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We need to talk – or do we?

Geographic distance and the commercialization of technologies from public research

Guido Buenstorf[*], Alexander Schacht[†]

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Abstract: Using a new dataset with detailed geographic information about licensing activities of the Max Planck Society, Germany's largest non-university public research organization, we analyze how the probability and magnitude of commercial success are affected by geographic distance between licensors and licensees. Our evidence suggests that proximity is not generally associated with superior commercialization outcomes. A negative association between distance and commercialization success is identified only for the specific cases of, first, spin-off licensees located outside Germany and, second, foreign licensees within the subsample of inventions with multiple licensees.

Key words: academic inventions, licensing, spin-off entrepreneurship, geographic distance.
JEL codes: L24, L26, O34, R30

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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 and possibly useful knowledge (Salter and Martin, 2001). It is therefore not surprising that policy makers around the globe have undertaken considerable efforts to strengthen the linkages 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" – of public research. Even though multiple channels of knowledge transfer including publications, conferences, consulting, and scientist migration to the private sector are relevant for industrial partners (Cohen et al., 2002; Agrawal and Henderson, 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; von Proff et al., 2012).

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). More specifically, commercialization of licensed academic inventions is a difficult task for private-sector firms because these 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 raises relevant issues of how licensees can best enlist the support of academic inventors in their commercialization efforts.

Several empirical studies have studied the commercialization of licensed university technology at the level of individual inventions. This research is limited by the lack of universities and PROs with sufficient numbers of successfully commercialized inventions, in particular outside the U.S.. Existing empirical findings are therefore restricted to a few leading U.S. universities. Licensed inventions by MIT scientists are explored by Shane (2002), while Lowe and Ziedonis (2006) study the University of California system. Both studies compare startup licensees with established firms, but do not find evidence suggesting that the former are disadvantaged. Also using data on MIT inventions, Dechenaux et al. (2008) analyze how appropriability conditions affect termination likelihood and the commercialization success of licensees. They find that patent strength and secrecy reduce the risk of license termination. Elfenbein (2004, 2007) explores the significance of contractual provisions and inventor seniority for commercialization outcomes in the empirical context of Harvard University. He concludes that inventors' prior scientific output is positively correlated with future licenses but is uncorrelated with the payment structure or the returns of the technology.

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 exists for Europe. However, studying commercialization outcomes outside the U.S. seems important because it raises issues such licensing to foreign licensees that are less relevant and therefore underexplored in the U.S. context (Arundel and Geuna, 2004). Within Europe, Germany's large non-university PROs probably provide the best opportunities for empirical research. In this context, Buenstorf and Geissler (2012) study inventions from the Max Planck Society. They compare the commercialization outcomes for university spin-offs to those of external licensees and fail to find systematic differences.

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. Some authors (e.g. Jaffe, 1989; Acs et al., 1992; Jaffe et al., 1993; Anselin et al., 1997; Fritsch and Slavtchev, 2007) suggest that proximity to public research yields substantial benefits to firms' innovativeness. Likewise, Mansfield and Lee (1996) find that firms prefer to work with university researchers who are less than 100 miles away from the firm's R&D laboratories. Based on a survey of R&D laboratories in the U.S., Adams (2002) concludes that geographic proximity plays a bigger role in university-firm interactions than in firm-firm interactions. Belenzon and Schankerman (2010) find that citation rates of both publications and university patents decline sharply with distance.

Other work tends to see 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 among spin-off founders, more than 40% of the researchers in their sample established firms outside the region of their university. Similar results have been found for Germany (e.g. Grotz and Braun, 1997). In their survey of 2,300 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 proximity to public research institutes does not influence the probability of public research-based innovations. However, this result might be due to the geographic differences between Germany and the U.S. as pointed out by Salter and Martin (2001).

Very little prior work has studied the role of geography in the context of commercializing licensed university inventions. Mowery and Ziedonis (2001) compare the geographic reach of two important knowledge flows, namely patent citations and licenses. They conclude that licenses are more geographically 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 location on commercialization outcomes.

In the present paper we contribute to this latter line of research, using and extending a dataset with detailed information about licensing activities of the Max Planck Society, Germany's largest non-university public research organization (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 rich dataset encompassing more than 2,300 inventions and about 770 license agreements for the time period 1980-2004. Our data also include 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. Finally, since we know the locations of both the originating Max Planck institute and the private-sector licensee, we can calculate the geographic distance between them.

We use this information to analyze whether and how probability and magnitude of commercial success are affected by geographic distance between inventors and licensees. We do not find evidence suggesting that geographic distance is generally a relevant obstacle to successful commercialization of academic inventions. Significantly negative associations between distance and commercialization success are identified only in two specific instances: first, for spin-off licensees located outside Germany, and second, for foreign licensees within the subsample of inventions with multiple licensees.

The remainder of the paper is organized as follows: The next section presents 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 the research design for the empirical analysis, whereas results are discussed in section 5. We conclude and discuss implications and limitations of our analysis in section 6.

2. Does geographic proximity matter for successful commercialization of university inventions?

Distance and commercialization outcomes

In a world of heterogeneous firms, allocating licenses to suitable licensees constitutes a non-trivial problem. Ideally, search processes and negotiations between inventors (or technology licensing offices as their agents) on the one hand and potential private-sector licensees on the other should result in perfect matching: the most suitable licensee (in terms of capabilities and complementary assets) will submit the highest offer for a license and thus become the actual licensee. Similar considerations apply if technologies are licensed non-exclusively. Among all firms interested in licensing a technology, those willing to pay at least as much as the licensor asks for become licensees. Under ideal conditions, this will again allocate licenses to those firms that can expect to gain most from the license because they command superior capabilities and/or better suited complementary assets than other potential licensees.

To structure our further considerations, let us consider the following simple model of the behavior of potential licensees. We assume that firm i is willing to license academic invention j iff its expected profit contribution from commercializing the invention is non-negative, $E(\pi_{ij}) \geq 0$. The expected profit contribution depends both on the level of profits that the successful firm can realize from the invention, π_{ij}, and on the probability that commercialization efforts are successful, p_{ij}. We initially assume that only π_{ij} but not p_{ij} depends on the distance s between inventor and licensee (we will relax this assumption later on) such that

$$\pi_{ij}(s) = R_{ij} - C_{ij}(s) \text{ with } \partial C_{ij}(s)/\partial s > 0, \tag{1}$$

where R_{ij} and C_{ij} denote, respectively, revenue and costs of producing and selling products based on the academic invention. R_{ij} depends on inherent (i.e., not distance-related) characteristics of the licensee, and also on characteristics of the licensed invention. Expected profits are then given by (because R_{ij} is zero if commercialization fails):

$$\mathrm{E}(\pi_{\mathrm{ij}}(s)) = p_{\mathrm{ij}}\ \pi_{\mathrm{ij}}(s) - (1 - p_{\mathrm{ij}})\ C_{\mathrm{ij}}(s) = p_{\mathrm{ij}}\ R_{\mathrm{ij}} - C_{\mathrm{ij}}(s). \tag{2}$$

The main reason to expect that costs of commercialization are higher when licensees are located farther away from the inventors of the technology is that distance plausibly increases the cost of inventor involvement. It is well established that at the time of licensing, academic inventions have often not been developed beyond the proof of concept stage or a lab scale prototype. Based on 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 moreover 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). One explanation for this finding is that not all elements of knowledge underlying academic inventions are accessible to licensees. Licensees' absorptive capacities (Cohen and Levinthal, 1990) may be insufficient to fully appreciate all information related to academic inventions. Since these inventions tend to be highly complex and involve knowledge from overlapping disciplines, they are often far from the knowledge base of the licensee (Agrawal, 2006). In addition, relevant knowledge may be partially tacit (Polanyi, 1966; Arora, 1995), i.e. it cannot adequately be codified using patents, publications or blueprints.

According to Agrawal (2006), much of the non-codified knowledge in public research could in principle be codified; he refers to this type of knowledge as "latent" knowledge. For example, academic inventions are often based on long series of experiments. These are characterized by failures and disappointments that are usually unreported, i.e. remain non-codified in the process of academic research. However, information about what was tried out and did not work would often be valuable for licensees trying to further develop an academic invention.

Direct personal interaction is generally required for the transfer of non-codified knowledge. Even video-conferencing or e-mails as novel ways of sharing knowledge all over the world cannot fully substitute face-to-face communication and collaboration (McDonough and Kahn, 1996). Technology transfer has therefore been described as a “contact sport” in which the transfer of knowledge necessitates the participation of the inventor and requires face-to-face communication (Mowery and Ziedonis, 2001). Geographic proximity reduces the cost of face-to-face interaction due to reduced travel costs and time losses (Beise and Stahl, 1999; Santoro and Gopalakrishnan, 2001). This should be most important for high-level scientists with high opportunity costs of time used for interaction with licensees rather than for doing research (Stephan, 1996).

