Not Invented Here: Technology Licensing, Knowledge Transfer and Innovation Based on Public Research

Guido Buenstorf and Matthias Geissler

Abstract Using a new dataset encompassing more than 2,200 inventions made by Max Planck Society researchers from 1980 to 2004, we explore the way in which inventor, technology, and licensee characteristics affect the commercialization of academic inventions. We find limited evidence suggesting that domestic and external licensees outperform foreign licensees and inventor spin-offs in the commercialization of academic inventions. Controlling for selection, spin-offs are indistinguishable from external licensees. Patented technologies and inventions by senior scientists are more likely to be licensed, but patent protection is related to lower commercialization odds and royalty payments.

1 Introduction

Throughout the developed world, public attention and policy initiatives increasingly focus on the transfer of knowledge from public research to the private sector. Following the Bayh-Dole Act of 1980 in the U.S. and subsequent legislative changes elsewhere, technology transfer has generally been accepted as a primary objective of universities and other public research organizations (cf. Mowery et al. 2001; Phan and Siegel 2006; Verspagen 2006). Notwithstanding the importance of alternative transfer channels (Cohen et al. 2002), commercialization of scientific results based on patents, licensing, and spin-off entrepreneurship has found particularly intensive policy attention as well as scholarly scrutiny (e.g.,

---

Reprinted from Journal of Evolutionary Economics 22(3), 481–511, Springer (2012).

G. Buenstorf (✉)
Institute of Economics and INCHER-Kassel (International Center for Higher Education Research), University of Kassel, Nora-Platiel-Strasse 5, 34109 Kassel, Germany
e-mail: buenstorf@uni-kassel.de

M. Geissler
Institute of Economics, University of Kassel, Kassel, Germany
e-mail: geissler@uni-kassel.de

G. Buenstorf et al. (eds.), *The Two Sides of Innovation*, Economic Complexity and Evolution, DOI 10.1007/978-3-319-01496-8_5,

Shane 2002; Lowe and Ziedonis 2006; Elfenbein 2007). Yet in spite of the increased emphasis on universities' intellectual property rights (IPRs) and IPR-based commercialization, little is known about the underlying processes of knowledge transfer.

Commercializing academic inventions is non-trivial because they are often far from being readily marketable. Prior work suggests that commercialization is complicated by uncertainty stemming from the early-stage character of most university inventions (Jensen and Thursby 2001), information asymmetry between inventor and potential licensee (Shane 2002), and also the non-codified nature of important elements of the knowledge base underlying the traded technology (Agrawal 2006). We lack conclusive evidence on how the challenges posed by these traits of academic inventions are related to inventor, technology, and licensee characteristics. For example, the relative commercialization performance of inventor spin-offs vis-à-vis external licensees is a contested issue (Shane 2002; Lowe and Ziedonis 2006). Other issues, including the effectiveness of international licensing, are largely unexplored.

Furthermore, prior empirical studies are based on U.S. data. In light of dissimilar academic traditions and substantial institutional differences, it cannot be taken for granted that their results generalize to other, in particular European, countries. We are not aware of any prior work studying the commercialization of academic inventions from Europe at the level of individual inventions. The dearth of empirical evidence is not surprising, given that, historically, European academic inventions were often owned by the inventors themselves (a practice known as the "professors' privilege"). European universities had little to license under these conditions.

In this paper, we begin to close this gap by studying the commercialization of inventions made by researchers at the Max Planck Society, Germany's largest non-university public research organization (PRO) dedicated to basic science. We exploit the fact that, in contrast to German university faculty, but similar to other German PROs such as the Fraunhofer Society, Max Planck scientists have never been covered by the "professors' privilege". Instead, the IPR regime that consistently has governed commercialization activities at the Max Planck Society since the 1970s closely resembles the one established in the U.S. by the Bayh-Dole Act, which has become the global template for dealing with academic inventions. The Max Planck Society, therefore, provides a rare opportunity to study the commercialization of European academic inventions in the now dominant institutional setting.

The dataset on the Max Planck Society's commercialization activities encompasses more than 2,200 inventions and about 700 license agreements providing for royalty payments over the time period 1980–2004. We use this dataset to analyze the way in which licensing and commercialization outcomes are affected by differences across inventors, technologies, and licensees that condition the relevance of information asymmetry and non-codified knowledge. Both the incidence and the level of royalties are utilized as measures of successful commercialization.

The present study aims to make the following specific contributions. First, we study licensing and commercialization outcomes across national boundaries. While less relevant in the U.S. context, licensing to foreign firms is a pertinent issue in the smaller and more open European economies, but has received little prior attention. Second, we also contribute new evidence to the unresolved issue of the effectiveness of inventor spin-offs as commercializers of academic inventions. Third, we analyze effects of technology and inventor characteristics on the outcomes of IPR-based technology transfer. In this context, we focus on the role of patent protection and inventor seniority. Fourth, the empirical analysis accounts for the possibility that non-random selection into licensing by different types of licensees may affect commercialization outcomes.

Our analysis indicates that information asymmetry and the difficulty of transferring non-codified knowledge are relevant in shaping the success of license-based technology transfer from public research, even though they cannot fully explain the empirical patterns. We find limited evidence suggesting that domestic and external licensees outperform foreign licensees and inventor spin-offs in the commercialization of academic inventions. However, these results are sensitive to varying model specifications. They moreover seem to reflect substantial effects of non-random selection into licensee types. Controlling for selection, spin-offs are indistinguishable from external licensees in their commercialization performance. Inventor seniority enhances the chances of technologies to be licensed, as does the presence and scope of patent protection. In contrast, patented inventions are less likely to yield successful commercial products.

The paper is structured as follows. The next section discusses the ways in which information asymmetry and knowledge transfer are relevant for commercialization activities in the empirical context of the Max Planck Society. A set of testable hypotheses is developed from the theoretical considerations. Section 3 introduces the methodology of the empirical analysis, while Section 4 describes data sources and the construction of our empirical measures. Results are presented in Section 5 and discussed in Section 6.

2 Technology Licensing at the Max Planck Society: Supply-Side and Demand-Side Considerations

2.1 The Role of Academic Inventions at the Max Planck Society

Scientists working in public research often make inventions that are suitable to provide the foundations of commercially viable innovations. However, developing products from these inventions and selling them in the marketplace is not part of the scientist's regular job. Instead, substantial "markets for technology" (Arora and Gambardella 2010) have developed for academic inventions. In these markets, licenses on academic inventions are sold to private-sector firms.

Since in most countries intellectual property rights in academic inventions are allocated to the inventors' employers (Lissoni et al. 2008), academic inventions are marketed by employers rather than inventors. To this purpose, most universities and PROs have set up dedicated entities known as technology licensing offices (TLOs). It is the representatives of these offices who actually operate in the markets for technologies. Inventors are nonetheless key players in the licensed-based commercialization of academic inventions. To assess their relevance in the present empirical context, a closer look at the organizational structure of the Max Planck Society is required.

The Max Planck Society is Germany's largest non-university PRO dedicated to basic research. At the end of the analyzed time period, it received almost 80 per cent of its budget from public, institutional funding (Max Planck Society 2008). The Max Planck Society's mission is to complement the German university system by taking up large-scale, interdisciplinary, or particularly innovative activities that are out of reach for individual universities or do not fit their organizational structure. To this purpose, the Max Planck Society operates about 80 individual institutes that are dispersed all over the country (plus three institutes located abroad) and cover a wide spectrum of research. Institutes are organized into three sections: the biomedical section; the chemistry, physics and technology section; and the humanities and social sciences section. Given its traditional orientation toward basic research, several patent-intensive fields of research, notably in engineering, are less important for the Max Planck Society than they are for universities and also for its more applied counterpart, the Fraunhofer Society.

In 2007, the Max Planck Institutes employed some 4,700 researchers (Max Planck Society 2008). While salaries are not much different from those paid at German universities, Max Planck researchers have no teaching obligations, and the availability of resources and equipment is generally better than in universities. In turn, Max Planck researchers are expected to attain academic excellence and to be international leaders in their fields. The performance of individual institutes is assessed by advisory bodies, and underachieving institutes can be restructured or even shut down. Individual-level performance is indicated by publications and their impact. Patent output is not generally used as a performance measure.[1] Likewise, given the relatively generous institutional funding enjoyed by the Max Planck Society, input-based performance measures (e.g., the amount of third-party funding attracted by researchers) are less relevant in the assessment of individual achievement than at other institutions. Again, in this regard, the Max Planck Society differs substantially from German universities and the Fraunhofer Society.

The internal organization of the Max Planck Society is unique. At the top of its scientific hierarchy are so-called Max Planck directors who enjoy particularly autonomous and powerful positions. New directors are recruited among the most successful researchers of domestic and foreign universities. The Max Planck Society currently has close to 300 active directors.

---

[1] Patents may have an indirect effect on the assessment of individual performance in fields where the scientific community values patents (Owen-Smith and Powell 2001). Prior research indicates that, in some cases, Max Planck researchers pursue patenting activities primarily to enhance their standing in the respective communities.

