
Volume 42, Issue 2, March 2013 ISSN 0048-7333
ELSEVIER
RESEARCH
POLICY
Policy, management and economic studies of science, technology and innovation
Available online at www.sciencedirect.com
SciVerse ScienceDirect

Research Policy 42 (2013) 465–480

Contents lists available at SciVerse ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

We need to talk – or do we? Geographic distance and the commercialization of technologies from public research

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ARTICLE INFO

Article history:
Received 21 September 2011
Received in revised form 30 April 2012
Accepted 29 June 2012
Available online 9 August 2012

JEL classification:
L24
L26
O34
R30

Keywords:
Academic inventions
Licensing
Spin-off entrepreneurship
Geographic distance

ABSTRACT

Using a new dataset with detailed geographic information about licensing activities of the German Max Planck Society, we analyze how the probability and magnitude of commercial success are affected by geographic distance between licensors and licensees. Our evidence suggests that proximity does not generally lead to superior commercialization outcomes. A significantly negative association between distance and commercialization success is identified only for foreign licensees within the subsample of inventions licensed to more than one firm. Positive associations between distance and performance indicators are not robust to controlling for invention quality or selection into licensing.

1. Introduction

Creation of new knowledge through research and development (R&D) is the main engine of technological change, and technological change is the main engine of growth and employment in modern economies. Universities and non-university public research organizations (PROs for short) are important generators of new knowledge (Salter and Martin, 2001). It is therefore not surprising that policy makers have undertaken considerable efforts to strengthen the links between public research and the private sector. Driven by the motivation to improve the utilization of new knowledge in the economy, the Bayh-Dole Act of 1980 in the U.S. and similar legislative changes elsewhere advanced technology transfer as one of the main objectives – a "third mission" (Etzkowitz and Leydesdorff, 2000) – of public research. Even though multiple relevant channels of knowledge transfer exist, including publications, conferences, consulting, and scientist migration to the private sector (Agrawal and Henderson, 2002; Cohen et al., 2002), recent legislative activities have often focused on university patenting and licensing as instruments to commercialize scientific results (Bozeman, 2000; Mowery et al., 2001; Shane, 2002; Sampat, 2006; Kenney and Patton, 2009; Della Malva et al., forthcoming; Von Proff et al., 2012).

Commercialization of academic inventions by private-sector firms is fraught with a variety of challenges. Similar to other "markets for technology" (Arora et al., 2001) the market for academic inventions is characterized by substantial information asymmetry between the inventor and the potential licensee (Shane, 2002; Siegel et al., 2003; Lowe, 2006). In addition, licensed academic inventions are usually far from being readily marketable (Jensen and Thursby, 2001) and the underlying knowledge possessed by the original academic inventors – which is often critical for success – is not fully codified (Agrawal, 2006).

This paper focuses on the role of geography in the commercialization of academic inventions. Geographic distance and licensing across national borders may aggravate problems of information asymmetry and complicate inventor engagement. This may lead to inferior commercialization outcomes, which in turn might provide an economic rationale for preferential licensing of academic inventions to regional firms. To assess the relevance of such concerns, we utilize the fact that license-based commercialization is a sequential process, and not all licenses of academic inventions

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http://dx.doi.org/10.1016/j.respol.2012.06.010

lead to commercial success stories. Specifically, we relate observable differences in outcomes of the commercialization stage to the geographic distance between licensor and licensee.

Empirical research on license-based commercialization of academic inventions is limited by the lack of universities and PROs having sufficient numbers of successfully commercialized inventions. Existing findings are largely restricted to a few leading U.S. universities. Shane (2002, for the MIT) and Lowe and Ziedonis (2006, for the University of California system) compare commercialization outcomes of startup licensees with those of established firms. Also using data on licensed MIT inventions, Dechenaux et al. (2008) analyze how appropriability conditions affect termination likelihood and commercialization success. Elfenbein (2004, 2007) explores the significance of contractual provisions and inventor seniority for commercialization outcomes in the empirical context of Harvard University. Given the traditionally different ownership model for academic inventions in Europe (Lissoni et al., 2008) and the ensuing lack of licensing data, very little prior evidence at the level of individual inventions exists for Europe. Buenstorf and Geissler (2012) use data for the German Max Planck Society to compare the commercialization outcomes of spin-offs and other licensees. Similar to Shane (2002) and Lowe and Ziedonis (2006) they find limited evidence of systematic differences between both types of licensees.

The contribution of public research to the *regional* innovation and growth performance has been explored in a long line of prior research. Results have been mixed. Several authors (e.g. Jaffe, 1989; Acs et al., 1992; Anselin et al., 1997; Fritsch and Slavtchev, 2007) suggest that proximity to public research yields substantial benefits to firms' innovativeness. Mansfield and Lee (1996) likewise find that firms prefer to work with university researchers who are located less than 100 miles away from their laboratories. Based on a survey of R&D laboratories in the U.S., Adams (2002) concludes that geographic proximity is more important in university-firm interactions than in firm-firm interactions. Adopting the methodology pioneered by Jaffe et al. (1993), Belenzon and Schankerman (forthcoming) find that citation rates of both publications and university patents decline sharply with distance.

Other work suggests a lesser role for geographic proximity. Audretsch and Stephan (1996) show that the majority of links between university scientists and U.S. biotechnology firms are non-local. Even about 40 percent of all spin-off founders among the studied researchers established firms outside the region of their university. Similar results have been obtained for Germany (e.g. Grotz and Braun, 1997). In a survey of 2300 German companies, Beise and Stahl (1999) do not detect a higher likelihood to innovate for firms that are located close to universities or polytechnics. They conclude that geographic proximity to public research does not influence the probability of public research-based innovations. However, as pointed out by Salter and Martin (2001), this result might be influenced by specificities of Germany's geography.

Very little prior work has studied the role of geography in the commercialization of licensed university inventions. Mowery and Ziedonis (2001) compare the geographic reach of patent citations and licenses. They conclude that licenses of academic inventions are more localized than patent citations. Survey-based work by Santoro and Gopalakrishnan (2001) suggests that geographic proximity favorably affects technology transfer activities between universities and firms. In contrast, controlling for inventor involvement in licensees' commercialization efforts, Agrawal (2006) finds no effects of co-location on commercialization outcomes.

In the present paper we contribute to this latter line of research at the intersection of academic inventions and geography. We use and extend a dataset with detailed information about licensing activities of the Max Planck Society, Germany's largest non-university public research organization focused on basic research (Buenstorf and Geissler, 2012). In contrast to the faculty of German universities, Max Planck researchers have never enjoyed the professors' privilege but have consistently been subject to a Bayh-Dole-like IPR regime since the 1970s. This circumstance provides us with a rare opportunity to study license-based commercialization of academic inventions in the European context. Our dataset encompasses more than 2300 inventions for the time period 1980–2004, of which 773 have been licensed. It also includes detailed information about payments to the Max Planck Society indicating whether or not an invention has been commercialized successfully, as well as the magnitude of the returns.

Most importantly for the present study, the available information includes the locations of the originating Max Planck institute and the private-sector licensee. While a considerable fraction of license agreements is with regional firms, there is substantial variation in distances, and international licensing accounts for almost a third of all licenses in our analysis. We exploit this variation to analyze whether and how probability and magnitude of commercial success are affected by geographic distance between inventors and licensees. Our findings suggest that geographic distance is generally not a relevant obstacle to successful commercialization of academic inventions. A significantly negative association between distance and commercialization success is identified only for foreign licensees of inventions licensed to more than one firm. In some models, more distant licensees have superior commercialization outcomes. However, these positive associations between distance and performance indicators are not robust to controlling for invention quality or selection into licensing.

The remainder of the paper is organized as follows: The next section develops theoretical considerations about the potential importance of geographic proximity for commercialization success. Section 3 provides information about the technology transfer process of the Max Planck Society. Section 4 describes our data and research design, whereas results are presented in Section 5. We discuss implications and limitations of our analysis in Section 6.

2. Geographic proximity and the commercialization of academic inventions

2.1. Why are licensees of academic inventions localized?

Belenzon and Schankerman (forthcoming) show that citations to U.S. university patents are concentrated around the location of the patenting university. Mowery and Ziedonis (2001) find for a sample of leading U.S. universities that licensees are even more localized than citations. A variety of factors could help explain these patterns.[2]

Non-codified knowledge is frequently invoked to account for geographic concentration of economic activities. Non-codified or "tacit" (Polanyi, 1966) knowledge is not expressed in patents, publications or blueprints and can only be learned through direct face-to-face contact. As a consequence, it tends to be geographically "sticky" (Von Hippel, 1994). In the context of license-based commercialization of academic inventions, non-codified knowledge related to the invention may contribute to localization in several ways.

