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Turning Scientific Results into Market: Technology Transfer and Commercialization of Inventions from Public Research

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Deutschsprachige Zusammenfassung

Der Technologie- und Wissenstransfer aus Universitäten und nicht-universitären öffentlichen Forschungseinrichtungen in die Privatwirtschaft hat in den letzten Jahren stetig an Bedeutung gewonnen. Im Besonderen wird der Grundlagenforschung in Hinblick auf die wirtschaftliche Entwicklung und den technischen Fortschritt eine tragende Rolle beigemessen. Wissenschaftliche Studien zeigen, dass Grundlagenforschung einen wichtigen Beitrag zum wirtschaftlichen Wachstum leistet, Arbeitsplätze schafft und die Wettbewerbsfähigkeit von Volkswirtschaften stärkt (Mansfield, 1991; 1995; 1998; Tijssen, 2002; Dalton and Guei, 2003; Bilbao-Osorio and Rodriguez-Pose, 2004; Toole, 2012). Aus politischer Sicht jedoch werden Forschungsleistungen nicht konsequent und schnell genug in die Praxis umgesetzt. Um den Technologie- und Wissenstransfer aus öffentlichen Forschungseinrichtungen zu vereinfachen und die wirtschaftliche Nutzung von wissenschaftlichen Erfindungen zu fördern, wurde in den USA das sogenannte Bayh-Dole Gesetz im Jahre 1980 eingeführt. Seit der Einführung dieses Gesetzes werden Forschungseinrichtungen das Eigentum und das Recht zur Verwertung öffentlich finanzierter Forschungsarbeiten zugesprochen. Somit ist es den Forschungsinstituten vorbehalten, Entdeckungen zu patentieren und diese durch Lizenzvergaben zu vermarkten. Zahlreiche europäische Länder wie Dänemark und Deutschland folgten dem Beispiel der USA und haben vergleichbare Änderungen vorgenommen, um die Vorteile von Grundlagenforschung zu nutzen. Die vorliegende Arbeit, die sich aus vier eigenständigen Studien zusammensetzt, beschäftigt sich mit der Lizenzierung und Kommerzialisierung von Erfindungen aus öffentlichen Forschungseinrichtungen. Für die empirischen Analysen werden detaillierte Datensätze der Max-Planck-Gesellschaft sowie ein Laborexperiment zurate gezogen. Insbesondere können mithilfe der Daten der Max-Planck-Gesellschaft neue Einblicke und Erkenntnisse in den bislang noch wenig erforschten Bereich der Kommerzialisierung innerhalb Europas gewonnen werden.

Nach einem ausführlichen Literaturüberblick in Kapitel 1 wird der Einfluss von Gruppenzugehörigkeit auf die Entscheidungen von Individuen in Kapitel 2 mithilfe eines Laborexperiments untersucht. Diese Studie macht sich die Theorie der Gruppenidentität zunutze. Diese ist definiert durch den Grad, mit der sich eine Person einer Gruppe zugehörig fühlt. In den letzten Jahren wurde dieses psychologische Konzept von der Ökonomik aufgegriffen, um dessen Einfluss auf die Diskriminierung und Informationsasymmetrie zu untersuchen (Akerlof and Kranton, 2000; 2005). Zusätzlich erforscht der Bereich der experimentellen Ökonomik den Einfluss von Gruppenidentität auf individuelle ökonomische Entscheidungen von

Individuen unter kontrollierten Laborbedingungen (Ahmed, 2007; Heap and Zizzo, 2009). Der Vorteil von Laborexperimenten ist, dass Gruppenzugehörigkeit unter kontrollierten Bedingungen induziert werden kann und Unterschiede gemessen werden können. Ziel der vorliegenden Studie in Kapitel 2 ist es herauszufinden, wie Forderungen, Angebote und Ansichten in unterschiedlichen Gruppenkonstellationen in einem Drei-Personen Verhandlungsspiel beeinflusst werden. Dabei wird argumentiert, dass Gruppenidentität in Märkten mit geringer Teilnehmerzahl, in denen Beziehungen und gemeinsame Erfahrungen einen besonderen Stellenwert einnehmen, eine größere Rolle spielt als in Märkten mit einer Vielzahl von Beteiligten (vgl. Li et al., 2011). Dies trifft vor allem auf Lizenzierungsmärkte zu, die durch eine begrenzte Anzahl von Marktteilnehmern charakterisiert sind (Jensen and Thursby, 2001). Um ein gemeinsames Gruppengefühl zu induzieren, wird im ersten Teil des Laborexperiments ein Koordinationsspiel gespielt (vgl. Bauernschuster et al., 2009). Im darauffolgenden wird ein Drei-Personen Verhandlungsspiel mit unterschiedlichen Gruppenkonstellationen durchgeführt, wobei jeder Spieler zweimal als Käufer und einmal als Verkäufer agiert. Die deskriptive und empirische Analyse zeigt, dass Käufer, die gemeinsame Erfahrungen mit dem Verkäufer im Koordinationsspiel gesammelt haben, signifikant mehr bieten als Käufer in der Kontrollgruppe ohne vorherige gemeinsame Erfahrung. Dieses Ergebnis wird interpretiert als Eigengruppenbevorzugung. Allerdings wird diese Eigengruppenbevorzugung durch den Verkäufer nicht erwidert. Dieses Ergebnis lässt die Vermutung zu, dass Eigengruppenbevorzugung von der Marktstärke beziehungsweise der Marktposition abhängt. Zusätzlich findet die Studie kein Indiz dafür, dass Verkäufer bei unterschiedlichen Gruppenzugehörigkeiten diskriminieren.

In Kapitel 3 wird der Einfluss der geografischen Distanz zwischen Lizenzgeber und Lizenznehmer auf den kommerziellen Erfolg von lizenzierten Erfindungen untersucht. Die Kommerzialisierung von lizenzierten Erfindungen aus öffentlichen Forschungseinrichtungen ist ein nicht-trivialer Prozess, der mit einer Vielzahl von Schwierigkeiten einhergeht. Wissenschaftliche Studien zeigen, dass offengelegte Erfindungen sich überwiegend in einer sehr frühen Entwicklungsphase befinden und deren kommerzielles Potenzial zu diesem Zeitpunkt nicht absehbar ist (Jensen and Thursby, 2001; Thursby and Thursby, 2004). Zusätzlich wird die Kommerzialisierung durch die hohe Komplexität der Erfindungen und die dafür notwendigen absorptiven Fähigkeiten, um das externe Wissen vollständig zu erfassen, erschwert (Cohen and Levinthal, 1989; 1990). Des Weiteren werden nicht alle relevanten Bestandteile des Wissens offengelegt und bleiben damit personenbezogen, was die Weiterentwicklung und Kommerzialisierung verkompliziert (Agrawal, 2006). Um Zugang zum taciden Wissen zu erhalten und eine erfolgreiche Kommerzialisierung voranzutreiben, ist die Partizipation der Erfinder während der Entwicklungsphase von entscheidender Bedeutung (Jensen and Thursby, 2001; Agrawal, 2006). Dabei sind Wissenschaftler jedoch nicht gewillt große geografische Entfernungen zurückzulegen. Zum einen steigen mit der geografischen Distanz die finanziellen Aufwendungen und zum anderen haben Wissenschaftler höhere Opportunitätskosten für die Zeit, die sie eher in Grundlagenforschung als in angewandte Forschung investieren (von Hippel, 1994; Stephan, 1996). Um den Einfluss von geografischer Distanz auf die Kommerzialisierung zu untersuchen, werden Daten von der Max-Planck-Gesellschaft für die empirische Analyse herangezogen. Im Speziellen werden detaillierte Informationen von offengelegten und lizenzierten Erfindungen verwendet. Für die empirische Untersuchung wird eine Teilmenge von Lizenzverträgen genutzt, die Lizenzgebühren als Indikator für den kommerziellen Erfolg enthalten. Somit können zwei Maße für den kommerziellen Erfolg generiert werden, die zum einen die Wahrscheinlichkeit und zum anderen die Höhe des Erfolgs abbilden. Zudem können mithilfe der Standorte von Lizenzgeber und Lizenznehmer präzise Entfernungen zwischen beiden berechnet werden. Die Ergebnisse der empirischen Analysen zeigen, dass geografische Distanz keinen systematischen Einfluss auf den kommerziellen Erfolg hat. Ein negativer Zusammenhang zwischen geografischer Distanz und kommerziellen Erfolg ist nur für ausländische Spin-offs sowie für ausländische Lizenznehmer von mehrfachlizenzierten Erfindungen beobachtbar. Diese Ergebnisse implizieren, dass lokaler Technologietransfer aus gesellschaftlicher Sicht kontraproduktiv sein kann (vgl. Belenzon and Schankerman, 2009).

Ausgangspunkt für die Studie in Kapitel 4 ist die Tatsache, dass die Geschwindigkeit, mit der Erfindungen vermarktet werden, seit den 90er Jahren an strategischer Bedeutung gewonnen hat (Kessler and Chakrabarti, 1996). Gründe hierfür sind das sich schnell ändernde wirtschaftliche Umfeld, der rapide technologische Fortschritt sowie der zunehmende Wettbewerbsdruck (Nadler and Tushman, 1999; Markman et al., 2005). Empirische Studien zeigen, dass eine schnellere Entwicklung und Vermarktung einen positiven Einfluss auf die Produktionskosten und den Erfolg von Produkten hat (Carbonell and Rodriguez, 2006; Langerak et al., 2010). Allerdings fokussiert sich die Mehrzahl der Studien auf unternehmensinterne Produktentwicklungen und vernachlässigt den Aspekt des Technologietransfers aus öffentlichen Forschungseinrichtungen. Aus diesem Grund wird in Kapitel 4 untersucht, inwieweit die Geschwindigkeit, mit der offengelegte

Erfindungen lizenziert werden, den Kommerzialisierungserfolg beeinflusst. Zusätzlich wird der Einfluss von erfindungsspezifischen Faktoren auf die Transfergeschwindigkeit analysiert. Dabei wird für die Geschwindigkeit die Zeit, die zwischen der Offenlegung und Lizenzierung vergangen ist, für die empirischen Analysen herangezogen. Wie im vorangegangenen Kapitel (Kapitel 3) werden auch für diese Studie die Datensätze der Max-Planck-Gesellschaft zurate gezogen. Die Resultate der empirischen Analyse zeigen, dass Erfindungen aus der biomedizinischen Sektion, kooperative Erfindungen zwischen Industrie und Wissenschaft sowie die Beteiligung von Direktoren während des Erfindungsprozesses einen positiven Einfluss auf die Lizenzierungsgeschwindigkeit haben. Weitere Analysen zeigen, dass die benötigte Lizenzierungszeit keinen signifikanten Einfluss auf den kommerziellen Erfolg hat. Betrachtet man jedoch den Effekt der Lizenzierungszeit für Erfindungen, die nach 1989 offengelegt worden sind, zeigt sich ein signifikant negativer Einfluss auf die Wahrscheinlichkeit und die Höhe des kommerziellen Erfolgs. Dieses Ergebnis bleibt robust, wenn für erfindungsspezifische Unterschiede mithilfe einer Teilstichprobe für mehrfach lizenzierte Erfindungen kontrolliert wird. Dieses Ergebnis bestätigt bisherige Studien über die Notwendigkeit eines effektiveren Technologietransfers.

Kapitel 5 dieser Arbeit widmet sich der Fragestellung, ob Aktivitäten von Institutsdirektoren sowie der kommerzielle Erfolg das Kommerzialisierungsverhalten in öffentlichen Forschungseinrichtungen beeinflusst. Zahlreiche Studien belegen am Beispiel von privaten Unternehmen, dass das Verhalten der Führungskräfte von Angestellten adaptiert wird und die Unternehmenskultur beeinflusst (Kogut and Zander, 1996; Beckman and Burton, 2008; Levy et al. 2011). Während eine Vielzahl von Studien private Unternehmen zum Hauptgegenstand von Untersuchungen machen, finden öffentliche Forschungseinrichtungen dagegen kaum Berücksichtigung. Ziel dieser Studie ist es herauszufinden, inwieweit Determinanten wie kommerzieller Erfolg und die Beteiligung von Direktoren in Erfindungsprozessen nachfolgende Offenlegungen in öffentlichen Forschungseinrichtungen beeinflussen. Für diese Fragestellung werden die Datensätze der Max-Planck-Gesellschaft verwendet und so umstrukturiert, dass Informationen über die Offenlegungen, Direktorenmitwirkungen sowie die Zahlungseingänge von lizenzierten Erfindungen pro Jahr und Institut vorliegen. Die Ergebnisse der empirischen Analyse bestätigen, dass Direktorenbeteiligungen und Lizenzeinnahmen die zukünftigen Offenlegungen positiv beeinflussen. Jedoch ist dieser Effekt kurzfristig und verschwindet für größere Zeitverzögerungen. Damit kann gezeigt werden, dass existierende

Organisationstheorien für öffentliche Forschungseinrichtungen nur bedingt Anwendung finden und damit angepasst werden müssen.

Im Schlusskapitel werden die einzelnen Studien zusammengefasst und zukünftige Forschungsrichtungen aufgezeigt.

1. Introduction

1.1 The Importance of Public Research Organizations

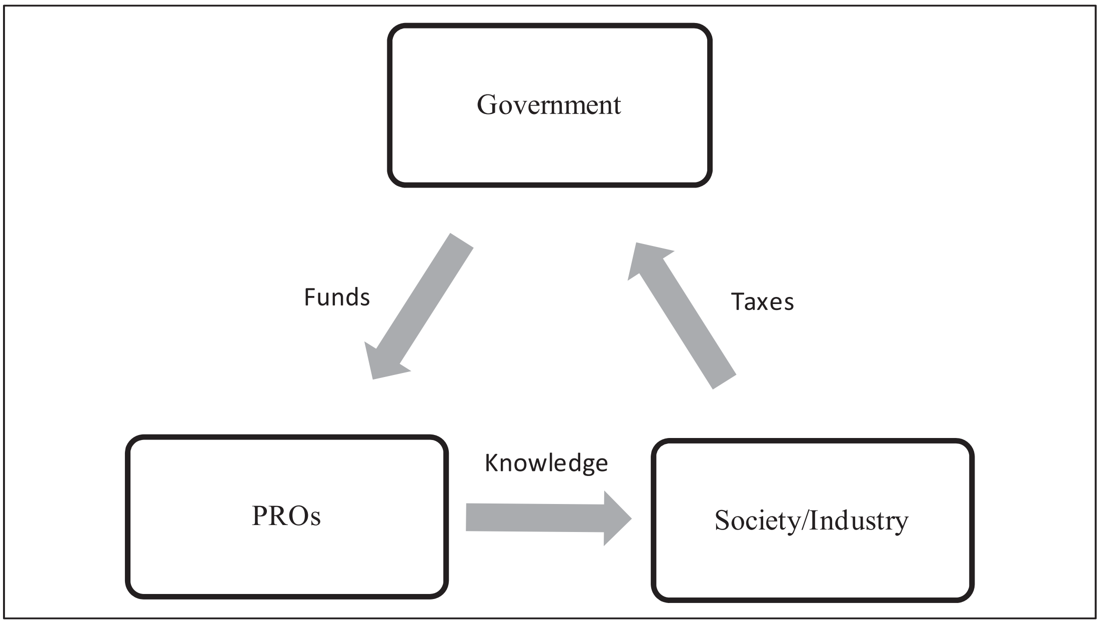
1.1.1 The Patronage System

It is widely acknowledged that basic research generates fundamental new knowledge that is the driving force behind economic development in modern economies. The European Commission states that basic research is essential to ensure economic standards and wealth and to maintain and enhance the European Union's long-term competitiveness (European Commission, 2004). The "Europe 2020" initiative that replaced the "Lisbon Strategy" in 2010, aims to enhance economic growth and competitiveness through basic research. Basic research not only expands the frontier of knowledge and addresses challenges such as health and environmental issues, but it also fosters new innovations derived from current research efforts. For example, the discoveries of the X-ray and the laser led to various new applications in medical diagnosis and therapy (European Commission, 2004). The time lags between the generation of new knowledge and subsequent applications may be long, but direct and indirect economic impacts are undisputed (Gibbons and Johnston, 1974; Stephan, 1996).

An increase in the stock of knowledge through basic research is an investment in the future that is rarely funded by private-sector firms. The literature discusses the main explanation for the underinvestment of firms in basic research and identifies the specific properties of knowledge as an investment barrier. Knowledge is often described as a public good characterized by non-rivalry and non-exclusion (Arrow, 1962). Several studies question the public good properties and claim that knowledge is tacit or latent (Polanyi, 1966; Callon, 1994; Agrawal, 2006). Thus, other considerations may better explain firm's underinvestment in basic research. Profit-seeking firms characterized by risk aversion and short-term orientation cannot guarantee the benefits of basic research due to uncertainty that limit their incentives of investment (Nelson, 1959; Pavitt, 1991). Although private-sector firms do invest in basic research to create new knowledge and to absorb, understand, interpret and appraise existing knowledge, the investments are rather socially sub-optimal (Cohen and Levinthal, 1990; Rosenberg, 1990). For instance, Jones and Williams (1998, 2000) find that private-sector investments in basic research are only a fraction of what would be socially optimal.

Several institutions seek to resolve the basic research investment incentive problem. David (1993) summarizes the three broad forms of institutions: Property

Rights, Procurement and Patronage. Property Rights include patents, the most common form of protection that grants producers of new knowledge the exclusive rights to the use and benefits of their creations. Procurement, often employed in the defense industry, is a contractual agreement between the producer of knowledge and a party (e.g., the government) that secures and finances the development. Patronage refers to the system in which the government takes financial responsibility for the development of new knowledge by means of public research organizations (PROs).[1] Figure 1-1 provides an overview of the patronage system, represented by a triangle where the government links the demand and supply of knowledge. More precisely, the government raises taxes that are partially transferred to the academic system. In return, the PROs in the system generate and disseminate knowledge.



Note: Adapted with minor changes from Antonelli (2008).

Figure 1-1: The Patronage System

PROs within the patronage system aimed to fulfill an intellectual purpose. The primary tasks of medieval universities were education and teaching, which inspired a second mission, the advancement of knowledge through basic research. The dual system of research and teaching is important to formulate new knowledge and techniques and to reduce the risk of conservative and uncritical diffusion of obsolete knowledge. The so-called Humboldtian reform in the early 19th century emphasized the mission to conduct research that is still embedded in the culture of

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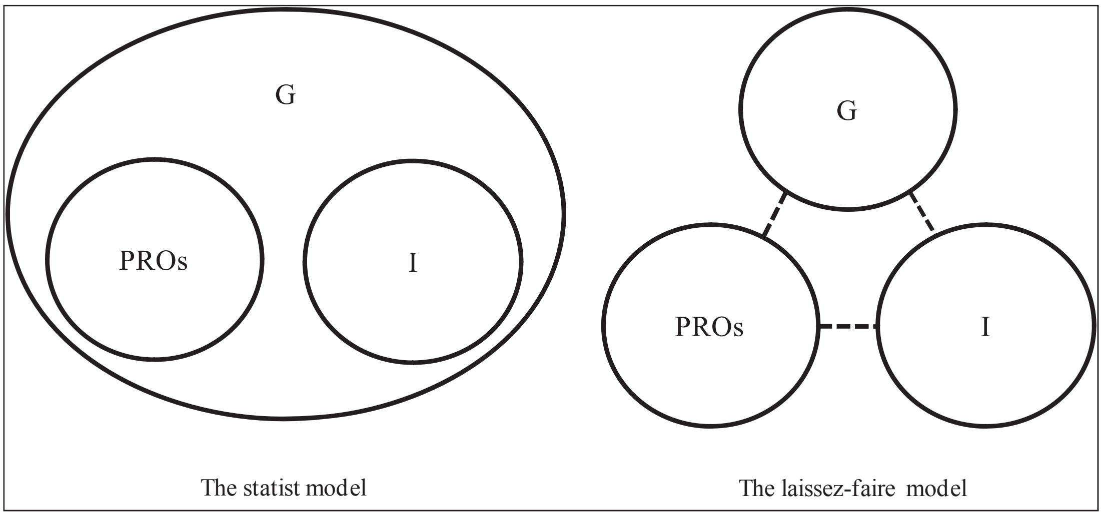
[1] The term public research organizations (PROs) encompass all research facilities that are financed by the government to a certain degree, including public universities and non-university public research organizations.

higher education facilities in Europe (Altbach, 1999; Goldstein, 2010). For instance, modern universities are responsible for the majority of the overall basic research conducted in Europe (OECD, 2003). To ensure a high quality of publicly funded knowledge generation and dissemination, the institutional setup has to provide sufficient incentives. The so-called priority reward system is expected to provide adequate incentives to invent and disclose (Dasgupta and David, 1994; Stephan, 1996). Within this system, scientists have a high incentive to be the first to publish their results in scientific journals that stimulate their reputations and further research funds. A scientific referee system serves as a control institution that monitors the quality and innovation of the findings.

Two opposing concepts, namely the statist model and the laissez-faire model depicted in Figure 1-2, capture the traditional intellectual purpose of PROs (Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2003; Etzkowitz, 2008). In the statist model, the government (G) is the dominant sphere that controls academia (PROs) and industry (I) and coordinates their actions. In the statist configuration, the academic system is separate from industry and primarily focuses on teaching and training. Specialized basic and applied research is only relevant in certain sectors funded and initiated by the government. In the laissez-faire model, all spheres are separated by strong boundaries and limited interaction. The main role of academic institutes in this model is to provide basic research and teaching. More precisely, PROs supply new knowledge, primarily in the form of publications and trained persons. However, it is the industry's task to find and use adequate knowledge without extensive support from the PROs.



Note: Adapted with minor changes from Etzkowitz and Leydesdorff (2000).

Figure 1-2: The Traditional Roles of Public Research Organizations

1.1.2 Empirical Evidence of the Benefits of Publicly Funded Basic Research

Publicly funded basic research makes numerous contributions to economic and social development. Based on the existing literature, the benefits of scientific research can be divided into two broad categories (Salter and Martin, 2001). First, various studies investigate the economic benefits of publicly funded research and focus on economic growth, the rate of return and innovation. Second, Martin et al. (1996) distinguish between various types of contributions, including an increase in useful knowledge, trained and skilled graduates and the creation of new instrumentation, techniques and new firms.

The Economic Benefits

In an early study, Williams (1986) states that publicly funded basic research both directly and indirectly benefits technological progress and economic performance. Early work has claimed that economic growth should be significantly related to technological change rather than changes in capital or labor (e.g., Solow, 1957). Several studies attempt to measure the impact of scientific research on economic growth (e.g., Bergman, 1990; Martin, 1998). Dalton and Guei (2003) estimate that the economic benefit associated with publicly funded research is many times larger than the annual investments. Bilbao-Osorio and Rodriguez-Pose (2004) analyze whether European research and development policies have a positive influence on economic growth in peripheral regions of Europe. They conclude that R&D investments in general, and higher education R&D investments in particular, are positively related to economic growth. Work by Griffith et al. (2004) shows that countries with lagging productivity are able to catch up faster if they invest in their knowledge base.

Mansfield conducted a series of studies to investigate the impact of basic research on industrial innovations (Mansfield, 1991; 1998). He surveyed R&D managers in U.S. firms to estimate what percentage of their new products and processes could not have been developed without academic research. In his first study, Mansfield (1991) finds that the development of 11 percent of the products and 9 percent of the processes would have been substantially delayed in the absence of academic research. He estimates that the social rate of return from basic research is 28 percent. In his follow-up study, Mansfield (1998) confirms that academic research has become increasingly important for industrial innovations. Beise and Stahl (1999) replicated Mansfield's survey with a larger sample of German firms and conclude that approximately 5 percent of new product sales could not have happened without academic research. Tijssen (2002) surveyed inventors in the Netherlands to investigate the contribution of academic research to innovations. He argues that 20 percent of the innovations are based to some extent on public research. Recently, Toole (2012) noted that public research has a significantly positive influence on pharmaceutical industry innovation. Additionally, he finds a positive return to public investment in basic biomedical research.

The Main Types of Contributions

Gibbons and Johnston (1974) investigate how scientific research fosters industrial innovations. They find that scientific research resolves technical problems primarily accessed in scientific publications and through direct personal contact in the scientific community. Moreover, an increased knowledge stock through basic research stimulates and enhances firm's R&D (Rosenberg and Nelson, 1994) and expands the range of technological opportunities (Klevorick et al., 1995). Other studies identify skilled graduates as the primary benefit of publicly funded research (e.g., Martin and Irvine, 1981). Zellner (2003) demonstrates that economic benefits from basic research are associated with the migration of scientists into the private sector. In particular, he finds that scientists formerly employed by the Max Planck Society transfer problem-solving knowledge rather than the latest theoretical insights.

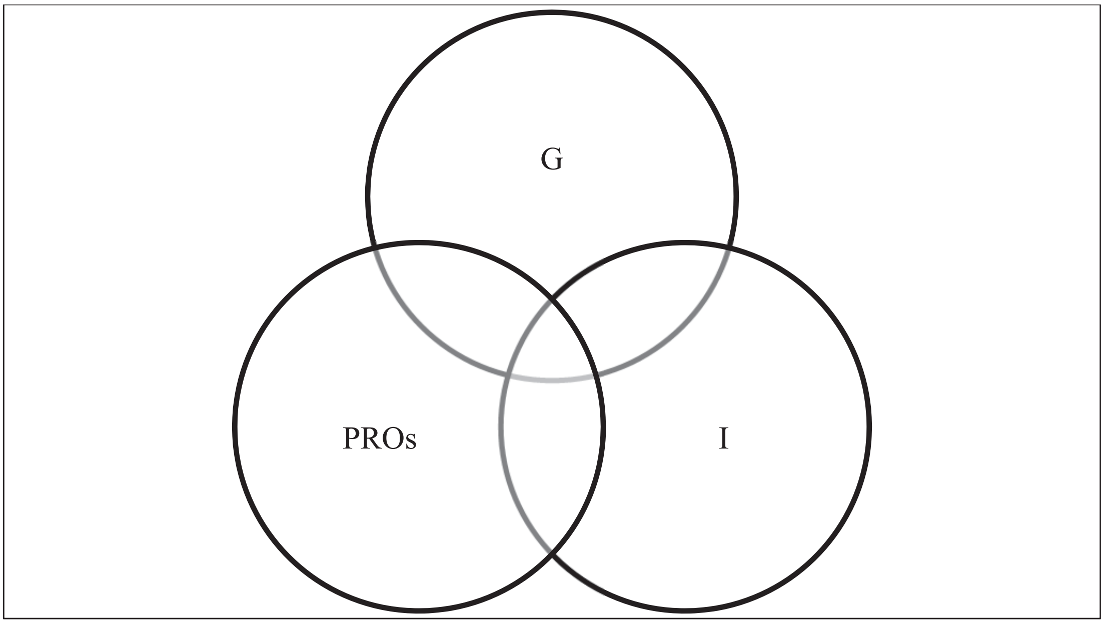
To tackle new research problems, scientists are forced to develop new equipment, laboratory techniques and analytical methods. Thus, much of public research output lies in instrumentation and techniques (Rosenberg, 1992). Work by Arundel et al. (1995) indicates that firms describe research tools and techniques as the second most important contribution of public research. Cohen et al.'s (2002) utilization of the Carnegie Mellon Survey on industrial R&D concludes that R&D projects across a wide range of industries frequently use instruments and techniques. Finally, academic research is often seen as a driving force for firm creation. Zucker et al. (1998) argue that basic research is crucial for the creation of the entire biotechnology market. Malo (2009) likewise discovers that publicly funded research led to the formation of many chemical-based firms and provided firms a great network of innovators. Similar development patterns emerge in the fields of nanoscience and nanotechnology (Darby and Zucker, 2006).

1.1.3 The New Role of Public Research Organizations

Recognizing the tremendous impact of publicly funded research results on economic growth, industrial innovations and its various types of contributions, a shift has taken place in the role and organization of PROs within the economic system. In addition to their traditional tasks of teaching and basic research, the so-called "third mission" extended the role of the PROs to include serving as an active contributor to innovation and economic change. More precisely, academic institutes have become increasingly active in areas such as patenting and licensing, collaborations with private-sector firms, science parks and university spin-offs (Mowery et al., 2004).

Several factors influenced the new PRO "third mission". First, the rise of the knowledge-based economy increased the importance of PROs as active contributors to innovations and economic development (von Hippel, 1988; OECD, 1996). For example, the emergence of knowledge-intensive industries such as biotechnology and nanotechnology raised the demand for academic science. Second, PROs are affected by tighter constraints on public funding leading to a more aggressive search for new financial sources and greater entrepreneurial activity (Thursby and Thursby, 2002; Mowery and Sampat, 2004). Finally, many potential useful discoveries remain in the ivory tower of PROs because researchers are less interested in commercialization issues. To initiate commercial activities, policy makers intended to foster knowledge transfer from science to industry. For instance, several countries established policy measures such as the Patent Act of 1977 in the UK and the U.S. legislation popularly known as the Bayh-Dole Act of 1980 to stimulate the technology transfer of publicly funded research results.

The new role of modern academic institutes is often depicted in the triple-helix model (Etzkowitz et al., 2000; Brenner and Sandstrom, 2000). Figure 1-3 illustrates the triple-helix model in which G stands for the government, I for the industry and PROs for public research organizations. In this setting, the traditional organizational culture is broken down to intertwine boundaries that previously separated the distinct spheres. In this model, the PROs take an active role in encouraging economic development, the industry moves closer to academic institutes, and the government provides a regulatory environment. While the industry and the government are traditionally conceptualized as the primary institutional spheres, the PROs in the triple-helix setting serve in a key role with strong linkages to industry and government (Etzkowitz, 2002).



Note: Adapted with minor changes from Etzkowitz and Leydesdorff (2000).

Figure 1-3: The Triple-helix Model

Various studies provide strong evidence of the increased linkages between PROs and industry. Linkages between PROs and industry are highly diversified both within and between sectors (Faulkner and Senker, 1994). Narin et al. (1997) investigate the citation linkage between U.S. industry patents and scientific publications. They conclude that a high proportion of papers cited by U.S. patents from nearly all scientific areas are from public science, while only a fraction are authored by industrial scientists. McMillan et al. (2000) likewise study the citation linkage between U.S. patents and scientific publications for the biotechnology industry. They find strong support that public research is closely linked to the biotechnology industry. Verbeek et al. (2002) examine the connection between science and technology through the use of patent citation data. Their results reveal a strong interaction between science and technology for a limited number of certain scientific and technological fields.