The main objective of our empirical analysis is to find out whether the dependence of expected profits on distance implied by (2) can be found in empirical data. To do so, we have to be more specific as to how we expect potential licensees to react to distance, and how this reaction would affect the observable outcomes of commercialization activities: the likelihood of successful commercialization and the profits realized through commercialization. A variety of outcomes (or scenarios) can be considered plausible in this context.

We take as our benchmark scenario (Scenario 1 in Table 1) the possibility that, in contrast to the above considerations, distance does not substantially influence commercial success from a license. In this case, we would expect that neither the likelihood to successfully commercialize licensed technologies nor the level of profits realized through commercialization vary with the distance between inventors and licensees.

Alternatively, assume that distance does affect the expected profit contribution from the commercialized technologies in non-negligible ways. In (2) we assumed that distance increases the cost of commercialization. Depending on what assumptions we make about firm heterogeneity and the effectiveness of competition for the license, this may still lead to different outcomes. One possibility is that firms are highly heterogeneous. This does not seem an unreasonable assumption 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). Accordingly, it may well be that the most suitable licensee for a specific technology happens to be located far from the academic inventors, and that its expected profits from licensing exceed those of more closely located potential licensees even after accounting for the costs of distance. (In the extreme case, it may be the only potential licensee expecting to generate positive profits from licensing the technology.) Aware of the fact that interaction with the inventors will be costly, the maximum price that this potential licensee is willing to pay for the license will be adjusted downward. Yet since there are no better offers from other potential licensees, the licensor may agree to the firm's terms and the licensing agreement will be concluded. As a consequence, we expect that a distant licensee's profits from successful commercialization are smaller than if the same technology had been licensed to a (hypothetical) identical licensee located more closely to the inventors. In the aggregate, longer distances between licensees and inventors should then be associated with lower profits (Scenario 2 in Table 1).

Now assume a slightly different situation where two potential licensees compete for a license on the same academic invention. One of them is more distant; i.e. it has to bear higher costs of commercialization according to (2). To obtain a license, the more distant licensee needs to offer at least the same price as the more closely located competitor. This is only consistent with the non-negativity constraint for expected profits if the more distant competitor has a higher inherent probability of successful commercialization compensating for its disadvantage in costs. Otherwise, it will not be able to license the invention. Put differently, the observable set of licensing agreements is truncated with more distant licensees having a higher minimum probability of success. In this situation, we would therefore expect to find that inventions licensed to more distant licensees yield lower profits, but have a higher chance of being commercialized. This outcome is expressed as Scenario 3 in Table 1.

There are yet further possible patterns of outcomes. Equation (2) assumed that distance reduces profit π_{ij} by increasing the cost C_{ij} of commercializing academic inventions, but does not reduce the probability p_{ij} of successful commercialization. This is obviously a restrictive assumption. We now explore the symmetric possibility that distance only affects p_{ij} but not C_{ij}. For example, imagine that licensees have a fixed budget for inventor interaction (or inventors have a fixed amount of time allocated for firm contacts). Increasing distance between licensee and inventor would then reduce the intensity of interaction, which would lower the chances that a successful outcome is realized. We can express this situation in a variant of equation (2) where p_{ij} is a function of distance (with $\partial p_{ij}(s)/\partial s < 0$) while C_{ij} no longer depends on distance:

$$E(\pi_{ij}(s)) = p_{ij}(s)\,\pi_{ij} + (1 - p_{ij}(s))\,C_{ij} = p_{ij}(s)\,R_{ij} - C_{ij}. \qquad (2')$$

If (2') is a valid model of expected profits, there are again two alternative scenarios analogous to Scenarios 2 and 3, respectively. If a distant firm is sufficiently superior to all other potential licensees to not face effective competition for the license, it will be able to negotiate a license agreement at a discounted price, thus satisfying its non-negativity constraint. In the aggregate this should lead to a negative association between commercialization likelihood and distance, constituting our Scenario 4. In contrast, if firms do face effective competition from other potential licensees and therefore a lower bound of licensing fees, profits of more distant licensees have to be higher to satisfy the non-negativity condition in spite of their lower commercialization likelihood. Otherwise, distant firms will refrain from licensing. Accordingly, in this situation (Scenario 5 in Table 1), higher profits in case of successful commercialization have to compensate distant licensees for lower chances of success. For the (truncated) sample of observable licensing agreements we therefore expect that distance is negatively associated with commercialization likelihood and positively associated with profits.

A look at Table 1 shows that it is difficult to come up with unequivocal predictions regarding the effect of distance on commercialization outcomes. In Scenarios 2-5, disadvantages of more distant licensees may lead to lower or higher commercialization likelihoods or profits. In essence, this is due to the fact that only mutually beneficial licensing agreements are entered into. The agreements we observe in reality are a selected subsample of all potential licensing agreements, where potential licensees self-select into profitable agreements. However, the higher commercialization likelihoods (profits) of more distant licensees expected in Scenarios 3 and 5 compensate for lower profits (commercialization likelihoods). Thus, if distance is a relevant impediment to successful commercialization we may observe a positive association of distance with one, but not both indicators of commercialization outcomes. (In contrast, Scenarios 2 and 4 could be combined to yield a negative association with both indicators: if distance affected both costs and probabilities of commercialization, this could result in lower commercialization likelihoods *and* lower profits if terms of licensing agreements adjust.)

There is a plausible scenario in which we would expect more distant licensees to have higher commercialization likelihoods *and* higher profits from commercialization (Scenario 6 in Table 1). In this scenario, we need to assume that local firms may obtain licenses for academic inventions even though they are inherently inferior to more distant firms. This could have different reasons. One simple possibility is that distant firms lack information about profitable licensing agreements. Alternatively, it could be that licensors of academic inventions are discriminating against more distant potential licensees. This latter assumption is plausible in the context of academic inventions since some universities and other PROs pursue regional development objectives as part of their general missions and more specifically in their technology transfer activities (Belenzon and Schankerman, 2009). If these objectives induce technology licensing offices to license inventions to local firms even though they are inferior to more distant competitors, local licensees may show a weaker commercialization performance, in terms of both commercialization likelihoods and profits, than their more distant counterparts.

Licensee-specific effects of distance

The above considerations about the costs of distance suggest that all other things being equal, it may be attractive for licensees to be in the proximity of academic inventors, even in a world where technology has dramatically improved the possibilities and reduced the costs of codifying and transmitting knowledge across the world by electronic communication superhighways. In addition, we assumed that all licensees are not equal.

Some forms of heterogeneity seem especially relevant. In particular, being less well equipped with capabilities and complementary assets (Teece, 1986; Teece et al., 1997; Shane, 2002) academic spin-offs may be more reliant on inventor cooperation. By definition, spin-offs are organized by academic inventors. Note, however, that often not all inventors of a technology join the spin-off. Moreover, even if all inventors are part of the spin-off team, proximity to the institute where an invention was made may still yield benefits to the firm because knowledge held by prior co-workers in the institute is relevant for its further development efforts. Differences between spin-off and external licensees may be further pronounced because successful commercialization of a specific invention will often be more relevant for the survival of a recently established spin-off licensee than for an external incumbent licensee (Lowe and Ziedonis, 2006). Furthermore, spin-off licensees can be expected to be more flexible in their location decisions than external licensees, which in our empirical context are almost exclusively established incumbents tied to their pre-existing locations. Given these potential differences, we will allow the effects of distance on commercialization outcomes to differ across licensee types in our empirical analysis.[1]

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[1] In unreported OLS regressions with distance as the dependent variable, we found that, controlling for other characteristics of inventions and licensees, spin-offs are significantly more closely located to inventors than external licensees.

Problems of knowledge transfer and efficient collaboration caused by geographic distance may be further increased 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, particularly if frequent face-to-face contact is required to access tacit knowledge (Maskell and Malmberg, 1999; Leamer and Storper, 2001). This is particularly important in a more open European Union, where licensees in border regions can be geographically close to a public research institution but separated by different languages and cultures (Arundel and Geuna, 2004). To allow for the possibility that cultural and linguistic differences rather than geographic distance drive differences in commercialization outcomes, we will distinguish between domestic and foreign licensees in the empirical analysis.

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 is characterized by a distinctive division of labor. Non-university public research organizations play an important role in this system, with the Max Planck Society being the largest organization focusing 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 Society receives almost 80 per cent of its budget from public, institutional funding and employs close to 5,000 researchers (Max Planck Society, 2008). These work in 80 disciplinary or topical institutes. Geographically, Max Planck Institutes are dispersed throughout the country; in most cases they are located close to a public university. The geographic 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, while their research agenda has shifted substantially over time. New institutes are generally located in the vicinity of universities. 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 law on employee inventions. This law mandates that employees have to disclose their inventions to their employer, which is the legal owner of the intellectual property. To manage its 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. Technologies are marketed to domestic and foreign firms, including spin-offs. The latter have been actively supported since the early 1990s.