The Max Planck Society officially characterizes knowledge transfer through technology licensing as part of its objective to make research results socially relevant (Max Planck Society 2002). Just as the employees of private-sector firms, employees of the Max Planck Society are subject to the law on employee inventions ("*Arbeitnehmererfindungsgesetz*") requiring employees to disclose all inventions to their employer, and assigning the property rights in these inventions to the employer.[2] In case of successful commercialization of an invention, the inventor receives 30 per cent of all revenues from licenses and patent sales.

Max Planck Innovation GmbH, a legally independent subsidiary, is in charge of all activities related to academic inventions, patenting, and licensing. Max Planck Innovation was organized in 1970, originally under the name Garching Innovation. For the past three decades it has consistently focused on patenting and licensing activities.[3] Disclosure of inventions is actively solicited at the individual institutes. Patents are applied for if the invention is patentable and considered sufficiently promising, even if no licensee for the technology has been identified yet.[4] Technologies are marketed to both domestic and foreign firms. Systematic support and counseling of spin-off activities was taken up in the early 1990s, and spin-off numbers have strongly increased since then. At the end of the analyzed time period, overall licensing income contributed about one per cent to the Max Planck Society's annual budget (Max Planck Society 2008).

2.2 The Supply of Academic Inventions: Incentives of Researchers and the Max Planck Society

As noted above, the Max Planck Society's mission in the German academic system is to pursue excellence in basic research. This focus has repercussions on the incentives that Max Planck researchers have for making inventions: inventions are not directly relevant for the assessment of their research performance, and may even harm their career chances if they compromise the researchers' "traditional" output in terms of publications. Given these incentives, two characteristics help explain the large number of academic inventions at the Max Planck Society. First, scientists frequently make inventions as joint products of their research activities. (Think of instrumentation or lab equipment first used for the researcher's own use.) Second, in the use-inspired fields of basic research known as "Pasteur's Quadrant" (Stokes 1997), results can regularly be published in a scientific journal *and* be

---

[2] Before the "professors' privilege" was abolished in 2002, the IPR regime in place at the Max Planck Society differed from that of German universities. University researchers used to be exempt from the law on employee inventions. They retained the intellectual property in their inventions (cf. Von Proff et al. 2012).

[3] Following failed attempts at constructing and marketing prototypes, in-house commercialization of Max Planck inventions was given up in the 1970s and was never taken up again.

[4] In this regard, Max Planck Innovation's patenting policy thus appears to be closer to that of MIT than that of the UC system (cf. Shane 2002; Lowe and Ziedonis 2006).

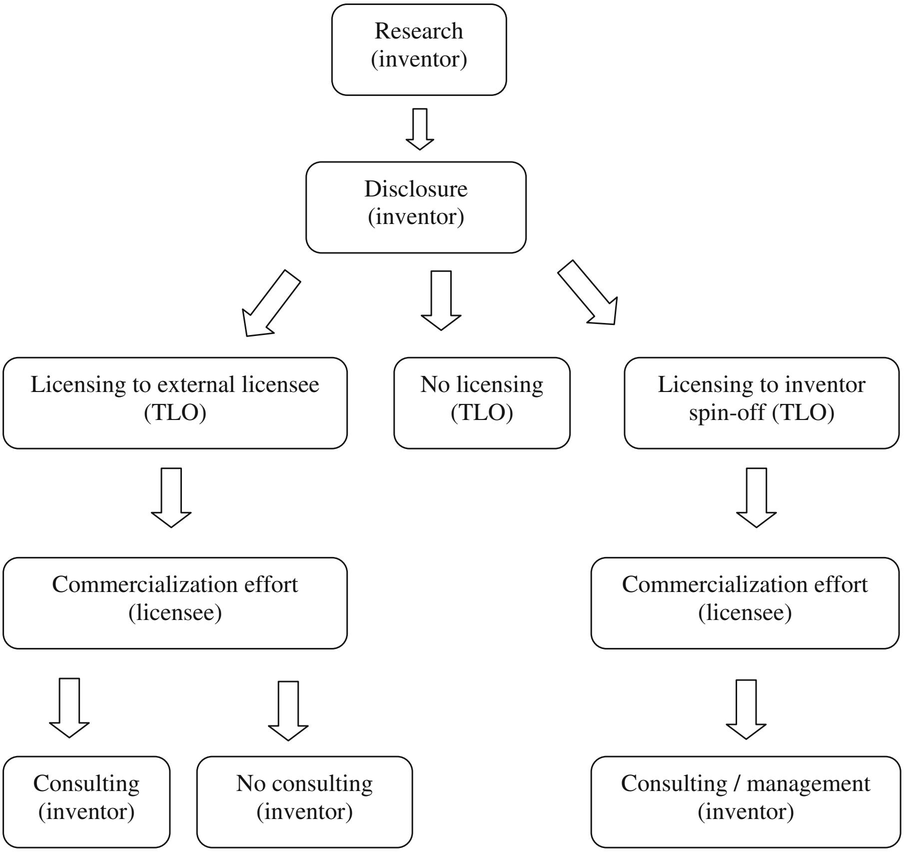

Fig. 1 Commercialization of academic inventions

applied commercially. For example, "patent-paper pairs" related to the same findings are widespread in the life sciences (Murray and Stern 2007).

The process leading from academic research to the successful commercialization of an invention is sketched in Fig. 1. Once an academic invention has been made by Max Planck researchers, it has to be disclosed to the Max Planck Society and becomes its intellectual property. As the Max Planck Society's agent, Max Planck Innovation then tries to license the invention, which at this time is frequently at an early stage of development. Prior research at U.S. universities has found that when inventions are marketed to potential licensees, the technology has often not advanced beyond the proof-of-concept or prototype stage (Jensen and Thursby 2001). Licensees accordingly need to engage in substantial further development efforts to obtain a marketable product.

Upon disclosure, an academic inventor has several options as to how to pursue the invention further. One possibility for the inventor is to focus on his (or her) academic research activities and to refrain from any further development of the invention. In this case, the fate of the invention entirely rests with Max Planck Innovation, which will try to find an external licensee for the (patented or unpatented) technology, often leveraging pre-established contacts to domestic or foreign firms. This may or may not be successful. For the Max Planck Society, successful licensing of technologies is attractive as a source of additional funding, and such licensing can be used to signal the societal relevance of its research activities to policy makers and the broader public. For Max Planck Innovation, successful licensing of inventions is attractive to signal its relevance to the Max Planck Society.

The inventor's second option is to become involved in the further development of the invention. If and when the invention is successfully licensed to an external licensee, he may choose to support the licensee's development efforts as a consultant. Such continued involvement of the academic inventor is often crucial for the successful commercialization of the invention, as it allows the licensee to draw on the inventor's non-codified knowledge (Agrawal 2006). On the downside, the inventor needs to allocate time to these consulting activities, which may have adverse effects on his research performance. In other words, continued involvement in the development of disclosed and licensed inventions comes with opportunity costs for the academic inventor. These opportunity costs will be the higher, the more complicated the interaction with the external licensee, and also the more valuable the research time of the inventor.

The third option available to the academic inventor is to pursue the commercialization of the technology himself by establishing a spin-off enterprise. Since the invention is owned by the Max Planck Society, the spin-off is required to license it back. The Max Planck Society supports spin-off activities of its researchers in various ways (Max Planck Society 2001) including cooperation agreements, access to the Society's infrastructure, and through assuming ownership positions in some of the new firms (substituting for upfront license payments). Ongoing involvement of researchers in the spin-off firms is allowed based on explicit consulting agreements. However, researchers may not assume management positions at the spin-off firm while maintaining their positions at the Max Planck Society (Max Planck Society 2002). An oft-observed pattern is that, within teams of academic inventors, the more senior partners (e.g., Max Planck directors) remain active researchers, while younger co-inventors (post-docs or doctoral students) join the spin-off management.

2.3 Adverse Selection and the Demand for Inventions from the Max Planck Society

The demand for inventions from the Max Planck Society ultimately depends on the ability of a potential licensee to make money from an obtained license. Whether or not a potential licensee expects a licensing agreement to be profitable hinges on a variety of factors. Three factors seem particularly pertinent: the ability to overcome information asymmetries in the negotiation of licensing agreements, successful knowledge transfer after a licensing deal has been made, and the command over sufficient capabilities and complementary assets actually to develop the technology further and to market it profitably. The first factor relates to the licensing stage of the technology transfer process and is discussed in the present subsection. The remaining two factors condition successful commercialization of licensed technologies and are the focus of the next subsection.

Technology markets tend to be thin; typically at best a few potential licensees exist for a particular technology, and licensing is based on small-numbers bargaining. Problems of asymmetric information are pervasive in these markets (Gallini and Wright 1990; Arora and Gambardella 2010) because, as opposed to technologies developed in-house, potential licensees of academic inventions lack in-depth knowledge of the underlying research. This limits their ability to assess the commercialization prospects of the invention, leading to problems of adverse selection.