Further studies focus on academic-industry collaborations. Meyer-Krahmer and Schmoch (1998) study the importance of various types of connections between German universities and private industry and find that from the perspective of academic researchers collaborations are most valuable. Fritsch and Schwirten (1999) analyze the role of German PROs in the regional context. They state that the majority of academic respondents are engaged in various forms of collaborations, and non-university research institutes have the highest proportion. Calvert and Patel (2003) examine collaborations between universities and industry in joint scientific publications in the UK. They conclude that there has been a rapid increase of co-publications between universities and industry since the 1980s. Similarly, Adams et al. (2001) analyze research centers in the U.S. and find evidence of the promotion of university and industry co-authorship.

This thesis analyzes the new role of PROs as active contributors to economic growth and innovations. More precisely, this thesis focuses on technology transfer and commercialization of publicly funded inventions. The next section provides a literature overview on technology transfer channels with a focus on licensing, technology transfer offices as a mediator between PROs and industry in the technology transfer process and the commercialization of publicly funded research results. I then outline the different studies and describe how they contribute to the literature on technology transfer and commercialization of academic research.

1.2 From Science to Business

1.2.1 Technology Transfer from Science to Industry

Recognition of the impact of academic science on economic growth, competitiveness and innovations dramatically increased the relevance of technology transfer from science to industry (OECD, 2003). Technology transfer is defined as the process by which knowledge and scientific results move from academia to industry (Siegel et al., 2004). Several reasons explain why PROs and industry are increasingly involved in technology transfer. As previously mentioned, declining public funds pressure PROs to find alternative financial sources. Geuna (2001) highlights that many European countries, such as France, Germany, the UK and Italy, decreased governmental research funding from 1981-1996. Universities and other public research facilities control a large amount of accumulated knowledge and scientific expertise available for commercial exploitation. Thus, PROs can advertise their valuable research through active technology transfer to increase their reputation and raise additional financial sources from industry. In addition to financial assistance, academia can benefit from technology transfer with industry through increased access to industry facilities and identification of industry problems that stimulate projects and ideas for future research (Bercovitz and Feldman, 2006).

From the policy perspective, technology transfer from PROs to industry is important to ensure an efficient societal use of public money and to justify the expenditures for basic research activities. Different policy measures such as the Bayh-Dole Act in the U.S. were established to foster the positive effect of PROs on economic growth, employment and productivity. This legislation promotes technology transfer by leaving academia the right to retain ownership of publicly funded research results, to protect the intellectual property (IP) through patent application and to assign IP rights to the industry. Other countries, such as Germany and Denmark, introduced similar legislation. In Germany, new legislation subjected universities to the German Employee's Inventors Act in 2002. This change guaranteed universities the ownership of publicly funded research results whereas university professors previously held exclusive IP rights to their inventions (Kilger and Bartenbach, 2002).

From the perspective of the private sector, the growing interest in technology transfer is a key element of a firm's exploration strategy that emphasizes the search, discovery and development of new knowledge (Rosenkopf and Nerkar, 2001). Technology transfer gives a firm access to complementary knowledge that may lead to path-breaking innovations. Moreover, technology transfer supplies new ideas, solutions or answers to current technical problems (Bercovitz and Feldman, 2006). Cohen et al. (2002) state that publicly funded research primarily addresses the particular needs or problems faced by a firm. In addition, a firm's investment into R&D is characterized by a high technological risk. Technology transfer activities allow a firm to partially outsource R&D activities and disperse associated risks (Bell, 1993).

Technology Transfer through Licensing

Technology transfer from PROs to industry occurs through a variety of channels ranging from recruitment of university graduates to personnel exchanges, collaborations, contract research, consulting, publications, licensing, spin-off companies and informal contacts such as meetings and conferences (Agrawal, 2001). Technology transfer channels can be divided into formal (e.g., collaborative research) and informal (e.g., publications and conferences) (D'Este and Patel, 2007). While the former technology transfer mode may result in direct legal commercial output such as patents or licenses, the latter instrumentalities often do not. Formal transfer modes are often focused on the allocation of IP rights and obligations; in informal technology transfer channels, property rights only play a minor role (Link et al., 2007).

The relevance of certain transfer channels has attracted considerable attention in the academic literature. Cohen et al. (2002) investigate the relative importance of various formal and informal transfer channels from a firm's perspective. Their results emphasize that publications, meetings and conferences, informal interaction and consulting are more important transfer mechanisms than patents in the majority of industries. Agrawal and Henderson (2002) study the relevance of transfer channels from a scientist's perspective through interviews at the Massachusetts Institute of Technology (MIT). They demonstrate that patents are a relatively less important channel for technology transfer. Most faculty members specify that patents only account for less than 10 percent of their knowledge transfer. The interviews with the MIT staff identify consulting activities, publications, the recruitment of graduates and collaborative research as the most important sources of technology transfer. More recently, Bekkers and Freitas (2008) examine the factors that influence the relative importance of a wide variety of transfer channels using responses from two Dutch questionnaires administered to industrial and university researchers. They find that the respondents rate patenting and licensing as a moderate technology transfer channel.

These studies suggest that patenting and licensing is just one of a myriad of sources of technology transfer. However, the economic contribution of patenting and licensing as a source of technology transfer is highly considerable. Agrawal (2001) indicates that licensing strongly contributed to the U.S. economy and created a wide range of new jobs. Notwithstanding the importance of informal transfer channels, a large number of scholarly literature focus on patenting and licensing mainly because these formal channels are directly measurable and available (Agrawal and Henderson, 2002; Markman et al., 2008). For instance, the topic of patenting and licensing before and after the Bayh-Dole Act has attracted much scholarly research. In an investigation of the influence of the Bayh-Dole Act on the growth of patenting and licensing activities of three leading U.S. universities, Mowery et al. (2001) conclude that the rise started before rather than after 1980. Thus, the Bayh-Dole Act was merely only one of several factors contributing to the increased patenting and licensing activity of PROs. The rise of new areas of university research, such as molecular biology, electronics and software, increased the industry demand to license publicly funded research results (Colyvas et al., 2002).

To provide deeper insights into licensing activity, a broad range of studies examine various determinants of this formal transfer mode. Based upon patent data from the University of California, Stanford University, and Columbia University, Mowery and Ziedonis (2001) compare the geographic reach of patent citations and licenses. Their results indicate that licensing activities are more geographically localized than patent citations. The difference of the geographic localization effect between citations and licenses is even stronger for exclusively licensed university patents. Sine et al. (2003) explore the effect of institutional prestige on the annual rate of technology licensing using a dataset of 102 U.S. universities collected from 1991 to 1998. They detect that institutional prestige, measured by two different graduate school rankings, significantly influences the university's licensing rate.

Using a dataset of 1,397 patents issued to MIT from 1980-1996, Shane (2002) analyzes which types of inventions are more likely to be licensed. Empirical results show that effectively patented inventions are more likely to be licensed, particularly to non-inventors. Elfenbein (2007) recently investigated to which degree scientists' publications, disclosures, commercialization experiences and the patent protection status influence the licensing event of disclosed inventions. He concludes that disclosures, publications and commercialization experiences are positively related to the licensing activity but that patent protection provides little support.

Technology Transfer Offices as Mediators between Academia and Industry

The technology transfer process of licensing between PROs and industry is characterized by several barriers. The cultural backgrounds and expectations of PROs and industry differ substantially from each other (see Siegel et al., 2003a; 2004). Scientists are primarily motivated by recognition from the scientific community, including publication in top-rated journals and achievement of scientific breakthroughs. Academic institutes typically undertake challenging projects with long time horizons and uncertain practical applications. In contrast, firms are mainly focused on less risky research with direct commercial applicability (Di Gregorio and Shane, 2003). Moreover, PROs are usually interested in a broad and open dissemination of scientific research results, while firms prefer exclusive licenses that appropriate all technological benefits. These differences between PROs and industry clarify the difficulty of providing an effective technology transfer mechanism.

Thursby and Thursby (2002) explain other reasons that scientists may avoid technology transfer activities. First, because individual scientists are mainly interested in basic research and have high opportunity costs of time, they are unwilling to spend additional effort and time on applied R&D to induce licensing. Second, to generate firm interest in licensing, inventions have to be protected by patents that often come along with publication delays. This circumstance may hamper invention disclosures by the faculty and adjacent technology transfer activities. Finally, scientists expect that commercialization of publicly funded research results is not in line with their open science mission.

To encourage formal technology transfer such as licensing, many PROs have established technology transfer offices (TTO) that are seen as intermediary agents linking academia and industry (O'Gorman et al. 2008). TTOs primarily evaluate scientific discoveries, seek patent protection, negotiate with firms and execute contracts on behalf of the PROs that own inventions. Furthermore, TTOs are expected to assist inventors in case of weak university-industry linkages and unsuccessful commercialization efforts (Colyvas et al., 2002; Lowe, 2006). Ambos et al. (2008) provide empirical evidence of the importance of these institutions in the technology transfer process. They analyze whether TTOs influence the scientific outcomes, such as patents, licenses, spin-off companies or a combination thereof, using a dataset of 207 Research Council-funded projects. Their results suggest that TTOs positively influence scientific output.

To improve the formal technology transfer process from PROs to industry, scholarly studies analyze various organizational challenges faced by TTOs. Siegel et al. (2003a) examine TTO organizational barriers in 98 interviews of university administrators, scientists and firms, the three main stakeholders involved in the technology transfer process. They state that bureaucratic inflexibility, poorly designed reward systems and ineffective management are the most important factors that prevent effective technology transfer. Debackere and Veugelers (2005) analyze the TTO of the Katholieke Universiteit Leuven in Belgium and compare it with 11 other European research universities. Consistent with the evidence in the U.S., they find that an inefficient management style, inflexible regulations and an inappropriate incentive structure are the main barriers that hinder an efficient technology transfer. Another challenge facing TTOs is the circumstance that not all scientific inventions are disclosed to the employer. Using a survey of TTOs in 62 U.S. universities, Thursby et al. (2001) detect that only half of the faculty inventions with a commercial potential are disclosed to the employer. To encourage scientists to disclose their inventions, a certain incentive structure is required. Jensen et al. (2003) construct and analyze a game-theoretic model of technology transfer and find that invention disclosure is a function of the faculty quality, equilibrium license income and inventor’s time preference.

Further scholarly studies examine determinants that enhance TTO productivity. Studies reveal that TTOs that are financially independent of their parent institution are more productive than those that depend on funding from their parent organization (e.g., Bercovitz et al., 2001; Feldman et al., 2002). Siegel et al. (2003b) show that institutional factors such as the reward system of academic scientists and staffing practices explain much of the productivity variation of TTOs, namely the average number of licenses and licensing revenues. Carlsson and Fridh (2002) find that the number of invention disclosures and the expertise of the TTOs positively influence patenting and licensing activities using a dataset of 170 U.S. universities and research institutes for the period 1991-1996. Chukumba and Jensen (2005) examine how various characteristics of academic inventors, TTOs and universities affect licensing performance. One notable result is that, contrary to the UK (Chapple et al. 2005), the age of the TTO is positively related to licensing activities.

1.2.2 Commercializing Licensed Inventions from Public Research

Whether scientific inventions are transformed into marketable products or processes leading to a financial success is highly uncertain. Various studies suggest that the amount of revenues of patented and licensed inventions is highly skewed (OECD, 2003; Sampat, 2006; Thursby and Thursby, 2007). The majority of licensed inventions generate only a small amount of money, if any, and just a few are responsible for the overall income. Mowery et al. (2001) show that the top 5 inventions of three leading U.S. universities generated between 66 and 94 percent of the overall licensing income in the 1995 fiscal year. This skewed distribution suggests that a substantial risk of commercial and financial success is associated with the development of new technologies, time to market and consumer response to new products.

The Complexity of Commercialization of Licensed Inventions

The transfer of inventions from PROs to the industry is the first step toward commercialization. Once scientific inventions are transferred through licenses, the firm becomes tasked with successful market placement. However, commercialization of academic inventions is a non-trivial process determined by the early stage character of inventions (Jensen and Thursby, 2001), information asymmetries (Shane, 2002), non-codified knowledge (Agrawal, 2006) and absorptive capacity of firms (Cohen and Levinthal, 1989; 1990).

The early stage of development in which inventions are transferred to the industry may hinder commercialization. Based on a survey of TTO licensing managers from 62 U.S. universities, Jensen and Thursby (2001) note that a large share of licensed inventions are just a proof of concept or a lab scale prototype. In a survey of 112 firms regarding their perception of the development stage of licensed inventions, Thursby and Thursby (2004) indicate that nearly 40 percent of the respondents evaluate inventions at the proof of concept stage, the earliest listed stage of development. Both licensing managers and firms specify that only a small fraction of licensed inventions are ready for commercial use. The economic potential of early stage inventions is hardly predictable, leading to a low practical and commercial use.

The tacit nature of knowledge also hampers the commercialization process of licensed inventions. Scientific results codified in publications, patents and blueprints only include a fraction of the underlying knowledge (Polanyi, 1966; Arora, 1995). Necessary knowledge components important for successful commercialization often remain with researchers. For example, the generation of academic results is a long lasting process characterized by failures and disappointments that generally remain unreported. However, this non-codified knowledge may contain information useful to understand the whole development process of the scientific invention. Lissoni (2001) states that although codified knowledge is sufficient for technological breakthroughs, person-embodied knowledge is required to transform the codified knowledge into economically valuable technologies.

Firms require a certain stock of knowledge to understand and exploit scientific results. The absorptive capacity of firms is the ability to assimilate and use external knowledge strongly related to their in-house R&D investments (Cohen and Levinthal, 1989; 1990). Cockburn and Henderson (1998) state that the connection to PROs is an important determinant necessary to build up absorptive capacity and to utilize external knowledge. Lim (2009) indicates that connectedness is the primary ingredient of absorptive capacity. Connections to academic researchers help firms to acquire knowledge from those sources and to increase their absorptive capacity. For instance, Zucker and Darby (1996) report that close links between academic and firm scientists support the accomplishment of scientific breakthroughs.

Scholarly Literature on the Commercialization of Licensed Inventions

In view of the early stage of inventions, the latent nature of knowledge and absorptive capacity, the involvement of the inventor during the development process is highly important. Business respondents claim that approximately 40 percent of licensed inventions require the participation of the inventor for further developments (Thursby and Thursby, 2004). Engagement with the inventor enables firm access to a scientist's non-codified knowledge and expertise and ensures the advancement of embryonic technologies (Pavitt, 1998). Agrawal (2006) examines the direct influence of inventor engagement on the likelihood and the degree of commercial success using a sample of 124 license agreements from MIT. He finds that inventor involvement in the development process positively influences the commercialization success of licensed inventions. Furthermore, the participation of academic inventors is a critical determinant of the speed of commercialization (Markman et al., 2005).

To get scientists on board for enhancements, a certain incentive mechanism is necessary to encourage involvement (e.g., Gallini and Wright, 1990; Jensen and Thursby, 2001). Licensing contracts include a fixed fee and an output-based payment, the royalty payment. The royalty payment is intended to incentivize additional efforts. If a licensed invention is successfully commercialized, the inventor gets a percentage of the revenues. Friedman and Silberman (2003) analyze several organizational characteristics, including greater rewards for faculty involvement, TTO experience, university location and support for technology transfer. They find that all four factors greatly impact university licensing income. Based on a dataset of 102 U.S. universities, Lach and Schankerman (2004) show that a higher inventor royalty share is associated with a larger licensing income. Link and Siegel (2005) confirm that PROs with attractive incentive structures, such as higher royalty shares for faculty members, generate greater licensing income.

The effect of appropriability on the commercial success of licensed inventions is a further research topic. Shane (2002) analyzes the impact of patent effectiveness on the hazard that licensed inventions reach their first sales. He distinguishes between inventor and non-inventor licensees, and he investigates whether patent effectiveness influences the extent of non-inventor's commercial success. The results show that the hazard of first sales from patents licensed to non-inventors is higher with greater patent effectiveness. Furthermore, the patent effectiveness positively influences the magnitude of commercial success in non-inventor firms. He concludes that non-inventors more effectively commercialize inventions when the inventions are appropriable through patents but inventor-founded firms best develop inventions that are more difficult to appropriate. Dechenaux et al. (2008) explore the role of appropriability in generating incentives that influence licensee investment in commercialization. They estimate the hazard rate of first sales and find that the effectiveness of learning as a measure of the appropriability mechanism taken from the Yale survey on innovation positively influences the hazard of technology commercialization.

Besides the organizational determinants and appropriability mechanisms, scholars have also explored the influence of different types of licensees and various attributes of technological inventions on commercial success. Thursby et al. (2001) show that licensed invention commercial success is positively related to the fraction of licenses executed at later stages of development. Using a dataset of 966 licensed inventions from MIT, Neklar and Shane (2007) examine the influence of technology attributes on the likelihood of commercialization. Their results show that inventions with a broader scope of patent protection and a pioneering nature are positively related to the likelihood of first sales. Additionally, the age of inventions has an inverted U-shaped relationship with commercial success. Analyzing the commercial success of licensed inventions, Lowe and Ziedonis (2006) find weak evidence that licenses to startup firms generate greater earnings than do invention licensed to established firms. Based on a dataset of 2,200 inventions of Max Planck Society researchers from 1980 to 2004, Buenstorf and Geissler (2012) analyze the impact of inventor, technology and licensee characteristics on the likelihood and magnitude of commercial success. They find limited evidence that domestic and incumbent licensees outperform foreign and spin-off firms. However, patented inventions are less likely to be commercialized and generate lower royalty payments.

1.3 Scope and Structure of this Thesis

The previous sections presented a literature overview of the importance and benefits of PROs within the economic system, described their shift to more entrepreneurial activity (section 1.1) and discussed the transfer and commercialization of academic technologies (section 1.2). This thesis contributes to the scholarly literature on technology transfer and commercialization of scientific inventions. Most of the existing studies are based on U.S. data. The empirical evidence for Europe is rare, which is not surprising because academic invention legislation in Europe recently changed. Moreover, the lack of detailed data of disclosed, licensed and commercialized inventions also explains the proportionally low amount of empirical studies (Neklar and Shane, 2007). Thus, the primary objective of this thesis is to provide new empirical insights into technology transfer and commercialization using data from Germany's largest non-university public research organization, the Max Planck Society.

In this thesis, four separate studies investigate technology transfer and commercialization activity. Thereby, each chapter in this thesis can be read independently and covers distinct research questions. Chapter 2 examines one part in the licensing process, the bargaining stage, and studies the influence of group identity on the determination of prices and beliefs. Chapter 3 considers the influence of the geographic distance between the licensor and the licensee on the likelihood and magnitude of commercial success of licensed inventions. Chapter 4 focuses on the speed by which inventions are transferred to private-sector firms. This study explores the impact of time inventions required for licensing on commercial success. Chapter 5 analyzes the impact of organizational performance measures such as royalty payments and director involvement on commercialization behavior in the public research sector.

Each chapter also utilizes different methodologies. While chapter 2 employs a laboratory experiment based on a psychological concept, chapters 3-5 are empirical studies. Chapter 2 employs a laboratory experiment due to a lack of available data necessary to adequately address the research question. Laboratory experiments are particularly suited to study individual economic behavior under conditions where differences can be controlled and measured. Chapters 3 and 4 utilize a dataset on disclosed and licensed Max Planck inventions. Chapter 5 utilizes the same dataset as in chapters 3 and 4 but at the institute level.

Although the four chapters consider diverse research questions and employ different methodologies, all studies cover the overarching topic of technology transfer and commercialization of publicly funded results. Each chapter aims to add new insights to the respective subfield. The following sections provide an overview of the four chapters of this thesis.

1.3.1 Group Identity and Discrimination in Small Markets: Asymmetry of In-group Favors[2]

Due to the early stage character of scientific results and various other difficulties inherent in the technology transfer process, only a few firms, if any, are interested in licensing academic inventions (Jensen and Thursby, 2001). In such small markets, common experiences and joint visions between firms and academia are important to foster trust and to create long term relationships (Bercovitz and Feldman, 2006). A firm's former positive licensing experience is expected to increase the likelihood of subsequent licensing agreements that may lead to a discriminative behavior of licensors against other interested parties. Thus, the level of social ties and relationships among actors may influence the licensing bargaining process.

To understand the psychological basis for intergroup relations and discrimination, Tajfel and Turner (1979) developed the theory of group identity that is defined as the degree to which individuals see themselves as members of a group. Economists recently adopted the group identity concept to analyze gender discrimination, economics of poverty and social exclusion, household division of labor, and principal-agent problems (Akerlof and Kranton, 2000; 2005). A growing number of studies utilize laboratory experiments to investigate the effect of group identity on individual economic decision-making (e.g., Ahmed, 2007; Heap and Zizzo, 2009). An emerging stream of experimental research focuses on the influence of group identity in small market settings (e.g., Ball et al., 2001). For instance, Li et al. (2011) study the impact of group identity on partner selection and price offers in oligopolistic markets. Utilization of a bargaining game with multiple

[2] This chapter is co-authored with Gerhard Riener.

proposers and responders demonstrates that in-group sellers are more likely to make offers to in-group buyers than to out-group buyers.

Chapter 2 aims to contribute to this field through application of the group identity aspect to a market setting in which subjects interact. More precisely, this chapter studies the influence of group identity on the determination of prices and beliefs in a small market game. Thereby, the group identity is induced through a focal point coordination game that offers a greater control and flexibility over the group formation process. After the group formation process, subjects play a three-person bargaining game in which one seller can sell an indivisible good to one of two competing buyers under four different treatments while varying the buyer-seller constellation. The results of the experiment provide robust evidence of in-group favoritism on the buyer's side. More precisely, buyers who share a common experience with the seller and compete with an out-group buyer offer a significantly higher price compared to the case in which all subjects belong to the out-group. Moreover, sellers expect in-group favoritism from in-group buyers, but they do not reciprocate the favoritism with lower ask prices.

1.3.2 We Need to Talk – or do we? Geographic Distance and the Commercialization of Technologies from Public Research[3]

Commercialization of PRO licensed inventions is a non-trivial process that is characterized by several difficulties. Highly complex academic inventions are often at an early stage of development and may involve cross-disciplinary knowledge, thus hampering the development process of a marketable technology. Relevant knowledge known to scientists is often not written or codified, making that progress even more difficult. Inventor participation and close face-to-face contact during the development process is required to overcome these problems (Jensen and Thursby, 2001; Agrawal, 2006). Nonetheless, the involvement of the inventor becomes increasingly expensive with geographic distance (von Hippel, 1994). Furthermore, it is questionable whether scientists facing high opportunity costs of time are willing to cover a large distance to spend additional time and efforts on applied tasks rather than focus on their own research (Stephan, 1996).

Several studies provide evidence that proximity to public research yields substantial benefits to firm innovativeness (e.g., Jaffe, 1989; Acs et al., 1992). For example, Fritsch and Slavtchev (2007) detect that the quality and intensity of research of German universities significantly influence the regional innovative

[3] This chapter is co-authored with Guido Buenstorf.

output. Adams (2002) finds that geographic proximity plays a greater role in university-firm interactions than in firm-firm interactions. Other studies find a lesser role for geographic proximity (e.g., Audretsch and Stephan, 1996; Beise and Stahl, 1999). Despite the numerous studies of the effect of public research on regional growth and innovative performance, only a few studies investigate the influence of geographic distance in the context of licensing and commercializing academic inventions. The work by Santoro and Gopalakrishnan (2001) suggests that geographic proximity positively influences technology transfer activities between universities and firms. Agrawal (2006) does not find that firm location affects commercialization outcomes.

This chapter attempts to fill a gap in the literature by analyzing the impact of geographic distance between the licensor and the licensee on the commercial success of licensed inventions from the Max Planck Society. The geographic distances between both of the Max Planck Institutes and the corresponding private-sector licensees are calculated. Royalty payments that serve as a proxy for commercial success enable us to construct two different measures. First, a binary indicator is constructed, indicating positive royalty payments. Second, the extent of commercial success is captured from the accumulated royalty payments. The analysis includes additional information about licensees as well as inventions and their inventors. The empirical analysis suggests that geographic distance is not associated with lower commercialization outcomes. A negative influence of distance on commercial success is identified only for spin-off licensees located outside Germany and for foreign licensees in the subset of inventions licensed multiple times.

1.3.3 Commercializing Inventions from Public Research: Does Speed Matter?

Researchers argue that quick invention placement into the market is essential due to the rapidly changing business environment and technological obsolescence (Nadler and Tushman, 1999). Moreover, Kessler and Chakrabarti (1996) state that since the 1990s, speed has become one of the most important strategic determinants to create and sustain competitive advantages. A multitude of studies analyze the determinants of speed by which discoveries are put on the market (e.g., Kessler and Chakrabarti, 1999; Tessarolo, 2007). A further string of research examines the impact of speed on economic outcomes such as development costs (e.g., Langerak et al., 2010), product quality (e.g., Kessler and Bierly, 2002) and product performance (e.g., Carbonell and Rodriguez, 2006).

However, most of the studies focus on in-house developments and neglect external sources such as patenting and licensing from PROs.

This chapter examines how speed influences the commercial success of licensed inventions. Thereby, the time elapsed between invention disclosure and the signed licensing contract (time-to-licensing) is used as a proxy for speed. Furthermore, the influence of different invention-specific determinants on time-to-licensing is investigated. The empirical evidence in this field is still scarce. Llor (2007) investigates the influence of the delay between patent filings and the corresponding transfer agreements on license revenues and finds no correlation. Markman et al. (2005) analyze organizational determinants of time-to-licensing and its influence on commercial success of patent-protected technologies. They find that TTO resources, competency in identifying licensees and participation of faculty-inventors positively influence the speed of technology transfer. Furthermore, their results suggest that a faster technology transfer is associated with a greater commercial success.

To analyze invention-specific determinants on time-to-licensing and its influence on commercial success, Max Planck data on disclosed and licensed inventions is employed. Regression results suggest that inventions from the biomedical section, collaborative inventions with private-sector firms and inventions co-invented with senior scientists require less time to get licensed. Using the subset of license agreements providing for royalty payments, the empirical analysis suggests that time-to-licensing does not influence the commercial success of inventions disclosed between 1980 and 2004. However, a separation of the effect of time-to-licensing for inventions disclosed after 1989 shows a robust negative influence on the likelihood and extent of commercial success.

1.3.4 The Influence of Leadership on Academic Scientists' Propensity to Commercialize Research Findings[4]

The last chapter focuses on the impact of leadership behavior and organization performance on individual behavior in public research. Although the influence of leadership behavior primarily utilizes firms as the unit of analysis, surprisingly few studies consider academic organizations. Azoulay et al. (2007) find that scientists are more likely to engage in patenting when their coauthors have patenting experience. Bercovitz and Feldman (2008) find that the decision of

[4] This chapter is co-authored with Stefan Krabel.

individual faculty members to participate in technology transfer is influenced by seemingly unsustainable leadership effects.

This paper aims to shed more light on academic institutions through an examination of the extent to which commercialization performance and leadership effects are related to invention disclosure. This study specifically investigates the influence of director participation in the invention development process and commercial success on subsequent disclosures at the institute level. The dataset of invention disclosures and licensing agreements of the Max Planck Society is utilized. The data are structured such that information on invention disclosures, director involvement, royalty and fixed fee payments is given per year and institute. A panel for 1980-2004 is constructed to allow the use of lagged variables.

Regression results suggest that director engagement in disclosure activity and the amount of royalties received positively influence the number of subsequent disclosures. However, these effects disappear when modeling longer time lags. Thus, academic scientists mimic successful behavior, while leadership behavior does not have long-lasting effects on commercialization behavior within the institute.

2. Group Identity and Discrimination in Small Markets: Asymmetry of In-group Favors

2.1 Introduction

Trade between members of groups with different non-economic social characteristics is almost ubiquitous in every society. Social characteristics should not be a factor for trade in a market setting where subjects attempt to maximize their gains from trade. However, discrimination between groups is frequently observed in market settings such as housing markets (Yinger, 1995), car markets (Goldberg, 1996), consumer markets (Yinger, 1998), and labor markets (Bertrand and Mullainathan, 2004). This phenomenon has been explained either with statistical discrimination (Phelps, 1972) or taste-based discrimination (Becker, 1957), where negative stereotypes or negative tastes toward another group result in unequal treatment. We are interested in how group identity influences the determination of prices and expectations on the demand and supply side in a simple market setting abstracting from statistical discrimination.

Early work in social psychology by Tajfel and Turner (1979) developed a theory of group identity to understand the psychological basis for intergroup relations and discrimination. People define themselves as members of particular groups in a society that may have behavioral consequences when two members of different groups interact with each other. As noted by Akerlof and Kranton (2000), the group identity plays an important role in economic decision-making, such as hiring decisions and bargaining. They propose a utility function that included the identity associated with different social norms and categories and apply this model to analyze phenomena such as gender discrimination, economics of poverty and social exclusion.

Following Akerlof and Kranton (2000), we focus on a minimal group design to isolate the effect of statistical discrimination that cannot be excluded from natural groups. We induce group identity by employing a simple coordination game. In our experiment, one seller is trying to sell an indivisible good to one of two buyers. The seller states her willingness to accept separately for each buyer, and the buyers state their willingness to pay. If the willingness to pay from both buyers is lower than the corresponding willingness to accept from the seller, there is no trade. If both buyers are over their respective willingness to accept, the seller can choose to whom to transfer the good. This trade happens under four different treatment conditions: (1) complete strangers - in this case, subjects have not interacted in the coordination game. (2) Both buyers and the seller are all in-group members; i.e., they have interacted in the coordination game. (3) Only one buyer and the seller are in-group (the other buyer is out-group). (4) Both buyers are in-group and the seller is out-group. Additionally, we elicit expectations of behavior over buyers and sellers. Our contribution to the literature is to directly compare markets where discrimination via group membership is possible versus markets where this is not.

Our results reveal that in-group buyers who compete with an out-group buyer offer significantly more compared to a stranger's framework. We also find that in-group seller expect in-group favoritism from their partner, i.e. expect a higher offer. However, we do not find evidence of discriminatory behavior of the seller, bargaining with an in-group and an out-group buyer. In-group favoritism appears to be asymmetric and depends on the market power of the actor: the seller, as the more powerful market participant, expects favorable treatment from in-group members; however, she is not willing to reciprocate by accepting lower offers from in-group buyers.