Max Planck Innovation has concluded more than 1,500 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 licensing, academic inventors receive 30 per cent of all revenues, and the Max Planck Institute employing the researcher gets an additional third of all income. The Max Planck Society uses the residual income to finance the operations of Max Planck Innovation.

4. Data and methods

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 3,012 inventions have been disclosed to the Max Planck Society, of which 1,885 resulted in a patent application. Information is available about the date of disclosure and patent application, the institute that the respective invention comes from, invention-specific characteristics such as the involvement of senior scientists, 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 1,172 license agreements. Furthermore, 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 (if any) equally among the bundled inventions and including an indicator variable denoting bundled licenses in the model specifications. For each license agreement, information is available about the name, type and the 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 2,376 disclosed inventions. Of these, 773 have been licensed; they are subject to a total of 1,047 license agreements.

Sample size is further reduced by restricting the analysis to license agreements providing 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.[2] 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). Accumulated payments for the individual license agreements are highly skewed (Figure 1).

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[2] Payments are discounted to the base year 2000 and are adjusted to *Deutsche Mark*.

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 as an alternative indicator of commercial success. 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.[3] In total, 720 distances were calculated for the restricted sample between all licensing Max Planck Institutes and their corresponding licensees. Since the Max Planck Society licenses its inventions on a global scale, geographic distance ranges from 0 to more than 16,000 kilometers.

As the distribution of distances is highly skewed we employ the natural logarithm of this variable (Figure 2a). Alternatively, distance is measured by a set of indicator variables for different ranges. To pick up interactions within the same urban area, our smallest category includes all distances shorter than 50 kilometers.[4] The other distance ranges are 50-100 kilometers, 100-500 kilometers (corresponding to the maximum distance that can normally be covered in a daytrip), as well as all distances larger than 500 kilometers. To study international licensing, licensees are further classified in domestic and foreign according to their postal address. Because our theoretical considerations focus on physical distance between the parties to a license agreement, foreign subsidies located in Germany are counted

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[3] 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, 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.

[4] Belenzon and Schankerman (2010) similarly use a 25-mile distance as their smallest category in studying knowledge flows from university research.

as German licensees. Of the 731 licenses for inventions disclosed between 1980 and 2004, 227 are classified as foreign and 502 as domestic. Based on this distinction we classify our distance measure into domestic or foreign distance. Figure 2b 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 the Max Planck Innovation's spin-off database. In total 228 license agreements with spin-offs and 470 with external licensees have been identified.[5] 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)[6] and whether or not they were invented at one of the leading five institutes in terms of disclosed inventions (which jointly account for 42% of all inventions). To identify inventions by senior researchers, an indicator variable denotes inventions having a Max Planck director among their inventors. Directors are the top-level researchers employed at the Max Planck Society. Depending on its size, each institute has between two and about twelve directors, many of whom can be considered star scientists. The dataset includes 282 cases of director involvement in the licensed invention. Time effects (older inventions are exposed longer to the hazards of licensing and commercialization than are younger ones) are recorded by an integer variable denoting the year of disclosure starting with a zero in 1980.

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 options for the licensee, which may be reflected in reduced commercialization rates (cf.

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[5] Small numbers of licensees could not be classified reliably; they are omitted in the empirical analysis.

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

Buenstorf and Geissler, 2012). Finally, to control for differences across technology fields, licensees are classified into three broad sectors 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. This makes for a total of five different fields of licensees.

Empirical approach

To assess the influence of geographic distance on commercialization outcomes, we estimate a set of models where we regress our measures of commercial success on a variety of licensee and technology characteristics, controlling for time effects. This leads to the general model:

$$y_{ij} = \beta_0 + \beta_1 DIST_{ij} + \boldsymbol{L}_i \beta_2 + \boldsymbol{T}_j \beta_3 + u_{ij} \tag{3}$$

where y measures commercial success of invention j licensed to firm i. Specifications of model (3) vary according to dependent variables. To analyze the likelihood of successful commercialization, a series of Probit models is estimated in which the dependent variable takes the value of one if positive royalty payments have been realized and zero otherwise. Tobit models are employed to estimate models in which accumulated license payments are the dependent variable. Payments are left-censored at zero which is taken into account in the Tobit models. Given that accumulated payments are highly skewed, we employ the natural log. Throughout the analysis, standard errors clustered by inventions are estimated to control for the occurrence of multiple licensing of the same technology.

Our empirical analysis is subject to several econometric concerns. One of these is selection bias, which may be caused by two different processes. 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 applied the two-stage estimation procedure proposed by Heckman (1979). As we show in more detail in the appendix, inventor characteristics are well-suited to explain selection into licensing. The empirical results of the Heckman models (reported in Table A1 in the appendix) indicate that non-random selection into licensing is not of major concern for our sample, as we cannot reject the null hypothesis that commercialization outcomes are independent of selection into licensing.

The second potential selection problem concerns licensee characteristics. Specifically, licensing decisions of spin-offs may differ substantially from those of external licensees. This is consistent with the empirical results obtained by Buenstorf and Geissler (2012) in the empirical context of the present study. To allow for differences in the factors shaping commercialization outcomes of both licensee types, including our distance measures, we estimate our principal 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. Endogenous location choices driven by the objective to be close to the origins of the licensed technology 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. We address the endogeneity issue by re-estimating (3) using instruments for the inventor-licensee distance.

Finally, while we analyze a homogeneous institutional context and control for a range of licensee and technology characteristics, unobserved heterogeneity across inventions may still affect observed commercialization outcomes. For the majority of inventions (those licensed to a single firm), we cannot avoid this problem. However, for the smaller subset of inventions that were licensed non-exclusively to different firms, we also report results from model specifications controlling for invention-specific effects.

5. Results

We begin by estimating how the distance between inventors and licensees is related to the likelihood that a licensed invention is successfully commercialized (indicated by positive royalty payments). Model 1a (Table 6) is estimated for the full population of licensed inventions. It finds no evidence that commercialization outcomes vary with the distance between inventors and licensees. Significant marginal effects are obtained for several other variables included in the model. First, more recent inventions are less likely to be commercialized than older ones. This finding (which is also reproduced in the subsequent models) may in part reflect the right-censored nature of our data. However, we suspect that it also indicates a reduced average quality of inventions, which may result from new entry of inventors into the market for technology.[7] Second, we find that patented inventions are less often commercialized than those for which no patent application is documented. This result is robust throughout our further analysis. It suggests that both spin-offs and external licensees obtain a substantial share of licenses for strategic reasons. In addition, spin-offs appear to be less likely to commercialize (the marginal effect of the spin-off variable is significant at the 10% level). Model 1b and 1c, respectively, re-estimate the same model separately for spin-offs and external licensees. The main result of Model 1a is reproduced: geographic distance is not systematically associated with differences in commercialization likelihoods. As regards the other explanatory variables, differences between the types of licensees are modest.

Tobit estimations of specifications analogous to Models 1a-c but using logged accumulated royalty payments to the Max Planck Society resulting from a license (our proxy of profits) as dependent variable are reported as Models 4a-c in Table 7. Similar to the results for commercialization likelihood, no systematic effects of geographic distance are suggested by these models. [8]

We further probe these findings in Models 2a-c (Table 6) and Models 5a-c (Table 7), where the continuous (log) distance variable is replaced by indicator variables denoting ranges of distances from 50-100, 100-500 and 500+ kilometers. (Inventions licensed within a 50-kilometer range from the inventors form the omitted reference group.) This leads to very similar results for the full sample (Models 2a and 5a) and for the external licensees (Models 2c and 5c). In both cases, neither the likelihood nor the extent of commercial success varies across the distance ranges. In contrast, for the spin-off sample Models 2b and 5b suggest superior outcomes for licensees located in the 100-500 kilometer range from the inventors. However, similar to Models 1a-c and 4a-c, there is no evidence suggesting that even more distant licensees are disadvantaged vis-à-vis firms located in close proximity to the inventing Max Planck Institute. In addition, none of the positive coefficients obtained in the models is counterbalanced by a negative coefficient for the alternative indicator of successful

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[7] Similar temporal patterns have been found for patents of U.S. universities (c.f. Henderson et al., 1998).

[8] As a robustness check we alternatively estimated OLS regressions. This did not lead to qualitative differences in results.

commercialization. This is not suggestive of distant firms compensating lower commercialization likelihoods with higher profits or vice versa (as was suggested above in Scenarios 3 and 5).[9]

In Models 3a-c (Table 6) and 6a-c (Table 7), the continuous distance measure from Models 1a-c (4a-c) is split up into separate measures for domestic and foreign licensees. Results from these models lend little support to the conjecture that distances across national borders have more adverse effects than domestic distances. For the full dataset analyzed in Model 3a, a significantly positive marginal effect of domestic distance is estimated. The marginal effect for the distance to foreign licensees is significantly smaller (p>0.04) and not significantly different from zero. In the corresponding Model 6a we likewise find a (marginally) significant positive association of domestic distance, but not of foreign distance, to the level of royalty payments. Both marginal effects do not differ significantly from each other (p>0.21). Looking at the individual types of licensees, the most pronounced patterns are obtained for the spin-off licensees studied in Models 3b and 6b. In both models, increasing domestic distance is associated with more favorable outcomes, while increasing distance to foreign licensees is related to inferior commercialization results. In contrast, for the external licensees both measures are insignificant and do not differ from each other (Models 3c and 6c).