Information asymmetry is minimized if a technology is licensed to a spin-off organized by its inventor(s). As regards external licensees, information asymmetries are expected to be more pronounced in licensing negotiations across national boundaries. Information is harder to obtain for foreign licensees, particularly if they do not come from countries speaking the same language. In addition, the design and enforcement of contracts is more difficult internationally.

The likelihood that a licensing agreement can be concluded with external licensees is enhanced by patents, which provide inventors with (imperfect) protection against being exploited by potential licensees. This enables Max Planck Innovation to disclose the invention more fully to potential licensees, thus mitigating the problem of adverse selection. Patents moreover signal that the invented technology conforms to an established standard of novelty, usefulness, and non-obviousness. The value of this signal is expected to be higher when information asymmetry is more pronounced. In addition, patents enhance the strategic value of a technology in blocking competitors' market access or in negotiating access to complementary technologies (Hall and Ziedonis 2001).

These arguments suggest that patents facilitate the licensing of academic inventions. They suggest that patents are more important in licensing technologies to foreign firms and external licensees. Based on similar considerations, Shane (2002) has suggested that spin-off licensing is a solution of last resort when attempts to find an external licensee have failed. Spin-off licensing would then be expected particularly when IPR protection is weak. However, patents are relevant as signals not only for potential licensees, but also for other transaction partners such as providers of external financing (Levin et al. 1987). This is particularly pertinent in the case of spin-offs, for which a substantial IPR base may be crucial to attract venture capital (Shane and Stuart 2002; Eckhardt et al. 2006). From this perspective, spin-off licensing may be even more dependent on the presence of patents related to an invention than licensing to external licensees. This is reflected in our predictions:

Hypothesis 1a: The likelihood that an invention is successfully licensed is enhanced by the presence and scope of patents related to the invention.

Hypothesis 1b: Patents have a stronger effect on the likelihood of licensing to a foreign firm than on the likelihood of licensing to a domestic firm.

Hypothesis 1c: Patents have a stronger effect on the likelihood of licensing to an inventor spin-off than on the likelihood of licensing to an external licensee.

Inventor reputation is another factor that helps overcome problems stemming from asymmetric information (Shane and Stuart 2002; Mora-Valentin et al. 2004). In this context, we expect that inventor seniority affects the likelihood of successful licensing negotiation as well as the probable type of licensee. Substantial prior empirical research finds positive correlations between inventive output and the quantity and quality of research output at the level of individual academic inventors (e.g., Azoulay et al. 2009; Breschi et al. 2008; Buenstorf 2009). Seniority, therefore, signals invention quality to potential licensees, which should increase their willingness to enter into a contractual agreement. In addition, inventor seniority enhances the visibility of academic inventions, which may further increase the likelihood of a successful licensing deal (Elfenbein 2007). Finally, if negotiations are mediated by a technology licensing office (as is the case in our empirical sample), it is likely that senior scientists have more influence on their employer institution than more junior ones. This is expected to increase further the chances that a licensing agreement is concluded.

As with patents, the value of the signal provided by seniority should be highest when information asymmetry is most pronounced, i.e. in the cases of foreign and external licensees. Again, we expect seniority to be relevant not only for finding external licensees, but even more so for securing finance (as well as other kinds of necessary resources such as first-round employees) in spin-off entrepreneurship. We accordingly conjecture:

Hypothesis 2a: Technologies (co-) invented by senior scientists are more likely to be licensed than those by more junior researchers.

Hypothesis 2b: (Co-) invention by senior scientists has a stronger effect on the likelihood of licensing to a foreign firm than on the likelihood of licensing to a domestic firm.

Hypothesis 2c: (Co-) invention by senior scientists has a stronger effect on the likelihood of licensing to an inventor spin-off than on the likelihood of licensing to an external licensee.

2.4 Knowledge Transfer, Capabilities, and the Commercialization of Max Planck Inventions

Adverse selection arises as a problem in negotiating licensing agreements because both parties have incentives to withhold information. In principle, asymmetric information may also give rise to moral hazard after a licensing agreement has been made, but this problem may be solved by contractual provisions in the licensing agreement (Jensen and Thursby 2001; Lowe 2006). If an agreement providing for sales-based royalties is entered into, inventors have an interest in successful commercialization. By contrast, even if both parties faithfully try to share their knowledge, substantial obstacles in communicating this knowledge typically have to be overcome after a licensing agreement has been reached. These obstacles derive from the nature of the relevant knowledge, which tends to be complex and imperfectly codified.

Agrawal (2006) argues that academic inventions often draw on multiple fields of knowledge. Potential licensees are unlikely to have prior knowledge in all these fields. Accordingly, their absorptive capacities (Cohen and Levinthal 1990) may be insufficient to understand fully information related to the invention, even if the inventor and/or the TLO disclose all their knowledge. In addition, relevant elements of that knowledge may be non-codified (even if they would in principle be codifiable), in which case they can be characterized as “latent” (Agrawal 2006). For example, knowledge that the inventor gained from failed and therefore unreported experiments is not normally accessible to an external licensee.

We expect that knowledge transfer between licensor (the academic inventor represented by his employer’s TLO) and licensee is the more difficult the larger the “cognitive distance” (Nooteboom 1999) between both parties. “Cognitive distance” is not observable. However, in our sample, we expect cognitive distance to be larger for foreign licensees because language barriers and geographic distance complicate communication and post-agreement inventor involvement. Traveling is more costly in terms of time and money, and the transfer of non-codified knowledge (which presupposes frequent face-to-face interaction) is possibly less effective if national boundaries have to be crossed. We therefore predict the following:

Hypothesis 3: Inventions licensed to foreign firms are less likely to be commercialized successfully than inventions licensed to domestic firms.

As compared to external licensees, commercialization activities by inventor spin-offs are expected to benefit from facilitated transfer of non-codified knowledge, as spin-offs are more intimately familiar with the scientific background of the licensed invention. However, additional factors are likely to affect commercialization outcomes. Firms differ in their dynamic capabilities of integrating new technologies, which derive from the firms’ prior activities and competences (Teece et al. 1997). In the present empirical context, we expect substantial differences in the kind and richness of capabilities possessed by external licensees, which are typically established firms active in a variety of markets related to the licensed technology, relative to inventor spin-offs that tend to be younger and smaller.

In addition, external licensees may be more likely to command substantial under-utilized complementary assets enabling them to benefit from innovation (Teece 1986). Shane (2002) stipulates that spin-offs are inferior in commercialization because they lack the required complementary assets. However, for their sample of licensed inventions from the University of California system, Lowe and Ziedonis (2006) find neither lower commercialization odds nor lower licensing income for spin-off licensees. This indicates that Shane's argument may be of secondary importance.

Finally, differences in the motivations of the different types of licensees may also affect observable commercialization outcomes. Given a smaller product portfolio, spin-off survival is typically more dependent on specific technologies than survival of established firms. Spin-offs consequently face stronger incentives for successful commercialization (Lowe and Ziedonis 2006). If spin-offs are cash-constrained, they should be less prone than established firms to license inventions for primarily strategic reasons, i.e. to block competitors from the access to the underlying technology or to enhance their negotiation position in contexts of "patent thickets" (Shapiro 2000; Hall and Ziedonis 2001). This would add to the likelihood that successful commercialization is observed in cases of spin-off licensing.

These considerations and the available prior evidence do not suggest a clear-cut ranking in the commercialization odds of external licensees and spin-offs. We therefore predict the following:

Hypothesis 4: Inventions licensed to inventor spin-offs do not differ significantly from inventions licensed to external licensees in their likelihood to be commercialized successfully.

Turning to technology characteristics, the relationship between patent protection and commercialization of academic inventions is likewise not immediately obvious. On the one hand, writing a patent application forces inventors to codify substantial parts of the knowledge underlying their inventions. This would be expected to help subsequent licensees turn the invention into a commercially successful product. At the same time, the above considerations regarding strategic licensing suggest that patented technologies may be less likely to be commercialized. Based on the assumption that the challenges of knowledge transfer are more relevant for the commercialization of academic inventions than purely strategic licensing, we predict the following:

Hypothesis 5: The presence and quality of patent protection related to an invention is positively related to its likelihood of commercialization.

Finally, successful commercialization of academic inventions may also depend on the seniority of the inventor(s). As with patents, two counteracting effects of inventor seniority on the commercialization odds of academic inventions seem plausible. On the one hand, as was argued above, prior research indicates that more successful researchers may also have inherently superior inventions. Inventor seniority would then be expected to be related to higher commercialization odds and higher royalty income. On the other hand, the more senior an inventor is, the higher are his opportunity costs of post-agreement involvement in the licensee's development efforts. *Ceteris paribus*, senior scientists are therefore expected to spend less time on developing their inventions, which will lower the likelihood of successful commercialization. In general, we expect the quality effect of seniority to outweigh the opportunity cost effect. This assumption informs our final hypothesis:

Hypothesis 6: Technologies (co-) invented by senior scientists are more likely to be commercialized than inventions made by more junior scientists.