A large body of experiments in social psychology (and increasingly in economics) studies the influence of group identity on behavior.[5] Thereby, experimental research relies on both natural identities (e.g., Goette et al., 2006) and artificially induced groups (e.g., Heap and Varoufakis, 2002). Studies dealing with natural groups identify significant effects on the behavior of subject in various experiments. For instance, Kramer et al. (1995) find that responders involving members of two rival business schools are more willing to accept unfair offers by in-group proposers than the same offer made by someone from the out-group in a bargaining game. Fershtman and Gneezy (2001) show that identifying natural groups with a distinct ethnic affiliation in the Israeli Jewish society leads to a discrimination of outsiders in both the trust game and the ultimatum game but not in the dictator game. Falk and Zehnde (2007) identify statistical discrimination and in-group favoritism in sequential trust games using natural groups divided into residential districts in Zürich. They find that the magnitude of investments depend on the district in which the responders live; additionally, people trust strangers from their own district significantly more than they trust strangers from other districts. More recently, Leider et al. (2009) explore group identity and social ties in the context of dictator games and find evidence of in-group favoritism; i.e., dictators give nearly 52 percent more to friends (in-group) in a real-world social network than to random strangers (out-group).

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[5] A detailed review of the literature in social psychology on social identity can be found in Charness et al. (2007) and Chen and Li (2009).

In contrast to natural identities, the use of induced identities gives the researchers more control and flexibility over the group formation process. In an early experiment, Vaughan et al. (1981) divide a group of 7- to 11-year-old children into red and blue groups to play a simple division game. They conclude that, irrespective of the age, children give more money to members of their own group than to members of the other group. Charness et al. (2007) investigate the influence of induced group membership and its salience on the individual behavior in the prisoner’s dilemma and battle-of-the-sexes games. In the minimal group treatment, they do not find differences in the cooperation rate between in-group and out-group members. However, after increasing the salience of the groups, the authors find that group membership significantly affects the individual behavior. Likewise, the introduction of artificially induced groups by color group assignment leads to the discrimination of outsiders in a repeated trust game (Heap and Zizzo, 2009). Chen and Li (2009) explore the effect of social identity across a variety of games and find that subjects are more altruistic towards in-group members.

While previous experiments have demonstrated the impact of group identity in various types of games, only a few papers deal with the influence of group identity in market settings. For example, Ball et al. (2001) investigate the impact of social status on market prices and earnings. They find that players randomly assigned to a high-status group earn significantly more of the surplus regardless of whether they are buyers or sellers. Recently, Li et al. (2011) study the impact of group identity on partner selection and price offers in oligopolistic markets. They conduct a bargaining game with multiple proposers and responders and find that in-group sellers are more likely to make offers to in-group buyers. The authors note that group identity may not be important in large markets where buyers and sellers act anonymously. However, group identity may be more important in markets with a small number of sellers and buyers and, as we argue, with infrequent trade.

There are several studies investigating the interaction between three people: Güth and Damme (1998) examine the effect of the presence of an observer in the ultimatum game. Holm (2000) conducts a three-person game with natural groups and looks at coalition formation and sharing within a coalition. He finds that Swedish subjects choosing between a partner with a Swedish or a foreign name would choose the person with the Swedish name significantly more often than they would choose the person with a foreign name. However, Holm (2000) does not observe a difference in the distribution of resources within the coalition. In a recent study, Bauernschuster et al. (2009) explore how competition and group identity affect trust and trustworthiness. They find that trustees react to competition among in-group and out-group investors by lowering return ratios. The work that is closest to our study is the work by Tremewan (2010). In that work, a three-person “divide the dollar” game is used to investigate the effect of group identity on the formation of coalitions and on the resulting distribution of resources. He concludes that players in the out-group earn less because they are more often excluded from the coalition.

Our design is applicable to a variety of small markets, such as licensing markets where only one seller (licensor) and a few buyers (licensees) bargain in the market. It is applicable because of the following reasons. First, licensing is comparable to a matching procedure: among all firms interested in licensing a technology, the firm that submits a price that is at least as much as what the licensor asks for while being the highest offer becomes the exclusive licensee. Second, the number of potential licensees is limited because the inventions are usually at an early stage with uncertain market success (Contractor, 1981; Jensen and Thursby, 2001). Thus, social ties among the actors may play an important role in these markets. For instance, some common experiences may already exist between certain participants at the time of negotiation due to prior collaboration. On the other hand, other participants may not have any common experience or relation to the in-group; hence, they belong to the out-group.

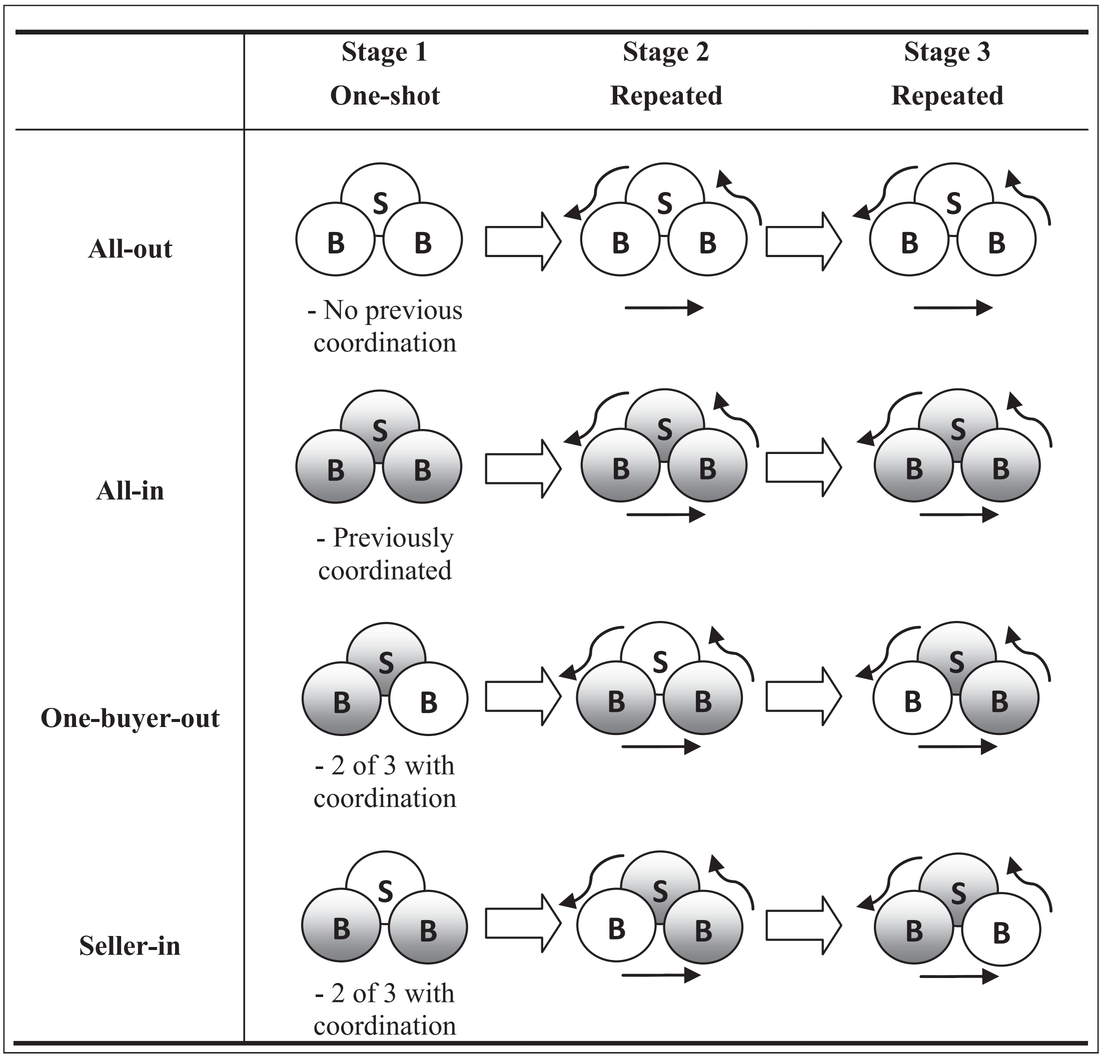
Several caveats should be mentioned here. Dealing with within-group manipulations might steer the behavior of the subjects into a direction the experiment is designed to test for and invoke an experimenter demand effect (EDE, Zizzo, 2010). To circumvent this problem, we formulate our instructions as neutral as possible. Moreover, we do not announce our objectives during the experiment; i.e., the key goals and claims that the experimenters are actually trying to achieve are not revealed. Additionally, we use the focal point game to avoid an obvious group formation process (Mehta et al., 1994). Furthermore, using a lump-sum payment is not a compatible incentive for belief elicitation. Nonetheless, a lump-sum payment can be justified because several studies report that incentivization does not significantly improve stated beliefs (Dufwenberg and Gneezy, 2000; Sonnemans and Offerman, 2001; Guarino and Huck, 2006).

The remainder of the paper is organized as follows: In section 2.2, we describe our experimental design; in sections 2.3, we outline our hypotheses and behavioral prediction. Then, we present the results in section 2.4. In section 2.5, we conclude and discuss the implications of our findings.

2.2 Experimental Design

To identify the influence of group identity on the determination of the offers of the buyers and the claims of the sellers in a market setting, we implement four distinct experimental treatments. Each treatment consists of three parts and a concluding questionnaire that are computerized using zTree (Fischbacher, 2007). In the first part of the experiment (identical for all four treatments), we introduce group identity using a three-person coordination game. This coordination ensures a common and positive experience among the upcoming in-group members. In the second part of the experiment, subjects are rearranged into groups of three according to the four different treatments with different group compositions. To strengthen group feelings, we introduce wording and color assignments to identify in-group and out-group members in the subsequent treatments. Subjects who are matched with at least one subject, with whom they play the first part together, are referred to as in-group members. Subjects who are matched with subjects with whom they do not play the first part together are referred to as out-group members. Additionally, in-group and out-group members vary according their color assignments.

In the second part, the bargaining game, one seller and two buyers have to bargain for an indivisible good. Stage 1 of the three-person bargaining game corresponds to a one-shot game because the subjects know that the second part of the experiment consists of 3 stages with the exact information regarding the content of stage 2 and stage 3 being disclosed at the end of the first bargaining game. This arrangement means that, after completing the first bargaining game, subjects are informed that the three-person bargaining game will be repeated in stages 2 and 3 while keeping the group membership and group identity constant. However, new roles will be assigned to the subjects. Every subject in each treatment plays once as a seller and twice as a buyer. Figure 2-1 gives a graphical overview of the treatments. Thereby, S stands for the seller and B stands for the buyer. In treatment *All-out*, all subjects are out-group members represented by white circles. In treatment *All-in*, all subjects belong to the in-group and are represented with gray circles. In treatment *One-buyer-out*, one buyer and seller belong to the in-group while the other buyer belongs to the out-group; this is represented with two gray and one white circles. In treatment *Seller-out*, both buyers belong to the in-group and the seller belongs to the out-group; this is represented with two gray and one white circles. All four treatments are conducted in each session. The third part concludes the experiment with a lottery choice game and a final questionnaire.



Note: S=Seller, B=Buyer. The unequal arrows indicate how subjects changed roles over the stages

Figure 2-1: Treatment Overview

2.2.1 First Part: The Coordination Game and Group Formation

In the first part of the experiment, groups of three subjects are formed randomly. All subjects participate in a three-person coordination game played within each group to establish common experiences among the randomly formed group. Subjects of a group, referred to as partners, have to choose a meeting point in Paris (France), either the Eiffel Tower or the Centre Georges Pompidou (see Bauernschuster et al., 2009). Coordination is successful if all three players of a group pick the same meeting point. In the case of a successful coordination, the group receives an amount of 1.50€ that is split equally among the subjects of the group. If the players disagree, the group receives 0€. After the coordination game, the subjects are informed of their own choice and the choices of their group mates, the outcome of the coordination and the profit of the group.

After completing the coordination game in the first part, the groups are rearranged according to the four treatments; additionally, the subjects receive information on the group composition. To strengthen the in-group membership, we use wording and color assignment. We assign a color (blue) to all members of the in-group and inform the participants of this color assignment. Subjects that are supposed to interact as out-group members are matched with two new subjects with whom they do not interact in the first part. We inform subjects belonging to the out-group that they are assigned to subjects that belong to the blue group (referred to as partners), who have already collected experience in the first part together. To strengthen the out-group feeling, we assign the color red to out-group members (see Heap and Varoufakis, 2002). Group membership, i.e., the colors and the corresponding information with whom they interacted in the first part, is public knowledge to all of the matching-group members. We use this minimal group design to avoid confounding the existence of groups with strong reciprocity motives.

2.2.2 Second Part: The Bargaining Game

In the second part of the experiment, the matching-group members participate in a three-person bargaining game for three rounds where two buyers and one seller negotiate for an indivisible good. The bargaining process proceeds as follows: all subjects of a matching-group make their individual offers simultaneously and in private. The seller has to announce a payment request to each of the two buyers (X_1, X_2), simultaneously, announcing the minimum level of acceptance in exchange for the good. On the screen of the seller, the two boxes for the payment request for each buyer are arranged vertically. The buyers are randomly assigned to the upper and lower boxes. At the same time, each buyer states her offer, indicating the willingness to pay for the indivisible good (Y_1, Y_2). Proposals and payment requests can range between an integer value of 0 and 113 Experimental Currency Units (ECUs). After all subjects confirm their proposal(s), the entry is obligatory and cannot be renegotiated. Once all subjects make their decisions, the offer of each buyer is compared to its corresponding threshold to decide if the good is sold and to determine which buyer successfully purchased the good. In case that none of the offers meet the corresponding threshold of the seller, the good is not sold. If both offers are at least equal to the threshold of the seller $[(X_1 \leq Y_1) \wedge (X_2 \leq Y_2)]$, she has to decide to whom the good has to be sold.[6] A single buyer acquires the good if her

[6] To the best of our knowledge, all prior studies investigating responder competition use a random draw to determine the winner (see Grosskopf, 2003). To check for potential discrimination in a bargaining process we allow for a choice of the seller in case that both buyers reach its corresponding

offer is equal to or exceeds the corresponding threshold of the seller and the offer of the other buyer does not $[((X_1 \leq Y_1) \wedge (X_2 > Y_2)) \vee ((X_1 > Y_1) \wedge (X_2 \leq Y_2))]$.

The payments of the subjects depend on successful contracting. If there is no agreement on the price, the buyers' endowment of 113 ECUs is lost and all participants receive no profit. If the seller concludes a contract with one of the two buyers, the seller receives the winning offer of the buyer. The successful buyer receives the difference between 113 ECUs and the price offered to the seller. The other buyer leaves the bargaining stage empty-handed. In total, the subjects play three bargaining rounds while keeping the group membership and group identity constant; however, new roles are assigned to the subjects. Thus, every subject plays once as a seller and twice as a buyer. The first stage of the bargaining game corresponds to a one-shot game. Subjects in the experiment are unaware of the fact that the game is repeated two more times. In all three bargaining stages, the subjects do not receive feedback about the prior bids or the outcome.

After each bargaining stage, we elicit beliefs from each subject depending on its role in the bargaining game. More precisely, we elicit the beliefs of the seller regarding the potential offer from each of the two buyers and the beliefs of the buyers regarding the potential payment request of the seller for herself and for the other buyer. For the elicitation, we use two different methods: first, we ask each subject for a point estimate; i.e., the subjects have to declare an integer between 0 and 113 ECUs. In the second step, we confront the subjects with twelve intervals of equal size apart from the first and the last one.[7] The subjects have to state a value between 0 and 100 for each interval to specify how likely the expected value is located in the corresponding interval. In the end, all stated values have to sum up to 100, which correspond to 100 percent.[8] Thus, each subject has to answer four bonus questions after each bargaining game independent from the role. In total, the subjects receive a lump-sum payment of 1.20€ for answering all bonus questions.

At the end of the second part, one stage is randomly chosen for payment. In case a clear result is achieved (i.e., either no agreement is reached or an agreement where one buyer meets the corresponding threshold of the seller and the other does

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threshold. However, we are aware that such a design could lead to payment requests of the seller close to zero.

[7] The first interval [0, 10] includes 11 values, whereas the last interval [111, 113] includes only 3 values. All other intermediate intervals include 10 values.

[8] Both methods ask the same question but in a different way. Whereas the first question just asks for an integer value, the second question asks for a probability distribution. The aim of the second method is to specify the beliefs of the subjects and to control for inequalities and inconsistencies. According to Delavande et al. (2008), eliciting probability distributions is more preferable than eliciting point expectations. Therefore, we only use probability distributions for the upcoming analysis. Furthermore, we do not incentivize belief elicitation to avoid risk hedging problems that may be prevalent, especially in market settings (see Blanco et al., 2010).

not), all subjects receive feedback immediately. In case both buyers meet the corresponding threshold of the seller, the buyers receive a message that the seller has to choose from one of the two buyers. The choice screen of the seller includes two adjacent (colored) boxes for each buyer that include the payment request of the seller and the corresponding offer. The buyers are randomly assigned to the box on the left or on the right. After the seller makes a choice, all subjects of the group receive feedback.

2.2.3 Third Part: Risk Aversion Elicitation and Questionnaire

To control for the role of risk aversion, we apply a simplified procedure of Holt and Laury (2002).[9] Subjects are presented with five different lottery choices. In each case, the subjects have a choice between a safe lottery S that guarantees a payment of 0.50€, and a risky lottery R that pays from 0.90€ to 1.50€ with a probability of 50 percent. In general, more risk-averse people should switch from lottery S to lottery R at a higher stage. At the end, one pair of lotteries is selected randomly and the decision is paid out.

2.3 Hypotheses

First, we are interested in whether differences among buyers with respect to group identity have an effect on the stated offers. We expect that a direct comparison of buyers in mixed groups lead to a stronger competition between the buyers, resulting in higher offers from both buyers compared to situations where the buyers are indistinguishable. One explanation for this conjecture might be that the sellers are not able to directly discriminate between two identical buyers, which might reduce the investment pressure of both buyers compared to situations where buyers have different group identities.

Alternatively, in-group buyers may follow an in-group favoritism pattern. For example, Robert and Carnevale (1997) analyze the impact of groups on the formulation of ultimatum offers and find that the proposers more often offer a fair share to a member of their own group than to a member from a different group. Likewise, Wilson (2007) conducts a dictator game with three different ethnic groups and finds strong in-group favoritism. The subjects send significantly higher economic awards to recipients from their own ethnic groups than to recipients belonging to another group. Furthermore, we predict that the out-group buyer in treatment *One-*

[9] This procedure has previously been used by Durante and Putterman (2007).

buyer-out will offer more compared to the *All-out* case because of anticipated in-group favoritism from the seller for the in-group buyer. Following these arguments, we predict:

Conjecture 1a: In treatment *One-buyer-out*, in-group buyers offer more compared to buyers in the *All-Out* treatment.

Conjecture 1b: In treatment *One-buyer-out*, out-group buyers offer more compared to buyers in the *All-Out* treatment.

Second, we are interested in the payment requests of the sellers and whether these requests differ between different group identities. We suppose that in-group sellers may demand either a lower or a higher price from in-group buyers compared to out-group buyers. On the one hand, in-group sellers may demand lower prices from in-group buyers because of in-group favoritism. On the other hand, opportunistic in-group sellers may take advantage of the in-group favoritism of the buyers and charge in-group buyers a higher price. Recently, Li et al. (2011) have observed that in-group sellers charge in-group buyers a higher price compared to out-group buyers. Therefore, we formulate following hypothesis for the case in which the sellers can directly distinguish between both buyers:

Conjecture 2: In treatment *One-buyer-out*, the payment requests of the in-group sellers are higher for in-group buyers than for out-group buyers.

Furthermore, we are interested in the beliefs regarding the behavior of each role of the other players with respect to different group identities. Several studies elicit beliefs regarding the actions of the other players, such as the contributions in public good games (e.g., Offerman et al., 1996) and the investments in trust games (e.g., Dufwenberg and Gneezy, 2000). In our experiment, the sellers might hold heterogeneous beliefs regarding the expected offers of the buyers considering differences in group memberships. In-group sellers might expect that their partners from the first part of the experiment make them a higher offer compared to the out-group buyer. This would be in line with the impact of in-group favoritism (Tajfel, 1982) and common identity, which are the major determinants for transactions in markets (Ben-Porath, 1980). The following relationship is expected:

Conjecture 3: In treatment *One-buyer-out*, in-group sellers expect a higher offer from in-group buyers than from out-group buyers.

The same argument (in-group favoritism) also holds for beliefs of buyers regarding the potential payment requests of the seller. If the buyers have different group identities, they may expect different payment requests for themselves and for their counterpart. According to in-group favoritism, in-group buyers may expect a lower price for themselves than for the out-group counterpart; whereas out-group buyers may expect a higher price for themselves than for the in-group counterpart. Therefore, we predict the following:

Conjecture 4: In treatment *One-buyer-out*, in-group buyers expect a lower threshold whereas out-group buyers expect a higher threshold for themselves.

2.4 Results

2.4.1 Implementation

We conducted the experiment in June 2010 at the laboratory of the Friedrich Schiller University Jena. All participants were undergraduate students from a broad variety of disciplines, excluding students from economics and psychology, recruited via ORSEE (see Greiner, 2004). In total, we conducted 10 sessions with 168 subjects; there were 18 subjects per session.[10] Before the experiment, the subjects received the same basic instructions in print (see appendix A). At the end of each session, the results of the first part and the results of one randomly picked stage from the second part were paid according to the decisions of the subjects. Furthermore, the subjects received a lump-sum payment of 1.20€ for all bonus questions and, on average, an additional 0.56€ from the lottery game. Each subject received a show-up fee of 2.50€. On average, the subjects earned a total of 7.28€, with a minimum payment of 4.20€ and a maximum payment of 14.50€. All rewards within the experiment were handled in ECUs, where 1 ECU corresponds to 0.08€.

2.4.2 Group Induction

[10] We had to restrict the number of subjects to 12 in two sessions due to no-shows. In these cases, the first three treatments were conducted. In general, treatments *All-out* and *All-in* were run with 1 group per session, and treatments *One-buyer-out* and *Seller-out* were run with 2 groups per session. However, the treatment *Seller-out* was run for 1 session with 4 groups to balance the number of executed treatments.

In the first part (the coordination game) 99.4 percent of all subjects chose the Eiffel Tower as the meeting point in Paris. This leads to a successful coordination in 98.2 percent of all groups. Only one group out of 56 groups did not coordinate on the same focal point. Thus, the coordination success is even larger compared to the results shown in the study of Bauernschuster et al. (2009).

2.4.3 Bargaining Game: First Stage

In this section, we use the results from the first stage of the bargaining game. First, we look at the differences of the stated offers depending on group identity and treatments. To test Conjectures 1a and 1b, the offers of in-group and out-group buyers in treatment *One-buyer-out* are compared with the pooled offers from buyers in treatment *All-out*, *All-in*, and *Seller-out*.[11] Figure 2-2 presents six bar plots where the upper three compare the offers of the in-group buyers with pooled offers in treatments *All-out*, *All-in*, and *Seller-out*; in the lower three plots, the offers of the out-group buyers are compared to the pooled offers in treatments *All-out*, *All-in*, and *Seller-out*.

The in-group buyers in treatment *One-buyer-out* offer 90.83 ECUs on average, whereas the pooled buyers in treatment *All-out* offer 79.15 ECUs on average, a difference of nearly 15 percent. The Mann-Whitney two-sample statistic shows that the difference is statistically significant (p-value = 0.048).[12] It implies that in-group buyers who compete with out-group buyers offer significantly more compared to the framework of the stranger. Additionally, we test the mean offers of the in-group buyers in treatment *One-buyer-out* with the pooled mean offers in treatment *Seller-out* (80.6 ECUs) and find that in-group buyers in treatment *One-buyer-out* offer significantly more than the pooled buyers in treatment Seller out (p = 0.069).

In the next step, we compare the mean offers of out-group buyers in treatment *One-buyer-out* with the pooled mean offers of treatments *All-out*, *All-in* and *Seller-out*. All three comparisons, i.e., the difference between treatments *All-out* and *One-buyer-out* (p = 0.988), *All-in* and *One-buyer-out* (p = 0.453), and *One-buyer-out* and *Seller-out* (p = 0.985) do not show any significant differences between the stated offers.

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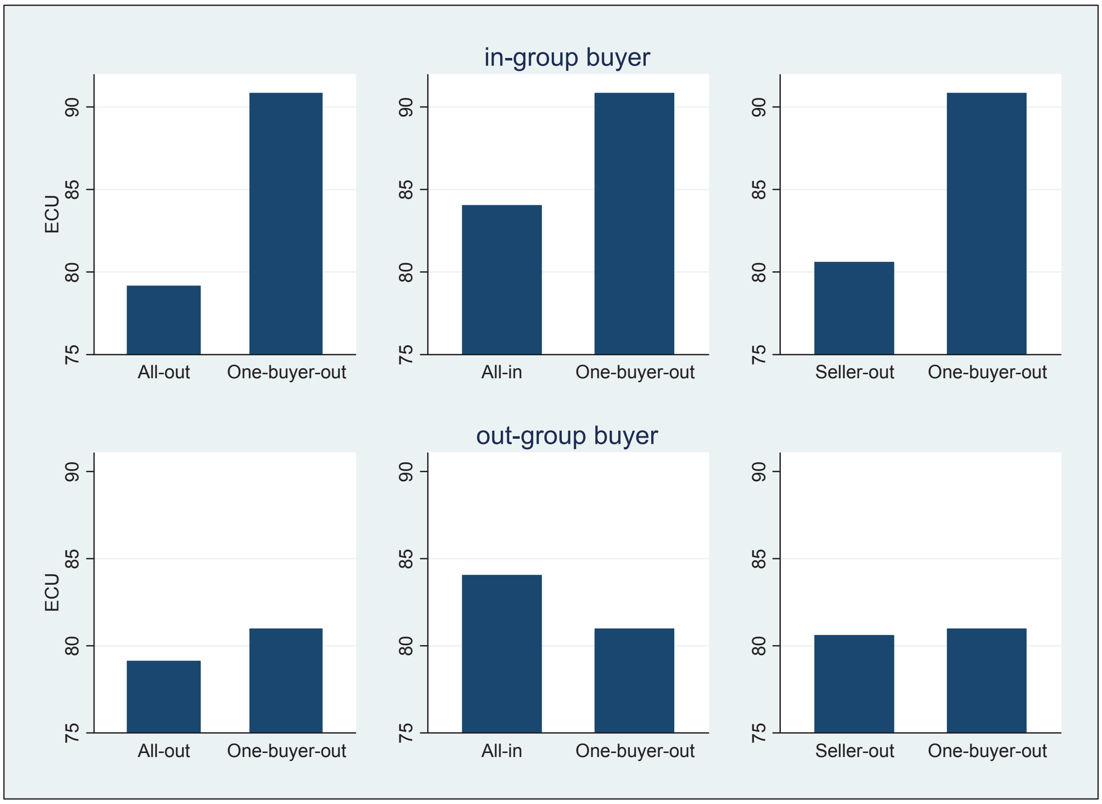
[11] The reason why we can pool the offers of the buyers in these treatments is because the buyers are indistinguishable. In both cases, the buyers have either no social identity or are both in-group members. Therefore, we pool the offers to get more observations for the comparison between treatments.

[12] We report test statistics from the Mann-Whitney test throughout the rest of the paper unless indicated otherwise.

Overall, the results suggest that in-group buyers tend to offer significantly more in treatment *One-buyer-out* compared to treatments *All-out* and *Seller-out*. For out-group buyers, no significant difference is observed. Our results confirm Conjecture 1a; i.e., in-group buyers in treatment *One-buyer-out* offer significantly more compared to the offers from the buyers in treatment *All-out*. However, we do not find support for Conjecture 1b that out-group buyers in treatment *One-buyer-out* offer a significantly larger amount to the in-group seller compared to the mean offers in treatment *All-out*.



Note: The upper three graphs compare the average offers from the in-group buyers in treatment 'One-buyer-out' with the pooled average offers in treatment 'All-out', 'All-in' and 'Seller-out'. The lower three graphs compare the average offers from the out-group buyers in treatment 'One-buyer-out' with pooled average offers in treatment 'All-out', 'All-in' and 'Seller-out'.

Figure 2-2: First Period Treatment Comparisons of Average Offers

To test Conjecture 2, we analyze the payment requests of in-group sellers in treatment *One-buyer-out*. Therefore, we look at the mean payment requests for both the in-group and the out-group buyers. The in-group sellers demanded on average 78.16 out of 113 ECUs from the in-group buyers compared to 76.61 out of 113 ECUs from the out-group buyers. The Wilcoxon signed rank test suggests no significant difference ($p = 0.547$) between both requests. Thus, we do not find evidence that the in-group sellers treat buyers that belong to either the same or to the other group differently; this conclusion contradicts Conjecture 2.

Additionally, in Figure 2-3 we depict the offers from the out-group and the in-group buyers for treatment *One-buyer-out* in cases where both offers meet the corresponding threshold of the seller. In total, the in-group seller had to choose nine times in the first stage of treatment *One-buyer-out*. We see that the highest offer was chosen most of the time (except two instances). These offers were mainly made by in-group buyers. In case of ties, the seller chose the in-group agent, indicating in-group favoritism. Surprisingly, the in-group seller chose the partner in one case although the in-group buyer offered less than the out-group buyer did. However, the difference is not significant.