As noted 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.[10] To address the endogeneity concern, we estimated models of commercializing outcomes using an instrumental variable (IV) 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 Ph.D. dissertations and from a published directory (Max Planck Society, 2006). We then calculated the distances between founder birthplaces and the locations of the respective licensing institutes, and used these to

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[9] We also experimented with (unreported) models using linear and quadratic measures of the continuous distance measure employed in models 1a-c. Both terms are insignificant in all specifications, which is not indicative of systematic effects of distance on commercialization outcomes.

[10] 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.

instrument the distance between spin-off location and licensing institute.[11] These distances qualify as an instrument because they are exogenous, correlated with the potentially endogenous distance variable, and do not predict commercialization outcomes.[12] Choosing them as an instrument is based on 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.[13]

Results of the IV regressions are reported as Models 7 and 8 in Table 8. Model 7 is an instrumental variable probit regression analogous to the above Model 1b (the coefficient estimates obtained for that model are also reported in Table 8 to allow for comparisons). The IV probit finds a positive association between distance and commercialization likelihood, which however is insignificant and considerably smaller than in the simple probit model. Coefficients for the other variables are nearly similar to Model 1b. Model 8 uses an IV tobit model analogous to Model 4b. It finds a negative association between distance and levels of royalties, which again is far from attaining statistical significance. We thus conclude that accounting for potential endogeneity of spin-off locations, we still do not find evidence suggesting systematic effects of distance on commercialization outcomes.

Finally, to assess the role of unobserved heterogeneity across inventions, we estimate model variants including indicator variables for each licensed invention to control for invention-specific effects. This approach is obviously limited to the subset of inventions that were licensed more than once (120 inventions yielding a total of 272 observations). Results from these models are of limited generality. Since exclusive access to a technology enhances the chances that a licensee can recoup its R&D expenditures, we would expect those

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[11] In some cases, information about birth places could not be obtained. Where possible, we used the location of the respective individual's Ph.D. 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.

[12] The instrument's correlation with the distance between spin-off location and licensing institute is 0.32. In a model analogous to Model 1, we obtained a coefficient estimate of -0.002 and a z-value of -0.03 ($p > 0.979$) for the instrument. Its first-stage F-statistic in a 2SLS IV regression of royalties analogous to Model 4b is 12.048.

[13] 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, in addition to not finding a systematic relationship with commercialization outcomes (cf. the previous footnote), 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).

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 9 (Table 9) replicates Model 4a using the log distance measure. This model does suggest that if the same invention is licensed to licensees at different distances, royalty payments decrease with the distance between inventors and licensees, which would be consistent with higher costs of commercialization for more distant licensees. Model 10, however, indicates that this conclusion may be problematic. In this model, which employs the set of indicator variables for the alternative distance ranges, licensees located in the 100-500 kilometer range generate significantly higher royalties than those located less than 50 kilometers away from the inventors. Likewise, licensees located more than 500 kilometers away from the inventors generate higher royalties than those in the 50-100 kilometer range. These nonlinear relationships are hard to reconcile with the argument that increasing distance impedes successful commercialization of academic inventions. Finally, Model 11 distinguishes domestic from foreign licensees. Similar to the pattern we had found above for spin-offs (Model 6b), royalties are positively associated with domestic distances, and negatively with foreign distances.[14]

6. Conclusions: a regional mission for technology licensing from public research?

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. Our findings provide little support to the conjecture that the commercialization of academic inventions is harmed by geographic distance between inventors and licensees. Results

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[14] One 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.

suggestive of adverse effects of distance were only obtained for foreign spin-off licensees, and for foreign firms among multiple licensees of inventions. The above theoretical considerations moreover indicated that a positive association between geographic distance and commercialization outcomes could be consistent with adverse effects of distance, provided that distant licensees self-select into profitable licensing agreements. As we argued above, this should result in higher commercialization likelihoods compensating for lower profits or vice versa (Scenarios 3 and 5 in Table 1). While we cannot directly observe licensee profits, based on our proxy variable – accumulated royalty payments to the Max Planck Society - we find no evidence that this kind of compensation can explain the positive coefficients obtained for some distance measures in some models. We thus conclude that geographic distance is generally not an important determinant of commercialization outcomes.

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.

Some universities and public research organizations emphasize their mission to support regional private-sector R&D activities. Preferential licensing to regional firms might be considered as one type of policy to attain this objective. Our results do not suggest this would be an efficient strategy from a societal perspective. This conclusion is in line with the finding of Belenzon and Schankerman (2009) that U.S. universities that pursued strong local development objectives generated about a third less income per license than those that did not. It runs counter, however, to the importance that policy makers and university administrations often attribute to the role of interactions with regional firms.

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, endogeneity and unobserved heterogeneity. Our estimates addressing these concerns indicate that the main results are not driven by endogeneity or unobserved heterogeneity, 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.

References

Acs, Z. J., D. B. Audretsch and M. P. Feldman, 1992. “Real Effects of Academic Research: Comment.” *American Economic Review*, 82: 363-367.

Adams, J. D., 2002. “Comparative localization of academic and industrial spillovers.” *Journal of Economic Geography*, 2: 253-278.

Agrawal. A., 2006. “Engaging the inventor: Exploring licensing strategies for university inventions and the role of latent knowledge.” *Strategic Management Journal*, 27: 63-79.

Agrawal, A. and R. Henderson, 2002. “Putting Patents in Context: Exploring Knowledge Transfer from MIT.” *Management Science*, 48: 44-60.

Anselin, L., A. Varga and Z. Acs, 1997. “Local Geographic Spillovers between University Research and High Technology Innovations.” *Journal of Urban Economics*, 42: 422-448.

Arora, A., 1995. “Licensing tacit knowledge: intellectual property rights and the market for know-how.” *Economics of Innovation and New Technology*, 4: 41-59.

Arora, A., A. Fosfuri and A. Gambardella, 2001. *Markets for Technology.* Cambridge, MA: MIT Press.

Arundel, A. and A. Geuna, 2004. “Proximity and the use of public science by innovative European Firms.” *Economics of Innovation and New Technology*, 13: 559-580.

Audretsch, D. B. and M. P. Feldman, 1996. “R&D Spillovers and the Geography of Innovation and Production.” *American Economic Review*, 86: 630-640.

Beise, M. and H. Stahl, 1999. “Public research and industrial innovations in Germany.” *Research Policy*, 28: 397-422.

Belenzon, S. and M. Schankerman, 2009. “University Knowledge Transfer: Private Ownership, Incentives and Local Development Objectives.” *Journal of Law and Economics*, 52: 111-144.

Belenzon, S. and M. Schankerman, 2010. “Spreading the Word: Geography, Policy and University Knowledge Diffusion.” London School of Economics and Political Science: CEP Discussion Paper No 1005.

Bozeman, B., 2000. “Technology transfer and public policy: a review of research and theory.” *Research Policy*, 29: 627-655.

Buenstorf, G. and M. Geissler, 2012. “Not invented here: Technology licensing, knowledge transfer and innovation based on public research.“ *Journal of Evolutionary Economics*, forthcoming.

Cohen, W. M. and D.A. Levinthal, 1990. “Absorptive Capacity: A New Perspective on Learning and Innovation.” *Administrative Science Quarterly*, 35: 128-152.

Cohen, W. M., R. R. Nelson and J. P. Walsh, 2002. “Links and Impacts: The Influence of Public Research on Industrial R&D.” *Management Science*, 48: 1-23.

Contractor, F. J., 1981. International *Technology Licensing: Compensation, Costs, and Negotiation.* Lexington, MA, Lexington Books.

Dahl, M. S. and O. Sorenson, 2011. “Home sweet home: Entrepreneurs' location choices and the performance of their ventures.” Mimeo.

Dechenaux, E., B. Goldfarb, S. Shane, and M. C. Thursby, 2008. “Appropriability and the timing of innovation: Evidence from MIT inventions.” *Management Science*, 54 (5): 893-906.

Elfenbein, D., 2004. “Contract Structure and Performance of Technology Transfer Agreements: Evidence from University Licenses,” Working Paper.

Elfenbein, D., 2007. “Publications, patents, and the market for university inventions.” *Journal of Economic Behavior and Organization*, 63: 688-715.

Fritsch, M. and V. Slavtchev, 2007. “Universities and Innovation in Space.” *Industry and Innovation*, 14: 201-218.

Grotz, R. and B. Braun, 1997. „Territorial or Trans-territorial Networking: Spatial Aspects of Technology-oriented Cooperation within the German Mechanical Engineering Industry.” *Regional Studies*, 31: 545-557.