3 Econometric Approach

We empirically analyze licensing and commercialization outcomes for the population of inventions disclosed by Max Planck researchers in the time period from 1980 to 2004. As detailed above, commercialization of academic inventions is a sequential process. In the first stage of licensing, we can construct outcome variables indicating the conclusion of a licensing agreement (or lack thereof) for each invention in the dataset. In the second stage, only the subset of licensed inventions is at risk of experiencing a successful commercialization outcome. Following the earlier work on U.S. academic inventions (Shane 2002; Agrawal 2006; Lowe and Ziedonis 2006), we measure successful commercialization by the incidence and level of sales-dependent royalty payments.

3.1 Likelihood of Licensing

Multinomial logit models are employed to analyze the likelihood that a given invention was licensed to a specific type of licensee. We estimate two sets of models, with the alternative outcomes being, respectively, licensing to a domestic versus foreign licensee, or licensing to an external licensee versus an inventor spin-off. No licensing is the reference outcome in both sets of models. A number of inventions were non-exclusively licensed or consecutively licensed to firms falling in both outcome categories (i.e, domestic *and* foreign; external *and* spin-off licensee). In these cases, we concentrate our attention on the first licensing agreement concluded for the respective invention. Right censoring issues are minimized by only analyzing inventions for which at least three years of licensing information is available and including measures of disclosure years in the analysis. (Academic inventions are mostly licensed in the first years after their invention.)

An endogeneity concern exists to the extent that potential licensees have been involved in the research leading to the invention. In our empirical context, this is the case for inventions based on collaborative research with industry partners constituting potential licensees. Problems of knowledge transfer should be less pronounced for these inventions. In addition, it could be true that an industry partner withdraws from cooperation even before an invention is arrived at because its assessment of the research is low. This should increase the average quality and thus the licensing odds of inventions based on collaborative research. However, as pointed out by Lowe (2002), the positive effect of collaborative research on the likelihood of licensing might be mitigated if, in the process of collaboration, industry partners acquired sufficient knowledge of the invention to render subsequent licensing unnecessary (or undesirable). Based on the available data, we cannot assess the importance of these concerns, but we can control for the fact that an invention is based on collaborative research in our empirical analysis.

3.2 Likelihood of Commercialization

Commercialization of licensed inventions is studied in three steps. First, we estimate a set of simple logit models with commercialization as the dependent variable, using the set of all licensing agreements as our sample, and estimating standard errors clustered by invention to account for multiple licensing of the same invention. As noted above, commercialization is defined as the existence of positive royalty payments. Obviously, this restricts the analysis to the subset of licensing agreements that provide for sales-dependent royalties. Second, we also analyze the commercial success of licensed inventions using the amount of royalties as the dependent variable. Royalties are censored at zero, which is taken into consideration by estimating Tobit models.

A shortcoming of both approaches is that they do not account for selection effects: Inventions licensed to different kinds of licensees may differ in their characteristics, and these differences may affect their subsequent commercialization odds. For example, it could be true that spin-off licensing is turned to when external licensees cannot be found, and that spin-offs therefore tend to license inferior inventions. Our analysis of licensing indicates that there are indeed substantial differences between the technologies licensed to different kinds of firms, which suggests that selection into the different kinds of licensing contracts (domestic versus foreign, spin-off versus external) is not random.

To test whether commercialization outcomes of different types of licensees are due to differences in observables affecting selection into licensee types, we interpret licensing to distinct types as treatments, and estimate how being treated affected the commercialization likelihood using propensity score matching. Specifically, two propensity score matching estimators are employed: in the first one, the treatment consists in being licensed to a foreign licensee. In the second one, licensing to a spin-off constitutes the treatment.

The intuition underlying propensity score matching is as follows (Rosenbloom and Rubin 1983, Heckman et al. 1998, cf. also Sianesi 2001, Wooldridge 2002, ch. 18). In non-experimental data, for each observation, only one outcome (here: commercialization success) is observed. If Y_{i0} denotes observation i's outcome without treatment, Y_{i1} denotes observation i's outcome with treatment, and $T \in \{0, 1\}$ denotes treatment, we would like to know the treatment effect $Y_{i1} - Y_{i0}$, but can only observe one of the two outcomes. If selection into treatment is nonrandom, the effect of treatment on the outcome cannot be separated from the selection effect in the data.

Propensity score matching uses the available information on individual observations to generate a counterfactual control group from the untreated observations, such that differences in observable characteristics are minimized between the treated observations and the members of the control group. The basic approach is to calculate the probability of receiving treatment for each observation based on its observable characteristics, using probit or logit models. This conditional probability is the propensity score, which is then used for matching the treated observations to similar non-treated ones. Under the (untestable) assumption that selection into treatment only depends on observables, the average effect of treatment can then be estimated at the population level. Specifically, both the *average treatment effect* (ATE), $E(Y_{i1} - Y_{i0})$, and the *average treatment effect on the treated* (ATT), $E(Y_{i1} - Y_{i0} \mid T = 1)$, can be estimated.

Various propensity score-based matching methods have been proposed. When large samples of non-treated observations are available, each treated observation can be matched to an "identical twin," i.e. a non-treated observation that is very similar in its propensity score, and the outcomes of both observations are then compared. Alternatively, each treated observation can be matched to a weighted average of untreated observations, where the weights are determined by how similar the propensity scores of the untreated observations are to that of the treated one. The latter approach is adopted below. We report results obtained by estimating propensity scores with logit models, using a Gaussian kernel for matching, where the weights of the untreated observations follow a normal distribution around the propensity score of the respective treated one. The estimations were performed using the *psmatch2* routine for Stata 9.0 (Leuven and Sianesi 2003).

4 Data

4.1 Inventions

This study is based on two sets of data made available by Max Planck Innovation. The first dataset contains all inventions disclosed by Max Planck researchers[5] from the early 1970s to 2004.[6] In total, it encompasses 3,012 inventions. Of these, 1,885

---

[5] Researchers employed on a scholarship basis, mostly Ph.D. students and international postdocs, are not subject to the German law on employee inventions (*Arbeitnehmererfindungsgesetz*). To the extent that these individuals made inventions without other Max Planck researchers being involved, they do not show up in the data.

[6] Our invention data end in February 2005 and include six inventions disclosed early in 2005. In the subsequent analysis, these are merged into the group of 2004 inventions.

Table 1 Inventions disclosed by Max Planck researchers between 1980 and 2004 and resulting licensing agreements

	Inventions		Licenses providing for royalties	
	All	Patented[a]	All	Patented[a]
Inventions	2,270	1,432 (1,387)		
Licensed (at least once)	744	536 (531)	717	503 (499)
Not licensed	1,526	896 (856)		
Commercialized			358	214 (211)
Licensed to domestic firms[b]	553	402 (398)	487	349 (346)
Licensed to foreign firms[b]	191	134 (133)	230	154 (153)
Licensed to external firms[b]	518	344 (342)	490	313 (311)
Licensed to spin-offs[b]	226	192 (189)	227	190 (188)

[a] Numbers for analyzed "patented-only" subsamples in parentheses

[b] In the invention dataset these refer to the type and region of the first licensee

resulted in at least one patent application.[7] The database includes the title of the invention, names and institute affiliations of its inventors, day of disclosure and (if eligible) patent application, as well as information regarding further use of the invention.

We restrict our empirical analysis to the 2,392 inventions disclosed in or after 1980. Earlier inventions are excluded for three reasons. First, the earliest entries in the inventions dataset are not consistently inventions by Max Planck researchers, since, at the time, Garching Innovation (the predecessor of Max Planck Innovation) was offering its services to a variety of other PROs and even some commercial firms, whose inventions then show up in our data. Second, the quality of the earliest data was below that related to later inventions. Third, Max Planck Innovation's commercialization strategy changed very little after a leadership change in 1979.

Another 122 inventions out of the 2,392 had to be dropped because essential data for our analysis was missing (24 cases) or the invention was not made at a Max Planck Institute (98 cases).[8] Accordingly, the final dataset used in the empirical analysis contains 2,270 inventions (cf. Table 1). Out of the 1,432 patented inventions in the final dataset, relevant data for the construction of variables in the analyses on "patented-only" subsample could not be obtained in some cases, which reduces the subsample to 1,387 inventions.

---

[7] In 141 cases, no patent information was found even though the inventions database identified them as patented. We suspect that most of these cases reflect cancelled applications. They are treated as not being patented in the subsequent analysis.

[8] This includes inventions coming out of temporary research groups and also, in a few cases, out of the Max Planck Society's central administration.