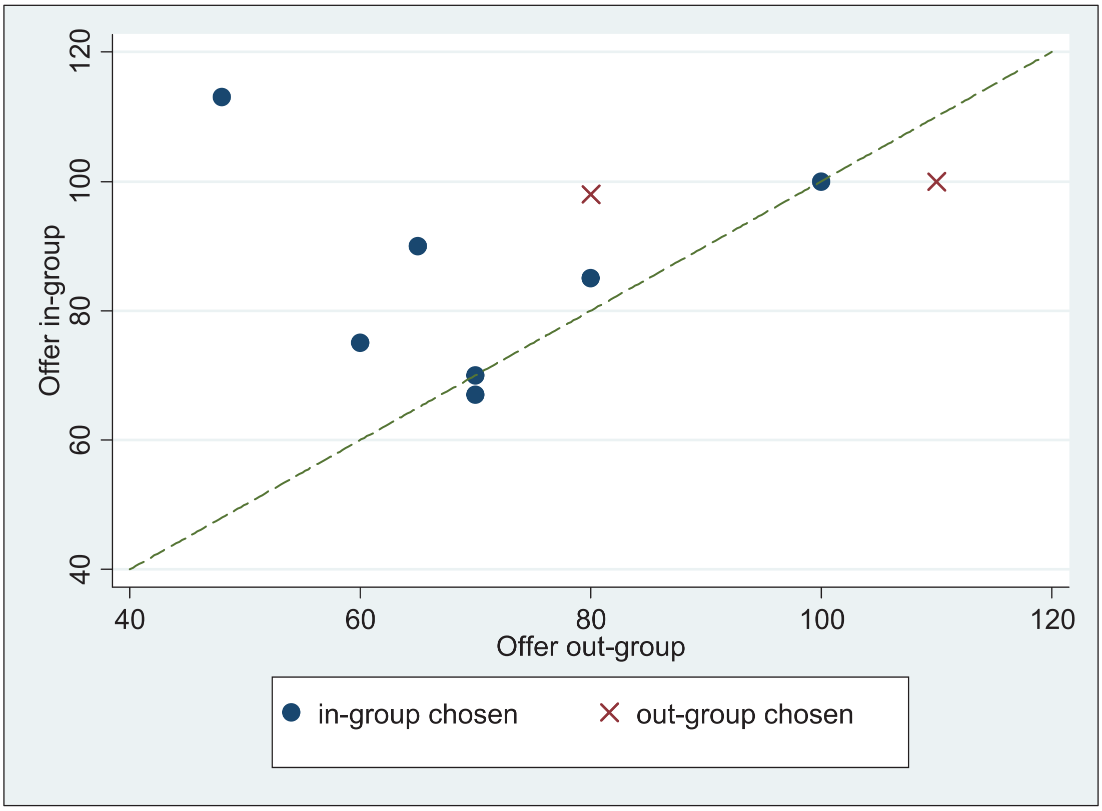


Figure 2-3: Choice of Sellers

<u>Expectations of Sellers</u>

In this section, we consider the expectations of the sellers regarding the potential offers of the buyers in the first stage among the 4 treatments. For this, we use the elicited probability distributions over the offers (Table 2-1). We are especially interested in the beliefs of the seller in treatment *One-buyer-out* to test Conjecture 3, where the two buyers have different group affiliations. Additionally, we investigate the differences in beliefs between treatments.

In treatment *One-buyer-out*, the in-group sellers expect a mean offer of 76.4 ECUs from the in-group buyers compared to an expected mean offer of 71.1 ECUs from the out-group buyers. The Wilcoxon signed rank test confirms that the expectations of the in-group sellers differ significantly from each other ($p = 0.064$). This result is in line with Conjecture 3 and suggests that in-group sellers expect (on average) a favorable offer from the in-group buyers.

We then compare the expectations of the sellers regarding the potential offers of the in-group buyers in treatment *One-buyer-out* with pooled beliefs of treatments *All-out* ($p = 0.090$), *All-in* ($p = 0.188$), and *Seller-out* ($p = 0.163$). The results suggest a significant difference between treatments *All-out* and *One-buyer-out*. The sellers in treatment *All-out* expect a mean offer of 62.69 ECUs from the pooled buyers, whereas the in-group sellers in treatment *One-buyer-out* expect a mean offer of 76.43 ECUs from the in-group buyers. This difference might be driven by in-group favoritism; i.e., the in-group sellers expect (on average) a higher offer from their partner. Another explanation may be that the in-group sellers expect a stronger competition among buyers with different group identities in the *One-buyer-out* treatment compared to the *All-out* treatment, where no direct difference can be observed.

With regard to the expectations of the sellers on the offers of the out-group buyers, we do not find any significant differences between the *One-buyer-out* treatment and the pooled beliefs in the *All-out* ($p = 0.335$), *All-in* ($p = 0.599$) and *Seller-out* ($p = 0.910$) treatments.

Table 2-1: Expectations of Sellers

Treatment	Expectations of the seller: Identity 1st buyer	Expectations of the seller: Identity 2nd buyer	Total
All-out	Out-group		
	62.34 *6.90* (10)	63.0 *6.67* (10)	62.69 *4.67* (20)
All-in	In-group		
	65.57 *4.76* (10)	66.02 *3.02* (10)	65.80 *2.74* (20)
One-buyer-out	In-group	Out-group	
	76.43 *4.53* (18)	71.08 *4.74* (18)	73.75 3.26 (36)
Seller-out	In-group		
	69.90 3.51 (18)	68.69 3.38 (18)	69.30 2.40 (36)

Note: This table presents the mean expectations of the seller differentiated with respect to both buyers; the standard errors are in italics and the number of observations is in parentheses. The 1st buyer corresponds to the buyer on the left, whereas the 2nd buyer corresponds to the buyer on the right in Figure 2-1.

Expectations of Buyers

We now analyze the expectations of the buyers regarding the potential payment requests of the sellers for themselves and for their counterpart. Table 2-2 summarizes the mean expectations of the buyers for the 4 treatments. First, we do not find a significant difference among the expectations of the in-group and out-group buyers in treatment One-buyer-out regarding the potential payment requests of the sellers for themselves (p = 0.506). The same is true for the expectations of the in-group and out-group buyers about the potential payment request for the counterpart of the seller (p = 0.506). Hence, we do not find any significant differences in the payment request for oneself and for the counterpart among in-group and out-group buyers under the *One-buyer-out* treatment; this result contradicts Conjecture 4.

Table 2-2: Expectations of Buyers

	Expectations (Exp.) of the buyers Identity 1st buyer		Identity 2nd buyer		Total	
Treatment	Exp. oneself	Exp. other	Exp. oneself	Exp. other	Exp. oneself	Exp. other
All-out	Out-group		Out-group			
	73.02 *6.06* (10)	76.05 *6.77* (10)	72.75 *3.71* (10)	72.75 *3.77* (10)	72.88 *3.46* (20)	74.40 *3.79* (20)
All-in	In-group		In-group			
	74.79 *6.61* (10)	77 *6.37* (10)	62.76 *2.94* (10)	67.24 *4.05* (10)	68.75 *3.78* (20)	72.12 *3.84* (20)
One-buyer-out	In-group		Out-group			
	80.89 *4.06* (18)	82.17 *4.17* (18)	76.98 *4.35* (18)	77.42 *4.83* (18)	78.94 *2.95* (36)	79.80 *3.17* (36)
Seller-out	In-group		In-group			
	72.96 *5.16* (18)	71.31 *4.97* (18)	73.67 *3.37* (18)	73.32 *3.51* (18)	73.32 *3.03* (36)	72.32 *3.01* (36)

Note: The 1st buyer corresponds to the buyer on the left, whereas the 2nd buyer corresponds to the buyer on the right in Figure 2-1. The mean values correspond to the expectations of the buyers with respect to the payment request of the sellers for oneself (exp. oneself) and for the counterpart (exp. other). The standard errors are written in italics, and the number of observations is written in parentheses.

Furthermore, we investigate whether beliefs, i.e., the expected payment requests for oneself and for the counterpart differ in the *One-buyer-out* treatment for each buyer. We are interested if both buyers with different group identities expect on average a difference between payment requests for oneself and for their counterpart. We do not observe a significant difference in beliefs (when we analyzed the expectations using the Wilcoxon signed rank test, p = 0.225) for in-group buyers regarding the payment requests for oneself and for their counterpart. For the expectations of the out-group buyers (Wilcoxon signed rank test, p = 0.627), we receive a similar result. This implies that buyers do not expect to receive significantly different payment requests from the seller.

To obtain a more precise picture, differences in the expectations across treatments are analyzed. In this regard, the expectations of the buyers in the *One-buyer-out* treatment are compared with the pooled expectations in treatments *All-out*, *All-in*, and *Seller-out*. The Mann-Whitney test suggests that the expectations for in-group buyers for themselves (80.9 ECUs) in the *One-buyer-out* treatment differ significantly from the pooled expectations (68.8 ECUs) in the *All-in* treatment (p = 0.037). All other differences among treatments are insignificant. This implies that in-group buyers expect a significantly larger payment request for themselves and, therefore, fierce competition in the *One-buyer-out* treatment compared to the *All-in* treatment, where both buyers belong to the in-group.

Moreover, we compare the expectation of the in-group buyer's counterpart with the pooled expectations in the *All-out*, *All-in* and *Seller-out* treatments. The expected payment requests for the counterpart (82.2 ECUs) in the *One-buyer-out* treatment do not differ significantly from the pooled expectations for the counterpart (74.4 ECUs) in the *All-out* treatment (p = 0.169). However, the Mann-Whitney test confirms a significant difference between the expectations of the in-group buyers in treatment *One-buyer-out* (82.2 ECUs) with the pooled expectations in the *All-in* treatment (72.1 ECUs) and the *Seller-out* treatment (72.3 ECUs) (p = 0.075 and p = 0.040, respectively). These results suggest that in-group buyers expect for their counterpart (with a different group affiliation) a higher payment request compared to treatments where differences among buyers cannot be directly observed. With regard to the expectations of the out-group buyers, i.e., the expected payment requests for oneself and for their counterparts, we do not find significant differences between treatments.

2.4.4 Panel Regressions

To determine whether the above findings regarding the offers of the buyer are consistent, we analyze all three stages of the bargaining game including various covariates. We focus on the behavior of the buyer according to the structure of the data; for each subject, we have two observations as a buyer and one observation as a seller. Table 2-3 presents the GLS regressions with individual random effects and robust standard errors.[13] The regressors are the offers of the buyers to acquire the indivisible good. We include indicator variables that state whether or not the group members (i.e., the seller and both buyers) belong to the in-group. In our analysis, we try to identify how the offer of the buyer is influenced by its own group affiliation and that of its teammates when compared to the offer of the buyers in the *All-out* treatment, which form the omitted reference group.

In all regression models (Models 1-3), the group constellation interacts with the stage variable to control for the learning effects caused by role reversals. Furthermore, we include the variables to control for session effects, gender effects, risk aversion and experience. More precisely, the variables are defined in the following manner: *Session* is a categorical variable transformed into a factor variable; *Female* is a binary variable and is equal to one for female; *Risk* is a ordinal variable and ranges from 1 to 6, where 1 corresponds to risk averse and 6 to risk loving; *Experience* is a binary variable that measures whether or not subjects already participated in an experiment.

Table 2-3: GLS Regression Results on the Offers of the Buyers

	Model 1	Model 2	Model 3
(Group constellation)			
(Blue seller x Blue self x Blue other)			
(1x1x1)	5.599	5.975	10.282*
	(5.180)	(5.802)	(5.983)
(1x0x1)	-1.511	-1.829	-2.192
	(4.995)	(5.463)	(5.071)
(1x1x0)	9.872*	12.238**	10.446*
	(5.396)	(6.181)	(5.884)
(0x1x1)	4.413	6.247	5.636
	(5.086)	(5.864)	(5.568)
Expectation self (EV)			0.449***
			(0.070)
Female		3.359	-1.370
		(3.169)	(2.860)
Risk		-0.272	0.069
		(1.022)	(0.871)
Stage	Yes	Yes	Yes
Session		Yes	Yes
Experience		Yes	Yes
Constant	79.34***	58.36***	28.64***
	(4.121)	(8.374)	(9.604)
Difference in coefs between In-group and out-group buyer in treatment One-buyer-out	-11.38**	-14.07***	-12.64***
Observations	336	296	296
Number of subjects	168	148	148

Note: The robust standard errors are in parentheses. *, **, *** denote significance at the .10, .05, and .01 percent levels, respectively. The coefficient of the group constellation term shows the difference of behavior of a buyer of a particular type (in- or out-group) in the respective buyer-seller constellation compared to the baseline treatment *All-out*. A zero indicates that the respective person belongs to the out-group, while a 1 indicates in-group. In models 2 and 3, we had to exclude twenty observations due to ambiguous choices in the 3rd part of the experiment. The variable experience indicates whether the person has participated in previous economic experiments (but not in this one).

[13] We estimated all models with GLS random effects and Tobit random effects. Because the estimated results are very similar, we report only GLS random effects. Further results are available upon request.

The first model in Table 2-3 investigates the influence of the group members' identity on the offer of the buyers while controlling for stage effects. The results suggest a weak significant positive effect for the in-group buyers who bargain with in-group sellers and compete with out-group buyers. In-group buyers in the *One-buyer-out* treatment offer significantly more compared to buyers who belong to the out-group and interact with out-group sellers and out-group buyers. Among the buyers in the *One-buyer-out* treatment, the coefficients of those belonging to the in-group differ significantly from those belonging to the out-group ($p < 0.011$). In Model 2, we control the session effects, gender, risk aversion, and experience. The results in Model 2 confirm that in-group buyers who bargain with in-group sellers and compete with out-group buyers offer significantly more compared to offers of the reference group. The coefficients of both buyers belonging to the *One-buyer-out* treatment differ significantly from each other ($p < 0.002$). Finally, in Model 3, we include the expectation of the buyers as an additional explanatory variable. The results are qualitatively similar to those obtained in Models 1 and 2. Surprisingly, we find that in-group buyers who interact with in-group sellers and compete with another in-group buyer (in the *All-in* treatment) offer significantly more compared to the control group in the *All-out* treatment after controlling for expectations.

Overall, the results of the regression Models 1-3 suggest that in-group buyers who bargain with an in-group seller and compete with an out-group buyer offer significantly more compared to the case where buyers bargain with an out-group seller and compete with an out-group buyer. These results confirm Conjecture 1a and suggest that the behavior of a buyer does not depend only on the buyer's own group identity but also on the group identity of the other members and, therefore, the entire group constellation.

2.5 Conclusion

Investigating bargaining behavior among involved parties using field data, especially among participants with different group identities, can be difficult. We conducted a laboratory experiment to investigate the influence of group identities on the behavior of subjects in a market setting where two buyers and one seller bargain for an indivisible good. We find that in-group buyers offer significantly more in situations where direct discrimination is possible and out-group buyers do not; this behavior might be expected due to in-group favoritism.

The most interesting finding is that sellers expect in-group favoritism from in-group buyers, but do not reciprocate the favoritism by offering lower ask prices. This could be because in-group favoritism is asymmetric and depends on the market power of the actor. A more powerful market participant – the seller – expects a favorable treatment, but she is not willing to accept lower offers from in-group members. This opens a path of further research whether market power (or other powers) could lead to asymmetric in-group favoritism that is in favor of the more powerful participant.

Future research may also focus on how different levels of experience (cf. Li et al., 2011) influence the behavior of the subject. Furthermore, repeated interactions among subjects with prior experience or particular group identities might lose its weight through ongoing interactions. To investigate a negotiation that is more related to a licensing process, the sellers and both buyers have to be unaware of the potential benefit of the indivisible good.

3. We Need to Talk – or do we? Geographic Distance and the Commercialization of Technologies from Public Research

3.1 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., 2003a; 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 licensed 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. Mansfield and Lee (1996) likewise 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 (2012) 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 a 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, as pointed out by Salter and Martin (2001), this result might be influenced by the geographic differences between Germany and the U.S.

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 3.3 provides information about the technology transfer process of the Max Planck Society. Section 3.4 describes our data and the research design for the empirical analysis, whereas results are discussed in section 3.5. We conclude and discuss implications and limitations of our analysis in section 3.6.

3.2 Does Geographic Proximity Matter for Successful Commercialization of University Inventions?

3.2.1 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

$$\pi_{ij} = R_{ij} - C_{ij}(s) \; with \; \partial C_{ij}(s)/\partial s > 0, \quad (3\text{-}1)$$

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):

$$E(\pi_{ij}(s)) = p_{ij}\pi_{ij}(s) - (1 - p_{ij})C_{ij}(s) = p_{ij}R_{ij} - C_{ij}(s). \qquad \text{(3-2)}$$

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 (3-2) 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 3-1) 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 equation (3-2) 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 3-1).

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 (3-2). 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 3-1.

There are yet further possible patterns of outcomes. Equation (3-2) 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 (3-2) where p_{ij} is a function of distance (with $\partial p_{ij}(s) \,/\, \partial s < 0$) while C_{ij} no longer depends on distance:

$$E\left(\pi_{ij}(s)\right) = p_{ij}(s)\pi_{ij} - (1 - p_{ij}(s))C_{ij} = p_{ij}(s)R_{ij} - C_{ij}. \qquad \text{(3-2')}$$

If (3-2') 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 3-1), 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 3-1 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 3-1). 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.

Table 3-1: 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 commercialization likelihood; no effective competition for license	–	o
5	Distance reduces commercialization likelihood; effective competition for license	–	+
6	Discrimination against more distant licensees	+	+

3.2.2 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.[14]

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.

3.3 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

[14] 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.

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.

3.4 Data and Methods

3.4.1 Data

The present study is based on information provided by Max Planck Innovation GmbH that has been analyzed in earlier work by Buenstorf and Geissler (2012). The dataset covers all inventions disclosed by Max Planck researchers from the mid-1960s to the beginning of 2005. In total 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.[15] In total, 731 contracts provide for royalty payments (with or without additional fixed fees), of which 365 (50 percent) have been successfully commercialized (Table 3-2).

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

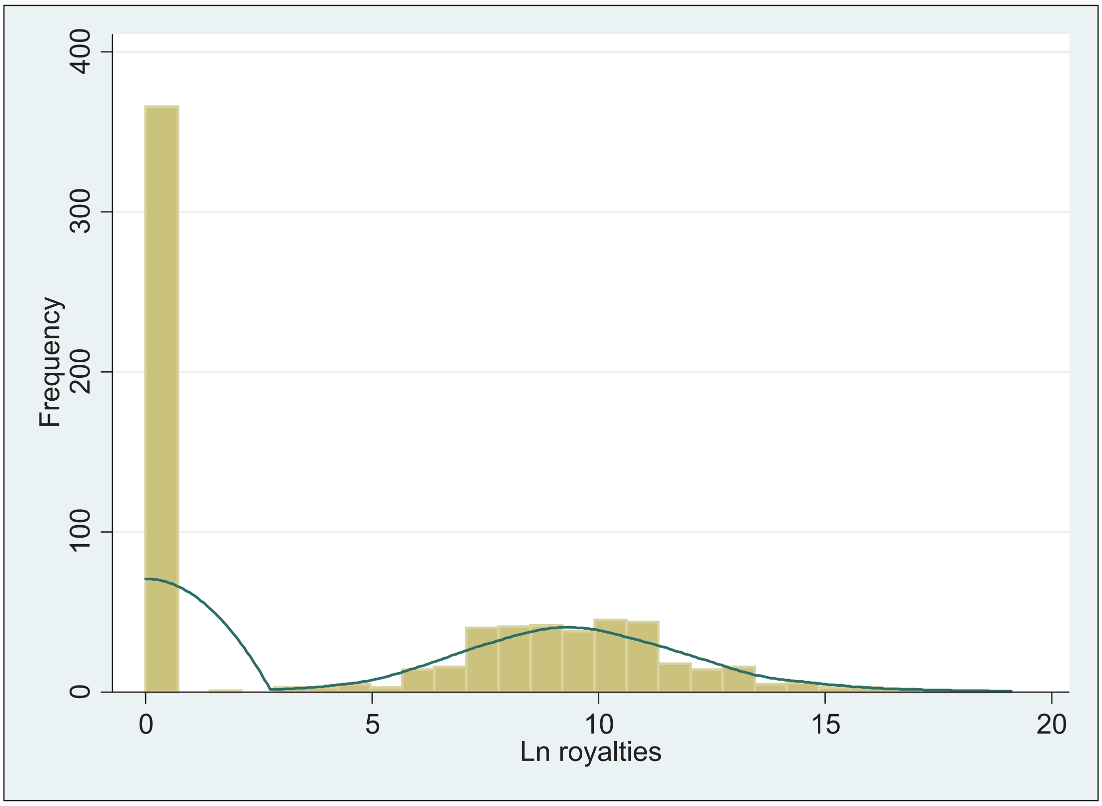
Table 3-2: Disclosed and Licensed Inventions, 1980-2004

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

For a small number of contracts key information about the invention or the licensee could not be retrieved, yielding a final sample size of 715 for the subsequent empirical analysis.

3.4.2 Variables

In line with the considerations in section 3-2, 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 sum of discounted royalty payments from the licensee to the Max Planck Society as an alternative indicator of commercial success. As payments for the individual license agreements are highly skewed we employ the natural logarithm of accumulated royalties (Figure 3-1). 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).



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

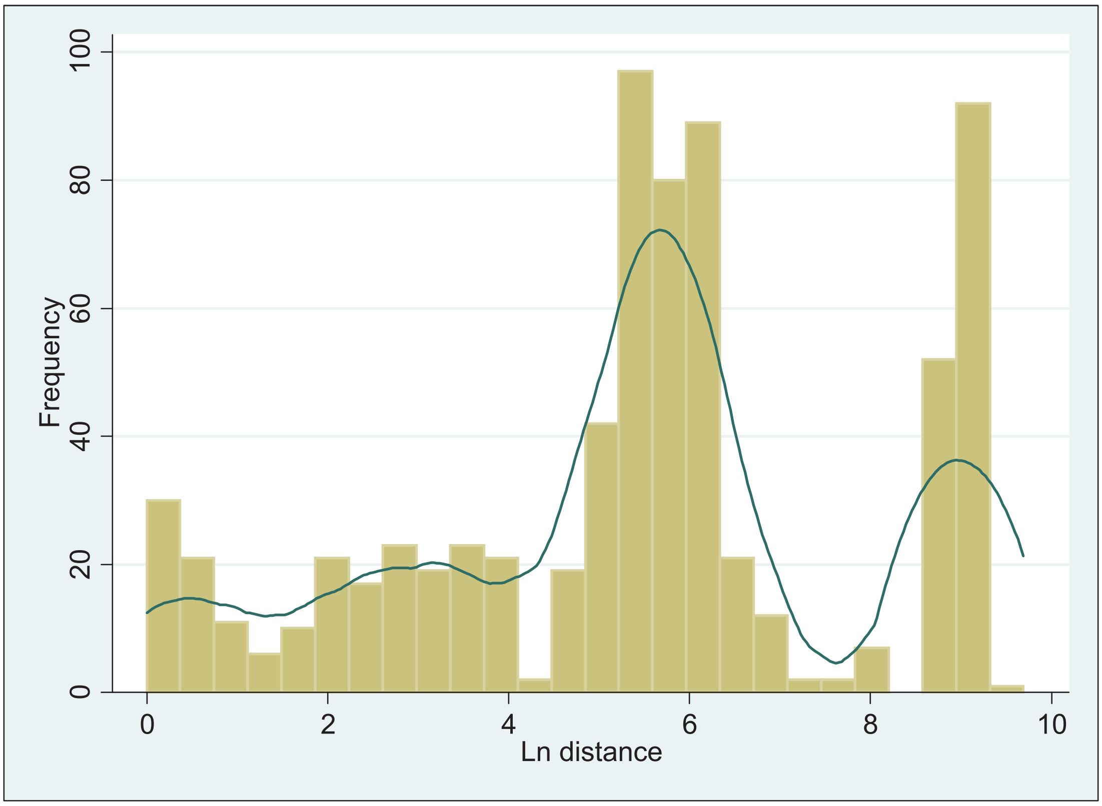
Figure 3-1: Cumulated Royalties

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.[16] 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 3-2). Alternatively, distance is measured by a set of indicator variables for different ranges. To pick up interactions within the same urban

[16] 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.

area, our smallest category includes all distances shorter than 50 kilometers.[17] 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 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 3-3 depicts log distance for both domestic and foreign licensees.



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

Figure 3-2: Geographic Distance

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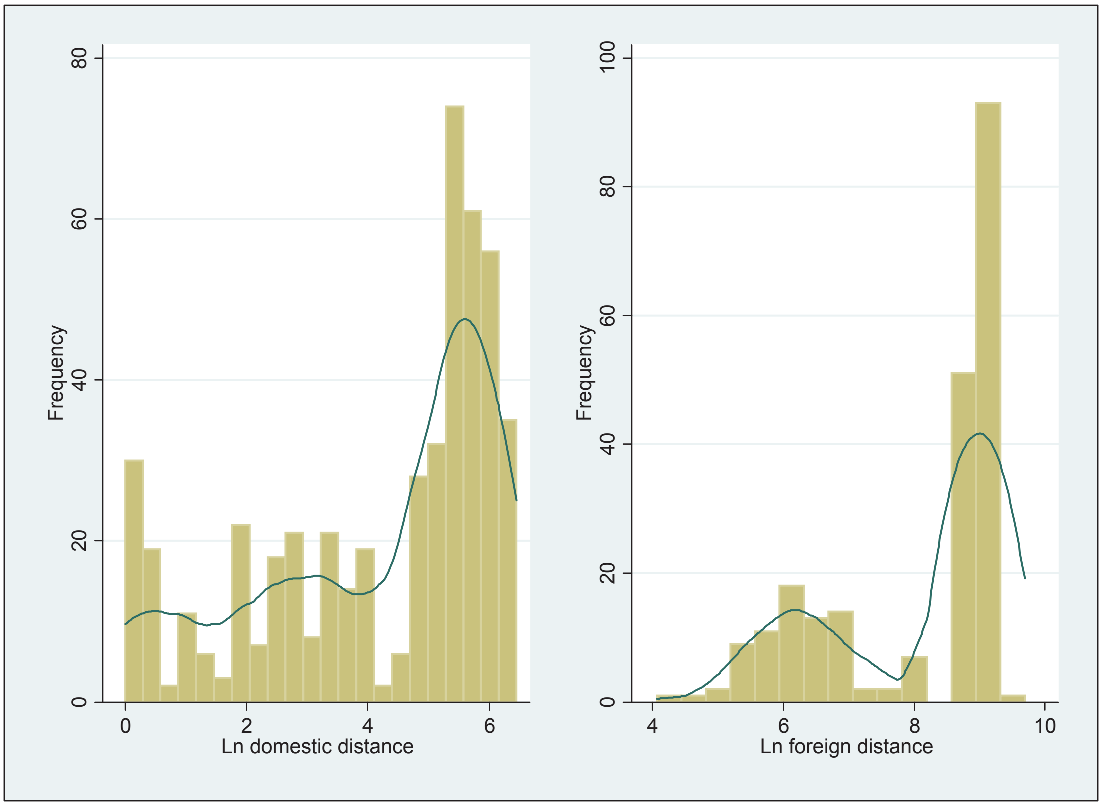
[17] Belenzon and Schankerman (2012) similarly use a 25-mile distance as their smallest category in studying knowledge flows from university research.



Note: The graph pictures two histograms of the natural logarithm of domestic and foreign distances of licensed inventions disclosed from 1980 through 2004 where licensing agreements provided for royalties. Additionally, a kernel density function is plotted.

Figure 3-3: Geographic Distance Separated by 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.[18] 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)[19] 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

[18] Small numbers of licensees could not be classified reliably; they are omitted in the empirical analysis.
[19] The Max Planck Society also has a third, social science, section. No invention in our dataset originated from this section.

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. 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. The descriptive statistics and correlations between the independent variables are provided in Tables 3-3 through 3-5.

Table 3-3: Descriptive Statistics, 1980-2004

	All inventions				Licensed inventions with provisions for royalties			
Variables	Obs.	Mean	Min	Max	Obs.	Mean	Min	Max
Commercial success					715	0.499	0	1
Ln royalties					715	4.774	0	19.109
Ln distance					715	5.395	0	9.692
Disclosure year	2,223	14.526	0	24	715	13.348	0	24
Biomed	2,223	0.615	0	1	715	0.775	0	1
Director involvement	2,223	0.143	0	1	715	0.393	0	1
Patent	2,223	0.633	0	1	715	0.706	0	1
Spin-off					715	0.327	0	1
Foreign					715	0.315	0	1
Bundle					715	0.299	0	1
Repeat licensee					715	0.761	0	1

Table 3-4: Correlation Matrix (Disclosed Inventions)

2,223 observations	Disclosure year	Biomed	Director involvement	Patent
Disclosure year	1.000			
Biomed	0.074*	1.000		
Director involvement	0.008	0.226*	1.000	
Patent	-0.000	-0.004	0.144*	1.000

Note: The asterisk * denotes significance of pairwise correlation at the one percent level.

Table 3-5: Correlation Matrix (License Agreements Providing for Royalties)

715 observations	Disclosure yr.	Ln distance	Biomed	Dir. inv.	Patent	Spin-off	Foreign	Bundle	Repeat Lic.
Disclosure year	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				
Spin-off	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

Note: The asterisk * denotes significance of pairwise correlation at the one percent level.

3.4.3 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:

$$y_{ij} = \beta_0 + \beta_1 Distance_{ij} + \boldsymbol{L}_i\beta_2 + \boldsymbol{T}_j\beta_3 + u_{ij} \quad (3\text{-}3)$$

where y measures commercial success of invention j licensed to firm i. Specifications of model (3-3) 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 the appendix B) 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 (3-3) 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.

3.5 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 3-6) 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.[20] 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

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

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 3-7. Similar to the results for commercialization likelihood, no systematic effects of geographic distance are suggested by these models.[21]

We further probe these findings in Models 2a-c (Table 3-6) and Models 5a-c (Table 3-7), 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 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).[22]

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

[22] 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.