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[2] Co-location of licensors and licensees might be spurious in that it might only reflect a concentration of potential licensees in the proximity of the licensing university. Previous work based on patent citations has accordingly sought to control for geographic concentration by finding suitable control groups. Jaffe et al. (1993; see also Thompson and Fox-Kean, 2005) find that knowledge flows as measured by patent citations are more localized than the overall population of patents in the respective technology field.

To begin with, knowledge about what academic inventions are available for licensing may not be fully codified. Even though technology licensing offices (TLOs) engage in the active marketing of their technology portfolios, pre-existing contacts of inventors and TLO staff to firm representatives are often leveraged to address potential licensees (Bercovitz and Feldmann, 2006). If these contacts are concentrated in the proximity of the licensing university, localization of licenses may entail. Local firms may also have a higher likelihood to learn about inventions available for licensing in more circumstantial ways, for instance in personal communication.

It is conceivable that the geographical spread of information related to an invention increases with invention quality. For example, if more prominent researchers on average make superior inventions, then better inventions will also be more visible to potential licensees located far away. This might lead to a sorting process with relatively few inventions being licensed to distant licensees, which however are of superior quality (Belenzon and Schankerman, forthcoming). Alternatively, geographic proximity could help overcome problems of asymmetric information by enhancing a potential licensee's ability to evaluate invention quality. Pre-established contacts or membership in the same social network facilitate the access to information about the invention, and inventors' (local) reputation will be used in making inferences about the quality of the invention (Elfenbein, 2007). This should again lead to localization of licensees, but also to superior quality of locally licensed inventions.

Better access to information about an invention and its inventors is mostly relevant before a license agreement is made. However, the need to transfer non-codified knowledge through face-to-face interaction may also lead to higher costs for more distant licensees in the post-agreement commercialization stage, making licensing more profitable for firms located close to the inventors of the licensed technology. Geographic distance increases the cost of inventor engagement due to higher travel costs and time losses (Beise and Stahl, 1999; Santoro and Gopalakrishnan, 2001). This should be most important for top-level scientists with high opportunity costs of time (Stephan, 1996).

At the time of licensing, academic inventions have often not been developed beyond the proof of concept or a lab scale prototype. In a survey of technology transfer managers of U.S. universities, Jensen and Thursby (2001) find that more than 75 percent of all licensed inventions were at an early stage of development. Under these conditions licensees need to make substantial R&D efforts of their own to obtain a marketable product from the licensed invention. Several studies have found that the success of these additional efforts is highly dependent on the continued involvement of the academic inventor(s) (Jensen and Thursby, 2001; Thursby and Thursby, 2004; Agrawal, 2006), as not all elements of knowledge underlying academic inventions are readily accessible to licensees (Arora, 1995; Agrawal, 2006). For example, academic inventions are often based on long series of experiments. Failures and disappointments in the process of academic research are usually unreported, i.e. remain non-codified. However, information about what was tried out and did not work would often be valuable for licensees in their efforts to further develop an academic invention. Commercialization activities are also complicated by the complex nature of academic inventions, which often involve knowledge far from a licensee's own knowledge base (Agrawal, 2006). Licensees' absorptive capacities (Cohen and Levinthal, 1990) may then be insufficient to fully appreciate all relevant information.

Further adding to the localization of licenses, licensees anticipating the difficulties of securing inventor engagement may choose their locations to minimize the distance to inventors. For pre-existing firms with substantial sunk investments, relocating to benefit from the proximity to a licensing university would seem like an extreme reaction. It is more plausible for university spin-offs, which account for a substantial share of licensees of academic inventions both in the U.S. and in Europe (cf., e.g., Shane, 2002; Lowe and Ziedonis, 2006; Buenstorf and Geissler, 2012). Being less well equipped with capabilities and complementary assets (Teece, 1986; Teece et al., 1997) spin-offs may be more reliant on external cooperation. In addition, successful commercialization of a specific invention will be more relevant for the survival of young spin-off firms, which normally have smaller portfolios of R&D projects than established external licensees (Lowe and Ziedonis, 2006). By definition, spin-offs are organized by academic inventors. However, often not all inventors of a technology join the spin-off's day-to-day operations. Moreover, even if all inventors are part of the spin-off team, proximity to the university where an invention was made may still yield benefits to the firm because it facilitates its access to knowledge held by prior co-workers working at the parent organization.

Finally, localization of licensees could be the outcome of discriminatory practices by licensors of academic inventions. Universities and other PROs frequently pursue regional development objectives as part of their general missions and more specifically in their technology transfer activities (Mowery and Ziedonis, 2001). Belenzon and Schankerman (2009) provide evidence indicating that some (primarily public) U.S. universities are foregoing licensing income by preferential treatment of in-state licensees. The same authors (forthcoming) also find stronger localization of patent citations for those universities that rank regional development objectives as relatively important.

2.2. Why may distance be related to commercialization outcomes?

In the previous subsection we presented various arguments why licensees of academic inventions might be expected to be localized. We now turn to the second stage of the commercialization process, in which licensees attempt to turn academic inventions into commercially viable products. The proposed causes of localization differ in their implications as to how the outcomes of this stage be related to the distance between licensee and licensor.

If only information about what inventions are available for licensing is geographically sticky, locations of licensees should not be systematically related to differences in the outcomes of the post-agreement commercialization stage. If, however, locally licensed inventions are of lower quality (as suggested by Belenzon and Schankerman, forthcoming), then distance should, ceteris paribus, be positively associated with commercialization outcomes. In contrast, localized information allowing for better assessments of local inventors and their technologies might result in a higher average quality, and therefore superior commercialization outcomes, of locally licensed inventions.

As suggested above, localization of licensees may also reflect that costs of inventor engagement increase with distance. In this case, expected outcomes of the commercialization stage depend on further assumptions about the extent of competition for individual licenses. In particular, it is conceivable that because firms self-select into profitable license agreements, more distant licensees may be found to have a higher likelihood of, and/or higher profits from, successful commercialization. To see this, assume that the licensing decision is made under the following stylized conditions. A firm is willing to license an academic invention if and only if its expected profits from commercializing the invention, minus the sum of payments to the licensor, exceed its costs of commercialization (incurred to develop the licensed invention further). The firm's expected profits are given by the discounted future flow of net income from producing and selling a product developed from the licensed invention times the probability that commercialization is successful.

Table 1
Predicted effects of distance on outcomes.

Scenario	Characterization	Expected effect of distance on commercialization outcomes
1	Localized knowledge about inventions available for licensing	o
2	Localized knowledge about quality of inventions	−
3	Geographic distance impairs inventor engagement (no effective competition for license)	−
4	Geographic distance impairs inventor engagement (effective competition for license/self-selection)	+
5	Larger geographic spread of knowledge about higher-quality inventions	+
6	Preferential licensing (discrimination against more distant licensees)	+

The absence of effective competition by other firms interested in licensing an invention increases the negotiation power of a potential licensee vis-à-vis the licensor.[3] In this situation, if inventor engagement is seriously constrained by distance, we may observe a negative association between distance and the likelihood of successful commercialization. In addition, the willingness to pay of distant licensees will be adjusted downward as they expect lower profits because of higher commercialization costs and/or a lower likelihood of success. Ceteris paribus, licensors will then receive smaller payments from more distant licensees.

Predictions are different if two or more firms compete for the same license. Assume that one of the potential licensees is located farther from the inventors and therefore faces higher costs of commercialization than its competitors. To obtain a license, the more distant firm needs to offer at least the same price that its competitors are willing to pay. This is worthwhile only if it has higher expected profits resulting from a higher likelihood of success and/or higher net income in case of successful commercialization. Otherwise, the more distant firm will refrain from licensing when there is effective competition among potential licensees. As a consequence of this self-selection into profitable license agreements, the observable set of agreements will be truncated, with more distant licensees having higher expected profits from successful commercialization. This suggests that observing superior commercialization outcomes for more distant licensees is consistent with distance-related increases in the costs of commercialization.

Two additional forces that could lead to the localization of licensees were suggested in the previous subsection: endogenous location choices and preferential licensing to regional licensees. Locating close to the licensing organization would seem most important when severe obstacles to inventor engagement have to be overcome, e.g., when spin-offs need to safeguard the future involvement of a star scientist who remains an active researcher at the spin-off's parent organization (from which the spin-off licenses its technology).[4] While complicating the empirical analysis (see below), it does not fundamentally alter the above predictions for how outcomes of the commercialization relate to geography. In contrast, if regional development objectives induce technology licensing offices to license inventions to local firms even though they are inferior to more distant competitors, local licensees should on average have poorer commercialization outcomes.