4.2 Licensing Agreements and Outcomes

We matched the inventions dataset with a second dataset assembled from Max Planck Innovation's licensing agreements. Our data on licensing agreements extend almost three years beyond the last disclosure date. In this way, right censoring issues for later inventions are minimized. In total 744 inventions in the dataset (536 patented inventions) have been subject to at least one licensing agreement. For each agreement, information is available about licensee name and address, the dates when the agreement was concluded and (possibly) terminated, contractual arrangements regarding fixed fees and royalties, as well as actual dates and amounts of payments as of 2007.

Two factors complicate the analysis of the licensing agreements: First, non-exclusive contracts may lead to multiple licensees for a single invention. Second, a number of licensing agreements cover multiple inventions. Because we are interested in the commercial potential of individual inventions (and use invention-specific control variables), we analyze all inventions covered by such "bundled" licenses separately and add an indicator variable denoting them in the empirical models. Payments from these agreements (if any) were split equally between the involved inventions. We thus deal with 1,014 invention-license pairs.

The presence of positive royalty payments is used as an indicator of successful commercialization. As noted above, commercialization outcomes can only be identified if licensing agreements provide for sales-dependent royalty payments. This is true for 717 invention-license pairs, 358 of which indeed yielded positive royalties (cf. Table 1). These numbers are comparable to U.S. institutions studied before. For example, Lowe and Ziedonis (2006) study 734 licensing deals closed by the UC system between 1981 and 1999, of which 188 led to positive royalty payments. We are also interested in the levels of returns from licenses. From the Max Planck Innovation files we identified annual royalty streams until 2007 for all contracts. As royalties are extremely skewed, we use the log of cumulative royalty payments in the empirical analysis.

4.3 Explanatory Variables and Controls

A central interest of the empirical analysis relates to the relative commercialization performance of different types of licensees. To study effects of international licensing, licensees were classified into domestic versus foreign according to the postal address given in the licensing agreements. Accordingly, German subsidiaries of foreign companies are classified as German licensees. This is in line with our primary interest in potential difficulties arising from information asymmetries and the transfer of non-codified knowledge, which we expect to depend more on the licensee's physical location than on whether or not the licensee is foreign-owned. Out of the 744 inventions that got licensed, 191 were licensed to a foreign firm.

Spin-offs among the licensees were identified on the basis of Max Planck Innovation's spin-off database. Here, 226 cases can be observed as opposed to 518 cases of licensing to an external licensee.

Information about patents related to the inventions in the dataset was obtained through a patent family search in *Depatisnet*, the publicly available patent search site of the German Patent Office (DPMA), using the patent applications listed in the Max Planck Innovation invention database as our point of departure. A simple indicator variable was first constructed that denotes inventions related to patent applications. In addition, within the subset of patented inventions we use the size of the patent family to account for differences in patent quality. Family size indicates the geographical scope of the IPR protection sought by the patent application and is widely accepted as a measure of patent quality (Harhoff et al. 2003). We employ a dummy variable indicating "triadic" patent families, including at least one application each at the European Patent Office and its Japanese and U.S. counterparts. We also experimented with the number of IPC classes and granted patents in the family as quality indicators, but they were less predictive. Finally, patent information is used to identify collaborative inventions. We define as collaborative all inventions that were not exclusively assigned to the Max Planck Society (i.e., those assigned either to the Max Planck Society and a private-sector firm or exclusively assigned to a private-sector firm).[9]

Senior scientist involvement in inventions is measured by the presence of one or (in rare cases) several Max Planck directors in the list of inventors. This is justified by the distinctive position directors have in the Max Planck hierarchy. We identified the directors using published sources (Henning and Ullmann 1998; Max Planck Society 2000) and information provided by the Max Planck Society's human resource department.

We control for discipline-specific factors with a dummy variable denoting inventions from the biomedical section, which accounts for 61% of all disclosed inventions. Controls are also included for inventions from the top five institutes in terms of the number of disclosed inventions. They include four institutes from the biomedical section and between them account for 42% of all disclosed inventions (45% of all licensed inventions). To capture time effects, we employ dummies denoting the year of invention disclosure.

Section and institute controls are the best indicator of the research field underlying an invention that we can develop for the full dataset including non-patented inventions. Table 2 provides more details on the composition of disclosure and licensing activities by sections and institutes. The table also distinguishes between patented and non-patented inventions. Inventions from the biomedical section

---

[9] Patent ownership is a restrictive measure of collaborative invention (Fontana and Geuna 2009), which is reflected by the comparatively small number of collaborative inventions we thus identified. We alternatively considered using information about collaboration from the Max Planck Innovation invention database. However, since the database is updated regularly and we do not have information about when the collaboration information was entered, we did not use it in the analysis based on endogeneity concerns.

Table 2 Descriptive statistics on license involvement by discipline, 1980–2004

	Not patented		Patented		
	Licensed	Not licensed	Licensed	Not licensed	Sum
Biomed section	148 (10.77%)	366 (26.64%)	403 (29.33%)	457 (33.26%)	1,374
- Top institute 1	36 (12.50%)	68 (23.61%)	85 (29.51%)	99 (34.38%)	288
- Top institute 2	20 (8.13%)	65 (26.42%)	80 (32.52%)	81 (32.93%)	246
- Top institute 4	14 (11.48%)	37 (30.33%)	35 (28.69%)	36 (29.51%)	122
- Top institute 5	10 (8.62%)	35 (30.17%)	37 (31.90%)	34 (29.31%)	116
- Other biomed section	68 (11.30%)	161 (26.74%)	166 (27.57%)	207 (34.39%)	602
Chem.-Phys.-Tech. Sec.	60 (6.70%)	264 (29.46%)	133 (14.84%)	439 (49.00%)	896
- Top institute 3	7 (3.70%)	61 (32.28%)	11 (5.82%)	110 (58.20%)	189
- Other CPT section	53 (7.50%)	203 (28.71%)	122 (17.26%)	329 (46.53%)	707
Overall	208 (9.16%)	630 (27.75%)	536 (23.61%)	896 (39.47%)	2,270

generally have a higher likelihood of being licensed. This holds both for patented and non-patented inventions, with the latter being less likely to be licensed throughout. Differences between the individual leading institutes within the biomedical section are less pronounced. The share of patented inventions is similar between both sections (62% in the medical section versus 64% in the chemistry, physics and technology section).

In the analysis of commercialization outcomes, we control for different experience of licensees by introducing an indicator for "serial" licensees showing up multiple times in our agreement dataset. Bundles of licensed inventions covered by individual contracts (cf. the above discussion) are also controlled for. Finally, four sectoral dummies denoting the broad area of activity of a licensee are included in the analyses of commercialization and royalty payments. These are based on NACE and SIC codes derived from the *LexisNexis* and *Hoppenstedt* firm databases as well as web searches. The dummies cover, respectively, manufacturing (SIC 20–39), wholesale/trade (SIC 50–51), services (SIC 70–89) and a catch-all variable including other industries, as well as licensees whose area of activity could not be reliably determined.

Descriptive statistics and correlations between the independent variables are shown in Tables 3, 4 and 5.

5 Results

5.1 Likelihood of Licensing

As detailed in the previous section, in terms of absolute numbers we observe more licensing to domestic firms (553 inventions) than licensing to foreign firms (191), and also more licensing to external licensees (518) than licensing to spin-offs (226). In this section, we employ two sets of multinomial logits to investigate the way in which the likelihood of being licensed by the different types of firms relates to

Table 3 Descriptive statistics

	All inventions (2,270 obs.)			Patented inventions (1,387 obs.)			Royalty contracts (all inventions, 717 obs.)			Royalty contracts (patented inventions, 499 obs.)		
	(mean)	(min)	(max)	(mean)	(min)	(max)	(mean)	(min)	(max)	(mean)	(min)	(max)
Director-inventor	.135	0	1	.180	0	1	.389	0	1	.437	0	1
Biomedical section	.605	0	1	.593	0	1	.778	0	1	.800	0	1
Patent application	.631	0	1	–	–	–	.702	0	1	–	–	–
Patent family size	–	–	–	5.416	1	120	9.062	1	74	9.062	1	74
Triadic family	–	–	–	.248	0	1	.383	0	1	.383	0	1
Collaborative invention	–	–	–	.208	0	1	.146	0	1	.146	0	1
Commercialization							.499	0	1	.423	0	1
Ln variable payments							4.761	0	19.109	4.152	0	19.109
Foreign licensee							.321	0	1	.307	0	1
Spin-off licensee							.317	0	1	.377	0	1
Bundle							.290	0	1	.363	0	1
Serial licensee							.760	0	1	.820	0	1

Table 4 Correlations between covariates I: likelihood of licensing (for patented inventions in parentheses)

2,270 obs. (1,387 obs.)	Biomed	Director-inventor	Patent	Patent family	Triadic family	Industry cooperation
Biomed	1.000 (1.000)					
Director-inventor	.168 (.201)	1.000 (1.000)				
Patent	− .013 (—)	.160 (—)	1.000 (—)			
Patent family	— (.148)	— (.218)	— (—)	— (1.000)		
Triadic family	— (−.036)	— (.138)	— (—)	— (.447)	— (1.000)	
Industry cooperation	— (−.121)	— (−.028)	— (—)	— (.112)	— (.194)	— (1.000)

observable characteristics of the respective inventions. Models 1–3 in Table 6 distinguish domestic from foreign licensees, whereas the corresponding Models 4–6 in Table 7 analyze licensing to inventor spin-offs versus external licensees. In both cases, we run models without (Models 1 and 4) and with (Models 2 and 5) controls for the top five institutes in terms of disclosed inventions, and also one model each (Models 3 and 6) with additional controls for invention quality. As they are based on patent information, these latter models are restricted to the subset of inventions related to patent applications.

