filed	Number of clients (mean)	Number of technology areas (mean)
Less than 6 applications	1,032	2.16	0.19%	1.77	1.73
Between 6 and 35 applications	880	16.34	1.23%	10.25	7.50
Between 36 and 176 applications	939	88.87	7.14%	42.22	16.65
More than 176 applications	950	1,124.39	91.43%	326.22	25.99
Total	**3,801**	**307.35**	**100.00%**	**94.82**	**12.81**

Table 2: Descriptive statistics for key explanatory variables for the matched sample used in the multivariate analysis of knowledge flows.

Mean values Median Values	**Citations** (n=136,706)	**Control pairs (same IPC4, same year)** (n=136,035)	**Control pairs (same year)** (n=273,404)	**Total** (n=546,145)
Geographical distance				
Distance (mean)	484 km	568 km	602 km	564 km
Distance (median)	389 km	467 km	494 km	464 km
Technological distance				
Different IPC4 classification (0/1)	42.41%	42.35%	99.25%	70.85%
Same attorney				
Citing patent filed by same law firm as cited patent (0/1)	2.41%	0.51%	0.08%	0.77%
Minimum distance between inventors for patents filed by same law firm (mean)	114 km	167 km	389 km	137 km
Different IPC4-classification for patents filed by same law firm	39.39%	27.85%	99.06%	40.50%

Table 3: Marginal effects from a weighted Probit regression of the likelihood of a citation involving two patents. Robust standard errors are reported in brackets.

Citation (0/1)	(1)	(2)	(3)	(4)	(5)
Same law firm (0/1)		0.0721***	0.0596***	0.0191**	0.0141*
		[0.0084]	[0.0102]	[0.0076]	[0.0082]
* Minimal KM distance			0.0615***		0.0392*
			[0.0233]		[0.0213]
* Different IPC4 classification (0/1)				0.1734***	0.1698***
				[0.0236]	[0.0232]
Geographical distance					
Distance between inventors on patent pairs in km	-0.0542***	-0.0523***	-0.0526***	-0.0522***	-0.0523***
	[0.0011]	[0.0011]	[0.0011]	[0.0011]	[0.0011]
Technological distance					
Citation pairs share no IPC4 class (0/1)	-0.0513***	-0.0510***	-0.0510***	-0.0519***	-0.0519***
	[0.0006]	[0.0006]	[0.0006]	[0.0006]	[0.0006]
Control Variables					
At least one inventor in common (0/1)	0.5550***	0.5166***	0.5194***	0.5268***	0.5284***
	[0.0173]	[0.0174]	[0.0172]	[0.0171]	[0.0169]
Number of patents filed by law firm per year	0.0800***	0.0804***	0.0803***	0.0803***	0.0803***
	[0.0031]	[0.0031]	[0.0031]	[0.0031]	[0.0031]
Number of different areas law firm is active in per year	0.0016***	0.0015***	0.0015***	0.0015***	0.0015***
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Number of different clients of law firm	-0.0000***	-0.0000***	-0.0000***	-0.0000***	-0.0000***
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Patent has not been filed by a law firm	0.0167***	0.0168***	0.0168***	0.0168***	0.0168***
	[0.0008]	[0.0008]	[0.0008]	[0.0008]	[0.0008]
Year of application dummies (for cited and citing patents)	YES	YES	YES	YES	YES
Citation lag (years)	YES	YES	YES	YES	YES
OECD 30 class (of cited patents) dummies	YES	YES	YES	YES	YES
Observations	544,820	544,820	544,820	544,820	544,820
log likelihood	-134,955	-134,837	-134,832	-134,730	-134,728
degrees of freedom	58	59	60	60	61
chi2	26,718	26,601	26,796	27,671	27,831

*** p<0.01, ** p<0.05, * p<0.1

Table 4: Marginal effects from Probit regressions of the likelihood that either a subsequent patent from a firm receiving knowledge transfer or a patent from the control group cites the patent underlying the initially observed knowledge transfer.

Citation (0/1)		
Subsequent patent from same applicant	0.0177***	0.0176***
	[0.0005]	[0.0005]
Subsequent patent from same applicant based on knowledge made available by PSF		0.0003
		[0.0003]
Geographical distance		
Minimal KM distance between inventors on patent pairs (logs)	-0.0018***	-0.0017***
	[0.0003]	[0.0003]
Technological distance		
Citation pairs don't have an IPC4 in common (0/1)	-0.0003*	-0.0003*
	[0.0002]	[0.0002]
Control variables		
Citation pairs have at least one inventor in common (0/1)	0.0078***	0.0078***
	[0.0018]	[0.0018]
Year of application dummies (of cited as well as citing patent)	YES	YES
Citation lag (years)	YES	YES
OECD 30 class (of cited patents) dummies	YES	YES
Observations	143,229	143,229
log likelihood	-7,935	-7,935
degrees of freedom	61	62
chi2	1,438	1,442

*** p<0.01, ** p<0.05, * p<0.1

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