Heckman, J. J., 1979. “Sample Selection Bias as a Specification Error.” *Econometrica*, 47(1): 153-161.

Henderson, R., A. B. Jaffe and M. Trajtenberg, 1998. „Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting, 1965-1988.“ *Review of Economics and Statistics*, 80: 119-127.

Jaffe, A. B., 1989. “Real Effects of Academic Research.” *American Economic Review*, 79: 957-970.

Jaffe, A. B., M. Trajtenberg and R. Henderson, 1993. “Geographic Localization of Knowledge Spillovers as Evidenced by Patents Citations.” *Quarterly Journal of Economics*, 63: 577-598.

Jensen, R. A. and M. Thursby, 2001. “Proofs and Prototypes for Sale: The Licensing of University Inventions.” *American Economic Review*, 91: 240-259.

Kenney, M. and D. Patton. 2009. “Reconsidering the Bayh-Dole Act and the Current University Invention Ownership Model.” *Research Policy*, 38: 1407-1422.

Leamer, E. E. and M. Storper, 2001. “The Economic Geography of the Internet Age.” *Journal of International Business Studies*, 32: 641-665.

Lissoni, F., P. Llerena, M. McKelvey and B. Sanditov, 2008. Academic Patenting in Europe: New Evidence from the KEINS database. *Research Evaluation*, 17: 87-102.

Lowe, R. A., 2006. “Who Develops a University Invention? The Impact of Tacit Knowledge and Licensing Policies.” *Journal of Technology Transfer*, 31: 415-429.

Lowe, R. A. and A. A. Ziedonis, 2006. “Overoptimism and the Performance of Entrepreneurial Firms.” *Management Science*, 52: 173-186.

Mansfield, E. and J.-Y. Lee, 1996. “The modern university: contributor to industrial innovation and recipient of industrial R & D support.” *Research Policy*, 25: 1047-1058.

Maskell, P. and A. Malmberg, 1999. “Localised Learning and Industrial Competitiveness.” *Cambridge Journal of Economics*, 23: 167-175.

Max Planck Innovation, 2007. *Connecting Science and Business*, Munich.

Max Planck Society, 2006. *Handbook of Scientific Members*. Munich.

Max Planck Society, 2008. *Annual Report 2007*. Munich.

McDonough, E. and K. B. Kahn, 1996. "Using 'hard' and 'soft' technologies for global new product development." *R&D Management*, 26: 241-253.

Mowery, D. C. and A. A. Ziedonis, 2001. "The Geographic Reach of Market and Non-Market Channels of Technology Transfer: Comparing Citations and Licenses of University Patents." *NBER Working Paper* 8568.

Mowery, D. C., R. R. Nelson, B. N. Sampat and A. A. Ziedonis, 2001. "The growth of patenting and licensing by U.S. universities: an assessment of the effects of the Bayh-Dole Act of 1980." *Research Policy*, 30: 99-119.

Polanyi, M., 1966. *The tacit dimension*. Routledge & Kegan Paul, London.

Salter, A. J. and B. R. Martin, 2001. "The economic benefit of publicly funded basic research: a critical review." *Research Policy*, 30: 509-532.

Sampat, B.N., 2006. "Patenting and US academic research in the 20th century: The world before and after Bayh-Dole." *Research Policy*, 35: 772-789.

Santoro, M. D. and S. Gopalakrishnan, 2001. "Relationship Dynamics between University Research Centers and Industrial Firms: Their Impact on Technology Transfer Activities." *Journal of Technology Transfer*, 26: 163-171.

Shane, S., 2002. "Selling University Technology: Patterns from MIT." *Management Science*, 48: 122-137.

Siegel, D. S., D. A. Waldman, L. E. Atwater and A. N. Link, 2003. "Commercial knowledge transfer from universities to firms: improving the effectiveness of university-industry collaboration." *Journal of High Technology Management Research*, 14: 111-133.

Sorenson, O., 2004. "Social networks, informational complexity and industrial geography." In: Fornahl, D., C. Zellner and D. B. Audretsch (eds.). *The Role of Labour Mobility and Informal Networks for Knowledge Transfer.* Kluwer, Dordrecht.

Stephan, P. E., 1996. "The Economics of Science," *Journal of Economic Literature*, 34: 1199-1262.

Teece, D. J., 1986. "Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy." *Research Policy*, 15: 285-305.

Teece, D. J., G. Pisano and A. Shuen, 1997. "Dynamic capabilities and strategic management." *Strategic Management Journal*, 18: 509-533.

Thursby, J. G. and M. C. Thursby, 2004. "Are faculty critical? Their role in university-industry licensing." *Contemporary Economic Policy*, 22: 162-178.

Von Proff, S., G. Buenstorf and M. Hummel, 2012. "University Patenting in Germany before and after 2002: What Role Did the Professors´ Privilege Play?" *Industry and Innovation*, forthcoming.

Table 1: Predicted effects of distance on outcomes

Scenario	Characterization	Effect of distance on probability of commercialization	Effect of distance on licensee profits
1	Costs of distance negligible	o	o
2	Distance increases cost; no effective competition for license	o	–
3	Distance increases cost; effective competition for license	+	–
4	Distance reduces comm. likelihood; no effective competition for license	–	o
5	Distance reduces comm. likelihood; effective competition for license	–	+
6	Discrimination against more distant licensees	+	+

Table 2: Disclosed and licensed inventions, 1980-2004

Inventions (patented)	2,376 (1,504)
Licensed inventions (patented)	773 (546)
License agreements (patented)	1,047 (728)
License agreements with royalties (patented)	731 (513)
Commercialized (patented)	365 (218)

Table 3: Descriptive statistics

	All inventions				Licensed inventions with provisions for royalties			
	obs	mean	min	max	obs	mean	min	max
Commercialization					731	.499	0	1
Log royalties					731	4.783	0	19.109
Log distance					720	5.380	0	9.692
Time (1980=0)	2,376	14.503	0	24	731	13.432	0	24
Biomedical section	2,264	0.604	0	1	719	0.776	0	1
Director involvement	2,376	0.130	0	1	731	0.386	0	1
Patent application	2,376	0.633	0	1	731	0.702	0	1
Spin-off licensee					731	0.327	0	1
Foreign licensee					729	0.311	0	1
Bundle					731	0.294	0	1
Repeat licensee					729	0.757	0	1

Table 4: Correlations between covariates (all inventions), 1980-2004

2,264 observations	Time	Biomed	Director involvement	Patent
Time	1.000			
Biomed	0.071	1.000		
Director involvement	0.026	0.168	1.000	
Patent	0.003	-0.010	0.156	1.000

Table 5: Correlations between covariates (license agreements providing for royalties), 1980-2004

715 observations	Time	Ln distance	Biomed	Dir. Inv.	Patent	Spinoff	Foreign	Bundle	Repeat Lic.
Time	1.000								
Ln distance	-0.132	1.000							
Biomed	0.158	0.089	1.000						
Director involvement	0.127	0.068	0.201	1.000					
Patent	0.056	-0.051	0.079	0.148	1.000				
Spinoff	0.262	-0.425	0.114	0.221	0.201	1.000			
Foreign	-0.019	0.710	0.171	0.139	-0.033	-0.247	1.000		
Bundle	-0.005	0.116	0.016	0.174	0.254	0.259	-0.022	1.000	
Repeat licensee	0.046	-0.130	0.137	0.163	0.214	0.297	-0.157	0.345	1.000

Table 6: Likelihood of commercialization (Probit), marginal effects, 1980-2004

Comm = 1	Model 1a (all licensees)		Model 1b (spin-offs)		Model 1c (external licensees)		Model 2a (all licensees)		Model 2b (spin-offs)		Model 2c (external licensees)	
Log distance	0.006	(0.010)	0.010	(0.022)	0.005	(0.014)						
50-100 km							0.168	(0.142)			0.097	(0.153)
100-500 km							0.053	(0.059)	0.223**	(0.111)	-0.043	(0.080)
> 500 km							0.064	(0.065)	-0.048	(0.124)	0.045	(0.086)
Time	-0.015***	(0.004)	-0.030***	(0.009)	-0.013***	(0.004)	-0.015***	(0.004)	-0.030***	(0.009)	-0.014***	(0.004)
Biomedical section	-0.022	(0.062)	-0.256**	(0.117)	0.041	(0.073)	-0.012	(0.064)	-0.290**	(0.115)	0.064	(0.077)
Patented invention	-0.217***	(0.047)	-0.253**	(0.105)	-0.228***	(0.054)	-0.219***	(0.047)	-0.260**	(0.106)	-0.222***	(0.054)
Repeat licensee	0.022	(0.055)	-0.296*	(0.167)	0.034	(0.057)	0.016	(0.056)	-0.322**	(0.159)	0.041	(0.058)
Director involvement	0.034	(0.047)	-0.006	(0.084)	0.045	(0.056)	0.035	(0.047)	-0.019	(0.082)	0.036	(0.056)
Spinoff	-0.101*	(0.052)					-0.086	(0.053)				
Bundle	0.128**	(0.053)	0.213**	(0.105)	0.124*	(0.065)	0.131**	(0.052)	0.163	(0.098)	0.134**	(0.065)
Top 5 institute	-0.008	(0.049)	0.198**	(0.089)	-0.051	(0.058)	-0.011	(0.050)	0.172*	(0.069)	-0.052	(0.058)
Sectoral controls	Included											
Number of obs. (inventions)	715	(564)	226	(213)	489	(376)	715	(564)	226	(213)	489	(376)
P > chi^2	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	
Pseudo R^2	0.119		0.353		0.079		0.121		0.369		0.084	

Standard errors (clustered by invention) in parentheses; *;**; and *** denote significance at the 0.10; 0.05; and 0.01 levels, respectively.