We find that patented inventions are more likely to be licensed to either type of licensee. The estimated coefficient of the patent indicator is significant for domestic, respectively spin-off, licensees.[10] Among the patented inventions analyzed in Models 3 and 6, patent family size enhances the likelihood of licensing for all licensee types, consistent with Hypothesis 1a. Counter to Hypothesis 1b, the estimated effects of patent protection are statistically indistinguishable between domestic and foreign licensees. Consistent with Hypothesis 1c, the likelihood of licensing by spin-offs is more strongly related to the presence of patent applications than the likelihood of licensing to external licensees. This result supports the above conjecture that a strong IPR position is critical to inventor spin-offs dependent on external financing. Apparently, this role of patents is more important in our empirical context than either their capacity to help overcome information asymmetries or issues of strategic patenting, which would be expected to be more relevant for external licensees.

Hypothesis 2a predicted that inventor seniority is positively related to the likelihood of licensing across all licensee types. This finds support in the coefficients estimated for the indicator variable denoting (co-) inventions by Max Planck directors. As regards the nationality of licensees (Hypothesis 2b), differences in the effects of seniority are small and insignificant. In line with Hypothesis 2c, we find

---

[10] In an unreported simple logit model of licensing (irrespective of licensee type), the patent indicator is significant at the 1% level.

Table 5 Correlations between covariates II: likelihood of commercialization (patented inventions in parentheses)

717 obs. (499 obs.)	Foreign	Spin-off	Biomed	Director-inventor	Bundle	Exp. licensee	Patent	Patent family	Triadic family	Industry cooperation
Foreign	1.000 (1.000)									
Spin-off	− .245 (−.248)	1.000 (1.000)								
Biomed section	.180 (.105)	.111 (.162)	1.000 (1.000)							
Director-inventor	.132 (.063)	.213 (.249)	.192 (.148)	1.000 (1.000)						
Bundle	− .031 (−.050)	.265 (.231)	.016 (−.039)	.190 (.151)	1.000 (1.000)					
Serial licensee	− .153 (−.231)	.298 (.289)	.133 (.117)	.160 (.119)	.338 (.332)	1.000 (1.000)				
Patent	− .048 (−)	.202 (−)	.070 (−)	.152 (−)	.249 (−)	.212 (−)	1.000 (−)			
Patent family size	− (.184)	− (−.035)	− (.152)	− (.167)	− (.215)	− (.127)	− (−)	− (1.000)		
Triadic family	− (.102)	− (−.076)	− (−.038)	− (.005)	− (.203)	− (.112)	− (−)	− (.446)	− (1.000)	
Industry cooperation	− (−.115)	− (−.053)	− (−.090)	− (−.102)	− (.065)	− (.061)	− (−)	− (.027)	− (.129)	− (1.000)

Table 6 Likelihood of licensing I: domestic versus foreign (multinomial logit models)

	Model 1(all inventions)		Model 2 (all inventions)		Model 3 (patented inventions)	
	Domestic licensee	Foreign licensee	Domestic licensee	Foreign licensee	Domestic licensee	Foreign licensee
Patent application	.397*** (.121)	.247 (.184)	.400*** (.122)	.249 (.184)		
Patent family size					.101*** (.022)	.115*** (.023)
Triadic family					.271 (.210)	.389 (.293)
Director-inventor	2.966*** (.193)	3.051*** (.234)	3.133*** (.200)	3.127*** (.243)	2.888*** (.233)	2.776*** (.295)
Biomedical section	.535*** (.119)	1.485***^{c} (.225)	.478*** (.145)	1.407***^{c} (.251)	.605*** (.194)	1.068*** (.313)
Collaborative invention					.416**^{c} (.184)	−1.110*** (.369)
Constant	−1.859*** (.227)	−4.087*** (.410)	−1.749*** (.233)	−3.829*** (.413)	−2.055 (.288)	−3.849*** (.495)
Time controls	Yes		Yes		Yes	
Top 5 institute controls	No		Yes		Yes	
Observations	2,270		2,270		1,387	
Log-likelihood ($p > chi^2$)	−1545.724 (.0000)		−1520.355 (.0000)		−931.239 (.0000)	
Pseudo-R^2	.169		.183		.238	

Standard errors in parentheses; *, ** and *** denote significance at the .10 .05 and .01 levels, respectively; ^{a}, ^{b} and ^{c} denote differences between licensee types significant at the .10 .05 and .01 levels, respectively

that inventor seniority seems to play an even bigger role in the licensing to spin-offs than in the licensing to external licensees.

Two results related to the control variables are noteworthy. First, while inventions from the biomedical section are generally more likely to be licensed than inventions from the chemistry, physics and technology section, the difference is more pronounced for foreign licensees ($p < .01$ in Models 1 and 2). This pattern may reflect more developed markets for technology for biomedical inventions and/or the sectoral structure of the German economy, which is not specialized toward biomedical technologies. Second, inventions based on collaborative research are not generally more or less likely to be licensed,[11] but they are predominantly licensed to domestic firms and to external licensees. We interpret this as reflecting the composition of industry partners with which Max Planck researchers cooperate.

---

[11] In an unreported simple logit model of licensing (irrespective of licensee type), the indicator of collaborative inventions is insignificant.

Table 7 Likelihood of licensing II: external licensees versus spin-offs (multinomial logit models)

	Model 4 (all inventions)		Model 5 (all inventions)		Model 6 (patented inventions)	
	External licensees	Spin-offs	External licensees	Spin-offs	External licensees	Spin-offs
Patent application	.163 (.118)	1.075***^{c} (.213)	.160 (.119)	1.072***^{c} (.213)		
Patent family size					.100*** (.022)	.110*** (.023)
Triadic family					.447**^{b} (.210)	−.122 (.290)
Director-inventor	2.761*** (.198)	3.427***^{c} (.223)	2.936*** (.205)	3.535***^{c} (.232)	2.643*** (.242)	3.264***^{c} (.266)
Biomedical section	.606*** (.120)	1.179***^{c} (.204)	.610*** (.144)	.973*** (.241)	.644*** (.197)	.966*** (.291)
Collaborative invention					.347*^{b} (.191)	−.348 (.270)
Constant	−1.950*** (.237)	−3.803*** (.356)	−1.818*** (.242)	−3.648*** (.362)	−2.357 (.308)	−2.990 (.391)
Time controls	Yes		Yes		Yes	
Top 5 institute controls	No		Yes		Yes	
Observations	2,270		2,270		1,387	
Log-likelihood (p > chi^2)	−1530.722 (.0000)		−1505.714 (.0000)		−947.060 (.0000)	
Pseudo-R^2	.191		.205		.254	

Standard errors in parentheses; *,** and *** denote significance at the .10 .05 and .01 levels, respectively; ^{a}, ^{b} and ^{c} denote differences between licensee types significant at the .10 .05 and .01 levels, respectively

5.2 Likelihood of Commercialization

To identify factors influencing the likelihood that licensed inventions are successfully commercialized, we begin by analyzing the odds of commercialization using logit models (Models 7–10 in Table 8), with successful commercialization measured by an indicator variable denoting licensing agreements that led to positive royalty payments. Second, the logged amount of royalties is adopted as an alternative measure of commercial success (Models 11–14 in Table 9). We finally assess potential effects of non-random selection into licensee types using propensity score matching (Models 15–18 in Tables 10 and 11).