Table 3-6: Likelihood of Commercialization (Probit; Marginal Effects)

Commercial success	Model 1a (All)	Model 1b (Spin-offs)	Model 1c (Externals)	Model 2a (All)	Model 2b (Spin-offs)	Model 2c (Externals)	Model 3a (All)	Model 3b (Spin-offs)	Model 3c (Externals)
Ln distance	0.006	0.010	0.005						
	(0.010)	(0.022)	(0.014)						
50-100 km				0.168		0.097			
				(0.142)		(0.153)			
100-500 km				0.053	0.223**	-0.043			
				(0.059)	(0.111)	(0.080)			
> 500 km				0.064	-0.048	0.045			
				(0.065)	(0.124)	(0.086)			
Ln domestic distance							0.029**	0.039*	0.007
							(0.014)	(0.022)	(0.023)
Ln foreign distance							0.010	-0.051**	0.006
							(0.010)	(0.025)	(0.016)
Disclosure year	-0.015***	-0.030***	-0.013***	-0.015***	-0.030***	-0.014***	-0.015***	-0.025***	-0.013***
	(0.004)	(0.009)	(0.004)	(0.004)	(0.009)	(0.004)	(0.004)	(0.009)	(0.004)
Biomed	-0.022	-0.256**	0.041	-0.012	-0.290**	0.064	-0.011	-0.259**	0.042
	(0.062)	(0.117)	(0.073)	(0.064)	(0.115)	(0.077)	(0.062)	(0.116)	(0.073)
Patent	-0.217***	-0.253**	-0.228***	-0.219***	-0.260**	-0.222***	-0.221***	-0.262**	-0.228***
	(0.047)	(0.105)	(0.054)	(0.047)	(0.106)	(0.054)	(0.048)	(0.105)	(0.054)
Repeat licensee	0.022	-0.296*	0.034	0.016	-0.322**	0.041	0.012	-0.414**	0.033
	(0.055)	(0.167)	(0.057)	(0.056)	(0.159)	(0.058)	(0.055)	(0.165)	(0.058)
Director involvement	0.034	-0.006	0.045	0.035	-0.019	0.036	0.045	0.008	0.045
	(0.047)	(0.084)	(0.056)	(0.047)	(0.082)	(0.056)	(0.048)	(0.078)	(0.057)
Spin-off	-0.101*			-0.086			-0.081		
	(0.052)			(0.053)			(0.053)		
Bundle	0.128**	0.213**	0.124*	0.131**	0.163	0.134**	0.107**	0.158	0.124*
	(0.053)	(0.105)	(0.065)	(0.052)	(0.098)	(0.065)	(0.053)	(0.100)	(0.065)
Top 5	-0.008	0.198**	-0.051	-0.011	0.172*	-0.052	-0.012	0.190**	-0.042
	(0.049)	(0.089)	(0.058)	(0.050)	(0.069)	(0.058)	(0.051)	(0.085)	(0.059)
Sectoral controls					Included				
Number of obs.	715	226	489	715	226	489	715	226	489
(inventions)	(564)	(213)	(376)	(564)	(213)	(376)	(564)	(213)	(376)
P > chi^2	0.0000	0.0000	0.0000	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	0.124	0.380	0.079

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

Table 3-7: Level of Royalty Income (Tobit)

Ln royalty payments	Model 4a (All)	Model 4b (Spin-offs)	Model 4c (Externals)	Model 5a (All)	Model 5b (Spin-offs)	Model 5c (Externals)	Model 6a (All)	Model 6b (Spin-offs)	Model 6c (Externals)
Ln distance	0.164	0.230	0.147						
	(0.194)	(0.337)	(0.283)						
50-100 km				3.373		2.192			
				(2.738)		(2.887)			
100-500 km				0.934	2.709*	-0.719			
				(1.025)	(1.489)	(1.351)			
> 500 km				1.414	-0.761	1.057			
				(1.254)	(2.248)	(1.566)			
Ln domestic distance							0.430*	0.606*	-0.091
							(0.250)	(0.333)	(0.386)
Ln foreign distance							0.211	-0.726*	0.053
							(0.192)	(0.424)	(0.281)
Disclosure year	-0.310***	-0.448***	-0.285***	-0.314***	-0.433***	-0.300***	-0.305***	-0.395***	-0.287***
	(0.064)	(0.115)	(0.071)	(0.066)	(0.113)	(0.071)	(0.066)	(0.110)	(0.071)
Biomed	-0.536	-3.771**	0.864	-0.281	-3.977**	1.348	-0.393	-3.523*	0.797
	(1.089)	(1.803)	(1.290)	(1.119)	(1.714)	(1.357)	(1.086)	(1.831)	(1.289)
Patent	-3.053***	-3.675***	-3.024***	-3.050***	-3.693***	-2.905**	-3.041***	-3.802***	-3.035***
	(0.928)	(1.394)	(1.166)	(0.946)	(1.399)	(1.154)	(0.945)	(1.380)	(1.150)
Repeat licensee	0.818	-3.189	1.194	0.692	-3.395*	1.298	0.689	-4.184**	1.290
	(0.924)	(1.940)	(0.968)	(0.932)	(1.890)	(0.981)	(0.924)	(1.800)	(0.973)
Director involvement	-0.060	0.101	-0.157	-0.052	0.299	-0.359	0.103	0.493	-0.251
	(0.880)	(1.389)	(1.099)	(0.895)	(1.318)	(1.088)	(0.923)	(1.319)	(1.127)
Spin-off	-1.978**			-1.807*			-1.792*		
	(0.944)			(0.937)			(0.941)		
Bundle	1.778*	2.926*	1.543	1.919**	2.619*	1.825	1.531	2.287	1.603
	(0.991)	(1.601)	(1.240)	(0.957)	(1.469)	(1.232)	(0.970)	(1.505)	(1.224)
Top 5	-0.042	2.374	-0.554	-0.088	2.058	-0.549	-0.094	2.226	-0.496
	(0.925)	(1.646)	(1.102)	(0.941)	(1.637)	(1.102)	(0.942)	(1.589)	(1.113)
Constant	6.529***	13.765***	5.405***	6.282***	13.263***	5.799***	5.533***	12.889***	6.374***
	(1.602)	(3.520)	(1.982)	(1.498)	(3.349)	(1.709)	(1.758)	(3.386)	(2.238)
Sectoral controls					Included				
Number of obs.	715	226	489	715	226	489	715	226	489
(inventions)	(564)	(213)	(376)	(564)	(213)	(376)	(564)	(213)	(376)
P > F	0.0000	0.0000	0.0000	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	0.042	0.149	0.026

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

In Models 3a-c (Table 3-6) and 6a-c (Table 3-7), the continuous distance measure from Models 1a-c and 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.[23] 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 (log) distances between founder birthplaces and the locations of the respective licensing institutes (Ln origin), and used these to instrument the distance between spin-off location and licensing institute.[24] These distances qualify as an instrument because they are exogenous, correlated with the potentially endogenous distance variable, and do not predict commercialization

[23] 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.

[24] 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.

outcomes.[25] 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.[26]

Results of the IV regressions are reported as Models 7 and 8 in Table 3-8. 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 3-8 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.

[25] 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.

[26] 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).

Table 3-8: Commercialization Outcomes (IV-Regressions)

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

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

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 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 3-9) 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. Licensees located more than 500 kilometers away from the inventors generate lower royalties than those located less than 50 kilometers away from the inventors. 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.[27]

Table 3-9: Multiple Licenses with Invention-specific Controls (Tobit)

Ln royalty payments	Model 9 (All)	Model 10 (All)	Model 11 (All)
Ln 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)	
Ln domestic distance			0.074***
			(0.012)
Ln foreign distance			-0.173***
			(0.004)
Repeat licensee	-0.020	0.182***	-0.045
	(0.039)	(0.035)	(0.039)
Spin-off	-4.561***	-4.474***	-4.648***
	(0.049)	(0.077)	(0.082)
Bundle	0.365***	-0.219***	0.196***
	(0.038)	(0.068)	(0.058)
Constant	-30.094***	-31.821***	-31.449***
	(0.033)	(0.031)	(0.034)
Sectoral controls		Included	
Invention-specific effects		Included	
Number of obs. (inventions)	272	272	272
	(120)	(120)	(120)
P>F	0.0000	0.0000	0.0000
Pseudo R^2	0.266	0.271	0.266

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

3.6 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

[27] 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.

commercialization of academic inventions is harmed by geographic distance between inventors and licensees. Results 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 3-1). 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.

4. Commercializing Inventions from Public Research: Does Speed Matter?

4.1 Introduction

Research and development (R&D) and the resultant product and process innovations are an important determinant for a firm's success and competitiveness, thereby enhancing the economic growth and employment in modern economies (Zahra and Nielsen, 2002; OECD, 2003). Due to the rapid changes in economic competitiveness, technologies and consumer preferences, the product life cycles have dramatically shortened and have increased the importance of the rapid development of new products and processes and their implementation into the market (Rosenau, 1988; Kessler and Chakrabarti, 1996).

Aside from a firms' in-house R&D, universities and public research organizations also adopt a particular role as a source of new technologies. According to Smith (1995), along with education, public research institutes promote scientific research and generate new knowledge, which fosters technological progress and new industrial developments. For example, surveyed pharmaceutical industry managers reported that a substantial fraction of the new drugs would not have been developed or would have been delayed without academic research (Mansfield, 1991). Further surveys of industrial R&D executives confirmed the importance of university research for innovation (e.g., Levin et al., 1987; Cohen et al., 2002). Policy makers undertake considerable efforts to increase the linkages between public research institutes and industry. For instance, the Bayh-Dole Act in the U.S. and other similar legislative changes advanced technology transfer as one of the main objectives of public research institutes. Aside from transfer channels such as publications, conferences, consulting, and scientists' migration (Cohen et al., 2002; Agrawal and Henderson, 2002), patenting and licensing has become one of the most common instruments for commercializing scientific inventions (Bozeman, 2000; Shane, 2002).

Licensing inventions from public research institutes enables firms to gain access to new technologies at the point of their discovery, which can result in product or process innovations (George et al., 2002). Not surprisingly, a stream of research investigates the determinants and the effectiveness of university-to-industry technology transfer (e.g., Lee, 1996; Sine et al., 2003; Phan and Siegel, 2006). A further stream examines the nature of technologies (e.g., Jensen and Thursby, 2001; Lowe, 2002; Agrawal, 2006), their commercialization process (e.g., Goldfarb and Henrekson, 2003; Debackere and Veugelers, 2005; Audretsch and

Lehmann, 2005) and the role of technology transfer offices within the transfer process (e.g., Bercovitz et al., 2001; Jensen et al., 2003; Wright et al., 2008; Swamidass and Vulasa, 2009).[28]

Moreover, licensing inventions from public research allows firms to skip the process of discovery, which reduces the technological risk and can increase the speed of innovation (Gold, 1987; Markman et al., 2005). The concept of innovation speed is not new and has been applied in a long line of prior studies that are related to product development, market launches, and firm performance (e.g., Kessler and Bierly, 2002; Carbonell and Rodriguez, 2006; Carbonell et al., 2009). However, the relationship between innovation speed and the commercial success of a licensed invention is rather unexplored. Furthermore, evidence for the influence of various determinants on the speed of technology transfer is still scarce. Consistent with the study of Markman et al. (2005), I use time-to-licensing as a proxy for innovation speed, which is defined as the elapsed time between the disclosure of an invention and the signed licensing contract, to investigate these questions.[29] Analyzing these questions is important because they contribute to theory on innovation speed, clarify the relevance of pace on technology commercialization, and thus can contribute to a more effective university-to-industry technology transfer.

More precisely, this paper aims to analyze how the pace of technology transfer is affected by the differences across technology characteristics, which can be explained by the problems of knowledge transfer for particular inventions (cf. Buenstorf and Geissler, 2012). In addition, the influence of time-to-licensing on both the likelihood and the extent of commercial success is studied. To the best of my knowledge, only the study of Markman et al. (2005) analyzes the determinants of time-to-licensing and its influence on commercial success. Their study is devoted to the institutional determinants of time-to-licensing, while I focus on the invention-specific characteristics. Specifically, inventions are distinguished with regard to the type of technology, i.e., whether an invention belongs to the biomedical section or to the chemistry, physics and technology section. Furthermore, the role of patent protection, collaboration, and inventor seniority is studied. While much is known about the institutional determinants of technology transfer (e.g., Siegel et al., 2004), thus far, the empirical studies have neglected to study the effects of the attributes of technological inventions on the pace of technology transfer.

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[28] A detailed literature review on technology transfer and the entrepreneurial role of public research organizations can be found in Rothaermel et al. (2007).

[29] While Markman et al. (2005) call this 'commercialization time,' the expression 'time-to-licensing' appears to be more intuitive and feasible. Nonetheless, the meaning and the definition of both expressions are the same.

To pursue these issues empirically, a dataset is used with detailed information on the licensing activities of the Max Planck Society, Germany's largest non-university public research organization. Whereas the intellectual property rights (IPRs) and the IPR-based commercialization of German universities have both changed with the introduction of the so-called "Arbeitnehmererfindergesetz" (ArbEG) in 2002, the Max Planck Society has been subject to a Bayh-Dole-like legislation since the 1970s. This circumstance provides a rich set of inventions and licensing activities with more than 2,300 inventions and approximately 770 license agreements for the 1980-2004 time period. To identify the time-to-licensing, the dataset includes information on the dates of disclosure and of the license execution. In addition, the dataset contains information on the royalty payments, i.e., whether the invention has been successfully commercialized, as well as on the magnitude of the returns.

The regression results reveal that time-to-licensing does not influence the commercial success of the inventions disclosed between 1980 and 2004. However, after separating the effect of time-to-licensing for the inventions disclosed after 1989, the regression results provide a robust negative influence on the likelihood and the extent of commercial success. Furthermore, the inventions from the biomedical section, the collaborative inventions with private-sector firms, and the participation of senior scientists in the invention development process all require less time to become licensed.

The remainder of the paper is organized as follows: The next section presents the related literature on innovation speed. In section 4.3, the hypotheses are derived regarding the influence of licensee and technology characteristics on the time-to-licensing and its impact on commercial success. Section 4.4 provides information about the Max Planck Society, which represents the organizational context of the empirical analysis. Section 4.5 describes the data and the research design for the empirical analysis, and the results are discussed in section 4.6. I conclude the analysis and discuss its implications in section 4.7.

4.2 Literature Review on Innovation Speed

In firms, there is scarce time for making strategic decisions, especially in frequently changing environments. Rapid decision making and organizational processes have become a crucial resource to gain and sustain competitive advantages (Eisenhardt, 1989; Jones, 1993). Several studies identify a positive relationship between the pace of strategic decision making and firm performance (e.g., Judge and Miller, 1991; Baum and Wally, 2003). Next to quick decision making, speeding up product development and innovation has become increasingly important and has become the focus of scholarly analysis. In this regard, innovation speed has been identified as one of the primary factors for strategic success, especially for firms that face highly competitive environments, rapid technological change and changing market demands (Nadler and Tushman, 1999).

Research on innovation speed has either addressed the determinants and/or the influence of speed on performance outcomes. The first string of research, which can be separated into the organizational, project and individual levels, examines the different determinants of innovation speed. More precisely, this research includes studies that address the various procedures within organizations that can accelerate innovation speed (e.g., Mansfield, 1988; Cordero, 1991; Ali et al., 1995; Tessarolo, 2007). For instance, Karagozoglu and Brown (1993) identify the different methods and procedures that firms can implement to accelerate their innovation speed using data from 35 high-technology firms. Specifically, the customers' involvement in the testing phase and the use of computer-aided tools in the planning phase have been identified as boosters for innovation speed.

Studies at the individual level discuss the person-specific preferences and perceptions that influence innovation speed (e.g., Rosenau, 1988). For example, the study of Gupta et al. (1992) investigates how R&D, marketing, and manufacturing managers in Germany evaluate three critical variables in the product development process, namely the development schedule, development costs, and product performance. The authors compare the results from Germany and the U.S. and assert that all types of German managers placed the greatest emphasis on the product development schedule, whereas the U.S. managers did not emphasize the product development speed to the same extent.

Project-based studies investigate the determinants of innovation speed associated with various aspects of the product development process (e.g., Millson et al., 1992; McDonough, 1993; Bstieler, 2005). For instance, Cooper and Kleinschmidt (1994) study the determinants of fast-paced product development using 103 new product projects in the chemical industry. They find that cross-functional, dedicated and accountable teams with a strong leadership and top management support positively influence the pace of product development. Likewise, Kessler and Chakrabarti (1999) test the effects of strategic orientation and organizational capability on the speed of 75 new product development projects. They conclude that clear time goals, longer tenure for the team members, and parallel developments increase the speed, whereas product testing decreases the speed.

The second string of research – the benefits of innovation speed – analyzes the impact of innovation speed on outcomes such as development costs, quality or performance. The research results suggest that innovation speed has a substantial positive impact on new product performance (e.g., Lynn et al., 2000; Chen et al., 2005). For example, Carbonell and Rodriguez (2006) study the influence of innovation speed on product performance based on a survey of 178 manufacturing firms. They conclude that innovation speed positively influences new product performance in terms of sales, market share and profitability. Further studies investigate the influence of innovation speed on product quality (e.g., Harter et al., 2000; Lukas and Menon, 2004) and development costs (e.g., Graves, 1989; Murmann, 1994; Langerak et al., 2008). For instance, Kessler and Bierly (2002) find evidence that the innovation speed is positively related to product quality using a sample of 75 new product development projects from 10 U.S. firms. Langerak et al. (2010) analyze the relationship between innovation speed and development costs using survey data from 115 completed product development projects from manufacturing firms. They find a U-shaped relationship between innovation speed and development costs. Although many studies advertise the benefits of innovation speed on outcome measures (e.g., Rosenthal, 1992; Meyer, 1993) other studies report opposite effects (e.g., Crawford, 1992; Carmel, 1995).

Because most studies of innovation speed are focused on in-house technological developments and routines, the use of external sources, such as licensing, is somewhat unexplored. In an early study, Gold (1987) discusses the advantages, limitations and risks of using different external sources to accelerate product and process development. Furthermore, Kessler and Chakrabarti (1996) suggest that exploiting external sources can increase the speed of innovation processes. Thus far, very little prior work has studied the relevance of speeding up the technology transfer of inventions from public research organizations. For instance, Dechenaux et al. (2003) study the relationship between patent age, which is defined as the elapsed time from patent issuance to license, and the commercial success or termination of 805 patented technologies from MIT. They observe an inverted and a direct U-shaped relationship for the corresponding hazard rates on the patent age. Llor (2007) investigates the influence of the delay between patent filings and the corresponding transfer agreements on the license revenues of a major public research organization in France and finds no correlation between them. Markman et al. (2005) analyze the determinants of commercialization time, defined as the elapsed time between invention disclosure and the signed licensing contract, and its influence on the commercial success of patent-protected technologies from public research institutes. More precisely, they investigate the commercialization time for 91 U.S. University Technology Transfer Offices (UTTOs) and find that the faster UTTOs generate greater returns and have a higher startup formation rate. Moreover, several key determinants of speed, such as UTTO resources, their competency in identifying licensees, and the participation of faculty-inventors in the licensing process, were identified.

The pace by which inventions are transferred to private-sector firms could be important for exploiting the benefits of these novelties to their full extent. Due to rapid technological development and change, it appears reasonable that as the shelf time of the invention increases, its value decreases and therefore its commercial potential (McGrath, 1999; Markman et al., 2005). Moreover, in the meantime, other innovative firms can invent similar technologies that substitute for the existing inventions (Agarwal and Gort, 2001). These substitutes can reduce the value and the returns of the initial disclosed invention. Thus far, insufficient evidence exists as to whether and how the speed of technology transfer influences commercial success. This study contributes to this gap by analyzing the determinants of time-to-licensing and whether time-to-licensing influences the commercial success of licensed inventions with data from the Max Planck Society. In the following, I derive hypotheses regarding the effect of invention-specific determinants on time-to-licensing, as well as the influence of time-to-licensing on commercial success.

4.3 Hypotheses Development

Inventions from public research organizations are one of the major sources of commercially viable innovations. Since the introduction of the Bayh-Dole Act in 1980, which has also been replicated outside of the U.S., public research organizations retain the ownership of publicly funded research results (Lissoni et al., 2008). To organize the protection of the scientists' IPRs and to actively market their inventions, most universities and public research institutes have established technology transfer offices (TTOs). Because technology transfer is a complicated and time-consuming process, TTOs act as agents and primarily support their institutions. This support includes controlling the commercial potential of the disclosed inventions, assessing them for patentability, searching for licensees, conducting negotiations, and monitoring licensees (Siegel et al., 2003b).

4.3.1 Invention-specific Determinants

Following the argument of Buenstorf and Geissler (2012), the difficulties in transferring technologies to private-sector firms vary with invention-specific determinants. In this regard, technology characteristics can not only influence the likelihood of successfully concluding licensing agreements (see Buenstorf and Geissler, 2012), but also the pace with which the inventions are transferred to the market. Therefore, in an initial step, I investigate how the technology characteristics influence the speed with which the disclosed inventions are transferred to the market.

Inventions from public research can be differentiated by the technological field in which the invention is generated. More specifically, inventions from public research can be separated into different fields such as biomedical, technical, mechanical, and other sections. It is argued that the technological and commercial potential of inventions can vary across the technological fields, which can influence the likelihood of licensing (Cohen and Levinthal, 1989). In this regard, several studies claim that biomedical inventions have a higher potential for being commercialized and are thus probably more likely to become licensed because of their broad industrial applicability and historical success (Zucker and Darby, 1996; Nerkar and Shane, 2007). Thus, the speed of the technology transfer of biomedical inventions is expected to be higher compared to the non-biomedical inventions, leading to the following hypothesis:

Hypothesis 1: Inventions from the biomedical section require less time to become licensed compared to non-biomedical inventions.

Furthermore, inventions can be separated by assessing the participation of senior scientists in the invention development process. Empirical research reveals a positive correlation between inventive output, such as patenting, and the quality of research of the individual academic scientists (e.g., Breschi et al., 2008; Azoulay et al., 2009). Specifically, senior researchers have a broad knowledge and experience in the field of science and close contacts with private-sector firms. Thus, senior scientists who participate in an invention process signal its outstanding quality and the greater applicability of its technologies, which can influence the likelihood of technology transfer to private sector firms. For instance, Buenstorf and Geissler (2012) find that seniority positively influences the likelihood of licensing across all licensees. Due to the higher reputation of senior scientists, it is expected that their inventions are licensed more quickly to private-sector firms compared to the inventions generated by more junior researchers. Furthermore, the senior scientist can have a stronger influence on the mediator, i.e., the TTO, which can increase its efforts toward technology transfer. The following is therefore predicted:

Hypothesis 2: Inventions co-invented by senior scientists require less time to become licensed compared to inventions invented by junior researchers.

The ability to appropriate economic returns from innovations is important for inventors and innovators, as well as for the whole economy (Harabi, 1995). Next to secrecy and lead time advantages, patenting is one possible method for protecting inventions and exploiting their returns (Levin et al., 1987; Cohen et al., 2002). Therefore, patented inventions from public research send a strong signal that indicates a verified novelty with a high potential usefulness and uniqueness. This signal is especially important for potential licensees who are interested in inventions that prevent competitors from developing rent-destroying imitations or work-around solutions (Shapiro, 2001). For instance, Buenstorf and Geissler (2012) find that patented inventions are more likely to be licensed than non-patented ones. However, because patent applications require expensive preparations and additional time, the technology transfer of patented inventions, which are complements to lead-time advantages, are expected to take longer compared to non-patented inventions. This conjecture leads to the next testable hypothesis:

Hypothesis 3: Patented inventions require more time to become licensed compared to non-patented inventions.

Negotiations for inventions from public research often include only a limited number of potential licensees and do not necessarily lead to successful agreements for several reasons: the early stage character of academic research (Jensen and Thursby, 2001), the issue of information asymmetry between the inventor and the potential licensee (Shane, 2002), and the problem of complex and non-codified knowledge (Agrawal, 2006). To overcome these problems, firms are often already involved during the early stage development process of inventions through collaborations and other means (Lowe, 2002). Specifically, collaborative research between firms and public research institutes can reduce information asymmetries and increase communication, which can foster the generation of commercially valuable inventions (Siegel et al., 2003a). Moreover, collaborative research has an advantage in that the potential licensee has the option to license the invention.

Thus, the TTO does not need to search for a potential licensee, which increases the speed of technology transfer. The following is therefore expected:

Hypothesis 4: Inventions from collaborative research require less time to become licensed to private-sector firms compared to non-collaborative inventions.

4.3.2 The Implications of Time-to-licensing

The emphasis on an innovation's speed is primarily suited to the rapidly changing business environment, the shrinking window for technological exploitation due to knowledge spillovers, and rapid technological obsolescence (Markman et al., 2005). Theoretically, R&D investments and inventions are related to real options, where the value is inversely related to time, i.e., reducing time-to-licensing increases the value of inventions (McGrath, 1999; Markman et al., 2005). Furthermore, the longer technologies are shelved, the larger the risk that substitutes will emerge (Agarwal and Gort, 2001). In this regard, the commercial potential for these technologies will be lower. At the same time, a faster technology transfer enables firms to gain a competitive advantage when developing and introducing a successful product or process. Thus, with a faster technology transfer, licensees can increase the distance from their competitors, extract more profits, and could develop next generation products due to first-mover advantages (Porter, 1980; Eisenhardt and Martin, 2000).

Certainly, speed can also have an adverse effect on the likelihood and extent of commercial success. One reason for this adverse effect is that a majority of disclosed inventions are at an early stage and the commercialization prospects are less than obvious (Jensen and Thursby, 2001). To better evaluate perspectives, access to information about the inventions and a structured approach with all involved parties is required rather than precipitate action. Nonetheless, consistent with the results of Markman et al. (2005), I hypothesize the following:

Hypothesis 5: Time-to-licensing is negatively related to the likelihood and the extent of commercial success.

4.4 Empirical Context: The Max Planck Society

To analyze the hypotheses developed above, I use detailed data from the Max Planck Society (MPS), Germany's most successful public research organization. The MPS is a German research association that was initially founded in the year 1911 as the Kaiser Wilhelm Society and adopted its current name in 1948. The MPS currently consists of 80 research institutes and three additional research facilities in Germany that perform basic research. The institutes are organized into three sections: (i) the biomedical section; (ii) the chemistry, physics and technology section; and (iii) the humanities and social sciences section.

The MPS is assigned to achieve research excellence, with large research projects that require special equipment or extraordinary expenses. 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. Approximately 80 percent of the MPS's expenditure is met by public funding from the Federal Government and the German States. The remaining funding stems from donations, member contributions, and a few funded projects. In the period from 2006-2011, the budget of the MPS accounted for 1.3 to 1.4 billion EUR per annum.

Before 2002, the inventions by Max Planck researchers were treated differently from those created by German university researchers. Max Planck researchers, similar to the employees of private-sector firms, are subject to the law on employee inventions, according to which the employees must disclose their inventions to their employer, who is the legal owner of the intellectual property.[30] To manage the patent applications and the technology licensing, the MPS established one legally independent technology transfer office, the Max Planck Innovation GmbH (named Garching Innovation GmbH until 1990), which is responsible for the inventions of all of the institutes. Established in 1970, the Max Planck Innovation GmbH is co-located with the Society's central administration in Munich. The patent applications are handled in cooperation with external patent attorneys.[31] The technologies are marketed to domestic and foreign firms, including spin-offs, which have been actively supported since the early 1990s. Max Planck Innovation GmbH has concluded more than 1,500 license agreements since 1979 (Max Planck Innovation, 2007). The accumulated returns from technology transfer activities exceeded 200 million EUR, with most of the income resulting from a handful of "blockbuster" inventions. In the case of a successful licensing, the academic inventors receive 30 per cent of all revenues and the Max Planck Institute that

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[30] In contrast, the so-called "professors' privilege" guaranteed the university researchers the retention of their property rights over their research findings. The professors' privilege was abolished in 2002 (see von Proff et al., 2012, for more details).

[31] Patent applications are applied in case the invention is patentable and even if no licensee has been identified. Thus, the Max Planck Innovation's patenting policy is comparable to that of MIT (cf. Shane, 2002).

employs the researcher receives an additional third. The MPS retains the rest of the revenues for financial purposes.

4.5 Data Description and Empirical Methods

4.5.1 Data

The present study is based on information provided by Max Planck Innovation GmbH that has been used in earlier works by Buenstorf and Schacht (2011) and Buenstorf and Geissler (2012). The dataset consists of all of the inventions disclosed by Max Planck researchers from the mid-1960s to 2005. Overall 3,012 inventions have been disclosed to the MPS, from which 1,885 resulted in a patent application. Information is available regarding the date of disclosure and the patent application, the institute that the respective invention belongs to, and further invention-specific characteristics such as the involvement of a Max Planck director, as well as whether an invention has been licensed or not. Overall, 864 inventions have been licensed to private-sector firms since the mid-1960s. Because a number of inventions are licensed non-exclusively to a multitude of licensees, there are in total 1,172 license agreements. For each license agreement, the dataset provides additional information on the date of the license agreement and (possibly) its termination, as well as all of the amounts of the payments received based on the license agreement.

To minimize right-censoring problems, the sample is restricted to inventions that were disclosed in 2004 or earlier while using information for payments up to 2007. The data are further restricted to inventions that were disclosed in 1980 or later for two reasons. First, before 1980, Garching Innovation GmbH not only managed the inventions disclosed by Max Planck researchers, but also offered its services to external customers, mostly other public research organizations. Second, the information regarding the pre-1980 inventions is inferior to that for the later inventions. These restrictions lead to a total of 2,376 disclosed inventions, with 773 of them being licensed with 1,047 license agreements.

To analyze the commercial success, the sample size is further reduced by restricting the analysis to the license agreements that provide for royalty payments.[32] This restriction is necessary because the commercial success of a licensed technology is not directly observable but must be deduced from the

[32] There are several ways in which licensed inventions generate income, including fixed fees and royalty payments. Fixed fees are charged to control for the seriousness of the licensee and include the reimbursement of patent and administrative costs. However, only royalty payments directly reflect the commercial success of the licensed inventions (cf. Agrawal, 2006).

incidence of royalty payments. The data includes yearly royalty payments for all individual contracts from conclusion to 2007 or prior termination. In total, 731 contracts provide for royalty payments (with or without additional fixed fees), of which 365 (50 percent) have been successfully commercialized. Table 4-1 provides an overview of the number of disclosed and licensed inventions from 1980 to 2004, as well as the number of license agreements that provide for royalty payments. For a number of contracts key information, such as the date of disclosure and the licensing date could not be retrieved, yielding a smaller sample size for the subsequent empirical analysis.