It follows from this discussion that different predictions about how geographic distance between inventors and licensees is related to commercialization outcomes can be derived from theoretical considerations and prior work (cf. also Table 1). Localized knowledge about inventions available for licensing can account for the localization of licensees, but would not be expected to lead to systematic differences in commercialization outcomes of licensees at different locations (Scenario 1 in Table 1). Poorer commercialization outcomes for more distant licensees could be explained by localized knowledge about the quality of inventions (Scenario 2), or by problems of engaging distant inventors provided there is little competition for licenses (Scenario 3). In contrast, when competition for the license forces disadvantaged licensees to self-select into profitable license agreements, problems of engaging distant inventors are also compatible with finding a positive relationship of distance and commercialization success (Scenario 4). Finally, superior commercialization outcomes of more distant licensees could also be caused by a larger geographic spread of knowledge about better inventions (Scenario 5) or by preferential licensing to local firms (Scenario 6).

2.3. *Geographic distance versus national borders*

Belenzon and Schankerman (forthcoming) emphasize the need to distinguish distance effects from effects of political borders in the context of U.S. states. A similar issue emerges in our empirical setting because almost a third of all licensees are located outside of Germany. National borders may restrict the flow of information about inventions available for licensing. Problems of inventor engagement caused by geographic distance may be further aggravated for foreign licensees because international travel tends to be more costly and time consuming than domestic travel. Cultural and linguistic differences also play an important role as potential obstacles to the transfer of tacit knowledge (Maskell and Malmberg, 1999; Leamer and Storper, 2001).

Licensees in border regions can be geographically close to a public research organization but separated by different languages and cultures (Arundel and Geuna, 2004). To allow for the possibility that border effects rather than geographic distance drive differences in commercialization outcomes, we will distinguish between domestic and foreign licensees in the empirical analysis and allow distance to have different effects on the commercialization outcomes of both groups.

3. Empirical context: the Max Planck Society

We analyze the geographic dimension of licensing in the context of the German Max Planck Society. Public research in Germany and other Continental European countries differs from the Anglo-Saxon countries in that non-university public research organizations account for a substantial fraction of all public research activities. In 2007, non-university PROs accounted for 46 percent of the budget and 44 percent of the research staff in the German public research system (EFI, 2010, p. 40). The Max Planck Society is one of the four largest PROs in Germany and focuses on basic research. Its primary task is to complement university research by engaging in large-scale, interdisciplinary, or particularly innovative activities in science, (parts of) engineering and the humanities. The Max Planck

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[3] This may be a widespread situation as markets for technologies from public research are usually thin. The number of firms interested in, and capable of, further developing and marketing academic inventions is in most cases small (Contractor, 1981; Jensen and Thursby, 2001).

[4] Note, moreover, that spin-offs' location choices in the proximity of the parent organization need not be motivated by a need to safeguard inventor engagement, but may reflect a more general "home bias" in the location choices of entrepreneurial ventures (Figueiredo et al., 2002; Dahl and Sorenson, 2011).

Society receives almost 80 percent of its budget from public, institutional funding. It employs close to 5000 researchers who work in 80 disciplinary or topical institutes (Max Planck Society, 2008).

Max Planck Institutes are geographically dispersed throughout the country; in most cases they are located close to a (public) university. The dispersion reflects the federalist character of the German political system, as federal and regional governments (*Bund* and *Länder*) share the costs of supporting the Max Planck Society. The roots of the Max Planck Society date back to the early 20th century when its predecessor was established. While the number of institutes has increased substantially over time, most institutes have been located in the same city for decades, even when their research agenda has shifted substantially over time. Given the Max Planck Society's mission, proximity to relevant industrial partners is not a major consideration in location choices.

Already before the professors' privilege was abolished in Germany in 2002, Max Planck researchers, just like employees of private-sector firms, were (and still are) subject to the German law on employee inventions. This law mandates that employees have to disclose all inventions to their employer, which is the legal owner of the ensuing intellectual property. To manage patent applications and technology licensing, the Max Planck Society in 1970 established a legally independent technology transfer subsidiary, which is presently named Max Planck Innovation GmbH. Staff members of Max Planck Innovation, which is co-located with the Society's central administration in Munich, regularly visit the individual institutes to solicit the disclosure of new inventions. Patent applications are handled in cooperation with external patent attorneys. New technologies are marketed to domestic and foreign firms, including spin-offs. The latter have been actively supported since the early 1990s. Explicit strategies of preferential licensing to regional/domestic licensees are not pursued.

Max Planck Innovation has concluded more than 1500 license agreements since 1979 (Max Planck Innovation, 2007). Accumulated returns from technology transfer activities exceed €200 million, with most income resulting from a handful of "blockbuster" inventions. In the case of successful commercialization, inventors receive 30 percent of all revenues, and the Max Planck Institute employing the researcher gets an additional third. The Max Planck Society uses the residual income to finance the operations of Max Planck Innovation.

4. Data and methods

4.1. Data

The present study is based on information provided by Max Planck Innovation GmbH that has been analyzed in earlier work by Buenstorf and Geissler (2012). The dataset covers all inventions disclosed by Max Planck researchers from the mid-1960s to the beginning of 2005. In total 3012 inventions have been disclosed to the Max Planck Society, of which 1885 resulted in a patent application. Information is available about inventor names, date of disclosure, the institute that the respective invention comes from, as well as whether an invention has been licensed or not.

Our empirical analysis focuses on the subset of all 864 inventions that have been licensed to private-sector firms. Since a number of inventions are licensed non-exclusively to multiple licensees, there are in total 1172 license agreements in the dataset. For each agreement, information is available about the name, type and location of the licensee, the dates of conclusion and (possibly) termination, as well as all amounts and dates of payments based on the license agreement. To minimize right censoring problems, we restrict the sample to inventions disclosed 2004 or earlier while using information about licenses and payments up to 2007. The empirical analysis is further restricted to inventions disclosed in 1980 or later for two reasons: First, before 1980 Max Planck Innovation (then named Garching Innovation GmbH) pursued a different overall strategy. For example, it not only managed inventions disclosed by Max Planck researchers, but also offered its services to external customers, mostly other public research organizations. Second, information available for the pre-1980 inventions is inferior to that related to the later inventions. These restrictions leave us with a total of 2376 disclosed inventions. Of these, 773 have been licensed; they are subject to a total of 1047 license agreements (Table 2).

Table 2
Disclosed and licensed inventions, 1980–2004.

Inventions (patented)	2376 (1504)
Licensed inventions (patented)	773 (546)
License agreements (patented)	1047 (728)
License agreements with royalties (patented)	731 (513)
Commercialized (patented)	365 (218)

Sample size is further reduced by restricting the analysis to license agreements that provide for sales-dependent royalty payments in the case of successful commercialization by the licensee. This restriction is necessary because the commercial success of a licensed technology is not directly observable but has to be inferred from the incidence and level of positive royalty payments. Our data include yearly royalty payments for all individual contracts from conclusion to 2007 or prior termination.[5] A substantial number of license agreements cover multiple inventions licensed to a single licensee in a bundle. Lacking more detailed information on the value of the individual inventions combined in such bundles, we treat them as separate observations in the empirical analysis, dividing observed royalty payments equally among the bundled inventions and including an indicator variable denoting bundled licenses in the model specifications. In total, 731 contracts provide for royalty payments (with or without additional fixed fees), of which 365 (50 percent) have been successfully commercialized (Table 2). For a small number of contracts key information about the invention or the licensee could not be retrieved, yielding a final sample size of 715 for the subsequent empirical analysis.

4.2. Variables

In line with the considerations in Section 2, the subsequent empirical analysis employs two different indicators of successful commercialization. First, we constructed a binary variable indicating all license agreements leading to positive royalty payments for the Max Planck Society. Second, to also account for differences in the returns from license agreements, we employ the logged sum of discounted royalty payments from the licensee to the Max Planck Society. Royalty payments are mostly proportional to the licensee's total revenues from the commercialized academic invention. They constitute the best proxy we could obtain for the profit contribution made by the respective invention (cf. also Lowe and Ziedonis, 2006).

The principal explanatory variable in the empirical analysis is the geographic distance between a licensee and the institute where the licensed invention was developed. Our measure of geographic distance was constructed as follows. We used postal addresses to derive latitude and longitude measures of the locations of licensors and licensees. Employing the method suggested by Sorenson (2004), these were then transformed into radian values to calculate geographic distances.[6] Since the Max Planck Society licenses

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[5] Payments were discounted to the base year 2000 and adjusted to *Deutsche Mark*.