Table 6: Likelihood of commercialization (Probit), marginal effects, 1980-2004 (continued)

Comm = 1	Model 3a (all licensees)		Model 3b (spin-offs)		Model 3c (external licensees)	
Log domestic distance	0.029**	(0.014)	0.039*	(0.022)	0.007	(0.023)
Log foreign distance	0.010	(0.010)	-0.051**	(0.025)	0.006	(0.016)
Time	-0.015***	(0.004)	-0.025***	(0.009)	-0.013***	(0.004)
Biomedical section	-0.011	(0.062)	-0.259**	(0.116)	0.042	(0.073)
Patented invention	-0.221***	(0.048)	-0.262**	(0.105)	-0.228***	(0.054)
Repeat licensee	0.012	(0.055)	-0.414**	(0.165)	0.033	(0.058)
Director involvement	0.045	(0.048)	0.008	(0.078)	0.045	(0.057)
Spinoff	-0.081	(0.053)				
Bundle	0.107**	(0.053)	0.158	(0.100)	0.124*	(0.065)
Top 5 institute	-0.012	(0.051)	0.190**	(0.085)	-0.042	(0.059)
Sectoral controls	Included					
Number of obs. (inventions)	715	(564)	226	(213)	489	(376)
$P > chi^2$	0.0000		0.0000		0.0000	
Pseudo R^2	0.124		0.380		0.079	

Standard errors (clustered by invention) in parentheses; *;**; and *** denote significance at the 0.10; 0.05; and 0.01 levels, respectively.

Table 7: Level of royalty income (Tobit), 1980-2004

Log royalty payments	Model 4a (all licensees)		Model 4b (spin-offs)		Model 4c (external licensees)		Model 5a (all licensees)		Model 5b (spin-offs)		Model 5c (external licensees)	
Log distance	0.164	(0.194)	0.230	(0.337)	0.147	(0.283)						
50-100 km							3.373	(2.738)			2.192	(2.887)
100-500 km							0.934	(1.025)	2.709*	(1.489)	-0.719	(1.351)
> 500 km							1.414	(1.254)	-0.761	(2.248)	1.057	(1.566)
Time	-0.310***	(0.064)	-0.448***	(0.115)	-0.285***	(0.071)	-0.314***	(0.066)	-0.433***	(0.113)	-0.300***	(0.071)
Biomedical section	-0.536	(1.089)	-3.771**	(1.803)	0.864	(1.290)	-0.281	(1.119)	-3.977**	(1.714)	1.348	(1.357)
Patented invention	-3.053***	(0.928)	-3.675***	(1.394)	-3.024***	(1.166)	-3.050***	(0.946)	-3.693***	(1.399)	-2.905**	(1.154)
Repeat licensee	0.818	(0.924)	-3.189	(1.940)	1.194	(0.968)	0.692	(0.932)	-3.395*	(1.890)	1.298	(0.981)
Director involvement	-0.060	(0.880)	0.101	(1.389)	-0.157	(1.099)	-0.052	(0.895)	0.299	(1.318)	-0.359	(1.088)
Spinoff	-1.978**	(0.944)					-1.807*	(0.937)				
Bundle	1.778*	(0.991)	2.926*	(1.601)	1.543	(1.240)	1.919**	(0.957)	2.619*	(1.469)	1.825	(1.232)
Top 5 institute	-0.042	(0.925)	2.374	(1.646)	-0.554	(1.102)	-0.088	(0.941)	2.058	(1.637)	-0.549	(1.102)
Constant	6.529***	(1.602)	13.765***	(3.520)	5.405***	(1.982)	6.282***	(1.498)	13.263***	(3.349)	5.799***	(1.709)
Sectoral controls	Included											
Number of obs. (inventions)	715	(564)	226	(213)	489	(376)	715	(564)	226	(213)	489	(376)
P > F	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	
Pseudo R^2	0.041		0.140		0.025		0.044		0.144		0.027	

Standard errors (clustered by invention) in parentheses; *;**; and *** denote significance at the 0.10; 0.05; and 0.01 levels, respectively.

Table 7: Level of royalty income (Tobit), 1980-2004 (continued)

Log royalty payments	Model 6a (all licensees)		Model 6b (spin-offs)		Model 6c (external licensees)	
Log domestic distance	0.430*	(0.250)	0.606*	(0.333)	-0.091	(0.386)
Log foreign distance	0.211	(0.192)	-0.726*	(0.424)	0.053	(0.281)
Time	-0.305***	(0.066)	-0.395***	(0.110)	-0.287***	(0.071)
Biomedical section	-0.393	(1.086)	-3.523*	(1.831)	0.797	(1.289)
Patented invention	-3.041***	(0.945)	-3.802***	(1.380)	-3.035***	(1.150)
Repeat licensee	0.689	(0.924)	-4.184**	(1.800)	1.290	(0.973)
Director involvement	0.103	(0.923)	0.493	(1.319)	-0.251	(1.127)
Spinoff	-1.792*	(0.941)				
Bundle	1.531	(0.970)	2.287	(1.505)	1.603	(1.224)
Top 5 institute	-0.094	(0.942)	2.226	(1.589)	-0.496	(1.113)
Constant	5.533***	(1.758)	12.889***	(3.386)	6.374***	(2.238)
Sectoral controls	Included					
Number of obs. (inventions)	715	(564)	226	(213)	489	(376)
P > F	0.0000		0.0000		0.0000	
Pseudo R^2	0.042		0.149		0.026	

Standard errors (clustered by invention) in parentheses; *;**; and *** denote significance at the 0.10; 0.05; and 0.01 levels, respectively.

Table 8: Commercialization outcomes (IV), 1980-2004

Log royalty payments	Model 7 (IV probit: Comm = 1) (spin-offs)		Comparison: Coefficient estimates from Model 1b		Model 8 (IV tobit: royalties) (spin-offs)		Comparison: Coefficient estimates from Model 4b)	
Log distance	0.003	(0.169)	0.028	(0.060)	-0.453	(1.313)	0.230	(0.337)
Time	-0.079***	(0.026)	-0.084***	(0.025)	-0.351**	(0.149)	-0.448***	(0.115)
Biomedical section	-0.642**	(0.323)	-0.666**	(0.301)	-7.466***	(2.139)	-3.771**	(1.803)
Patented invention	-0.699**	(0.275)	-0.659**	(0.275)	-5.600***	(1.796)	-3.675***	(1.394)
Repeat licensee	-0.794*	(0.480)	0.274*	(0.439)	-4.347	(3.015)	-3.189	(1.939)
Director involvement	-0.024	(0.241)	-0.015	(0.230)	-1.703	(1.605)	0.101	(1.389)
Bundle	0.648	(0.603)	0.588**	(0.296)	4.100	(4.972)	2.926*	(1.601)
Top 5 institute	0.545*	(0.290)	0.558**	(0.264)	3.022	(2.081)	2.374	(1.646)
Constant	2.573***	(0.881)	2.515***	(0.663)	21.504***	(6.330)	13.765***	(3.520)
Sectoral controls	Included							
Number of obs. (inventions)	223	(210)	226	(213)	223	(210)	226	(213)
P>F	0.0000		0.0000		0.0000		0.0000	

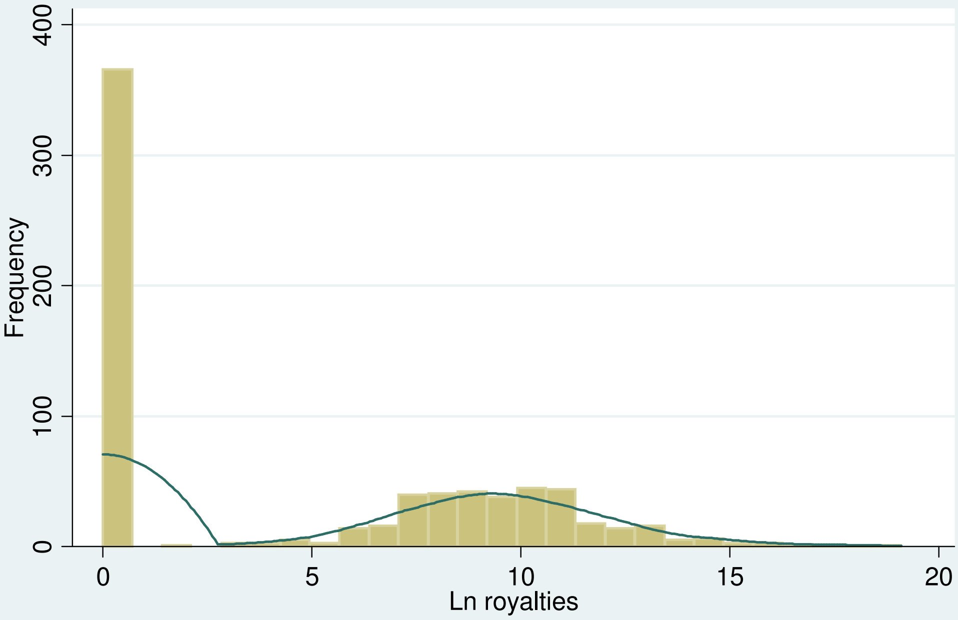
Standard errors (clustered by invention) in parentheses; *;**; and *** denote significance at the 0.10; 0.05; and 0.01 levels, respectively.