Table 4-1: Disclosed and Licensed Inventions, 1980-2004

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

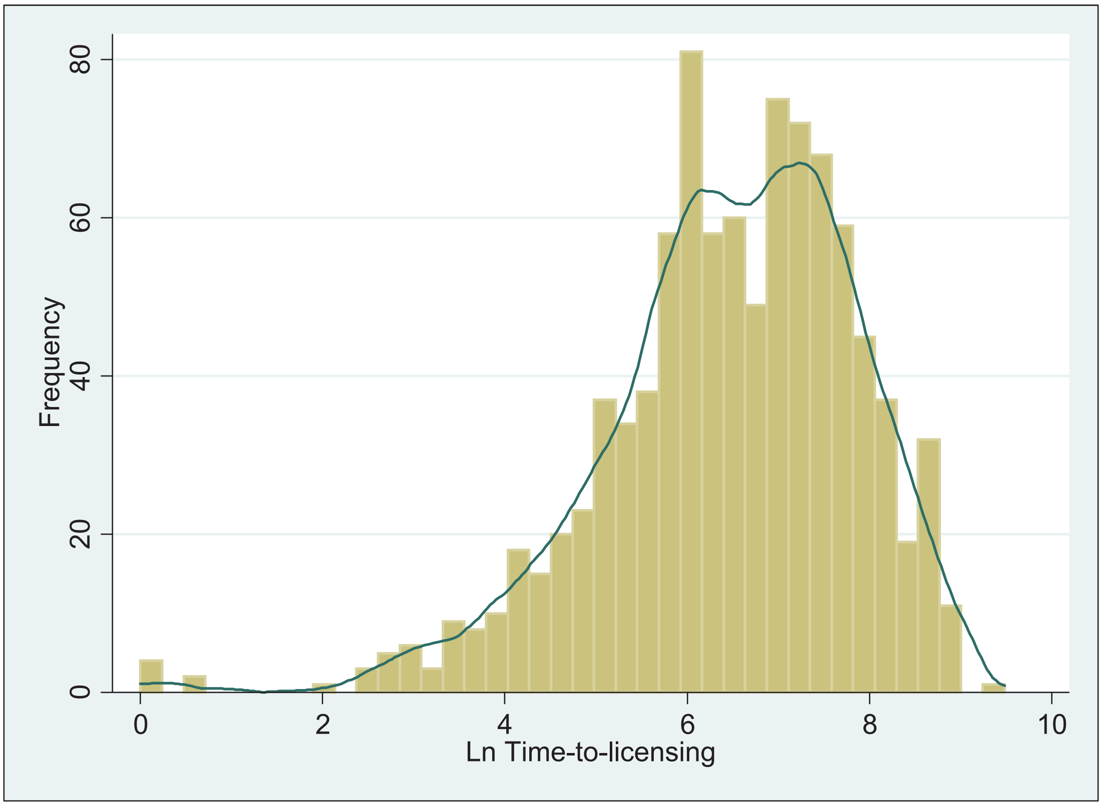
4.5.2 Variables

Three dependent variables are used in the subsequent empirical models: First, a binary variable denotes whether an invention has been licensed. Furthermore, two variables specify the commercial success of the licensed inventions. Specifically, a binary variable is constructed indicating whether the license agreements lead to positive royalty payments. Moreover, because the data includes the yearly payments for all of the individual contracts from conclusion to 2007 or prior termination, the sum of the discounted payments is used as an alternative indicator for commercial success.[33] Because the accumulated payments for individual license agreements are highly skewed, I employ the natural logarithm to normalize it.

The empirical analysis includes additional information about license agreements, inventions and their licensees. The main variable of interest is *Time-to-licensing*, which measures the elapsed number of days between the disclosure of an invention and the signed licensing contract. To abate concerns regarding non-

[33] Royalty payments are discounted to the base year 2000 and are adjusted to the currency *Deutsche Mark*.

normality, I employ the natural logarithm of this variable. Figure 4-1 depicts the natural log of Time-to-licensing for inventions disclosed between 1980 and 2004.



Note: The graph pictures a histogram of the natural logarithm of the elapsed number of days between the disclosure of an invention and the signed licensing contract from 1980 through 2004 for licensed inventions. Additionally, a kernel density function is plotted.

Figure 4-1: Time-to-licensing

A substantial number of license agreements cover multiple inventions that are licensed in the form of a bundle. Lacking more detailed information on the individual inventions covered in these bundles, I treat them as separate observations in the empirical analysis, dividing the royalty payments (if any) equally among the number of bundled inventions. The dummy variable *Bundle* is implemented as a control in the model specifications. Furthermore, the inventions are classified according to the section of the MPS from which they originate (biomedical section versus chemistry/physics/technology section)[34] and whether a Max Planck director is among the inventors. The binary variable *Biomed* captures the first distinction. For the latter distinction, the indicator variable *Director involvement* is constructed to identify the inventions by senior researchers.[35] The year of the invention's disclosure is captured by the integer variable *Disclosure year*,

[34] The humanity section is not taken into account because no inventions are disclosed in this field.
[35] Directors are the top-level researchers employed at the MPS. Depending on its size, each institute has between two and twelve directors, who can often be considered to be the star scientists (cf. Buenstorf, 2009, for a more detailed account).

which begins with a zero in 1980. Additionally, the indicator variable *Top 5* is employed for the 5 most active Max Planck Institutes with regard to disclosures.

I also employ information about patent applications that are related to licensed inventions. To control for patent applications, the indicator variable *Patent* is employed. For the subset of inventions that are related to patent applications (1,504), further information could be derived from the patent statistics. First, the collaborative inventions are identified on the basis of the patent assignments. The binary variable *Collaboration* identifies inventions that are not (exclusively) related to the Max Planck Society but are (co-) assigned to a private-sector firm.[36] Furthermore, the integer variable *Patent family size* and a dummy that indicates triadic patent applications in the U.S., the EU and Japan (*Triade*) are employed as proxies for the patent quality.[37]

The binary variable *Foreign* classifies the licensees into domestic or foreign according to their postal address. Thereby, the foreign subsidies located in Germany are counted as German licensees. Additionally, the indicator variable S*pin-off* divides licensees into spin-offs (i.e., firms started by Max Planck researchers) and external licensees using the Max Planck Innovation's spin-off database. Furthermore, the indicator variable *Repeat licensee* denotes those licensees for which the earlier license agreements with the MPS are found. This variable is motivated by the conjecture that if the later license agreements are related to the earlier ones, their odds of commercialization could be larger due to pre-established contacts and accumulated knowledge. To control for the fields of activity (*Sectoral controls*), licensees are classified into five broad branches employing the standard industrial classification (SIC) numbers. More precisely, I divide the firms into manufacturing, services, and others, whereupon the former is split into chemical products, instruments and related products, as well as into other manufacturing products and equipment.

The descriptive statistics and correlations are provided in Tables 4-2 through 4-5. More precisely, Table 4-2 provides the descriptive statistics for all of the disclosed inventions and for the subset of disclosed inventions with patent applications that are employed in the subsequent empirical analysis. Table 4-3 reports the descriptive statistics for the number of licensed inventions providing for royalty payments used in the upcoming empirical models. Furthermore, Table 4-4 and 4-5 report, respectively, the correlation matrixes for all of the disclosed

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[36] This definition of collaborative inventions is very restrictive (cf. Fontana and Geuna, 2009). However, no better alternative can be provided due to data limitations.
[37] Patent family size is a widely used and accepted measure of patent quality (see Lanjouw et al., 1998; Harhoff et al., 2003).

inventions and for the license agreements providing for royalty payments. The highest correlations in both correlation tables show up among the variables *Top 5* and *Biomed*. The correlations for the two independent variables are between 0.3 and 0.5. However, these correlations turn out to be irrelevant in the subsequent analysis. The results are robust to different model specifications, i.e., either excluding the variables or taking them separately into the regression models.

Table 4-2: Descriptive Statistics (Disclosed Inventions), 1980-2004

	All inventions				Disclosed inventions with patent application			
	Obs.	Mean	Min	Max	Obs.	Mean	Min	Max
Biomed	2,197	0.598	0	1	1,350	0.586	0	1
Director involvement	2,197	0.126	0	1	1,350	0.168	0	1
Patent	2,197	0.633	0	1				
Disclosure year	2,197	14.720	0	24	1,350	14.519	0	24
Top 5	2,197	0.418	0	1	1,350	0.419	0	1
Patent family size					1,350	5.354	1	120
Triade					1,350	0.245	0	1
Collaboration					1,350	0.206	0	1

Table 4-3: Descriptive Statistics (License Agreements Providing for Royalties), 1980-2004

	License agreements providing for royalties			
Variables	Obs.	Mean	Min	Max
Commercial success	681	0.504	0	1
Ln royalties	681	4.824	0	19.109
Ln Time-to-licensing	681	6.525	1.343	9.484
Disclosure year	681	13.419	0	24
Biomed	681	0.775	0	1
Director involvement	681	0.377	0	1
Patent	681	0.706	0	1
Spin-off	681	0.307	0	1
Foreign	681	0.305	0	1
Bundle	681	0.288	0	1
Top 5	681	0.501	0	1
Repeat licensee	681	0.755	0	1

Table 4-4: Correlation Matrix (Disclosed Inventions)

2197 observations.	Disclosure year	Biomed	Patent	Director inv.	Top 5
Disclosure year	1.000				
Biomed	0.072*	1.000			
Patent	0.003	-0.013	1.000		
Director involvement	0.023	0.166*	0.154*	1.000	
Top 5	-0.048	0.340*	-0.001	0.148*	1.000

Note: The asterisk * denotes significance of pairwise correlation at the one percent level.

Table 4-5: Correlation Matrix (License Agreements Providing for Royalties)

681 observations.	Ln Time-to-licensing	Disclosure year	Spin-off	Foreign	Biomed	Patent	Director inv.	Repeat licensee	Bundle	Top 5
Ln Time-to-licensing	1.000									
Disclosure year	-0.156*	1.000								
Spin-off	0.028	0.276*	1.000							
Foreign	0.072	-0.028	-0.310*	1.000						
Biomed	0.087	0.166*	0.099*	0.151*	1.000					
Patent	0.389*	0.044	0.184*	-0.062	0.062	1.000				
Director involvement	0.128*	0.111*	0.172*	0.122*	0.201*	0.123*	1.000			
Repeat licensee	0.065	0.036	0.291*	-0.178*	0.127*	0.195*	0.141*	1.000		
Bundle	0.081	-0.003	0.224*	-0.077	-0.015	0.232*	0.154*	0.340*	1.000	
Top 5	0.091	-0.021	0.040	0.095	0.455*	-0.006	0.214*	0.080	0.006	1.000

Note: The asterisk * denotes significance of pairwise correlation at the one percent level.

4.5.3 Empirical Methods

To analyze the incidence of a licensing event, the appropriate empirical method is a Cox proportional hazard model. The advantage of this model, compared to other models, is that it takes the occurrence of an event, the right censoring, and the elapsed time into account. Time is measured in days, begins with the date of disclosure and ends with the day of the initial license agreement.[38] If a disclosed invention is not licensed, it is treated as censored. The following model is specified:

$$h_j(t) = lim \frac{\Pr\{\mathrm{t} \leq \mathrm{T} \leq \mathrm{t} + \Delta | \mathrm{T} \geq \mathrm{t}\}}{\Delta \mathrm{t}} \tag{4-1}$$

where $h_j(t)$, the hazard function, is the probability that invention j becomes licensed at time $t + \Delta$, conditional on not having been licensed at time t and Δ being a short interval of time. To account for the influence of covariates, the hazard function is redefined as follows:

$$h_j(t) = h_0(t)\exp(\beta' x_j) \tag{4-2}$$

On the left-hand side of equation (4-2), $h_j(t)$ represents the hazard rate. The baseline hazard function is described by h_0, whereas x_j indicates the invention-specific covariates.

To study the potential influence of time-to-licensing on the respective outcomes, I subsequently estimate a set of models where the measures of commercial success are regressed on a variety of licensee and technology characteristics.[39] First, a probit model analyzes the likelihood of commercialization success in which the dependent variable takes the value of 1 if positive royalty payments are realized and zero otherwise. The model is specified as

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[38] For a few number of inventions, the date of disclosure or license execution could not be identified. Moreover, in several cases, a licensing agreement is concluded before the disclosure, mainly because of an option to license a nascent technology. These cases are excluded in the subsequent empirical models.

[39] The commercialization of inventions from public research is a two-stage process. In the first step, technologies must be licensed. Because not all inventions are licensed, it is likely that the selection of technologies into licensing is not a random process. Because commercial success is only observable for a subset of licensed inventions, the results might be biased by using such a non-randomly selected sample. However, in the study of Buenstorf and Schacht (2011), the results of the two-stage methodology developed by Heckman (1979) reveal that non-random selection into licensing is not of major concern in the sample analyzing the commercialization of licensed technologies.

$$y_{ij}^* = \beta_0 + \beta_1 LicTime_{ij} + \boldsymbol{L}_i\beta_2 + \boldsymbol{T}_j\beta_3 + u_{ij} \quad (4\text{-}3)$$

with

$$y_{ij} = \begin{cases} 1 \; if \; y_{ij}^* > 0 \\ 0 \; if \; y_{ij}^* \leq 0 \end{cases}$$

where y_{ij} takes the value of 1 if firm *i* successfully commercializes invention *j*, and y_{ij}^* is an unobserved or a latent variable. $LicTime_{ij}$ represents the elapsed log number of days between the disclosure of invention *j* and the signed licensing contract by firm *i*; *L* and *T* are, respectively, the matrices of licensee- and technology-specific characteristics; and u_{ij} is the error term. Alternatively, tobit models are employed in which the accumulated royalty payments are used as the dependent variable. The respective model has the following form:

$$y_{ij}^* = \beta_0 + \beta_1 LicTime_{ij} + \boldsymbol{L}_i\beta_2 + \boldsymbol{T}_j\beta_3 + u_{ij} \quad (4\text{-}4)$$

with

$$y_{ij} = \begin{cases} y_{ij}^* \; if \; y_{ij}^* > 0 \\ 0 \; if \; y_{ij}^* \leq 0 \end{cases}$$

where y_{ij} takes the values of the latent variable for the positive values and zero otherwise. As in equation (4-3), the same explanatory variables enter the regression equation. Throughout the analysis, the standard errors are clustered by inventions to control for the occurrence of multiple licensing of the same technology.

4.6 Results

4.6.1 Speed-related Determinants

First, I analyze the determinants that can influence the pace by which inventions are transferred to the market. The results of the Cox proportional hazard models are reported in Table 4-6.[40] More precisely, the first two models (Models 1a and 1b) in Table 4-6 account for all of the inventions and include invention-specific covariates. Specifically, Model 1a includes the indicator variable for the patent application, the director involvement, and the technological section to which the

[40] Additionally, I employed competing risk models following the method of Lunn and McNeil (1995) to separate the competing events. More precisely, licensing to foreign versus domestic firms and licensing to spin-offs versus external licensees are interpreted as competing events. The results of the invention-specific determinants are similar to the outcomes of the Cox proportional hazard model. These results are available upon request.

invention belongs. Model 1b additionally controls for the top 5 institutes and the year of disclosure. The last two models (Models 2a and 2b) in Table 4-6 consider a subset of patented inventions and include the same invention-specific covariates and controls as in Models 1a and 1b. Furthermore, in Model 2b quality measures such as the patent family size and the breadth of the patent protection are implemented as additional controls.

Table 4-6: Licensing Hazards (Cox Proportional Hazard Model; Hazard Ratios)

Licensing	All inventions		Patented inventions	
	Model 1a	Model 1b	Model 2a	Model 2b
Patent	1.029	1.017		
	(0.095)	(0.094)		
Biomed	1.495***	1.717***	2.080***	2.041***
	(0.129)	(0.150)	(0.228)	(0.224)
Director involvement	5.250***	5.638***	4.858***	4.431***
	(0.450)	(0.482)	(0.481)	(0.458)
Top 5		0.696***	0.695***	0.719***
		(0.054)	(0.065)	(0.066)
Disclosure year		0.984***	0.994	0.998
		(0.006)	(0.007)	(0.008)
Collaboration			1.316**	1.229**
			(0.163)	(0.162)
Patent family size				1.009**
				(0.004)
Triade				1.274**
				(0.138)
Observations	2197	2197	1350	1350
(events)	(689)	(689)	(488)	(488)
$p>chi^2$	0.0000	0.0000	0.0000	0.0000

Robust standard errors in parentheses; *; **; and *** denote significance at the 0.10; 0.05; and 0.01 levels, respectively.

The regression results in Models 1a and 1b (Table 4-6) identify a strong, significant hazard ratio for biomedical inventions. The hazard ratios (larger than one) suggest that the biomedical inventions that have not been licensed by a certain time have a higher chance of being licensed at the next point in time compared to the inventions from the chemistry-physics-technology section. Thus, the inventions from the biomedical section require less time to become licensed, which is consistent with Hypothesis 1. Models 2a and 2b suggest that the patented biomedical inventions require even less time to become licensed compared to the patented inventions from the chemical-physics-technology section, which confirms Hypothesis 1. These results indicate that the inventions with higher technological and commercial opportunities, such as biomedical inventions, require less time to become licensed. Furthermore, Models 1a and 1b show that inventions that are co-invented by the Max Planck directors are more likely to be licensed at the next point in time compared to the inventions generated by junior researchers. To put it differently, the hazard ratios that are greater than one imply that director participation reduces the time until an invention is licensed to private-sector firms, which is consistent with

Hypothesis 2. For the subset of patented inventions (Models 2a and 2b), significant hazard ratios confirm this result. Thus, the qualitative and reputational effects appear to influence the pace of technology transfer.

With respect to patent protection, the results in Models 1a and 1b do not support Hypothesis 3, namely that patented inventions require more time to become licensed. Moreover, the results in Models 2a and 2b suggest that collaborative inventions require significantly less time to become licensed compared to non-collaborative inventions, which is consistent with Hypothesis 4. Thus, the collaborations between public research institutes and private firms can not only reduce any information asymmetries but can also reduce the pace by which the inventions are transferred to the market. Finally, two more control variables are noteworthy. First, I find that the inventions from the five most active Max Planck Institutes with respect to disclosures require significantly more time to become licensed compared to the disclosed inventions from the other institutes. Second, Model 2b shows that a broad patent protection (Triade) and a larger patent family size promote the speed of technology transfer for an invention. Thus, high-quality technologies are transferred more quickly to private-sector firms than lower quality inventions.

4.6.2 The Implications of Time-to-licensing

The second part of the analysis covers the impact of time-to-licensing on commercial success. To address this question, two alternative approaches are employed, namely probit and tobit models. For each approach, four regression models are estimated employing licensing agreements that provide for royalty payments. Specifically, Models 3a-3d (Table 4-7) denote probit regressions using a binary measure for commercial success as the dependent variable, whereas Models 4a-4d (Table 4-8) denote tobit regressions employing the natural log of cumulated royalty payments. In Tables 4-7 and 4-8, different model specifications are used. More precisely, Models 3a and 4a represent the baseline specification with time-to-licensing as the main variable of interest. In Models 3b and 4b, additional invention-specific controls are implemented, such as whether the invention has been patented, the disclosure year, as well as the section that the invention comes from. Furthermore, Models 3c and 4c include licensee-specific controls, such as the type of firm and the sectoral controls. Finally, in Models 3d and 4d, the complete set of invention- and licensee-specific covariates is integrated.

The results in Table 4-7 indicate that the logged time-to-licensing does not significantly influence the likelihood of commercial success. Significant marginal effects are obtained for the patented inventions that are less likely to be commercialized than those for which no patent application is documented (Models 3b and 3d). Thus, licensees appear to obtain a substantial share of licenses for strategic reasons such as "shelving," which is reflected in the reduced commercialization rates. Furthermore, the time of disclosure indicates that the more recent inventions are less likely to be commercialized than the older ones. This finding could reflect some effects of the right-censored nature of the data. However, this finding could also indicate a reduced average quality of inventions (cf. Buenstorf and Geissler, 2012). Inventions that are licensed as bundles positively influence the likelihood of commercial success. This result could be due to the complementary character of the licensed inventions, which lead more often to commercial success. Finally, the results in Models 3c and 3d suggest that the spin-off licensees are less likely to commercialize the scientific inventions compared to the incumbent firms.

Table 4-7: Likelihood of Commercialization (Probit; Marginal Effects)

Commercial success	Model 3a	Model 3b	Model 3c	Model 3d
Ln Time-to-licensing	-0.025	-0.011	-0.021	-0.016
	(0.019)	(0.019)	(0.018)	(0.019)
Disclosure year		-0.016***		-0.016***
		(0.003)		(0.004)
Biomed		-0.038		0.023
		(0.059)		(0.063)
Director involvement		-0.022		0.032
		(0.049)		0.049
Patent		-0.222***		-0.185***
		(0.047)		(0.049)
Bundle		0.128***		0.169***
		(0.048)		(0.050)
Top 5		0.023		0.009
		(0.051)		(0.051)
Spin-off			-0.154***	-0.110**
			(0.047)	(0.050)
Foreign			-0.014	-0.020
			(0.053)	(0.053)
Repeat licensee			0.053	-0.004
			(0.053)	(0.056)
Sectoral controls	no	no	yes	yes
Observations	681	681	681	681
(inventions)	(531)	(531)	(531)	(531)
Pseudo R^2	0.003	0.072	0.057	0.111

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

To check whether the above findings depend on the choice of the binary measure of commercialization success, a set of tobit models are additionally estimated (Models 4a-4d in Table 4-8). Models 4a-4d correspond to the previous model specifications in Table 4-7. The results in Table 4-8 are qualitatively very similar to those obtained before. Overall, I do not find any evidence suggesting that the time-to-licensing lowers the likelihood and the extent of commercial success, which contradicts Hypothesis 5.[41]

Table 4-8: Level of Royalty Income (Tobit)

Ln royalty payments	Model 4a	Model 4b	Model 4c	Model 4d
Ln Time-to-licensing	-0.271	-0.091	-0.184	-0.189
	(0.433)	(0.364)	(0.371)	(0.331)
Disclosure year		-0.348***		-0.336***
		(0.064)		(0.065)
Biomed		-0.577		0.220
		(1.078)		(1.119)
Director involvement		-1.075		-0.247
		(1.011)		(0.944)
Patent		-3.701***		-2.655***
		(0.917)		(0.908)
Bundle		2.150**		2.581***
		(0.933)		(0.924)
Top 5		0.580		0.221
		(1.036)		(0.950)
Spin-off			-3.438***	-2.078**
			(0.913)	(0.902)
Foreign			0.064	0.344
			(1.107)	(1.077)
Repeat licensee			1.291	0.425
			(0.944)	(0.952)
Constant	3.190	9.272***	3.113	7.860***
	(2.640)	(2.304)	(2.385)	(2.313)
Sectoral controls	no	no	yes	yes
Observations	681	681	681	681
(inventions)	(531)	(531)	(531)	(531)
Pseudo R^2	0.000	0.024	0.020	0.038

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

However, the insignificant result of time-to-licensing does not imply that speed is unimportant for certain time spans. It could be that speed has become more important as the economic environment has changed. For instance, Kessler and Chakrabarti (1996) assert that since the 1990s, innovation speed has become one of the most important strategic determinants to create and sustain competitive advantage. To check this conjecture, I replicate the regression models conducted above and include a dummy variable for the inventions disclosed after 1989. Furthermore, I integrate an interaction term that effectively separates the additional effect of time-to-licensing on inventions that were disclosed between 1990 and 2004.[42] Models 5a-5d (Table 4-9) report the probit regressions, and Models 6a-6d (Table 4-10) report the tobit regressions, including the same set of controls as in the former regression models.

[41] In unreported regression models, I experiment with a quadratic measure of time-to-licensing in both probit and tobit models. None of these specifications provide significant results.

[42] A Chow test to find whether the particular date causes a break in the coefficients is significant at the 1 percent level.

In Models 5a-5d (Table 4-9), a significant positive correlation is obtained for the inventions that were disclosed between 1990 and 2004. This result suggests that the inventions disclosed after 1989 are more likely to have been commercialized than the inventions disclosed before 1990 in cases where the log time-to-licensing is close to zero. Because the interaction effect is significantly negative, the positive effect of the inventions disclosed after 1989 decreases with the rising log time-to-licensing, which is consistent with the conjecture.[43] Because the interaction effects in the non-linear models can vary for different observations, I employ the method of Norton and Wang (2004) to depict the interaction effect as an example for Model 5d in Table 4-9. More precisely, Figure 4-2 shows that the interaction effect in Model 5d is negative for all observations. In terms of the significance of the interaction effect, Figure 4-3 suggests that the interaction term is significant for all of the predicted probabilities.

Table 4-9: Likelihood of Commercialization with Interaction Term (Probit; Marginal Effects)

Commercial success	Model 5a	Model 5b	Model 5c	Model 5d
Ln Time-to-licensing	0.033	0.059**	0.044	0.059**
	(0.029)	(0.030)	(0.028)	(0.028)
1990-2004	0.392*	0.407*	0.450**	0.436**
	(0.198)	(0.197)	(0.183)	(0.187)
Ln time-to-licensing * 1990-2004	-0.102***	-0.102***	-0.109***	-0.106***
	(0.037)	(0.037)	(0.036)	(0.036)
Biomed		-0.034		0.028
		(0.061)		(0.065)
Director involvement		-0.027		0.030
		(0.048)		(0.048)
Patent		-0.204***		-0.172***
		(0.046)		(0.048)
Bundle		0.155***		0.191
		(0.046)		(0.049)
Top 5		-0.001		-0.017
		(0.050)		(0.050)
Spin-off			-0.097**	-0.115**
			(0.049)	(0.049)
Foreign			-0.033	-0.050
			(0.050)	(0.050)
Repeat licensee			0.039	-0.004
			(0.053)	(0.056)
Sectoral controls	no	no	yes	yes
Observations	681	681	681	681
(inventions)	(531)	(531)	(531)	(531)
Pseudo R^2	0.055	0.082	0.095	0.121

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

[43] To verify this result, I also employed Cox proportional hazard models to investigate the influence of log time-to-licensing on commercial success. Thus, the elapsed time between the initial licensing agreement and the first sale is taken into account. The results are quite similar to the corresponding probit models with respect to directions and significance levels. The respective results are available from the author on request.

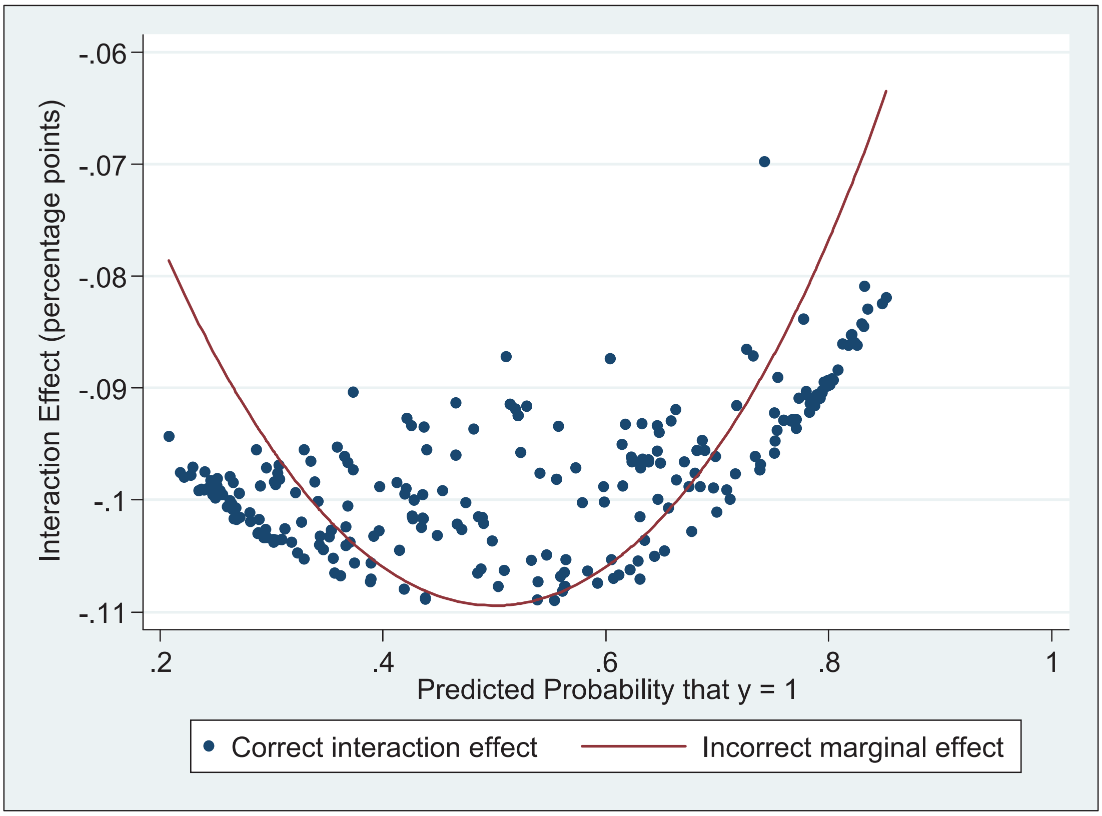

Figure 4-2: Interaction Effects after Probit

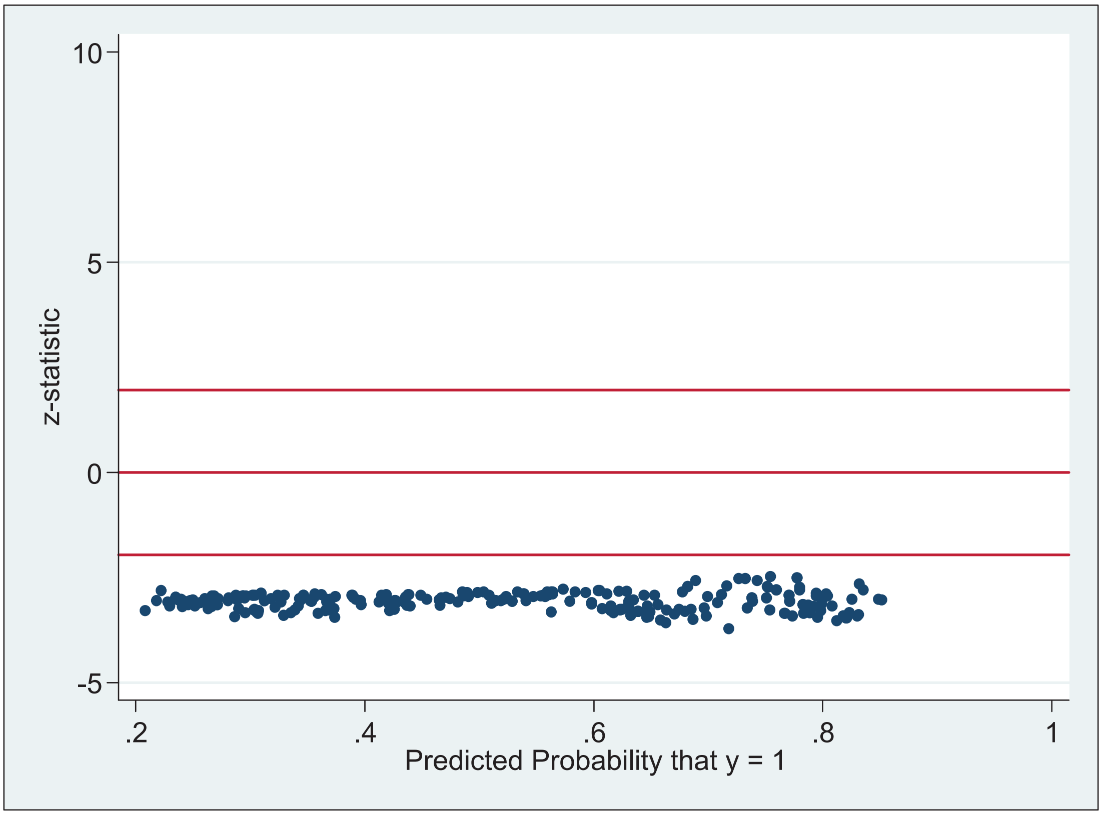

Figure 4-3: Z-Statistics of the Interaction Effects after Probit

Furthermore, to check whether the above findings depend on the choice of the binary measure of commercialization success, again a set of tobit models are estimated (Models 6a-6d in Table 4-10). The results of these models are qualitatively very similar to those obtained before and confirm the significant negative influence of log time-to-licensing for inventions disclosed after 1989.