[6] Even though Germany is a relatively small country, accounting for the earth's curvature is relevant in our context because of the presence of international,

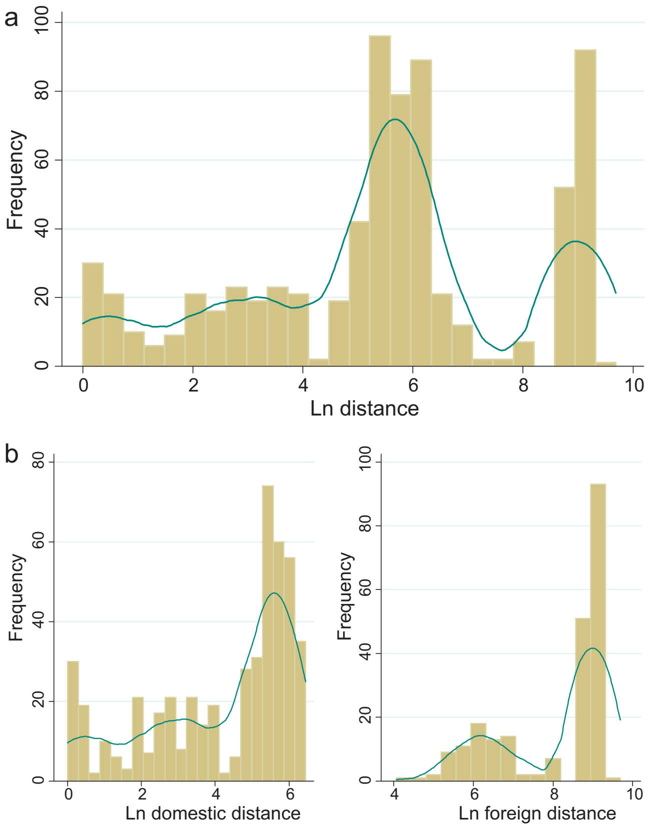

Fig. 1. (a) Log distance, 1980–2004. (b) Log distance for domestic and foreign licensees, 1980–2004. *Notes*: (a) The graph pictures a histogram of log distances with a kernel density function of licensed inventions disclosed from 1980 through 2004 where licensing agreements provided for royalty payments. (b) The graph pictures two histograms of log distances with kernel density function of licensed inventions disclosed from 1980 through 2004: the left histogram depicts the log distance for inventions licensed to domestic licensees where licensing agreements provided for royalties. The right histogram pictures the log distance for inventions licensed to foreign licensees where licensing agreements provided for royalties.

its inventions on a global scale, geographic distance ranges from 0 to more than 16,000 km.

As the distribution of distances is highly skewed we employ the natural logarithm of the distance variable (Fig. 1a). Alternatively, distance is measured by a set of indicator variables. To pick up interactions within the same urban area, our smallest category includes all distances shorter than 50 km.[7] The other distance ranges are 50–100 km, 100–500 km (corresponding to the maximum distance that can normally be covered in a daytrip), as well as all distances larger than 500 km. The distribution of licensees across the alternative distance brackets attests to a modest degree of localization. 184 licensees (accounting for 26 percent of all license agreements in our empirical sample) are located less than 50 km away from the Max Planck Institute where the underlying invention was made. 22 (3 percent) are located in the 50–100 km range, 296 (41 percent) in the 100–500 km range and the remaining 213 (30 percent) are located more than 500 km away. Even among spin-offs, which are more strongly localized than the external licensees, 44 percent are located more than 100 km away from the inventor institute. This modest degree of spin-off localization is consistent with previous findings by Egeln et al. (2004) on German academic spin-offs.

Belenzon and Schankerman (forthcoming) raise the issue of distance being related to the inherent quality of the invention. We are limited in our ability to infer invention quality from our data, which includes inventions from a wide range of technologies, some of which are not associated with patent applications. However, one (admittedly rough) measure of invention quality that we could establish for the subset of patents associated with patent applications is whether patents were applied for at the "triade" of the EPO, the USPTO and the Japanese Patent Office. Since patenting decisions for all inventions are made by the central Max Planck Innovation office in Munich, "triadic" patents are a valid measure of patent quality; they indicate that Max Planck Innovation assessed the respective inventions as having substantial commercial potential. Using this measure, we find some evidence that inventions with higher quality patents tend to be licensed at longer distances. For inventions related to "triadic" patent applications, the median licensee is located 284 km away from the licensing institute (average distance: about 2100 km). For other patented inventions, the median is 226 km (average: about 1700 km). A Wilcoxon rank-sum test suggests that the difference between the two groups is significant at the 0.01 level.[8]

To study international licensing, licensees are classified into domestic and foreign according to their postal address. Because our theoretical considerations focus on physical distance between the parties of a license agreement, foreign subsidies located in Germany are counted as German licensees. Of the 715 licensees for inventions disclosed between 1980 and 2004, 226 are classified as foreign and 489 as domestic. Based on this distinction we classify our distance measure into domestic or foreign distance. Fig. 1b depicts log distance for both domestic and foreign licensees.

The analysis includes further information about licensees as well as inventions and their inventors. Licensees are classified into spin-offs (i.e., firms started by Max Planck researchers) and external licensees on the basis of Max Planck Innovation's spin-off database. In total 226 license agreements with spin-offs and 489 with external licensees have been identified. We also employ an indicator variable denoting repeat licensees for which earlier license agreements with the Max Planck Society can be found. (This includes a number of spin-offs.) This variable is motivated by the conjecture that if later license agreements are related to earlier ones, their odds of commercialization may be larger due to pre-established contacts and accumulated knowledge.

Inventions are classified according to the section of the Max Planck Society from which they originate (biomedical section versus chemistry/physics/technology section).[9] In addition, we identified all inventions made at one of the leading five institutes in terms of disclosed inventions (which jointly account for 51 percent of all inventions in the sample). We also employ information about patent applications related to licensed inventions. Patent applications indicate that intellectual property on the underlying technology can in principle be obtained. This could facilitate commercialization because it is less risky for the licensee to spend money on the further development of the technology. On the other hand, with patented inventions, strategic use of the intellectual property and "shelving" become more relevant strategic options for the licensee, which may be reflected in reduced commercialization rates (Dechenaux et al., 2009). Finally, to control for differences

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particularly intercontinental license agreements. Travel times are inferior to geographic distance in our context because they vary over time and are difficult to reconstruct reliably for earlier years.

[7] Belenzon and Schankerman (forthcoming) similarly use a 25-mile distance as their smallest category in studying knowledge flows from university research.

[8] The average distance between licensor and licensee is 1978 km for unpatented inventions and 1858 for inventions related to a patent application. This difference is significant at the 0.10 level.

[9] The Max Planck Society also has a third, social science, section. No invention in our dataset originated from this section.

Table 3
Descriptive statistics.

	All inventions				Licensed inventions with provisions for royalties			
	Obs	Mean	Min	Max	Obs	Mean	Min	Max
Commercialization					715	0.499	0	1
Ln royalties					715	4.774	0	19.109
Ln distance					715	5.395	0	9.692
Biomed	2223	0.615	0	1	715	0.775	0	1
Director involvement	2223	0.143	0	1	715	0.393	0	1
Patent	2223	0.633	0	1	715	0.706	0	1
Triade					505	0.378	0	1
Spin-off					715	0.327	0	1
Foreign					715	0.315	0	1
Bundle					715	0.299	0	1
Repeat licensee					715	0.761	0	1

across technology fields, licensees are classified into five broad categories using standard industrial classification (SIC) codes. More precisely, we first divided firms into manufacturing, services, and others. Manufacturing firms were then further divided into chemical products, instruments and related products, as well as other manufacturing products and equipments. Descriptive statistics and correlations between variables are given in (Tables 3–5).

4.3. Empirical approach

To assess the influence of geographic distance on commercialization outcomes, we estimate a set of models regressing commercial success on measures of the geographic distance between the licensee and the institute from where the respective invention was made. Model specifications differ according to outcome measures of commercial success.

To analyze the likelihood of successful commercialization, a series of Probit models are estimated, for which we report marginal effects of the explanatory variables. The baseline model has the following form:

$$y^*_{ij} = \alpha_0 + \alpha_1 Distance_{ij} + \beta' Sector_i + \gamma' Institute_j + \delta' Year_j + u_{ij} \quad (1)$$

with

$$y_{ij} = \begin{cases} 1 & \text{if } y^*_{ij} > 0 \\ 0 & \text{otherwise} \end{cases}$$

where y_{ij} takes the value of one if positive royalty payments from invention j licensed to firm i have been realized and zero otherwise. $Distance_{ij}$ measures the geographic distance between the licensee and the institute where invention j was made, $Sector_i$, $Institute_j$ and $Year_j$ are sets of indicator variables denoting industrial sectors, institutes, and years of disclosure, respectively, and u_{ij} is the error term.