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

Log royalty payments	Model 9 (all licensees)		Model 10 (all licensees)		Model 11 (all licensees)	
Log distance	-0.277***	(0.004)				
50-100 km			-6.880***	(0.085)		
100-500 km			0.712***	(0.065)		
> 500 km			-0.939***	(0.044)		
Log domestic distance					0.074***	(0.012)
Log foreign distance					-0.173***	(0.004)
Repeat licensee	-0.020	(0.039)	0.182***	(0.035)	-0.045	(0.039)
Spinoff	-4.561***	(0.049)	-4.474***	(0.077)	-4.648***	(0.082)
Bundle	0.365***	(0.038)	-0.219***	(0.068)	0.196***	(0.058)
Constant	-30.094***	(0.033)	-31.821***	(0.031)	-31.449***	(0.034)
Sectoral controls	Included					
Invention-specific effects	Included					
Number of obs. (inventions)	272	(120)	272	(120)	272	(120)
P>F	0.0000		0.0000		0.0000	
Pseudo R^2	0.266		0.271		0.266	

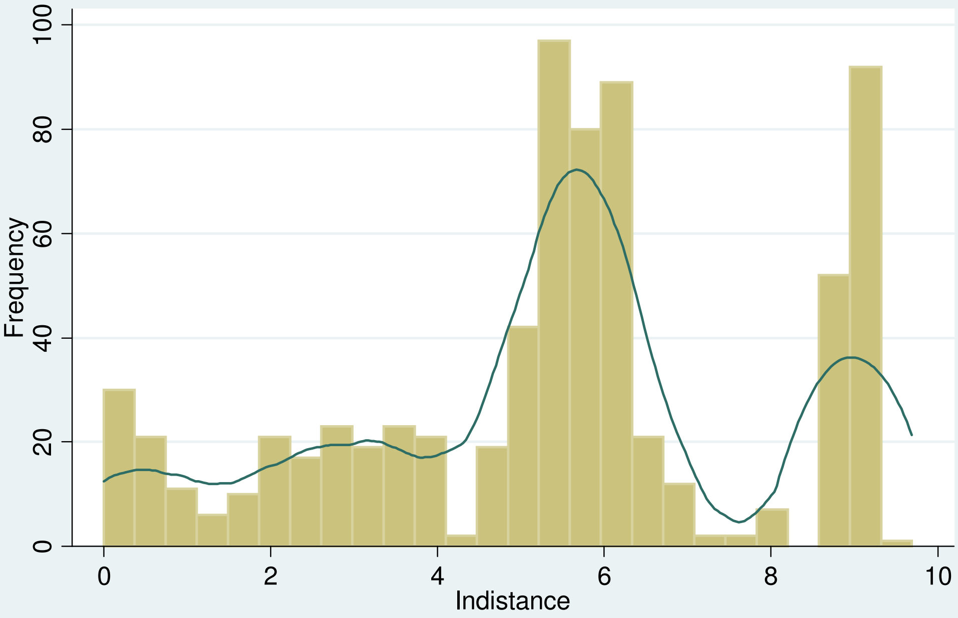
Standard errors (clustered by invention) in parentheses; *;**; and *** denote significance at the 0.10; 0.05; and 0.01 levels, respectively.

Figure 1: Cumulated log royalties, 1980-2007



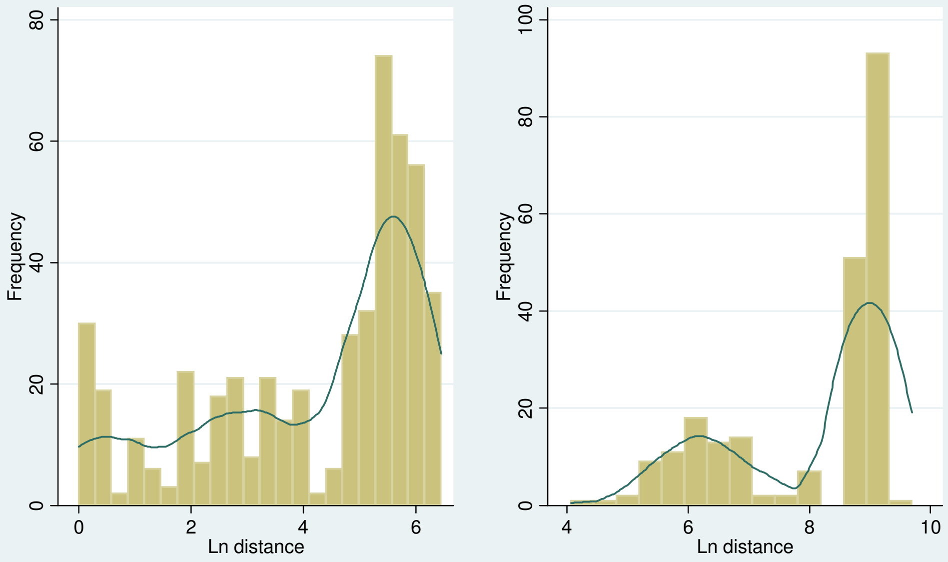
Note: The graph pictures a histogram of the log of cumulated royalty payments from 1980 through 2007 for licensed inventions where licensing agreements provided for royalty payments. Additionally, a kernel density function is plotted.

Figure 2a: Log distance, 1980-2004



Note: The graph pictures a histrogram of log distances with a kernel density function of licensed inventions disclosed from 1980 through 2004 where licensing agreements provided for royalties.

Figure 3b: Log distance separated by domestic and foreign licensees, 1980-2004



Note: The graph pictures two histograms of log distances with a 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.

Appendix A

Commercialization of technologies from public research is a two-stage process. Technologies first have to be licensed. The attempt to sell products based on the licensed technology then constitutes the second stage, particularly because inventions from public research are often embryonic in nature (Jensen and Thursby, 2001; Agrawal, 2006). Not all inventions from public research are licensed, and selection of technologies into licensing is most likely not a random process. It therefore seems a valid concern that non-random selection into licensing may lead to biased results when the commercialization odds of licensed technologies are analyzed.

In this appendix we show that the empirical analysis presented above is not invalidated by non-random selection into licensing. For this purpose, the two-stage methodology developed by Heckman (1979) is adopted. An equation for selection into licensing is estimated first, which then informs the second stage equation estimating commercialization outcomes.

In the first stage, the selection equation predicts the likelihood that an invention will be licensed. The underlying selection equation looks as follows:

$$s = 1[\boldsymbol{z}\gamma + v \geq 0] \tag{A1}$$

where z are observable variables and v is an unobserved error term. s is equal to 1 if an invention has been licensed and commercial success is observable and zero otherwise. The prediction from the first stage is used to calculate the inverse Mills ratio as $\lambda(\boldsymbol{z}_{ij}\gamma)$. The inverse Mills ratio is then included as an additional exogenous variable in the modified version of commercialization equation (3):

$$y_{ij} = \beta_0 + \beta_1 DIST_{ij} + \boldsymbol{L}_i\beta_2 + \boldsymbol{T}_j\beta_3 + \rho\lambda(\boldsymbol{z}_{ij}\gamma) + u_{ij} \tag{A2}$$

For the Heckman model to be consistent, the selection equation must include exogenous variables that determine sample selection, i.e. the probability of licensing, but do not directly affect the outcome of interest, i.e. successful commercialization. Results by Buenstorf and Geissler (2012) indicate that technologies (co-) invented by Max Planck directors have higher chances of being licensed, while their commercialization odds are not different from other inventions. This suggests an impact of reputation effects on the chances of technologies being licensed. Second, explanatory variables in the outcome equation should also be included in the selection equation provided they are observable. Explanatory variables that are not observable in the first stage have to be excluded from the selection equation.