Hypothesis 3 predicted that foreign licensees are less likely to commercialize a licensed technology. The evidence regarding this prediction is mixed. We consistently find lower commercialization likelihoods for foreign licensees, but three out of four estimated coefficients are only significant at the 10% level. In the models analyzing levels of royalty payments, the variable denoting foreign licensees is negative and sizable but never significant. The propensity score matching models indicate that the observed differences in the full sample of inventions (Model 15 in

Table 8 Likelihood of commercialization (logit models)

	Model 7 (all inventions)	Model 8 (all inventions)	Model 9 (patented inventions)	Model 10 (patented inventions)
Foreign licensee	−.365* (.197)	−.340* (.196)	−.608** (.288)	−.496* (.295)
Spin-off licensee	−.497** (.213)	−.542** (.218)	−.357 (.272)	−.471* (.280)
Director-inventor	.184 (.220)	.139 (.222)	−.004 (.290)	−.021 (.292)
Biomedical section	−.497* (.266)	−.517* (.266)	−.660* (.352)	−.746** (.356)
Patent application	−1.400*** (.266)	−1.389*** (.229)		
Patent family size			−.000 (.015)	−.001 (.015)
Triadic family			−.069 (.296)	−.165 (.299)
Collaborative invention			.469 (.325)	.583* (.332)
Bundled license	.595*** (.227)	.573** (.230)	.497* (.290)	.479* (.287)
Serial Licensee	−.014 (.236)	−.015 (.241)	−.000 (.339)	.031 (.359)
Constant	1.413*** (.428)	1.176** (.500)	.170 (.512)	−.539 (.683)
Time controls	Yes	Yes	Yes	Yes
Top 5 institute controls	Yes	Yes	Yes	Yes
Sector controls (licensee)	No	Yes	No	Yes
Observations	717	717	499	499
Log-likelihood ($p > chi^2$)	−407.548 (.0000)	−404.818 (.0000)	−265.922 (.0000)	−261.670 (.0000)
Pseudo-R^2	.180	.186	.218	.230

Clustered standard errors in parentheses; *, ** and *** denote significance at the .10 .05 and .01 levels, respectively

Table 10) are mostly due to selection.[12] In contrast, within the subsample of patented inventions Model 16 selection does not explain the lower commercialization likelihood of foreign licensees, as the average treatment effect on the treated is significantly negative.

Turning to the commercialization performance of inventor spin-offs, Models 7 and 8 find a significantly lower commercialization likelihood of inventions licensed to spin-offs. In Model 10, restricted to patented inventions, we obtain a marginally significant negative coefficient for the spin-off variable. Similarly, royalty payments realized by spin-off licensing are significantly smaller than those of external licensees in Models 11, 12, and 14. Propensity score matching (Models 17 and 18 in Table 11) indicates that these differences mostly reflect effects of selection into the alternative types of licensees. Without matching, the commercialization likelihood of technologies licensed to spin-offs is 10 to

---

[12] To obtain propensity scores, a logit model for the likelihood of being licensed to a foreign licensee was estimated first. We use a specification similar to Model 2. Kernel-based matching of treated and untreated observations was then performed (cf. also Section 3). The common support condition is satisfied for all reported propensity score matching models.

Table 9 Royalty payments from commercialization (Tobit models)

	Model 11 (all inventions)	Model 12 (all inventions)	Model 13 (patented inventions)	Model 14 (patented inventions)
Foreign licensee	−.811 (.817)	−.781 (.801)	−2.051 (1.255)	−1.639 (1.235)
Spin-off licensee	−1.929** (.858)	−2.163** (.862)	−1.727 (1.102)	−2.175** (1.102)
Director-inventor	−.105 (.886)	−.297 (.887)	−.512 (1.215)	−.540 (1.197)
Biomedical section	−1.880* (1.027)	−1.825* (1.008)	−2.648* (1.508)	−2.839* (1.489)
Patent application	−4.716*** (.794)	−4.576*** (.792)		
Patent family size			−.006 (.059)	−.002 (.059)
Triadic family			.407 (1.195)	−.147 (1.193)
Collaborative invention			1.988 (1.367)	2.501* (1.357)
Bundled license	1.787** (.880)	1.664* (.877)	1.307 (1.243)	1.119 (1.207)
Serial licensee	.481 (.842)	.485 (.860)	.273 (1.408)	.533 (1.443)
Constant	6.510*** (1.556)	5.547*** (1.792)	1.898 (2.280)	−.684 (2.842)
Time controls	Yes	Yes	Yes	Yes
Top 5 institute controls	Yes	Yes	Yes	Yes
Sector controls (licensee)	No	Yes	No	Yes
Observations	717	717	499	499
Log-likelihood ($p > chi^2$)	−1474.272 (.0000)	−1469.755 (.0000)	−907.864 (.0000)	−902.640 (.0000)
Pseudo-R^2 (ML)	.241	.250	.277	.291

Clustered standard errors in parentheses; *, ** and *** denote significance at the .10, .05 and .01 levels, respectively

14 percentage points lower than that of technologies with external licensees. When matched technologies are compared, this difference is reduced to 5 percentage points or less. None of the estimated treatment effects of spin-off licensing on commercialization is significant at the 5% level. Based on these findings, we fail to reject Hypothesis 4, which predicted indistinguishable commercialization outcomes for spin-offs and external licensees.

In both the logit and the Tobit models, the coefficient of the dummy variable denoting patented inventions is sizable and strongly negative, indicating that these inventions had lower commercialization chances than unpatented technologies. The proxies for patent quality are non-predictive throughout. Accordingly, both parts of Hypothesis 5—predicting both the presence and the scope of patents to be positively related to commercialization outcomes—do not find support in the empirical evidence. The same holds for the conjecture about inventor seniority Hypothesis 6, as the

Table 10 Likelihood of commercialization, domestic vs. foreign licensees (propensity score matching)

		Model 15 (all inventions, 717 obs.)			Model 16 (patented only, 499 obs.)		
		Unmatched	ATT	ATE	Unmatched	ATT	ATE
Treated		.457	.457		.359	.359	
Untreated		.520	.476		.451	.475	
Difference		− .063	− .020	− .075	− .091	− .115	− .081
S.E. (bootstrapped)			.042	.039		.051	.053
95% Confidence interval	Lower bound		− .085	− .131		− .212	− .181
	Upper bound		.069	.014		− .026	.037

Kernel matching (Gaussian kernel); standard errors obtained through bootstrapping (n = 100), bias corrected confidence interval for standard errors

Table 11 Likelihood of commercialization, external licensees vs. spin-offs (propensity score matching)

		Model 17 (all inventions, 717 obs.)			Model 18 (patented only, 499 obs.)		
		Unmatched	ATT	ATE	Unmatched	ATT	ATE
Treated		.405	.405		.362	.362	
Untreated		.543	.454		.460	.362	
Difference		− .137	− .049	− .050	− .098	− .000	− .020
S.E. (bootstrapped)			.045	.041		.049	.050
95% Confidence interval	Lower bound		− .135	− .128		− .093	− .116
	Upper bound		.016	.036		.096	.062

Kernel matching (Gaussian kernel); standard errors obtained through bootstrapping (n = 100), bias corrected confidence interval for standard errors variable denoting Max Planck directors among the inventors of a technology has no discernible impact on commercialization success.

5.3 Robustness Checks

A variety of robustness checks were performed to deal with limitations of the empirical analysis.[13] To check the robustness of the multinomial logit models, we also estimated the corresponding multinomial probit models. They yielded very similar results to those reported above. We also experimented with estimating hazard rate models that simultaneously analyze the incidence and timing of licensing events. We prefer the multinomial logits and concentrate on reporting their results below because time to licensing may vary across the technologies covered in our dataset, adding to the unobserved heterogeneity and possibly biasing the results of hazard rate models.

In the analysis of commercialization likelihoods, we estimated two-stage Heckman selection models (Heckman 1979) to deal with the issue that commercialization outcomes are only observable for the non-random sample of licensed inventions. To this purpose, we employed the indicator variable denoting (co-) inventions by senior researchers, along with the other variables employed in the licensing models reported above, to predict selection into licensing. Using inventor seniority as the instrument in the Heckman models is in line with the above empirical results showing that (co-) inventions by senior researchers are substantially more likely to be licensed, but not systematically related to commercialization. Second-stage results of the Heckman probit models are similar to the simple logit models reported above. The null hypothesis of independence between licensing and commercialization cannot be rejected in any of the models.

6 Discussion

In the present article, we studied technology transfer based on the commercialization of academic inventions from a major European non-university PRO, Germany’s Max Planck Society. Due to peculiarities in the treatment of academic inventions in Germany before 2002, data on the incidence and outcomes of technology licensing from the Max Planck Society are available over an exceptionally long period of time. These data inform our econometric analysis, which is based on the full population of Max Planck inventions for the 1980–2004 period and takes into consideration that only the selected subset of licensed technologies is actually at risk of being commercialized.

We guided our empirical analysis by theoretical predictions based on notions of information asymmetry (for the first stage of licensing) respectively knowledge

---

[13] All unreported results are available from the authors upon request.

transfer from inventors to licensees (for the second stage of commercializing licensed technologies). Our empirical findings regarding these hypotheses were mixed.

We found that foreign licensees were less frequent than domestic ones. There is also substantial evidence suggesting they were less successful in commercializing inventions, even though the differences to domestic licensees were not consistently found to be statistically significant. To our knowledge, these are the first results for international licensing and commercialization of academic inventions.

We also found that, when controlling for non-random selection of inventions into licensee types, inventor spin-offs were indistinguishable from external licensees, both in their likelihood of commercializing academic inventions and in the level of royalties they generate from product sales. This result is consistent with the only directly comparable study by Lowe and Ziedonis (2006) for the University of California system, who did not find systematic differences between established firms and startups (in many cases inventor spin-offs). It indicates that spin-offs' advantages in access to inventors' non-codified knowledge, and possibly their stronger motivation to commercialize, enable them to overcome their disadvantages in terms of lacking complementary assets and organizational capabilities.