Tobit models are employed to estimate models in which accumulated license payments are the dependent variable. Tobit models can account for the fact that royalty payments are left-censored at zero. The specification of the baseline model is given by (2):

$$y^*_{ij} = \alpha_0 + \alpha_1 Distance_{ij} + \beta' Sector_i + \gamma' Institute_j + \delta' Year_j + u_{ij} \quad (2)$$

Table 4
Correlations between covariates (all inventions), 1980–2004.

2223 observations	Biomed	Director involvement	Patent
Biomed	1.000		
Director involvement	0.226*	1.000	
Patent	–0.004	0.144*	1.000

* Significance of pairwise correlation at the 0.01 level.

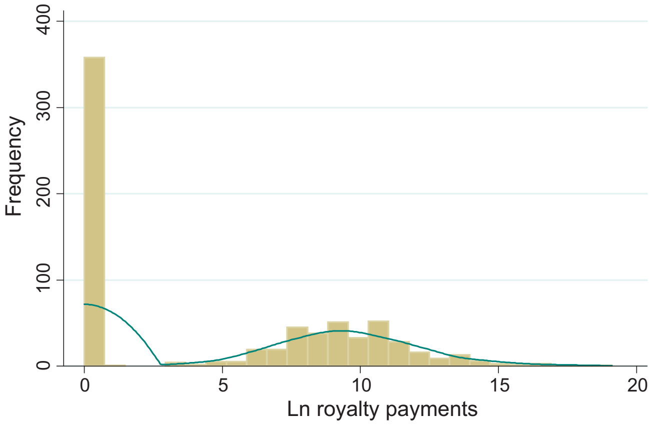

Fig. 2. Cumulated log royalties, 1980–2007. *Note*: The graph pictures a histogram of the log of cumulated royalty payments from 1980 through 2007 for licensed inventions where licensing agreements provided for royalty payments. Additionally, a kernel density function is plotted.

with

$$y_{ij} = \begin{cases} y^*_{ij} & \text{if } y^*_{ij} > 0 \\ 0 & \text{otherwise} \end{cases}$$

Given that accumulated royalty payments are highly skewed (Fig. 2), we employ the natural logarithm in the empirical analysis.

The baseline Probit and Tobit models (1) and (2) are re-estimated including further control variables denoting, respectively, inventions from the Max Planck Society's biomedical section, inventions associated with patent applications, spin-off and repeat licensees, as well as inventions licensed as part of a bundled license agreement. We also employ extended specifications including controls for invention quality or studying within-invention differences in outcomes for the subsample of inventions licensed to more than one firm. Throughout the analysis, standard errors are clustered by inventions to control for the occurrence of multiple licensing of the same technology.

Our empirical analysis is subject to several econometric concerns, which inform further model specifications. Two different forms of selection bias are particularly relevant in our empirical setting. First, commercialization outcomes are only observable for the subset of *licensed* inventions, which are a non-random sample of all inventions. To control for the bias that could result from non-random selection into licensing, we apply the two-stage estimation procedure proposed by Heckman (1979), using (co-) invention by Max Planck directors (which are the highest-ranking scientists employed at Max Planck) to identify the selection equation. This specification is based on results by Buenstorf and Geissler (2012) indicating that technologies (co-) invented by Max Planck directors

Table 5
Correlations between covariates (license agreements providing for royalties), 1980–2004.

715 observations	Ln distance	Biomed	Dir. Inv.	Patent	Spinoff	Foreign	Bundle	Repeat Lic.
Ln distance	1.000							
Biomed	0.089	1.000						
Director involvement	0.068	0.201*	1.000					
Patent	−0.051	0.079	0.148*	1.000				
Spin-off	−0.425*	0.114*	0.221*	0.201*	1.000			
Foreign	0.710*	0.171	0.139*	−0.033	−0.247*	1.000		
Bundle	0.116*	0.016	0.174*	0.254*	0.259*	−0.022	1.000	
Repeat licensee	−0.130*	0.137*	0.163*	0.214*	0.297*	−0.157*	0.345	1.000

[*] Significance of pairwise correlation at the 0.01 level.

have higher chances of being licensed, while their commercialization odds are not different from other inventions.

The second potential selection problem concerns licensee characteristics. Specifically, licensing decisions of spin-offs may differ substantially from those of external licensees. To allow for differences in the factors shaping commercialization outcomes of both licensee types, including our distance measures, we estimate our main models jointly for spin-offs and external licensees, and also separately for the two types of licensees.

The sample split into spin-offs and external licensees also helps to limit the problem that distances between inventors and licensees may not always be exogenously given. As was argued above, endogenous location choices (driven by the objective to be close to the institute where a licensed technology was invented) are a particularly relevant concern in the case of (first-time) spin-off licensees. In contrast, most external licensees in our sample are large, pre-existing firms, and there are no indications they set up new facilities to commercialize in-licensed Max Planck technologies. To address the endogeneity issue, we re-estimate the models for the spin-off subsample and instrument for the inventor–licensee distance. Specifically, the (log) distance between a spin-off founder's birthplace and the location of the institute where the licensed invention was invented is used as an instrument for the distance between spin-off location and the licensing institute. This choice of instrument is informed by the empirical observation that entrepreneurial location choices are often biased toward the entrepreneur's home region (cf., e.g., Dahl and Sorenson, 2011). Even though most scientists move repeatedly during their career, we still expect this bias to show in spin-off location patterns. This expectation is borne out by the empirical evidence (see Section 5).

5. Results

We begin by directly estimating how the distance between inventors and licensees relates to the likelihood that a licensed invention is successfully commercialized (indicated by positive royalty payments). The baseline specification, Model 1 in Table 6, includes only the continuous measure of (log) distance between the licensee and the institute where the licensed invention was made, as well as year, institute and industry controls. This model is first estimated for the full population of licensed inventions (Model 1a). A positive marginal effect is estimated for the distance measure, which however is only significant at the 0.10 level. Re-estimating the model for the subsamples of spin-offs (Model 1b) and external licensees (Model 1c) does not suggest systematic effects of distance on the likelihood of successful commercialization.

In Model 2 additional control variables are added, and the Heckman procedure is adopted to control for non-random selection into licensing. The results do not indicate that commercialization success varies with the distance between inventors and licensees in any of the three samples. As regards the other explanatory variables, significant marginal effects are obtained for patented inventions, which are less often commercialized than those for which no patent application is documented. This result is significant for the entire sample (Model 2a) and for the subset of external licensees (Model 2c); it is robust throughout the further analysis. A possible interpretation is that licensees obtain a substantial share of licenses for strategic reasons, and that shelving of technologies may be a relevant concern. In addition, in Model 2a spin-offs appear to be less likely to commercialize than external licensees.

Tobit estimations of specifications analogous to Model 1 but using logged accumulated royalty payments to the Max Planck Society as dependent variable are reported as Model 5 in Table 7. Similar to the results for commercialization likelihood, a positive coefficient of the distance measure is obtained for the full sample in Model 5a, which is significant at the 0.05 level. Insignificant coefficients are estimated in Models 5b and 5c looking at both types of licensees separately. Model 6 re-estimates Model 2 for the alternative dependent variable, yielding very similar results. One exception is that in Model 6b patented inventions licensed to spin-off firms generate significantly less royalties compared to non-patented ones.[10]

We further probe the initial findings in Models 3 (Table 6) and 7 (Table 7), where the continuous (log) distance variable is replaced by indicator variables denoting ranges of distances from 50–100, 100–500 and 500+ km. (Inventions licensed within a 50-km range from the inventors form the omitted reference group.) In Model 3a, positive marginal effects are estimated for all three distance ranges, which are significant at the 0.10, 0.10, and 0.05 levels, respectively, but are not suggestive of differences across the larger distance categories. Again, using royalty payments as the dependent variable (Model 7a) leads to very similar results.[11] For the spin-off subsample, only the coefficient of the indicator variable denoting licensees located in the 100–500 km range is marginally significant at the 0.10 level for both outcome variables (Models 3b and 7b).[12] In contrast, no systematic effects of distance on commercialization outcomes are suggested by Models 3c and 7c restricted to the subsample of external licenses. The distant variables are likewise insignificant in the full models including control variables and Heckman corrections for selection into licensing (Models 4 and 8).