In line with the empirical strategy employed above, two types of models are employed to control for selection bias: To investigate the likelihood of commercial success we initially employ Probit models at both the selection and the outcome stages. Subsequently, Probit models are employed in the selection stage whereas the outcome stage estimates the magnitude of cumulated royalties.

Results of the various model specifications are reported in Table A1-A2.[15] The inverse Mills ratios as an additional exogenous variable are not significant in each regressed model. This implies that the null hypothesis that both the likelihood and the magnitude of commercial success are independent of selection into licensing cannot be rejected throughout. Estimations obtained in the outcome models are quite similar to the corresponding Probit and Tobit models with respect to directions and significance levels.

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[15] We report results of the second stage, i.e. the likelihood and magnitude of commercial success. Results of the first stage, i.e. the likelihood to license, or the likelihood to license to each subgroup (spinoffs, externals) are available upon request.

Table A1: Likelihood of commercialization (Heckman), 1980-2004

Comm = 1	Model A1a (all licensees)		Model A1b (spin-offs)		Model A1c (external licensees)		Model A2a (all licensees)		Model A2b (spin-offs)		Model A2c (external licensees)	
Log distance	0.013	(0.024)	0.029	(0.060)	0.013	(0.036)						
50-100 km							0.428	(0.388)			0.246	(0.407)
100-500 km							0.133	(0.149)	0.600**	(0.291)	-0.109	(0.201)
> 500 km							0.157	(0.165)	-0.129	(0.355)	0.110	(0.217)
Time	-0.036***	(0.009)	-0.084***	(0.025)	-0.028**	(0.012)	-0.037***	(0.010)	-0.084***	(0.024)	-0.031**	(0.012)
Inverse Mills ratio	-0.107	(0.114)	-0.016	(0.249)	-0.191	(0.219)	-0.108	(0.115)	-0.092	(0.245)	-0.157	(0.218)
Biomedical sec.	-0.092	(0.162)	-0.667**	(0.311)	0.047	(0.199)	-0.066	(0.168)	-0.784**	(0.311)	0.113	(0.210)
Patented inv.	-0.566***	(0.125)	-0.675**	(0.311)	-0.584***	(0.145)	-0.570***	(0.127)	-0.723**	(0.312)	-0.568***	(0.145)
Repeat licensee	0.051	(0.139)	-0.770*	(0.436)	0.084	(0.144)	0.037	(0.139)	-0.839**	(0.423)	0.103	(0.147)
Spinoff	-0.259**	(0.132)					-0.219*	(0.133)				
Bundle	0.322**	(0.135)	0.579**	(0.296)	0.320*	(0.172)	0.331**	(0.133)	0.441	(0.278)	0.347**	(0.174)
Top 5 institute	-0.011	(0.121)	0.553**	(0.265)	-0.105	(0.142)	-0.020	(0.123)	0.482*	(0.267)	-0.112	(0.142)
Constant	0.861***	(0.284)	2.561***	(0.902)	0.820**	(0.394)	0.792**	(0.269)	2.682***	(0.902)	0.809**	(0.360)
Sectoral controls	included											
Number of obs. (inventions)	715	(564)	226	(213)	489	(376)	715	(564)	226	(213)	489	(376)
P > chi^2	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	
Pseudo R^2	0.120		0.353		0.080		0.122		0.369		0.084	

Standard errors (clustered by invention) in parentheses; *;**; and *** denote significance at the 0.10; 0.05; and 0.01 levels, respectively.

Table A1: Likelihood of commercialization (Heckman), 1980-2004 (continued)

Comm = 1	Model A3a (all licensees)		Model A3b (spin-offs)		Model A3c (external licensees)	
Log domestic distance	0.071**	(0.036)	0.112*	(0.063)	0.017	(0.057)
Log foreign distance	0.024	(0.025)	-0.144**	(0.071)	0.014	(0.039)
Time	-0.035***	(0.010)	-0.073***	(0.024)	-0.028**	(0.012)
Inverse Mills ratio	-0.134	(0.117)	-0.058	(0.242)	-0.193	(0.222)
Biomedical section	-0.071	(0.163)	-0.701**	(0.311)	0.048	(0.199)
Patented invention	-0.579***	(0.128)	-0.726**	(0.305)	-0.584***	(0.146)
Repeat licensee	0.025	(0.139)	-1.094**	(0.472)	-0.082	(0.145)
Spinoff	-0.208	(0.134)				
Bundle	0.269**	(0.135)	0.442	(0.292)	0.319*	(0.171)
Top 5 institute	-0.020	(0.124)	0.557**	(0.264)	-0.106	(0.143)
Constant	0.691**	(0.295)	2.679***	(0.906)	0.805*	(0.415)
Sectoral controls	included					
Number of obs. (inventions)	715	(564)	226	(213)	489	(376)
$P > chi^2$	0.0000		0.0000		0.0000	
Pseudo R^2	0.125		0.380		0.080	

Standard errors (clustered by invention) in parentheses; *;**; and *** denote significance at the 0.10; 0.05; and 0.01 levels, respectively.

Table A2: Level of royalty income (Heckman), 1980-2004

Log royalty payments	Model A4a (all licensees)		Model A4b (spin-offs)		Model A4c (external licensees)		Model A5a (all licensees)		Model A5b (spin-offs)		Model A5c (external licensees)	
Log distance	0.159	(0.194)	0.236	(0.336)	0.145	(0.282)						
50-100 km							3.362	(2.734)			2.200	(2.890)
100-500 km							0.943	(1.025)	2.750*	(1.485)	-0.715	(1.350)
> 500 km							1.393	(1.255)	-0.723	(2.251)	1.052	(1.567)
Time	-0.309***	(0.069)	-0.455***	(0.115)	-0.290***	(0.096)	-0.313***	(0.071)	-0.44***	(0.113)	-0.315***	(0.096)
Inverse Mills ratio	-0.113	(0.851)	-0.318	(1.495)	0.136	(1.692)	-0.110	(0.863)	-0.539	(1.418)	0.464	(1.675)
Biomedical section	-0.586	(1.169)	-3.856**	(1.895)	0.899	(1.440)	-0.332	(1.206)	-4.147**	(1.821)	1.480	(1.530)
Patented invention	-3.071***	(0.943)	-3.833**	(1.593)	-3.032***	(1.145)	-3.069***	(0.963)	-3.927**	(1.562)	-2.929***	(1.134)
Repeat licensee	0.804	(0.923)	-3.210*	(1.927)	1.189	(0.967)	0.677	(0.932)	-3.418*	(1.877)	1.294	(0.980)
Spinoff	-2.014**	(0.946)					-1.832*	(0.939)				
Bundle	1.770*	(0.994)	2.852*	(1.606)	1.548	(1.240)	1.906**	(0.960)	2.539*	(1.472)	1.828	(1.232)
Top 5 institute	-0.056	(0.895)	2.352	(1.653)	-0.581	(1.039)	-0.102	(0.909)	2.042	(1.642)	-0.618	(1.036)
Constant	6.693***	(2.038)	14.592***	(5.018)	5.258*	(3.135)	6.422***	(1.845)	14.678***	(4.929)	5.261**	(2.675)
Sectoral controls	included											
Number of obs. (inventions)	715	(564)	226	(213)	489	(376)	715	(564)	226	(213)	489	(376)
P > F	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	
Pseudo R^2	0.041		0.140		0.025		0.042		0.144		0.027	

Standard errors (clustered by invention) in parentheses; *;**; and *** denote significance at the 0.10; 0.05; and 0.01 levels, respectively.

Table A2: Level of royalty income (Heckman), 1980-2004 (continued)

Log royalty payments	Model A6a (all licensees)		Model A6b (spin-offs)		Model A6c (external licensees)	
Log domestic distance	0.431*	(0.250)	0.614*	(0.332)	-0.090	(0.386)
Log foreign distance	0.207	(0.192)	-0.724*	(0.422)	0.052	(0.282)
Time	-0.301***	(0.072)	-0.408***	(0.110)	-0.296***	(0.098)
Inverse Mills ratio	-0.274	(0.888)	-0.738	(1.417)	0.273	(1.730)
Biomedical section	-0.494	(1.164)	-3.755**	(1.899)	0.873	(1.433)
Patented invention	-3.072***	(0.963)	-4.110***	(1.569)	-3.050***	(1.129)
Repeat licensee	0.671	(0.923)	-4.206**	(1.788)	1.283	(0.973)
Spinoff	-1.822*	(0.943)				
Bundle	1.519	(0.973)	2.208	(1.507)	1.607	(1.225)
Top 5 institute	-0.090	(0.909)	2.223	(1.590)	-0.542	(1.043)
Constant	5.883***	(2.064)	14.862***	(4.890)	6.054**	(3.073)
Sectoral controls	included					
Number of obs. (inventions)	715	(564)	226	(213)	489	(376)
P > F	0.0000		0.0000		0.0000	
Pseudo R^2	0.042		0.149		0.026	

Standard errors (clustered by invention) in parentheses; *;**; and *** denote significance at the 0.10; 0.05; and 0.01 levels, respectively.