Academic entrepreneurship through inventor spin-offs is of substantial interest to policy makers. Our results suggest that spin-offs may indeed be a suitable channel for the commercialization of academic inventions and not just a second-best commercialization when external licensees cannot be found (as suggested even though not directly addressed by Shane (2002)). At the same time, our results do not support a privileged treatment of spin-offs relative to external licensees. We would rather interpret them as suggesting that an unbiased quest for the most suitable licensee in each individual case may be the best policy for universities and PROs operating under a Bayh-Dole-like IPR regime. This conclusion resonates with recent findings by Belenzon and Schankerman (2009), who showed that U.S. universities pursuing a selective licensing policy based on regional development objectives performed worse than those that did not.

A complex role of patents emerges from our results. Spin-off licensing is more strongly related to patents than licensing to external licensees, and inventions related to patents are less likely to be commercialized than those that are not. These findings point to an important role of patents as signals to external providers of capital and to the strategic licensing of patented inventions, which resonates with recent work indicating that the traditional interpretation of patents as devices allowing innovators to appropriate the returns of their R&D efforts is too narrow (cf., e.g., Shapiro 2000; Hall and Ziedonis 2001; Jaffe and Lerner 2004).

Inventors' academic status is in the focus of Elfenbein's (2007) study of licensing at Harvard University. Similar to our results, he found that inventions by more prestigious scientists were more likely to be licensed, while contractual provisions did not differ with inventor status. This is interpreted as indicating that inventor status operates mostly through increasing an invention's visibility to external licensees—an interpretation that seems difficult to reconcile with our finding that seniority has stronger effects on licensing by spin-offs rather than external licensees.

Further theoretical and empirical work is clearly required to better understand the process through which academic inventions are turned into commercial success stories. That our knowledge about the commercialization of academic inventions is so limited is partly due to the paucity of suitable data. However, this may be a temporary problem: given the Bayh-Dole-like policies adopted in many countries and the setup of TLOs at most universities and PROs, data availability is bound to improve over time. In this context, it is also noteworthy that the Max Planck Society, which has consistently been subject to a Bayh-Dole-like IPR regime since the 1970s, was among the pioneers of IPR-based technology transfer in Europe. As a consequence, while the generality of our results is limited because they refer to a single organization, their relevance is enhanced by the fact that the same kind of IPR regime now governs the vast majority of European universities and PROs.

Acknowledgements We are grateful to Max Planck Innovation GmbH for granting us access to their data. For helpful comments and discussions we thank Joerg Erselius, Astrid Giegold, Dietmar Harhoff, Bernhard Hertel, Evelyn Kaiser, Lionel Nesta, Alexander Schacht, Vangelis Souitaris and Dieter Treichel, as well as two anonymous reviewers. Wolfgang Ziegler and Sebastian Schmidt at the Patent Information Office of the University of Jena helped us assemble the patent database. Wolfhard Kaus provided valuable research assistance. This article is based on research done while both authors were at the Max Planck Institute of Economics. The usual caveat applies.

References

Agrawal A (2006) Engaging the inventor: exploring licensing strategies for university inventions and the role of latent knowledge. Strateg Manage J 27:63–79

Arora A, Gambardella A (2010) Ideas for rent: an overview of markets for technology. Ind Corp Change 19:775–803

Azoulay P, Ding W, Stuart T (2009) The impact of academic patenting on the rate, quality and direction of (Public) research output. J Ind Econ 57:637–676

Belenzon S, Schankerman M (2009) University knowledge transfer: private ownership, incentives, and local development objectives. J Law Econ 52:111–144

Breschi S, Lissoni F, Montobbio F (2008) University patenting and scientific productivity: a quantitative study of Italian academic inventors. European Management Review 5:91–109

Buenstorf G (2009) Is commercialization good or bad for science? Individual-level evidence from the Max Planck Society. Res Policy 38:281–292

Cohen WM, Levinthal DA (1990) Absorptive capacity: a new perspective of learning and innovation. Adm Sci Q 35:128–152

Cohen WM, Nelson RR, Walsh JP (2002) Links and impacts: the influence of public research on industrial R&D. Manag Sci 48:1–23

Eckhardt JT, Shane S, Delmar F (2006) Multistage selection and the financing of new ventures. Manag Sci 52:220–232

Elfenbein D (2007) Publications, patents, and the market for university inventions. J Econ Behav Organ 63:688–715

Fontana R, Geuna A (2009) The nature of collaborative patenting activities. Bocconi University, mimeo

Gallini NT, Wright BD (1990) Technology transfer under asymmetric information. RAND J Econ 21:147–160

Hall BH, Ziedonis RH (2001) The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry, 1979–1995. RAND J Econ 32:101–128

Harhoff D, Scherer FM, Voper K (2003) Citations, family size, opposition and the value of patent rights. Res Policy 32:1343–1363

Heckman JJ (1979) Sample selection bias as a specification error. Econometrica 47:153–161

Heckman JJ, Ichimura H, Todd P (1998) Matching as an econometric evaluation estimator. Rev Econ Stud 65:261–294

Henning E, Ullmann D (1998) Wissenschaftliche Mitglieder der Max-Planck-Gesellschaft zur Förderung der Wissenschaften im Bild. Duncker & Humblot, Berlin

Jaffe AB, Lerner J (2004) Innovation and its discontents. Princeton University Press

Jensen R, Thursby M (2001) Proofs and prototypes for sale: the licensing of university inventions. Am Econ Rev 91:240–259

Leuven E, Sianesi B (2003) PSMATCH2: Stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing. http://ideas.repec.org/c/boc/bocode/s432001.html

Levin RC, Klevorick AK, Nelson RR, Winter SG (1987) Appropriating the returns from industrial research and development. Brookings Pap Econ Act 1987(3):783–820

Lissoni F, Llerena P, McKelvey M, Sanditov B (2008) Academic patenting in Europe: new evidence from the KEINS database. Res Eval 17:87–102

Lowe RA (2002) Entrepreneurship and information asymmetry: theory and evidence from the University of California. Carnegie Mellon University, mimeo

Lowe RA (2006) Who develops a university invention? The impact of tacit knowledge and licensing policies. J Technol Transf 31:415–429

Lowe RA, Ziedonis AA (2006) Overoptimism and the performance of entrepreneurial firms. Manag Sci 52:173–186

Max Planck Society (2000) Handbook of scientific members. Munich

Max Planck Society (2001) Start-up companies: guidelines for scientists of the Max-Planck-Gesellschaft. Munich

Max Planck Society (2002) Guidelines for knowledge and technology transfer. Munich

Max Planck Society (2008) Annual Report 2007. Munich

Mora-Valentin EM, Montoro-Sanchez A, Guerras-Martin L (2004) Determining factors in the success of R&D cooperative agreements between firms and research organizations. Res Policy 33:17–40

Mowery DC, Nelson RR, Sampat BN, Ziedonis AA (2001) The growth of patenting and licensing by U.S. universities: an assessment of the effects of the Bayh-Dole act of 1980. Res Policy 30:99–119

Murray F, Stern S (2007) Do formal intellectual property rights hinder the free flow of scientific knowledge? An empirical test of the anti-commons hypothesis. J Econ Behav Organ 63: 648–687

Nooteboom B (1999) Innovation and inter-firm linkages: new implications for policy. Res Policy 28:793–805

Owen-Smith J, Powell WW (2001) To patent or not: faculty decisions and institutional success at technology transfer. J Technol Transf 26:99–114

Phan PH, Siegel DS (2006) The effectiveness of university technology transfer. Foundations and Trends in Entrepreneurship 2:77–144

Rosenbloom PR, Rubin DB (1983) The central role of the propensity score in observational studies for causal effects. Biometrika 70:41–55

Shane S (2002) Selling university technology: patterns from MIT. Manag Sci 48:122–137

Shane S, Stuart T (2002) Organizational endowments and the performance of university start-ups. Manag Sci 48:154–170

Shapiro C (2000) Navigating the patent thicket: cross licenses, patent pools, and standard setting. Innov Policy Econ 1:119–150

Sianesi B (2001) Implementing propensity score matching estimators with STATA. Prepared for the UK Stata Users Group, VII Meeting, London, May 2001

Stokes DE (1997) Pasteur's Quadrant. Basic science and technological innovation. Brookings Institution Press, Washington

Teece DJ (1986) Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. Res Policy 15:285–305

Teece DJ, Pisano G, Shuen A (1997) Dynamic capabilities and strategic management. Strateg Manage J 18:509–533

Verspagen B (2006) University research, intellectual property rights and European Innovation Systems. J Econ Surv 20:607–632

Von Proff S, Buenstorf G, Hummel M (2012) University patenting in Germany before and after 2002: what role did the professors' privilege play? Industry and Innovation (in press)

Wooldridge JW (2002) Econometric analysis of cross section and panel data. MIT Press, Cambridge