In Models 9–12 (Table 8) the continuous distance measure is split up into two separate measures for domestic and foreign licensees, respectively, to probe the conjecture that distances

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[10] We also experimented with (unreported) models using linear and quadratic measures of the continuous distance measure employed in Models 1 and 5. For the subset of spin-off licensees we found a significant positive influence for the linear and a significant negative influence for the quadratic term on both commercialization measures. This suggests an inverted u-shaped relationship between distance and commercial success of spin-off licensees. However, results are only significant for our baseline specification (Models 1b and 5b) and not robust to including further control variables (Models 2b and 6b).

[11] The effects of the three distance indicators do not differ significantly from each other in both the Probit and the Tobit models ($p \geq 0.25$).

[12] The 50–100 km variable is not included because no spin-off licensee is located in this distance bracket.

Table 6
Likelihood of commercialization (Probit), marginal effects, 1980–2004.

Comm = 1	1a All	1b Spin-offs	1c Externals	2a All	2b Spin-offs	2c Externals	3a All	3b Spin-offs	3c Externals	4a All	4b Spin-offs	4c Externals
Ln distance	0.016*	0.025	0.002	−0.002	0.011	−0.003						
	(0.008)	(0.018)	(0.014)	(0.010)	(0.022)	(0.014)						
50–100							0.251*		0.093	0.207		0.133
							(0.123)		(0.159)	(0.143)		(0.162)
100–500							0.099*	0.193*	−0.062	0.048	0.203	−0.051
							(0.055)	(0.120)	(0.083)	(0.062)	(0.133)	(0.086)
+500							0.132**	0.030	0.028	0.040	−0.048	0.012
							(0.059)	(0.133)	(0.089)	(0.067)	(0.127)	(0.090)
Biomed				−0.113	−0.357***	−0.082				−0.100	−0.387***	−0.057
				(0.071)	(0.119)	(0.088)				(0.073)	(0.117)	(0.093)
Patent				−0.285***	−0.224	−0.271***				−0.287***	−0.230*	−0.267***
				(0.048)	(0.144)	(0.056)				(0.048)	(0.140)	(0.056)
Repeat licensee				0.008	−0.181	0.017				0.003	−0.205	0.020
				0.057	(0.190)	(0.061)				(0.058)	(0.185)	(0.062)
Bundle				0.160***	0.089	0.186***				0.162***	0.044	0.196***
				(0.056)	(0.121)	(0.066)				(0.056)	(0.110)	(0.066)
Spin-off				−0.156***						−0.128**		
				(0.054)						(0.056)		
Institute controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sectoral controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inverse Mills				−0.105**	−0.010	−0.229**				−0.100**	−0.032	−0.218**
				(0.051)	(0.096)	(0.099)				(0.050)	(0.091)	(0.099)
Number of obs. (inventions)	715 (564)	226 (213)	489 (376)	715 (564)	226 (213)	489 (376)	715 (564)	226 (213)	489 (376)	715 (564)	226 (213)	489 (376)
$p > \text{chi}^2$	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
Pseudo R^2	0.155	0.398	0.132	0.201	0.446	0.177	0.159	0.403	0.137	0.203	0.456	0.182

Robust standard errors (clustered by invention) in parentheses.

[*] Significance at the 0.10 level.

[**] Significance at the 0.05 level.

[***] Significance at the 0.01 level.

Table 7
Level of royalty income (Tobit), 1980–2004.

Ln royalties Comm = 1	5a All	5b Spin-offs	5c Externals	6a All	6b Spin-offs	6c Externals	7a All	7b Spin-offs	7c Externals	8a All	8b Spin-offs	8c Externals
Ln distance	0.302**	0.344	0.030	0.041	0.204	−0.009						
	(0.149)	(0.299)	(0.231)	(0.169)	(0.299)	(0.233)						
50–100							4.915**		1.599	3.470		2.075
							(2.483)		(2.680)	(2.572)		(2.783)
100–500							1.787*	2.730*	−1.004	0.717	2.374	−1.089
							(0.921)	(1.570)	(1.307)	(0.971)	(1.564)	(1.310)
+500							2.324**	0.594	0.472	0.819	−0.452	0.109
							(0.992)	(2.214)	(1.403)	(1.068)	(2.021)	(1.402)
Biomed				−1.734	−3.666**	−0.619				−1.440	−4.033**	−0.076
				(1.158)	(1.846)	(1.441)				(1.192)	(1.849)	(1.526)
Patent				−4.012***	−5.548***	−3.720***				−4.005***	−5.572***	−3.630***
				(0.792)	(1.665)	(0.944)				(0.793)	(1.660)	(0.943)
Repeat licensee				0.714	−1.650	0.840				0.575	−1.890	0.892
				(0.853)	(2.124)	(0.922)				(0.861)	(1.958)	(0.930)
Bundle				1.957**	1.072	2.077*				2.088**	0.815	2.322**
				(0.913)	(1.638)	(1.100)				(0.911)	(1.513)	(1.125)
Spin-off				−2.625***						−2.319***		
				(0.913)						(0.898)		
Institute controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sectoral controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inverse Mills				−0.981	−0.606	−2.022				−0.917	−0.796	−1.760
				(0.852)	(1.452)	(1.698)				(0.839)	(1.396)	(1.692)
Constant	5.885	0.515	6.168*	11.004**	10.569**	10.950**	5.932	0.372	6.588*	10.475**	11.643***	10.648**
	(4.406)	(2.808)	(3.588)	(4.475)	(4.577)	(4.376)	(4.558)	(2.750)	(3.566)	(4.593)	(4.332)	(4.296)
Number of obs. (inventions)	715 (564)	226 (213)	489 (376)	715 (564)	226 (213)	489 (376)	715 (564)	226 (213)	489 (376)	715 (564)	226 (213)	489 (376)
$p > \text{chi}^2$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pseudo R^2	0.058	0.177	0.048	0.070	0.199	0.057	0.060	0.180	0.048	0.071	0.201	0.059

Robust standard errors (clustered by invention) in parentheses.

* Significance at the 0.10 level.

** Significance at the 0.05 level.

*** Significance at the 0.01 level.

Table 8
Domestic and foreign distance, 1980–2004.

	Probit						Tobit					
	9a All	9b Spin-offs	9c Externals	10a All	10b Spin-offs	10c Externals	11a All	11b Spin-offs	11c Externals	12a All	12b Spin-offs	12c Externals
Ln domestic distance	0.039***	0.030	0.004	0.017	0.021	−0.004	0.612***	0.400	−0.126	0.228	0.285	−0.250
	(0.014)	(0.021)	(0.024)	(0.016)	(0.025)	(0.024)	(0.229)	(0.351)	(0.380)	(0.248)	(0.365)	(0.373)
Ln foreign distance	0.018**	−0.006	0.003	0.001	−0.047	−0.003	0.338**	0.032	−0.029	0.071	−0.151	−0.098
	(0.009)	(0.024)	(0.016)	(0.010)	(0.031)	(0.016)	(0.153)		(0.259)	(0.172)	(0.359)	(0.257)
								(0.405)				
Biomed				−0.105	−0.352***	−0.054				−1.641	−3.547*	−0.665
				(0.071)	(0.120)	(0.085)				(1.163)	(1.880)	(1.445)
Patent				−0.285***	−0.198	−0.272***				−3.982***	−5.623***	−3.748***
				(0.048)	(0.141)	(0.056)				(0.793)	(1.677)	(0.940)
Repeat licensee				0.001	−0.288	0.017				0.609	−1.889	0.939
				(0.057)	(0.201)	(0.062)				(0.854)	(2.127)	(0.924)
Bundle				0.147***	0.054	0.186***				1.830**	0.854	2.110*
				(0.056)	(0.112)	(0.066)				(0.902)	(1.646)	(1.100)
Spin-off				−0.140**						−2.494***		
				(0.056)						(0.911)		
Institute controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sectoral controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inverse Mills				−0.109**	0.003	−0.230**				−1.035	−0.643	−1.949
				(0.051)	(0.085)	(0.100)				(0.852)	(1.456)	(1.698)
Constant							4.617	0.375	6.765*	10.280**	10.780**	11.799***
							(4.529)	(2.871)	(3.763)	(4.597)	(4.604)	(4.401)
Number of obs. (inventions)	715 (564)	226 (213)	489 (376)	715 (564)	226 (213)	489 (376)	715 (564)	226 (213)	489 (376)	715 (564)	226 (213)	489 (376)
$p > \text{chi}^2$	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pseudo R^2	0.161	0.401	0.132	0.204	0.452	0.177	0.059	0.178	0.048	0.071	0.199	0.058

Robust standard errors (clustered by invention) in parentheses.

[*] Significance at the 0.10 level.

[**] Significance at the 0.05 level.

[***] Significance at the 0.01 level.

Table 9
Level of royalty income (Tobit), 1980–2004 (mult. licenses; invention controls).