Table 4-10: Level of Royalty Income with Interaction Term (Tobit)

Ln royalty payments	License agreements providing for royalties			
	Model 6a	Model 6b	Model 6c	Model 6d
Ln Time-to-licensing	0.913	1.315**	1.030**	1.257**
	(0.593)	(0.591)	(0.501)	(0.508)
1990-2004	9.605**	9.572**	10.285**	9.956**
	(4.488)	(4.525)	(4.133)	(4.200)
Ln time-to-licensing * 1990-2004	-2.272***	-2.192***	-2.257***	-2.193***
	(0.714)	(0.722)	(0.631)	(0.648)
Biomed		-0.488		0.279
		(1.105)		(1.136)
Director involvement		-1.171		-0.229
		(0.932)		(0.880)
Patent		-3.220***		-2.339***
		(0.909)		(0.870)
Bundle		2.563***		2.908***
		(0.871)		(0.889)
Top 5		0.003		-0.354
		(0.951)		(0.903)
Spin-off			-1.997**	-2.063**
			(0.898)	(0.901)
Foreign			-0.353	-0.375
			(0.922)	(0.960)
Repeat licensee			0.994	0.361
			(0.895)	(0.940)
Constant	-0.986	-1.605	-2.198	-2.656
	(3.717)	(3.825)	(3.378)	(3.466)
Sectoral controls	no	no	yes	yes
Observations	681	681	681	681
(inventions)	(531)	(531)	(531)	(531)
Pseudo R^2	0.021	0.028	0.037	0.042

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

The regression results in Tables 4-9 and 4-10 could be influenced by unobserved heterogeneity. To control for unobserved heterogeneity across inventions, the regression models are replicated for the inventions that are licensed multiple times, including indicator variables to control for the invention-specific effects. This approach is limited to the subset of inventions that were licensed more than once. In total, 120 inventions have been licensed multiple times, which leads to 272 license agreements.[44] However, this number of license agreements is restricted to the level of commercial success as the dependent variable. In the case of the likelihood to commercialize, the majority of observations are dropped due to a non variation in the binary outcome variable across the licensees of a single invention.

[44] For two license agreements, no information is available for time-to-licensing. Thus, 270 license agreements are left for robustness checks.

Thus, I focus on the extent of commercial success employing tobit models with invention-specific fixed effects (Table 4-11). Because fixed effects models rely on a certain amount of within-group variation, I drop the invention-specific controls and include only the licensee controls.

The regression results in Table 4-11 (Models 7a and 7b) are consistent with the results in Table 4-10 with respect to the time-to-licensing. Specifically, I find that the inventions disclosed after 1989 generate lower royalty payments with a rising log time-to-licensing, which is consistent with prior results. Thus, after controlling for any unobserved heterogeneity across inventions, I find strong evidence that the time-to-licensing is an important determinant for commercial success for the inventions disclosed after 1989. This finding implies that the speed of technology transfer has become a crucial determinant for commercial success due to the rapidly changing business environments and technological obsolescence.

Table 4-11: Multiple Licenses with Invention-specific Controls (Tobit)

Ln royalty payments	License agreements providing for royalties	
	Model 7a	Model 7b
Ln Time-to-licensing	1.707***	1.602***
	(0.002)	(0.003)
1990-2004	50.024***	53.404***
	(0.027)	(0.035)
Ln Time-to-licensing * 1990-2004	-3.161***	-3.186***
	(0.002)	(0.004)
Bundle		-0.528***
		(0.040)
Spin-off		-4.790***
		(0.049)
Repeat licensee		0.460***
		(0.032)
Constant	-40.822***	-31.952***
	(0.021)	(0.013)
Sectoral controls	no	yes
Invention-specific effects	yes	yes
Observations	270	270
(inventions)	(120)	(120)
Pseudo R^2	0.263	0.274

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

4.7 Conclusion

The importance of technology transfer from public research as a key source for innovation, and therefore for economic growth and employment in developed countries, has increasingly aroused the interest of policy makers and researchers. In particular, technology transfer through patenting and licensing is seen as a useful tool to encourage innovation. Whereas a multitude of studies investigate the technology transfer of inventions and their commercialization process, only a few works analyze how the speed by which the inventions are transferred to private-sector firms is related to their commercial success.

In this paper, I investigate two questions related to speed. First, I raise the question as to which invention-specific determinants influence the time-to-licensing, which is defined as the elapsed time between the disclosure of the invention and the signed licensing contract. Second, I analyze how the time-to-licensing is related to the likelihood and magnitude of commercial success. The regression results reveal that the inventions from the biomedical section, the collaborative inventions with private-sector firms, and the co-invented inventions with senior scientists (Max Planck directors) require less time to become licensed. According to the influence of time-to-licensing on commercial success, I do not find significant evidence that time-to-licensing negatively influences the commercial success of the inventions disclosed between 1980 and 2004. However, separating the effect of time-to-licensing for the inventions disclosed after 1989, I find a significant negative influence for the time-to-licensing on the likelihood and extent of commercial success. Thus, the regression results partially confirm the findings of Markman et al. (2005) and support the conjecture that the speed of technology transfer has become an important strategic factor since the 1990s (cf. Kessler and Chakrabarti, 1996).

The above analysis is characterized by several limitations. First, the findings of this study cannot be generalized because the analysis covers only one public research organization. However, because the Max Planck Society is one of the most important non-university research organizations worldwide, it takes a key position in Germany's public research landscape. Furthermore, the Max Planck Society is one of the first public research organizations in Europe to be subject to a Bayh-Dole-like IPR regime. Second, it appears plausible that any unobserved heterogeneity could influence the regression results. Conducting a robustness check to control for unobserved heterogeneity in the licensed inventions does not influence the main finding. However, I cannot conclusively rule out this possibility.

It should be clear that the results of the invention-specific determinants of time-to-licensing should not be taken as a request to interfere in the invention development process. The results provided in this study should be considered by the TTOs, which are responsible for technology transfer and which tend to form the link between public research organizations and private-sector firms. Thus, it appears plausible that improvements in the TTOs' organizational routines and procedures could facilitate the speed of the technology transfer. A more efficient technology transfer has (at least) two advantages. First, from the policy perspective, an efficient technology transfer fosters the effective use of scarce public sources. Second, a more efficient technology transfer could advance the economic and social benefits from basic research. Because the IPR system has recently been adopted by German and other European universities, additional studies are required to better understand the determinants of time-to-licensing and its influence on commercial success.

5. The Influence of Leadership on Academic Scientists' Propensity to Commercialize Research Findings

5.1 Introduction

To what extent is individual behavior influenced by past behavior within the organization? This question has long been the focus of a scholarly debate in various disciplines. Previous literature has highlighted that individuals tend to mimic successful behavior observed within the organization in order to perform well themselves. In doing so, individuals tend to follow the behavior of organization leaders and adapt to peers whose behavior is observed to be rewarded. Organizational theory postulates that leadership behavior and organizational routines have a long-term impact on subsequent behavior because role model effects persist over time, leading to a long-term path dependency on organizational routines. Existing empirical evidence largely supports this theory by showing that organizational leaders or founders influence individual behavior (see, e.g., Johnson, 2007; Beckman and Burton, 2008; Levy et al. 2011).

The effects of leadership behavior have been empirically investigated largely in the context of private firms, while surprisingly few studies deal with organizational influences in academia. The discipline of science has strong institutional norms, which guide scientists' behavior (Merton, 1973; Mitroff, 1974). These norms are independent of the organization. For example, "open science" demands that scientists and scholars share their results with the global scientific community as soon as possible after discovery (Stephan and Levin, 1992). Scientific careers depend upon peer recognition (i.e., scientists working in the same field of research worldwide). Thus, in academic institutes, the effects of leaders' and organizational peers' behavior on individual scientists and whether academic scientists adapt to past organizational behavior are less clear.

One of the rare studies that examined peer and leadership effects in academia was conducted by Bercovitz and Feldman (2008). By tracking 1,780 faculty members across 15 matched departments in two medical schools, the study found that department members are more likely to participate in invention disclosures when the department head is also actively involved in the process. Yet, when the scientists switched from one department where the chair was not involved in disclosure activities to another department where the chair was actively involved in disclosure activities, the department members tended to engage in disclosure activities only once. Thus, the study concludes that adaptation to leadership behavior is primarily *symbolic.*

In this study, we extend the research on the effect of leadership in academia. By utilizing panel data of invention disclosure activities within the Max Planck Society (MPS), a research organization in Germany devoted to basic research, we examine the influence of director involvement in disclosures on subsequent disclosure activity. In so doing, we utilize the unique structure of the MPS, which has independent research institutes that belong to one parent organization. Thus, our study is able to analyze leadership (and peer) influence and measure its impact in the organizational context. This research is of interest to economists for (at least) two reasons. First, from a behavioral economics perspective, this analysis improves our understanding of the influence of leadership in academia, and it addresses the question of to what extent existing research in organizational theory applies to academic institutions. Second, from an innovation economics perspective, our study contributes to the understanding of the extent to which organizational behavior may impact an individual scientist’s participation in technology transfer.

For the organizational portion of our study, we chose to examine the MPS because the MPS has several attributes that are beneficial to the purpose of our study. Most importantly, the MPS is a parent organization, which comprises 80 autonomous institutes. This organizational structure allows for an analysis of institutional commercialization effects because external factors, such as organizational research structure or the quality of the technology transfer office, are constant across all of the institutes (because research goals set by the MPS apply to all of the institutes who share one central technology transfer office). Furthermore, the Max Planck Institutes follow the so-called “Harnack principle,” where institutes are built solely around the world's leading researchers who are appointed as directors of research units. The directors determine their own research subjects, are provided with the best working conditions and have free reign in selecting their staff. Thus, the MPS is structured as a person-centered research organization. This unique structure allows us to analyze the effects of leadership because directors at the Max Planck Institutes have similar powers as leading managers in private firms. Moreover, generous public funding is provided to the MPS, accounting for 1.3 to 1.4 billion € per year, so that scientists are not pressured to obtain external funding.

Our analysis is based on several sources. First, we rely on a dataset containing information on inventions disclosed by Max Planck researchers in the natural and life sciences from the mid-1960s through 2005. The second dataset considers a subset of all disclosed inventions, which have been licensed to private-sector-firms.

Our results suggest that director engagement in disclosure activities and the amount of royalties received lead to a significant increase in invention disclosures the following year. However, these effects disappear when modeling longer time lags. Thus, academic scientists mimic successful behavior, but leadership behavior does not have long-lasting effects on commercialization behavior in the institute. These results are roughly in line with the findings of Bercovitz and Feldman (2008), who suggest that adaptation to leadership behavior is opportunistic and symbolic but does not have any sustainable effects. We conclude that existing organizational theories need to be modified for academic organizations.

The remainder of the paper is structured as follows. In section 5-2, the theoretical background of organizational theory is presented. In section 5-3, we describe the organizational structure of the MPS, which represents the organizational context of our analysis. The datasets and variables of interest are introduced in section 5-4. Section 5-5 describes our empirical research methodology, while the results are presented in section 5-6. Finally, we discuss the results and conclude the study in section 5-7.

5.2 The Role of Leadership in Organization

5.2.1 Leadership Behavior and its Influence on Individual Behavior

When individuals join an organization, they often imitate the behavior of their leaders or co-workers. This behavior may, in part, be due to a selection process. Individuals may deliberately self-select into organizations where individual behaviors and attitudes match the orientation of the parent organization (Sorensen, 2001; Duflo and Saez, 2002). Behavioral adaptation to leadership and peer behavior is often observed over time; therefore, organizational theory explains that individual behavior is influenced by organizations without excluding the potential self-selection mechanism. Adaptations due to peer behavior can be seen as a response to imperfect information because individuals have insufficient knowledge of the type of behavior required to succeed in the organization. Thus, individuals imitate the behavior of their more experienced peers (March and Simon, 1958; Williamson, 1999).

Leaders influence behavior in organizations by serving both as role models and by fostering a particular culture (Kogut and Zander, 1996; Levy et al. 2011). By serving as role models, organizational leaders signal what type of behavior is expected and likely to be rewarded (Schein, 1985; Beckman and Burton, 2008). A finding often stressed in experimental psychology in support of the theory that leadership behavior serves as a benchmark for individual behavior is that learning through identification and induced beliefs is more powerful than attempts to teach individuals via incentives or propaganda (Wood and Bandura, 1989). Furthermore, given that individual behavior is shaped by the observation and imitation of others in social contexts, organization members may find that actions performed by their leaders are legitimate and worthy of imitation (Bandura, 1986). Several studies have identified adaptation processes for individual behavior empirically. In the context of entrepreneurship, Wagner (2004) provides evidence that small, young firms have a pronounced share of nascent entrepreneurs, meaning that workers within such firms are relatively more likely to become involved in startup endeavors themselves. When observing entrepreneurs in young firms at work, the likelihood that the employee later becomes an entrepreneur increases significantly. Thus, individuals tend to mimic behaviors that have been shown to be successful in the past. When individuals recognize what past behaviors were successful, they orient their own behavior in past organization routines in order to perform well themselves.

Moreover, leaders or founders of firms may have a long-lasting *imprinting* effect on organizational behavior. Sociological organizational theory emphasizes that an organization's initial structures and routines tend to persist over time because the founding team's prior functional experiences and initial organizational and functional structures predict subsequent top manager backgrounds and later functional structures (Stinchcombe, 1965; Beckman and Burton, 2008). This persistence is grounded in the tendency of individuals in organizations to follow inherited organizational scripts and routines (Johnson, 2007). Ecologists have operationalized the concept of "structural inertia" (Hannan and Freeman, 1984) in which persistence is a function of the difficulty of changing course once investments have been made in specific organizational technologies and routines. Because of the difficulty in changing existing behavioral routines, it is likely that routines will persist over time.

5.2.2 Leadership in Academia

Traditionally, academic research has often been described as a public good that does not deplete when shared with others (Arrow, 1962; Scherer, 1982). The public good nature of academic research requires scientists to devote their efforts to the growth of the stock of knowledge, which is freely available. Thus, academic institutions have operated under *Mertonian* norms, which emphasize the open dissemination of research discovery and the disdain for commercial activity (Nelson, 2001; Bercovitz and Feldman, 2008). According to Merton's studies on the sociology of science (Merton, 1957; 1973), scientists are described as following a norm of "communalism," meaning that scientists share their discoveries with the scientific community for the common good. In doing so, a scientist gains recognition and esteem by being the first to communicate discoveries to peers (Stephan and Levin, 1992).

Despite the potential change in academic values and norms, it is often acknowledged that scientific recognition in academia is determined by international standards of research evaluation instead of by organization-specific routines. Through comparative statistics of research output, such as the Tinbergen list of AA, A and B journal rankings of publications in economics, academic scientists are evaluated using comparable, international standards. Moreover, the relevance of commercializing research output and academic reputation through commercialization may depend more on the degree of peer recognition within the particular research community than upon institutional colleagues. Therefore, it is unclear whether the impact of organizational behavior described above applies to academic organizations.

In universities or public research institutes, the impact of an organization on individual behavior usually is measured with regard to peer effects in publication and commercialization output. Azoulay et al. (2007) find that scientists are more likely to patent their research when their coauthors have patent experience. Further, Stuart and Ding (2006) find that scientists who work with peers who are active in the commercialization process are more likely to engage in entrepreneurial activity than other scientists. Furthermore, several studies validate that royalty shares impact the likelihood of disclosure and the licensing activities of scientists (Thursby et al., 2001; Jensen et al., 2003; Siegel et al., 2003b).

In academic organizations and departments, there is typically one director who officially leads the department. In light of the aforementioned findings on role model effects in private firms, it is likely that similar effects will also be detected in academia. Typically, directors of research organizations are prestigious scientists who are appointed to be directors as a result of their academic merit. Observing the behavior of directors may lead scientists to behave in a similar way. Thus, if the chair pursues commercialization, such activity may be seen as legitimate, and scientists may follow such paths in the future. Existing evidence of this relationship, however, is scarce. By investigating 15 matched departments from two medical schools, Bercovitz and Feldman (2008) found that commercial activity, measured by disclosures filed, is weakly correlated to previous director involvement with commercial disclosures.

Even though existing evidence hints that an organization's influence in academia is slightly different than its influence in private firms, a comprehensive picture of organizational effects does not yet exist. To fill this gap, we analyze the extent to which leadership behavior and past organizational performance influence individual behavior by examining the commercialization of research results via invention disclosures. In so doing, we analyze disclosure behavior at different research institutes over time.

5.3 Organizational Context: The Max Planck Society

The MPS is a German research association that was initially founded in the year 1911 as the Kaiser Wilhelm Society. In 1948, the association adopted its current name. The MPS currently consists of 80 research institutes and three additional research facilities in Germany that perform basic research. The institutes are organized into three sections: (i) the biomedical section, (ii) the chemistry, physics and technology section, and (iii) the humanities and social sciences section.

Within the German public science sector, major science and research organizations - namely universities, the MPS, the Helmholtz Association, the Fraunhofer Society, and the Leibniz Science Association - serve different functions. The Helmholtz Association pursues long-term, applied research objectives, which are based primarily in the technical and medical-biological fields with the aim of application. The Fraunhofer Society, which undertakes applied research with direct utility to public and private enterprises, conducts even more applied research than the Helmholtz Association. Both of these organizations generate a large amount of funding from contract research, comprising approximately 30 percent of the Helmholtz Association's total funding and approximately 75 percent of the Fraunhofer Society's total budget. The Leibniz Association is almost completely publicly funded and is characterized by its close cooperation with universities. As a rule, each director of a Leibniz Institute is also an appointed professor at a university. Thus, universities and the Leibniz Association often perform joint research. The goal of the MPS is to achieve research excellence, with large research projects that require special equipment or such high levels of funding that they cannot be managed by other higher education institutions. Research within the MPS is basic and thought to be internationally competitive.

MPS institutes are chosen as the organizational context for our study because the MPS has four advantages for our purposes. First, the MPS is an independent, publicly funded research organization. Approximately 82 percent of the MPS's expenditures are publically funded by the federal government and the German states. The remaining funding comes from donations, member contributions, and from a few funded projects. Over the last 5 years, the total budget of the MPS accounted for 1.3 to 1.4 billion € per annum. Given the generous budget and the nature of the funding, the scientists at the MPS hardly face any pressure to commercialize their research to attract external sources of funding.

Second, the MPS Institutes seek research excellence and promote academic freedom. Because research at the MPS is mostly basic, and given the Society's demand for excellent research, scientists work at the frontiers of research without regard to commercial potential. Therefore, MPS research can be described as seeking ground-breaking new results, though not necessarily with the goal of application. Thus, scientists' commercialization incentives are hardly affected by the research agenda.

Third, Max Planck researchers share one central technology transfer office (TTO), the Max Planck Innovation GmbH, which is responsible for the inventions of all the institutes. Established in 1970, Max Planck Innovation GmbH (named Garching Innovation GmbH until 1990) is co-located with the Society's central administration in Munich. Staff members of the transfer office 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, which have been actively supported since the early 1990s. Max Planck Innovation has entered into 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 revenue, and the particular Max Planck Institute employing the researcher gets an additional third of all the income. The MPS obtains the rest of the revenue to finance the technology transfer efforts of its TTO. According to German law, inventors must report their inventions to their employer if the invention is a result of work outcome (Kilger and Bartenbach, 2002).

Fourth, each institute focuses on a special, specific, statutory task, such as researching the structure of matter, the function of the nervous system, or the birth and development of stars and galaxies. Although the MPS consists of many different institutes, the institutional setting is consistent throughout. All institutes select and carry out their research autonomously and independently within the aforementioned scope of the MPS. Each institute administers its own budget and is free to set the focus of its own research.

In sum, the consistent structure of the autonomous MPS institutes, which belong to one parent organization with one central technology transfer office, allows us to analyze scientists' commercialization behavior.

5.4 Data and Variables

We utilize two sources of data to analyze the impact of organizational commercialization successes on individual scientists' commercialization behavior. As a first data source, we rely on collected information of all inventions disclosed by Max Planck scientists. The second dataset covers a subset of all inventions that have been licensed. Details on how we structure this data are provided in the following subsection.

5.4.1 Commercialization Data at the Organizational Level

Data on commercialization activities by MPS scientists are based on information provided by Max Planck Innovation GmbH. This data has also been used in previous studies conducted by Buenstorf and Schacht (2011) and Buenstorf and Geissler (2012).

The first dataset contains all inventions disclosed by Max Planck researchers from the mid-1960s through 2005. Overall, 3,012 inventions have been disclosed by the MPS. The data provide information regarding the date of disclosure and patent application, the institute the invention belongs to, invention-specific characteristics, such as the involvement of a Max Planck director, and whether an invention has been licensed.[45]

The second dataset involves a subset of 864 inventions, which are licensed to private-sector firms. Because a number of inventions are licensed non-exclusively to multiple licensees, there are a total of 1,172 license agreements. Whether a licensed invention is commercially successful is not directly observable. However, as in previous studies (e.g., Agrawal, 2006; Lowe and Ziedonis, 2006), we take into account royalty payments as an indirect indicator of commercial success. The data include yearly royalty payments (and fixed fees, if any) for all individual contracts

[45] Note that only two sections are active in disclosures, namely the biomedical and the chemistry, physics and technology sections.

from conclusion until 2007 or a prior termination date. In total, 731 inventions provide royalty payments (with or without fixed fees) from which 365 (50 percent) have been successfully commercialized.

For the empirical analysis, we restrict the sample to inventions disclosed in 2004 or earlier. Moreover, we restrict the sample to inventions disclosed in 1980 or later for two reasons: First, before 1980, Max Planck Innovation GmbH was not only responsible for inventions from Max Planck researchers, but it also offered its services to other public research organizations. Thus, a clear assessment of disclosed inventions belonging to Max Planck researchers is not possible. Second, information available for the pre-1980 inventions is inferior to the information available for later inventions. These restrictions leave us with a total of 2,376 disclosed inventions.

We structured the data such that information on royalties, invention disclosures, director involvement and fixed fees payments is provided by year and by institute. Information on royalty payments and fixed fees are credited to the year in which they were paid. In so doing, we constructed a panel for the years 1980-2004, which allows for the use of time lagged variables.

5.4.2 Variables of Interest

Our panel-dataset at the institute level comprises annual variables related to commercialization success, measured by royalty payments and fixed fees, and invention disclosures. As additional measures, we included institute maturity, size and the research section of the respective institute. A detailed description of our variables for the panel analysis is provided in Table 5-1.

Table 5-1: Overview of Variables

Variables	Description
TOTAL DISC$_{it}$:	This variable captures the number of annual invention disclosures of institute *i* in year *t*.
DIRECTOR DISC$_{it}$ (Binary):	A binary variable that denotes whether inventions have a Max Planck director among their inventors.
LN ROYALTIES$_{it}$:	The annual royalty payments (normalized to Deutsche Mark payments in year 2000) received by institute *i* in year *t*. As the distribution is highly skewed we employ the natural logarithm of this variable
LN FIXED FEES$_{it}$:	This variable identifies annual fixed fee payments to inventors (normalized to Deutsche Mark payments in year 2000) received by institute *i* in year *t*. As the distribution is highly skewed we employ the natural logarithm of this variable
BIOMED$_i$:	In our analysis, we comprise Max Planck Institutes within the biomedical section and the chemistry, physics and technology section. This binary variable has a value of 1 to indicate that an institute belongs to the biomedical section and zero to indicate that an institute belongs to the other section.
SIZE$_i$:	The size of an institute *i* is measured by the number of research directors. Because each department is led by one director, the number of directors equals the number of departments, excluding temporary junior research groups. Because no reliable information on the annual number of employees was available, the number of directors is the most precise information on the size of the institutes.
INST MATURITY$_{it}$:	This variable captures the age of institutes measured in years.

Descriptive statistics are summarized in Table 5-2. Furthermore, correlations are reported in Table 5-3. The correlations indicate that commercialization activities and commercialization success at the institute level correlate in such a way that we must carefully account for the possibility of multicollinearity in our study. More precisely, in Table 5-3, a multitude of variables are correlated at a very high rate ($r > 0.40$). The highest correlation ($r = 0.62$) between any two independent variables is between the indicator of director involvement and the number of scientific disclosures. Thus, significantly more inventions are made when the director is involved.

Table 5-2: Overview of Variables

Variables	Commercialization Panel Obs.	Mean	Min	Max
TOTAL DISC	929	2.140	0	25
TOTAL DISC (Binary)	929	0.560	0	1
DIRECTOR DISC (Binary)	929	0.135	0	1
LN ROYALTIES	929	3.703	0	18.729
ROYALTIES (Binary)	929	0.402	0	1
LN FIXED FEES	929	1.822	0	17.708
FIXED FEES (Binary)	929	0.169	0	1
BIOMED	929	0.493	0	1
SIZE	929	4.422	1	12
INST MATURITY	929	38.782	1	92

Table 5-3: Correlation Matrix

929 observations	TOTAL DISC$_{t-1}$	DIRECTOR DISC$_{t-1}$ (Binary)	LN ROYALTIES$_{t-1}$	LN FIXED FEES$_{t-1}$	SIZE$_i$	BIOMED$_i$	INSTITUTE MATURITY$_{it}$
TOTAL DISC$_{t-1}$	1.000						
DIRECTOR DISC$_{t-1}$ (Binary)	*0.622**	1.000					
LN ROYALTIES$_{t-1}$	*0.419**	0.278*	1.000				
LN FIXED FEES$_{t-1}$	*0.549**	0.570*	0.241*	1.000			
SIZE$_i$	*0.498**	0.288*	0.375*	0.261*	1.000		
BIOMED$_i$	*0.124**	0.165*	0.234*	0.229*	-0.038	1.000	
INSTITUTE MATURITY$_{it}$	*-0.024*	0.001	0.118*	-0.020	0.102*	-0.023	1.000

Note: The asterisk * denotes significance of pairwise correlation at the one percent level.

5.5 Econometric Approach

We utilize our panel data on disclosure activities between 1980 and 2004 to examine whether previous director involvement and the magnitude of commercial success affect the extent of subsequent disclosure activities. This analysis is implemented with a negative binominal regression model, which is used to correct for overdispersion. We use negative binominal regressions with fixed effects to identify how invention disclosures are related to one-year lagged organizational performance measures. This approach is expressed in equation (5-1).

$$TOTAL\ DISC_{it} = \beta_0 + \boldsymbol{X}_{it-1}\beta_1 + \boldsymbol{Z}_{it}\beta_2 + v_i + u_{it} \qquad (5\text{-}1)$$

In equation (5-1), the left-hand side measures the total number of disclosed inventions at the institute i at time t. On the right-hand side of equation (5-1), X_{it-1} represents a matrix of organizational performance measures in the previous time period, such as log royalties, fixed fees and an indicator variable for director disclosures. Z_{it} includes institute characteristics such as the research section an institute belongs to. v_i is the unobserved time-invariant individual effect, and u_{it} is the error term.

We focus on one-year time lags to analyze the extent to which scientists react to recently observed organizational success. Invention disclosures can be completed within weeks (or days) when a scientist thinks that his or her research outcome is innovative. Thus, to test whether disclosure behavior is related to peer effects and commercialization measures, we focus on short time lags. Further, because institutional settings and the work force in public research change frequently, it is expected that short-term organizational performance measures will have a greater influence on the public research outcome. Yet, because we acknowledge that the focus on short-term time lags may seem arbitrary, we also analyze models with different time lags as robustness checks.

5.6 Results

The results of the negative binomial panel regressions with fixed effects are reported in Tables 5-4 and 5-5. In the first step, we analyze the impact of leadership effects and the extent of commercial successes on the total number of disclosed inventions. More precisely, Model 1a includes a one-year lagged binary variable indicating whether at least one Max Planck director is listed as an inventor. In Model 1b, additional control variables such as the size and age of the institute and the institutional section are implemented. In Models 2a and 2b, one-year lagged commercialization measures are included. Specifically, we employ the logged amount of royalties and fixed fees as indicators of commercial success. Furthermore, in Model 2b, the full range of controls is implemented. In Model 3a, both organizational performance measures are accomplished. Finally, Model 3b contains the controls for the institution-specific factors. Additionally, we implement the lagged number of scientific disclosures in all regression models to control for path dependency.[46]

Results in Models 1a-1b (Table 5-4) show that the one-year lagged indicator of director involvement has a positive and significant influence on the number of disclosed inventions, which supports our conjecture of a positive leadership effect. Thus, the prior behavior of Max Planck directors who act as role models positively affects subsequent disclosure activity. This result remains robust when institute-specific controls (Model 1b) are included. In Model 2a, the lagged measures of commercialization success indicate a significant positive influence on scientific disclosures. More precisely, the significant positive influence of the lagged amount of royalties and fixed fees suggests that prior commercial successes encourage the disclosure of inventions. These results, including the institute controls in Model 2b, remain robust. The significant positive influence of organizational leaders and royalty payments on invention disclosures is confirmed in Models 3a and 3b, while fixed fees do not seem to play an important role. In models with institute-specific control variables, the size of the institute has a positive impact on the number of disclosed inventions. Furthermore, in all regression models, the lagged number of disclosures significantly influences the number of subsequent disclosures, suggesting a path dependency of academic disclosure activity.