Log royalty payments	13	14	15
	All licensees		
Ln distance	−0.277***		
	(0.004)		
50–100		−6.880***	
		(0.085)	
100–500		0.712***	
		(0.065)	
+500		−0.939***	
		(0.044)	
Ln domestic distance			0.074***
			(0.012)
Ln foreign distance			−0.173***
			(0.004)
Repeat licensee	−0.020	0.182***	−0.045
	(0.039)	(0.035)	(0.039)
Spin-off	−4.561***	−4.474***	−4.648***
	(0.049)	(0.077)	(0.082)
Bundle	0.365***	−0.219***	0.196***
	(0.038)	(0.068)	(0.058)
Sectoral controls	Yes	Yes	Yes
Invention-specific effects	Yes	Yes	Yes
Constant	−30.094***	−31.821***	−31.449***
	(0.033)	(0.031)	(0.034)
Number of obs. (inventions)	272 (120)	272 (120)	272 (120)
$P > \text{chi}^2$	0.0000	0.0000	0.0002
Pseudo R^2	0.266	0.271	0.266

Robust standard errors (clustered by invention) in parentheses.
*** Significance at the 0.01 level.

across national borders differ in their effects from domestic distances. For the full dataset, significantly positive effects of both distance measures are estimated in Models 9a and 11a. Both distance measures are significantly different from each other ($p < 0.02$ in Model 9a and $p < 0.07$ in Model 11a). Similar to the above findings, with further control variables and/or disaggregated samples no significant relationships between the distance measures and commercialization outcomes are identified.[13]

Taken together, our results are not yet fully conclusive. On the one hand, no negative relationships between distance and commercialization outcomes were found, which would have been expected if local licensees command better knowledge about inventions (Scenario 2 in Table 1) or if inventor engagement were impaired by distance (without effective competition for the license; cf. Scenario 3). On the other hand, in some models we obtained significant positive relationships between distance and commercialization outcome. Even though these were not very robust to additional controls and alternative model specifications, it seems warranted to further probe into these findings. As argued above, positive relationships between distance and commercialization outcomes are compatible with several competing accounts: problems of engaging distant inventors (with effective competition; cf. Scenario 4), higher quality of inventions licensed to distant licensees (Scenario 5), or preferential treatment of (inferior) local licensees (Scenario 6). While our data are insufficient to fully discriminate between these explanations, some further analyses can be performed to shed more light on the empirical patterns in the data.

We begin by estimating commercialization outcomes for the subset of inventions that were licensed more than once (120 inventions yielding a total of 272 observations) and controlling for invention-specific effects. If distant licensees were more successful only because they licensed superior inventions (Belenzon and Schankerman, forthcoming), then distance should not be associated with superior outcomes in these models. We acknowledge that results from these models are of limited generality because they relate to a non-representative subsample of our data. Since exclusive access to a technology enhances the chances that a licensee can recoup its R&D expenditures, we would expect those inventions that require most further development effort by the licensee to be most likely to be licensed exclusively. They would therefore not be included in the subset of inventions with multiple licensees. We are moreover limited to the level of royalties as a dependent variable, because in many cases there is no variation in the binary outcome variable across the licensees of a single invention.

Three models controlling for invention-specific effects are estimated. Model 13 (Table 9) using the continuous distance measure suggests that if the same invention is licensed to licensees at different distances, royalty payments decrease with the distance between inventors and licensees. Following the above line of reasoning, this is consistent with higher costs of commercialization for more distant licensees, but only if terms of license agreements adjust sufficiently to make licensing profitable for the distant licensees – a somewhat problematic assumption for the subset of inventions with multiple licensees that the model analyzes. Further questioning the importance of geographic distance, in Model 14 which employs the set of indicator variables for the alternative distance ranges, licensees located in the 100–500 km range generate significantly higher royalties than those located less than 50 km away from the inventors. Licensees located more than 500 km away from the inventors generate lower royalties than those located less than 50 km away from the inventors. These nonlinear relationships are hard to reconcile with the argument that increasing distance impedes successful commercialization of academic inventions. In addition, Model 15 indicates that the negative association of distance and royalties is limited to foreign licensees, while a positive association holds for the domestic licensees.

We further probe into the relevance of quality differences by re-estimating our initial models adding an indicator variable denoting inventions with triadic patent applications to the model specification. As we have seen above, inventions with triadic patent applications are on average licensed to more distant licensees than other patented inventions. Controlling for triadic applications should thus indicate to what extent quality differences picked up by this (admittedly crude) indicator can account for distance-related differences in commercialization outcomes.

We first estimate a version of Model 1a including the indicator for triadic patents (Model 16a in Table 10). This model also includes an indicator variable denoting all patented inventions, because the earlier results consistently showed that patented and unpatented inventions significantly differed in their commercialization odds. Compared to Model 1a, the marginal effect obtained for the distance measure is reduced by about 18 percent; it remains positive but is no longer significant. For royalties as performance measure (Model 18a), the coefficient of the distance measure is reduced by 20 percent. Again, it is no longer significant. In the ensuing models for the different subsamples and outcome measures, the indicator of triadic patent applications is positive throughout, and at least marginally significant at the 10 percent level in three of the Tobit models. The distance measure remains insignificant in all models. In six of the nine models yielding positive point estimates for this measure, these are reduced as compared to the initial models. These findings suggest that some of the observed positive associations

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[13] Survey-based results for Belgium by Veugelers and Cassiman (2005) indicate that foreign-owned firms are less likely to engage in R&D cooperation with domestic universities. To analyze this possibility in our empirical context, foreign firms were alternatively coded according to ownership rather than address. This yielded very similar results (available from the authors upon request). A further set of models was estimated in which we explored the association of distance and commercialization outcomes changed over time, possibly because of improved communication technology becoming available in the 1990s. The (unreported) results do not suggest systematic differences between the subsamples of pre-1995 and later inventions.

Table 10
Quality and distance of licensed inventions, 1980–2004.

	Probit						Tobit					
	16a All	16b Spin-offs	16c Externals	17a All	17b Spin-offs	17c Externals	18a All	18b Spin-offs	18c Externals	19a All	19b Spin-offs	19c Externals
Ln distance	0.013	0.028	0.004	−0.002	0.008	−0.003	0.241	0.273	0.050	0.032	0.182	−0.010
	(0.009)	(0.018)	(0.014)	(0.010)	(0.022)	(0.014)	(0.148)	(0.283)	(0.230)	(0.169)	(0.302)	(0.232)
Triade	0.095	0.166	0.061	0.064	0.157	0.027	2.064**	2.552*	1.735	1.674*	2.297	1.331
	(0.059)	(0.111)	(0.073)	(0.060)	(0.117)	(0.074)	(1.004)	(1.384)	(1.249)	(0.998)	(1.436)	(1.257)
Patent	−0.277***	−0.302***	−0.251***	−0.303***	−0.242*	−0.280***	−4.347***	−6.399***	−3.875***	−4.544***	−6.061***	−4.203***
	(0.049)	(0.119)	(0.060)	(0.050)	(0.144)	(0.060)	(0.807)	(1.573)	(1.010)	(0.838)	(1.719)	(1.014)
Biomed				−0.110	−0.337***	−0.081				−1.663	−3.246*	−0.607
				(0.071)	(0.122)	(0.088)				(1.153)	(1.850)	(1.436)
Repeat licensee				0.005	−0.228	0.015				0.632	−2.359	0.776
				(0.058)	(0.191)	(0.062)				(0.852)	(2.221)	(0.919)
Bundle				0.154***	0.079	0.184***				1.777*	0.735	1.964*
				(0.057)	(0.122)	(0.067)				(0.921)	(1.653)	(1.111)
Spin-off				−0.155***						−2.592***		
				(0.055)						(0.910)		
Institute controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sectoral controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inverse Mills				−0.100**	0.007	−0.226**				−0.890	−0.415	−1.913
				(0.051)	(0.094)	(0.099)				(0.846)	(1.444)	(1.688)
Constant							8.882*	6.136*	8.783**	11.066**	11.070**	11.035**
							(4.610)	(3.422)	(3.897)	(4.545)	(4.639)	(4.414)
Number of obs. (inventions)	715 (564)	226 (213)	489 (376)	715 (564)	226 (213)	489 (376)	715 (564)	226 (213)	489 (376)	715 (564)	226 (213)	489 (376)
$p > \text{chi}^2$	0.0000	0.0000	0.0002	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pseudo R^2	0.184	0.423	0.158	0.202	0.452	0.178	0.067	0.197	0.055	0.071	0.202	0.058

Robust standard errors (clustered by invention) in parentheses.

[*] Significance at the 0.10 level.

[**] Significance at the 0.05 level.

[***] Significance at the 0.01 level.

Table 11
Commercialization outcomes (IV regressions), 1980–2004.

	First stage (Ln distance)	Second stage		First stage (Ln distance)	Second stage		First stage (Ln distance)	Second stage		First stage (Ln distance)	Second stage	
	20a	20b (IV probit: Comm = 1)	Coefficient estimates from Model 1b	21a	21b (IV probit: Comm = 1)	Coefficient estimates from Model 2b	22a	22b (IV Tobit: royalties)	Coefficient estimates from Model 5b	23a	23b (IV Tobit: royalties)	Coefficient estimates from Model 6b
Ln distance		−0.132	0.073		−0.142	0.030		−1.138	0.344		−1.281	0.204
		(0.118)	(0.053)		(0.196)	(0.062)		(0.812)	(0.299)		(1.187)	(0.299)
Ln origin	0.570***			0.414***			0.644***			0.468***		
	(0.174)			(0.153)			(0.187)			(0.172)		
Biomed				−1.947***	−1.095***	−0.945***				−2.151***	−6.028**	−3.666**
				(0.475)	(0.312)	(0.321)				(0.610)	(2.557)	(1.846)
Patent				−0.036	−0.568	−0.597				−0.046	−5.045***	−5.548***
				(0.519)	(0.354)	(0.373)				(0.590)	(1.746)	(1.665)
Repeat licensee				−1.531	−0.700	−0.477				−0.560	−3.049	−1.650
				(1.045)	(0.552)	(0.480)				(1.378)	(3.582)	(2.124)
Bundle				2.581***	0.735	0.253				2.380***	5.278	1.072
				(0.514)	(0.579)	(0.344)				(0.560)	(3.776)	(1.638)
Institute controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sectoral controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.016	1.248*	0.522	2.688*	2.605***	2.069**	0.568	6.286	0.515	1.868	15.021**	10.569**
	(1.562)	(0.656)	(0.521)	(1.616)	(0.857)	(0.993)	(1.672)	(4.596)	(2.808)	(2.241)	(6.385)	(4.577)
Instrumented		Ln distance			Ln distance			Ln distance			Ln distance	
Instrument		Ln origin			Ln origin			Ln origin			Ln origin	
Number of obs. (inventions)	223	223 (210)	226 (213)		223 (210)	226 (213)	223	223 (210)	226 (213)	223	223 (210)	226 (213)
$p > \text{chi}^2$		0.0000	0.0000		0.0002	0.0000		0.0000	0.0000		0.0000	0.0000

Robust standard errors (clustered by invention) in parentheses.

[*] Significance at the 0.10 level.

[**] Significance at the 0.05 level.

[***] Significance at the 0.01 level.

between distance and commercialization outcomes reflect a higher quality of (patented) inventions located at longer distances.

Finally, as discussed above, the distance between inventors and licensees may plausibly be endogenous in the case of newly established spin-offs, which might strategically select their location to benefit from the proximity to the origins of licensed inventions.[14] To address the endogeneity concern, we estimated IV models of commercializing outcomes instrumenting for the distance between inventors and spin-off licensees. Specifically, we identified the founders of all spin-off licensees and retrieved their place of birth, primarily using biographic information from doctoral dissertations and from a published directory (Max Planck Society, 2006). We then calculated the (log) distances between founder birthplaces and the locations of the respective licensing institutes and used these to instrument the distance between spin-off location and licensing institute (Ln origin).[15] These distances qualify as an instrument because they are exogenous, correlated with the potentially endogenous distance variable, and do not predict commercialization outcomes.[16]

Results of the IV regressions are reported in Table 11. First-stage results show that the distance between the founder birthplace and the location of the respective licensing institute is strongly related to our original distance measure. Models 20b and 21b in Table 11 are IV Probit regressions analogous to Models 1b and 2b, respectively. (Coefficient estimates for these models are also reported to allow for comparisons.) In both models an insignificant negative association between distance and commercialization likelihood is obtained. Models 22b and 23b are IV Tobit models analogous to Models 5b and 6b. Again we find a negative and insignificant association between distance and levels of royalties. We thus conclude that accounting for potential endogeneity of spin-off locations, positive empirical relationships between distance and commercialization outcomes are no longer estimated for this type of licensee. This is noteworthy because in the initial models a stronger positive relationship was obtained for spin-offs than for external licensees.

6. Conclusions

In this paper we studied potential effects of geographic distance on the commercialization of inventions made in public research and licensed to private-sector firms. A significantly negative relationship between distance and commercialization outcomes was obtained only for foreign licensees of inventions that were licensed to more than one firm. Our findings therefore provide little support to the conjectures that local licensees have superior information about the quality of inventions, or that the commercialization of academic inventions is harmed by geographic distance between inventors and licensees.

In contrast, we found a positive relationship between distance and commercialization outcomes in our baseline specification. This could be consistent with adverse effects of distance if distant licensees self-selected into profitable license agreements. However, additional analyses indicated that the observed positive relationship between distance and commercialization outcomes is in part attributable to the higher quality of inventions licensed to more distant firms. Furthermore, controlling for invention-specific effects or potentially endogenous location choices of spin-offs, distance was no longer systematically related to the likelihood of successful commercialization or the level of royalty payments. We thus conclude that geographic distance is generally not an important determinant of commercialization outcomes. Our results likewise do not suggest that the Max Planck Society discriminates against (superior) distant licensees in its licensing decisions.

Earlier results obtained by Agrawal (2006) indicate that inventor involvement plays a crucial role for commercialization academic inventions. In light of his evidence, our results suggest that inventor involvement is not seriously impaired by geographic distance, not even for senior and “star” scientists. This interpretation resonates with the earlier findings by Audretsch and Stephan (1996) that the majority of firm-scientist links in U.S. biotechnology were non-local. At the same time, while they only observed that interaction patterns were dispersed geographically, our results provide evidence that this dispersion seems to be functional.

The above analysis is not without limitations. While focusing on a single organization helps limit the impact of organizational policies on observed outcomes, the Max Planck Society’s dedication to basic research may limit the extent to which our findings generalize to other organizational contexts. In addition, we already discussed potential issues of selection and endogeneity. Our analysis indicates that the main results are not driven by selection into licensing or endogenous location choices, but we cannot conclusively rule out this possibility.

In the broader context of regional impacts of public research, the present study indicates that distance may be much less important for knowledge transfer via contractual licensing relationships between public research and private sector firms than for other transfer channels such as disclosure via publications and patents or labor mobility. Apparently, some of the “real effects of academic research” (Jaffe, 1989) are more localized than others, and the multidimensional nature of knowledge transfer is still not sufficiently well understood.

Acknowledgments

We are grateful to Max Planck Innovation GmbH for granting us access to their data. For helpful comments and discussions we thank Thomas Brenner, Matthias Geissler, Stefan Krabel, Ljubica Nedelkoska, Viktor Slavtchev, Arvids Ziedonis and Andreas Ziegler, as well as two anonymous reviewers of this journal. Financial support from Deutsche Forschungsgemeinschaft through RTG 1411 is gratefully acknowledged.

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[14] To some extent, this concern is mitigated by the fact that only about 50% of the inventions licensed to spin-offs were licensed in the spin-off’s first two years. For the subsequent licenses obtained by spin-offs, endogeneity of location choices seems much less of a problem.

[15] In some cases, information about birth places could not be obtained. Where possible, we used the location of the respective individual’s Ph.D. university as a substitute. Three observations had to be eliminated from the sample because neither birth places nor Ph.D. locations could be identified. In the case of founder teams, distances were calculated for the first founder listed. We alternatively experimented with selecting the most senior (in terms of academic standing) founder in the team to estimate the distance used as an instrument. While IV regressions using that alternative instrument led to qualitatively identical results to the ones reported below, they are less trustworthy because the instrument is considerably weaker.

[16] The instrument’s correlation with the distance between spin-off location and licensing institute is 0.32. In a simple Probit model of commercialization likelihood with the instrument as the only explanatory variable, we obtained a coefficient estimate of -0.029 and a z-value of -0.03 ($p > 0.68$). Its first-stage F-statistic in a 2SLS IV regression of royalties analogous to Model 5b is 16.98. Recent work in entrepreneurship (e.g., Dahl and Sorenson, 2011) finds a positive association between startup success and regional founder backgrounds, which might compromise the validity of our instrument. However, this concern seems less relevant in our context because (i) we use information about birthplaces, which are often not close to where founders lived prior to establishing their spin-off, and (ii) we study scientists, who given their career specialization are less likely than other entrepreneurs to possess resources that have been suggested to underlie the success of regional founders (such as in-depth knowledge about local sources of capital).

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