[46] In unreported regression results we abstain from the lagged number of scientific disclosures as a control for path dependency. The results of the main variables of interest do not change with regard to signs and significance levels. The respective results are available from the authors on request.

Table 5-4: Annual Number of Invention Disclosures - I (Negative Binomial Panel Regression)

	TOTAL DISC					
	Model 1a	Model 1b	Model 2a	Model 2b	Model 3a	Model 3b
TOTAL $DISC_{t-1}$	0.057***	0.049***	0.055***	0.050***	0.046***	0.043***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
DIRECTOR $DISC_{t-1}$	0.290***	0.231***			0.258***	0.217**
(Binary)	(0.092)	(0.087)			(0.095)	(0.090)
LN $ROYALTIES_{t-1}$			0.036***	0.028***	0.036***	0.029***
			(0.009)	(0.009)	(0.009)	(0.009)
LN FIXED $FEES_{t-1}$			0.016**	0.013*	0.009	0.008
			(0.008)	(0.008)	(0.008)	(0.008)
SIZE		0.201***		0.182**		0.173**
		(0.070)		(0.073)		(0.072)
BIOMED		-0.055		-0.134		-0.095
		(0.304)		(0.304)		(0.302)
INSTITUTE MATURITY		0.008**		0.005		0.004
		(0.004)		(0.004)		(0.004)
Constant	0.821***	-0.436	0.689***	-0.286	0.695***	-0.246
	(0.150)	(0.434)	(0.157)	(0.446)	0.158	(0.444)
Observations	929	929	929	929	929	929
Number of Institutes	48	48	48	48	48	48
Prob>chi^2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Standard errors in parentheses; *; **; and *** denote significance at the 0.10; 0.05; and 0.01 levels, respectively.

To draw a comprehensive picture and reduce the correlation among covariates, we employ binary variables next to the indictor of director participation for the organizational performance measures (Table 5-5). More precisely, in Models 5a and 5b, two dummy variables are implemented in place of the magnitude of royalties and fixed fees indicating whether revenues have been generated. Furthermore, in all six models (Models 4a-6b), we use an indicator variable to control for precedent disclosure activity. Again, both baseline models and extended models with institutional controls are provided.

In Models 4a and 4b (Table 5-5), the results reveal evidence that prior activity by Max Planck directors positively affects scientific disclosures the following year. In the following two models (Models 5a and 5b), the influence of one-year lagged organizational performance measures – royalty payments and inventor fixed fees – is analyzed. The results suggest that both indicators have a significant positive influence on the number of inventions disclosed in the subsequent year. This finding suggests that scientists are more inclined to engage in disclosures in cases of observable short term commercialization success. Combining all organizational performance measures in Models 6a and 6b, the regression results suggest that the activity of organizational leaders and the inclusion of royalty payments significantly influence scientists' activities, while the fixed fees have no significant impact on invention disclosures. Furthermore, institute size and the existence of previous invention disclosures have a positive impact on the number of subsequent disclosed inventions.

Table 5-5: Annual Number of Invention Disclosures - II (Negative Binomial Panel Regression)

	TOTAL DISC					
	Model 4a	Model 4b	Model 5a	Model 5b	Model 6a	Model 6b
TOTAL $DISC_{t-1}$ (Binary)	0.554***	0.521***	0.532***	0.497***	0.493***	0.471***
	(0.104)	(0.104)	(0.106)	(0.107)	(0.107)	(0.107)
DIRECTOR $DISC_{t-1}$	0.414***	0.325***			0.380***	0.302***
(Binary)	(0.084)	(0.083)			(0.089)	(0.086)
$ROYALTIES_{t-1}$ (Binary)			0.320***	0.225***	0.310***	0.231***
			(0.083)	(0.085)	(0.082)	(0.085)
FIXED $FEES_{t-1}$ (Binary)			0.215**	0.190**	0.084	0.099
			(0.084)	(0.082)	(0.088)	(0.085)
SIZE		0.182***		0.184***		0.163***
		(0.062)		(0.062)		(0.062)
BIOMED		-0.212		-0.318		-0.230
		(0.302)		(0.302)		(0.299)
INSTITUTE MATURITY		0.011***		0.010***		0.009**
		(0.004)		(0.004)		(0.004)
Constant	0.520***	-0.625	0.409**	-0.621	0.428**	-0.519
	(0.163)	(0.419)	(0.166)	(0.419)	(0.168)	(0.418)
Observations	929	929	929	929	929	929
Number of Institutes	48	48	48	48	48	48
Prob>chi^2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Standard errors in parentheses; *; **; and *** denote significance at the 0.10; 0.05; and 0.01 levels, respectively.

In the previous regressions, we employed lagged organizational performance measures to investigate their impact on the total number of disclosed inventions. To strengthen our decision to use one-year lagged variables, we experiment with different lag structures. Specifically, we use up to five-year lags to exploit their relevance on outcome performance.[47] Table 5-6 reports regression results for up to five-year lags of organizational performance measures. More precisely, Models 7a-7e investigate the influence of up to five-year lagged organizational performance measures on the number of disclosed inventions using negative binomial panel regressions with fixed effects. Additionally, we control for the size, age, and section of each institute and for the amount of invention disclosures with the corresponding lag.

The results in Table 5-6 indicate that we do not have a clear lag structure. More precisely, in contrast to the one-year lagged model (Model 7a), none of the other models provide a significant influence of director participation on invention disclosure. With regard to the commercialization performance measures, only Models 7b and 7d provide evidence that the amount of logged commercial measures influences disclosure activity. In all of the other models, performance measures are insignificant. While the true lead-lag relationship is unknown and may

[47] The number of lags that can be included in the model is restricted by the size of the dataset because any additional lag comes at the cost of a decrease in the number of observations. Hence, we allow for detecting the impact of organizational performance measures on the number of disclosed inventions for up to five years later but not beyond.

vary among institutes, the one-year lag seems to be most appropriate for our analysis.

Table 5-6: Lag Structures

	TOTAL DISC				
	Model 7a	Model 7b	Model 7c	Model 7d	Model 7e
TOTAL $DISC_{t-1}$	0.043***				
	(0.009)				
DIRECTOR $DISC_{t-1}$ (Binary)	0.217**				
	(0.090)				
LN $ROYALTIES_{t-1}$	0.029***				
	(0.009)				
LN FIXED $FEES_{t-1}$	0.008				
	(0.008)				
TOTAL $DISC_{t-2}$		0.040***			
		(0.009)			
DIRECTOR $DISC_{t-2}$ (Binary)		0.054			
		(0.088)			
LN $ROYALTIES_{t-2}$		0.010			
		(0.009)			
LN FIXED $FEES_{t-2}$		0.021***			
		(0.008)			
TOTAL $DISC_{t-3}$			0.023**		
			(0.010)		
DIRECTOR $DISC_{t-3}$ (Binary)			0.009		
			(0.092)		
LN $ROYALTIES_{t-3}$			0.015		
			(0.010)		
LN FIXED $FEES_{t-3}$			0.008		
			(0.008)		
TOTAL $DISC_{t-4}$				0.013	
				(0.011)	
DIRECTOR $DISC_{t-4}$ (Binary)				0.078	
				(0.096)	
LN $ROYALTIES_{t-4}$				0.017*	
				(0.010)	
LN FIXED $FEES_{t-4}$				0.012	
				(0.008)	
TOTAL $DISC_{t-5}$					0.010
					(0.012)
DIRECTOR $DISC_{t-5}$ (Binary)					0.074
					(0.098)
LN $ROYALTIES_{t-5}$					0.016
					(0.010)
LN FIXED $FEES_{t-5}$					0.011
					(0.008)
SIZE	0.173**	0.203***	0.193***	0.210***	0.215***
	(0.072)	(0.077)	(0.069)	(0.074)	(0.075)
BIOMED	-0.095	-0.294	-0.433	-0.291	-0.263
	(0.302)	(0.335)	(0.344)	(0.361)	(0.373)
INSTITUTE MATURITY	0.004	0.007	0.004	0.001	0.000
	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
Constant	-0.246	-0.171	0.132	0.122	0.155
	(0.444)	(0.481)	(0.469)	(0.506)	(0.525)
Observations	929	858	810	764	718
Number of Institutes	48	47	46	46	46
$Prob>chi^2$	0.0000	0.0000	0.0000	0.0004	0.0053

Standard errors in parentheses; *; **; and *** denote significance at the 0.10; 0.05; and 0.01 levels, respectively.

5.7 Conclusion

In the present study we utilize data on the commercialization activities of the MPS to investigate organizational effects in academic settings. In so doing, we take advantage of the unique structure of the MPS, which has autonomous institutes that belong to one parent organization while sharing the same central technology transfer office. This specific structure allows for the identification of organizational effects. Our results provide two noteworthy conclusions.

First, leadership behavior has an impact on individual behavior. Director involvement in disclosure activities positively relates to subsequent disclosure activity the following year. However, this effect disappears when time lags of two or more years are used. This finding suggests that academic scientists' adaptation of leadership behavior is rather *symbolic.* When directors are involved in invention disclosures, academic scientists' disclosure activities increase in the short run, but long-term effects are not found. This finding is roughly in line with the finding of Bercovitz and Feldmann (2008), who reported evidence that scientists are more likely to disclose inventions if the director is involved in invention disclosure, but scientists often do so only once.

Second, scientists' commercialization activities are significantly related to previous commercialization activities and successes - measured in license royalties and inventor fixed fees of distinct institutes. However, this effect is only significant at the 1 percent level when short-term lags of one year are included. Thus, we conclude that scientists react to recently observed organizational success in commercialization, which serves as a financial incentive for disclosure activities. Moreover, scientists tend to be more inclined to commercialize research when peers were successful in commercializing their research in recent years. However, we acknowledge that this effect can also be explained by scientific opportunities. Chances for commercial success may critically depend on the research agenda as some research areas are of high relevance to the private sector. Therefore, one could argue that the correlation of disclosure activities of scientists with the same indicator in previous years indicates that an institute follows a research program that is close to private research. Because both explanations suit our data, we leave the question of how to disentangle these potential factors of organizational effects for future research.

In sum, we conclude that the influence of organizations on individual behavior in academia can only partially be explained by existing organizational theory. Short-term effects of leadership behavior and past organizational performance can be explained by role model effects and financial incentives, respectively. This is in line with existing organizational theory addressing how individuals tend to adapt to behavior that appears worthy of following. The finding that these effects disappear when modeling time lags of more than one year are considered suggests, however, that long-lasting leadership effects are barely detected. Directors in the MPS have a central role in shaping the research agenda. If directors do not have a long-lasting effect on scientists' behavior in the MPS, it is likely that such effects are also not found in other academic settings. Thus, we conclude that the absence of persistent effects of leadership disclosure activities and performance measures address the question of the effectiveness of organizational theory to explain the behavior of academic organizations.

6. Conclusions

Scholarly literature provides evidence that basic research has a considerable impact on economic growth, employment and innovation in industrial countries (e.g., Mansfield, 1995; Mansfield and Lee, 1996). Thereby, public research organizations (PROs) adopt an important role within the knowledge society and the economy. To strengthen the link between PROs and industry and improve the applicability of publicly funded research results, policy makers undertake considerable efforts to foster formal technology transfer. The Bayh-Dole Act in the U.S. aimed to encourage the economic use of scientific inventions. Recently, several national legislations in European countries converged toward a Bayh-Dole like regime. For example, in Germany, professor's privilege was abolished in 2002, and universities became subject to the Employee's Invention Act that was already common to private-sector firms. This thesis focuses on technology transfer and commercialization of publicly funded inventions. This thesis is subdivided into four chapters that analyze the influence of certain group constellations among market participants on bargaining prices and beliefs (chapter 2), antecedents of commercial success of licensed inventions (chapters 3 and 4) and the impact of leadership behavior and organization performance on subsequent commercialization behavior in public research (chapter 5). The following section discusses the summarized results and contributions in each single chapter and highlights directions for further research.

Chapter 2 considers the impact of group identity on the determination of prices and beliefs in a small-market bargaining game. While a growing number of studies explore the effect of group identity on individual economic decision making, only a few studies investigate the influence of group identity in small market settings with more than two interacting parties. The central idea of this study is that common experiences may already exist between certain participants at the time of negotiation due to prior common collaborations or other former relationships (Bercovitz and Feldmann, 2006). However, other participants may not have any relation to the in-group and thus belong to the out-group. This scenario is applicable to licensing markets that are characterized by small bargaining numbers (Jensen and Thursby, 2001). Employing a coordination game to induce group identity and conducting a three-person bargaining game with different group constellations, chapter 2 provides robust evidence that in-group buyers who compete with out-group buyers offer significantly more when compared to strangers. However, buyer in-group favoritism is not reciprocated from in-group sellers in lower asking prices. Thus, in-group favoritism seems to be asymmetric and possibly dependent on the market power of the actors.

Chapter 3 analyzes the influence of geographic distance on the likelihood and magnitude of commercial success. The research question considers that most of the licensed inventions, characterized by an early stage of development (Jensen and Thursby, 2001; Thursby and Thursby, 2004) and highly complex character (Agrawal, 2006), require further inventor participation in the development process. However, academic scientists are not necessarily poised to cover a large distance due to travel expenses (e.g., Beise and Stahl, 1999) and high opportunity costs of time (Stephan, 1996), so geographic proximity is expected to foster frequent in person interactions and face-to-face contacts. This chapter aims to contribute to the few extant empirical studies. A dataset of disclosed and licensed inventions from the Max Planck Society (MPS) is employed to analyze the influence of geographic distance on commercial success. Utilization of different distance measures the regression results suggest that geographic distance is not associated with lower commercialization outcomes. A negative association between distance and commercialization success is only identified for spin-off licensees located outside Germany and for foreign firms within the subsample of inventions with multiple licensees.

Previous studies recognize the importance of speed when products are developed and placed into the market. Although speed has a positive impact on various outcomes, such as product performance (e.g., Carbonell and Rodriguez, 2006) and development costs (e.g., Langerak et al., 2010), it is unclear whether the speed by which publicly funded inventions are transferred to private-sector firms influences commercial success. Chapter 4 analyzes the determinants of time-to-licensing, defined as the elapsed time between the invention disclosure and the signed licensing contract, and its impact on commercial success. More precisely, this study analyzes how invention-specific characteristics influence time-to-licensing and investigates the impact of time-to-licensing on the likelihood and magnitude of commercial success. The primary goal of this chapter is to provide additional empirical evidence on the impact of speed on commercial success. Moreover, this study contributes to the importance of a more effective technology transfer. The results from the utilization of disclosed and licensed inventions from the MPS suggest that inventions from the biomedical section, collaborative inventions with private-sector firms and inventions co-invented with senior scientists require less time to get licensed. Moreover, regression results show that time-to-licensing does not influence the commercial success of inventions disclosed between 1980 and 2004. Kessler and Chakrabarti argue (1996) that since the 1990s, speed has become one of the most important strategic determinants to create and sustain competitive advantages, and the regression models account for their argument. A separation of the effect of time-to-licensing for inventions disclosed after 1989 provides a robust negative influence of time-to-licensing on the likelihood and extent of commercial success.

Chapter 5 analyzes the impact of leadership behavior and organization performance on commercialization behavior. This study focuses on the influence of commercial performance and director engagement on subsequent disclosure activity. Bercovitz and Feldman (2008) find that the decision of individual faculty members to participate in technology transfer is influenced by leadership effects that are more symbolic than sustainable. This chapter aims to contribute to the rare empirical evidence on leadership effects in academia. Data on disclosed and licensed inventions from the MPS are employed to investigate this research question. The data are structured to list invention disclosures, director involvement, royalty and fixed fee payments per year and institute. The results suggest that director engagement in disclosure activity and the amount of royalties received lead to a significant increase in invention disclosure in the following year. However, these correlations disappear when modeling longer time lags.

Although this thesis generates new research results and contributes to the understanding of technology transfer and commercialization, the present chapters are not free of limitations. First, the empirical studies in chapters 3-5 rest upon a single organization, the MPS. Other scientific organizations across different European countries need to be analyzed to ensure more comprehensive and verifiable results. Due to the recent change in European policy, more and more PROs are active in technology transfer and commercialization, facilitating access to more European data. Second, the empirical analysis considers royalty payments as an indicator for commercial success. Although this indicator is frequently used as a proxy of the commercial success of licensed inventions, no information is available about the details of the licensing contracts. To justify the use of royalty payments, additional information about the payment structure is required. Third, the commercial success of licensed inventions may be influenced by unobserved determinants for which the regression models in this thesis partially do not control for due to data restrictions. Although various robustness checks are conducted to confirm the results, additional insights might be gained by further analysis of more detailed datasets.

Research on licensing and commercializing academic inventions could benefit from a more detailed perspective across different levels of analysis. Current research lacks in-depth understanding of the interdependent processes of actors and agents involved in technology transfer and commercialization. A recent study began a detailed investigation of TTO contributions to university-industry technology transfer (Tahvanainen and Hermans, 2011). Most of the studies, however, focus on distinct subsystems and neglect multilevel interactions across units. It would be beneficial to explore how negotiations between PROs and industry occur and which determinants influence the conclusion of license agreements. The policy question of how licensees find out about new inventions may be relevant to encourage a more efficient technology transfer. These mostly unexplored questions are potential avenues for future research.

A further promising future research path related to commercialization is firm surveying. Such studies could better understand the commercialization process of licensed inventions. The influence of a firm's capabilities, knowledge, technological relatedness and personnel equipment may be important to successfully commercialize scientific inventions. It is necessary to follow the entire development process from the initial licensing contract to the successful commercialization to understand commercialization procedures. Investor involvement is suggested to be beneficial for commercial success (Agrawal, 2006), but we do not know much about the extent and the type of involvement or at which development stage participation matters most. These areas of research may be an interesting entry point for more detailed micro-oriented studies.

Despite the need for further scholarly work on technology transfer and commercialization, this thesis presents several recommendations. The results in chapter 3 suggest that licensing to more distant firms is not associated with lower commercialization success. Preferential licensing to geographically closely located firms to support the local economy may be counterproductive from the societal point of view. For example, Belenzon and Schankerman (2009) confirm that universities with a strong local development objective generate much less income per license compared to universities that do not follow such local strategy. To ensure economic growth and wealth, academic inventions should be licensed to the best qualified licensees independent of their locations or former relationships. The results in chapter 4 provide evidence that the longer a technology (disclosed after 1989) is shelved, the lower its likelihood and magnitude of commercial success. The primary objective of public investors such as the federal government is to encourage an efficient technology transfer and guarantee an effective use of decreasing financial sources. For example, to enhance formal technology transfer, the number of high-skilled employees and the course of internal procedures in TTOs are highly important (see Swamidass and Vulasa, 2009). Chapter 5 confirms the result of

Bercovitz and Feldman (2008) that indicate that leadership effects do not have long-lasting effects on commercialization behavior. The results propose that existing organization theories cannot be transferred one-to-one in academia and need to be adjusted.

Formal technology transfer in the form of patenting and licensing is merely one of several options available to exploit PRO research results. However, publicly funded research results are of little value for the society until they are successfully utilized. To quote Thomas Edison, one of the most famous inventors in our history: "The value of an idea lies in the using of it" (Battersby and Grimes, 2010, p. 241). To encourage economic development and long-term competitiveness, the direct exploitation of research results will remain an important aspect of developed economies, as confirmed by the recent IP legislation changes in European countries.

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Appendix

A. Printed Instructions (English Translation)

Welcome to the experiment and thank you for your participation! In this experiment financed by the German Research Foundation (DFG) you can earn money, depending on your own decisions and the decisions of the other participants. It is therefore important to read the instructions carefully! If you have any questions at any time during the experiment, please press the “pause” key on the keyboard. We will come to you and answer your questions immediately and in privacy. Please pose your question quietly. All participants of this experiment receive the same printed instructions. Any additional information displayed on your screen is only intended for the respective participant. Please do not communicate or look at the screen of other participants. If you violate these rules, we are unfortunately required to remove you from the experiment. Please switch off your mobile phone.

General schedule: This experiment will take approximately 60 minutes. It consists of three parts and a final questionnaire.

The experiment:

1. Part: You will take part in a game with two other players. Detailed descriptions are displayed on your screen.

2. Part: The second part is divided into 3 stages.

In the first stage you will participate in a negotiation game. Two buyers and one seller are negotiating for an indivisible good. The roles are matched randomly. The task of the seller is to sell the single good and the task of the buyers is to buy the indivisible good. Please note that the entity offered can only be bought by one of the buyers. A total of 113 Experimental Currency Units (ECUs) are available to each of the buyers for the purchase of the good.

The negotiation process: During the negotiation process, either one of the buyers and the seller get into action: the seller will note the minimum price he or she is asking for the good from each buyer. At the same time, each buyer notes down his or her offer. To determine who will purchase the good, the demand of the seller is compared to the respective offers. If both offers do not match the demand of the seller, the good will not be sold. In this case, all parties end up with 0 ECU from this part of the experiment. If both offers match or exceed the demand of the seller, the seller may choose between the two offers. If only one offer matches the demand of the seller, the good will automatically be sold to the respective buyer.

The second and third stage of part 2 will be explained to you during the course of the experiment.

3. Part: The third part concludes the experiment with a lottery choice game and a final questionnaire.

Payment: Show-up fee (2.50€) + profit (in ECUs) from part 1 + profit randomly selected from the three stages of part 2 (in ECUs) + profit randomly selected from a chosen lottery pair. The conversion rate is 1 ECU = 0.08€. Your earnings will be privately paid to you after you fill in the questionnaire. No other participant will know how much you have earned.

Further schedule: After you have read the instructions carefully, please wait for the other participants to finish reading, and then start with the computer program on your screen.

Good luck!

B. Heckman Selection Model

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:

$$s = 1[\boldsymbol{z}\gamma + v \geq 0] \qquad \text{(B-1)}$$

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 (3-3):

$$y_{ij} = \beta_0 + \beta_1 Distance_{ij} + \boldsymbol{L}_i\beta_2 + \boldsymbol{T}_j\beta_3 + \rho\lambda(\boldsymbol{z}_{ij}\gamma) + u_{ij} \qquad \text{(B-2)}$$

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 selection stage and of the various model specifications for the outcome stage are reported in Tables B-1 through B-3. The inverse Mills ratio as an additional exogenous variable is not significant in Tables B-2 and B-3. 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.

Table B-1: Selection into Licensing (Probit; Marginal Effects)

Licensing	(All)	(Spin-offs)	(Externals)
Disclosure year	-0.011***	0.002***	-0.012***
	(0.002)	(0.000)	(0.002)
Biomed	0.178***	0.053***	0.106***
	(0.025)	(0.012)	(0.021)
Director involvement	0.640***	0.265***	0.314***
	(0.026)	(0.034)	(0.043)
Patent	0.045*	0.054***	-0.018
	(0.026)	(0.012)	(0.024)
Top 5	-0.063**	-0.007	-0.046
	(0.027)	(0.012)	(0.022)
Observations	2223	2223	2223
(inventions)	(2072)	(2072)	(2072)
Pseudo R^2	0.220	0.200	0.107

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

Table B-2: Likelihood of Commercialization (Probit with Sample Selection Control; Marginal Effects)

Commercial success	Model B1a (All)	Model B1b (Spin-offs)	Model B1c (Externals)	Model B2a (All)	Model B2b (Spin-offs)	Model B2c (Externals)	Model B3a (All)	Model B3b (Spin-offs)	Model B3c (Externals)
Ln distance	0.005	0.010	0.005						
	(0.010)	(0.022)	(0.014)						
50-100 km				0.166		0.095			
				(0.142)		(0.153)			
100-500 km				0.053	0.226**	-0.043			
				(0.059)	(0.111)	(0.080)			
> 500 km				0.063	-0.046	0.043			
				(0.065)	(0.124)	(0.080)			
Ln domestic distance							0.028**	0.039*	0.007
							(0.014)	(0.022)	(0.023)
Ln foreign distance							0.010	-0.050**	0.006
							(0.010)	(0.025)	(0.016)
Inverse Mills ratio	-0.043	-0.006	-0.075	-0.043	-0.033	-0.062	-0.054	-0.020	-0.077
	(0.046)	(0.091)	(0.087)	(0.046)	(0.090)	(0.086)	(0.047)	(0.086)	(0.088)
Disclosure year	-0.015***	-0.031***	-0.011**	-0.015***	-0.031***	-0.012**	-0.014***	-0.025***	-0.011**
	(0.004)	(0.009)	(0.005)	(0.004)	(0.009)	(0.005)	(0.004)	(0.009)	(0.005)
Biomed	-0.037	-0.256**	0.019	-0.027	-0.301**	0.045	-0.028	-0.265**	0.019
	(0.065)	(0.120)	(0.079)	(0.067)	(0.119)	(0.084)	(0.065)	(0.120)	(0.079)
Patent	-0.222***	-0.259**	-0.225***	-0.223***	-0.278**	-0.219***	-0.226***	-0.274**	-0.225***
	(0.047)	(0.120)	(0.054)	(0.048)	(0.120)	(0.054)	(0.048)	(0.118)	(0.054)
Repeat licensee	0.020	-0.299*	0.033	0.015	-0.325**	0.041	0.010	-0.416**	0.033
	(0.055)	(0.166)	(0.057)	(0.056)	(0.158)	(0.058)	(0.055)	(0.164)	(0.058)
Spin-off	-0.103**			-0.087*			-0.083		
	(0.052)			(0.053)			(0.053)		
Bundle	0.128**	0.209*	0.124*	0.131**	0.160	0.135**	0.107**	0.155	0.124*
	(0.053)	(0.105)	(0.065)	(0.052)	(0.098)	(0.065)	(0.053)	(0.100)	(0.065)
Top 5 institute	-0.005	0.196**	-0.042	-0.008	0.171*	-0.044	-0.008	0.189**	-0.042
	(0.048)	(0.089)	(0.056)	(0.049)	(0.091)	(0.056)	(0.049)	(0.085)	(0.057)
Sectoral controls					Included				
Number of obs. (inventions)	715	226	489	715	226	489	715	226	489
	(564)	(213)	(376)	(564)	(213)	(376)	(564)	(213)	(376)
P > chi^2	0.0000	0.0000	0.0000	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	0.125	0.380	0.080

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

Table B-3: Level of Royalty Income (Tobit with Sample Selection Control)

Ln royalty payments	Model B4a (All)	Model B4b (Spin-offs)	Model B4c (Externals)	Model B5a (All)	Model B5b (Spin-offs)	Model B5c (Externals)	Model B6a (All)	Model B6b (Spin-offs)	Model B6c (Externals)
Ln distance	0.159	0.236	0.145						
	(0.194)	(0.336)	(0.282)						
50-100 km				3.362		2.200			
				(2.734)		(2.890)			
100-500 km				0.943	2.750*	-0.715			
				(1.025)	(1.485)	(1.350)			
> 500 km				1.393	-0.723	1.052			
				(1.255)	(2.251)	(1.567)			
Ln domestic distance							0.431*	0.614*	-0.090
							(0.250)	(0.332)	(0.386)
Ln foreign distance							0.207	-0.724*	0.052
							(0.192)	(0.422)	(0.282)
Inverse Mills ratio	-0.113	-0.318	0.136	-0.110	-0.539	0.464	-0.274	-0.738	0.273
	(0.851)	(1.495)	(1.692)	(0.863)	(1.418)	(1.675)	(0.888)	(1.417)	(1.730)
Disclosure year	-0.309***	-0.455***	-0.290***	-0.313***	-0.444***	-0.315***	-0.301***	-0.408***	-0.296***
	(0.069)	(0.115)	(0.096)	(0.071)	(0.113)	(0.096)	(0.072)	(0.110)	(0.098)
Biomed	-0.586	-3.856**	0.899	-0.332	-4.147**	1.480	-0.494	-3.755**	0.873
	(1.169)	(1.895)	(1.440)	(1.206)	(1.821)	(1.530)	(1.164)	(1.899)	(1.433)
Patent	-3.071***	-3.833**	-3.032***	-3.069***	-3.927**	-2.929***	-3.072***	-4.110***	-3.050***
	(0.943)	(1.593)	(1.145)	(0.963)	(1.562)	(1.134)	(0.963)	(1.569)	(1.129)
Repeat licensee	0.804	-3.210	1.189	0.677	-3.418*	1.294	0.671	-4.206**	1.283
	(0.923)	(1.927)	(0.967)	(0.932)	(1.877)	(0.980)	(0.923)	(1.788)	(0.973)
Spin-off	-2.014**			-1.832*			-1.822*		
	(0.946)			(0.939)			(0.943)		
Bundle	1.770*	2.852*	1.548	1.906**	2.539*	1.828	1.519	2.208	1.607
	(0.994)	(1.606)	(1.240)	(0.960)	(1.472)	(1.232)	(0.973)	(1.507)	(1.225)
Top 5 institute	-0.056	2.352	-0.581	-0.102	2.042	-0.618	-0.090	2.223	-0.542
	(0.895)	(1.653)	(1.039)	(0.909)	(1.642)	(1.036)	(0.909)	(1.590)	(1.043)
Constant	6.693***	14.592***	5.258*	6.422***	14.678***	5.261**	5.883***	14.862***	6.054**
	(2.038)	(5.018)	(3.135)	(1.845)	(4.929)	(2.675)	(2.064)	(4.890)	(3.073)
Sectoral controls					Included				
Number of obs. (inventions)	715	226	489	715	226	489	715	226	489
	(564)	(213)	(376)	(564)	(213)	(376)	(564)	(213)	(376)
P > F	0.0000	0.0000	0.0000	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	0.042	0.149	0.026

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

Erklärung gemäß § 4 Abs. 1 S. 3 PromO, Wirtschaftswissenschaftliche Fakultät, Friedrich-Schiller-Universität Jena

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Jena, 03.02.2013

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Lebenslauf

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Arbeitspapiere

Jena Economic Research Papers # 2011-61	Buenstorf, Guido and Schacht, Alexander (2011). We need to talk – or do we? Geographic distance and the commercialization of technologies from public research
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Wissenschaftliche Vorträge

21 - 23 September 2011	"Technology Transfer in a Global Economy", Augsburg
07 - 09 April 2011	"International Meeting on Experimental and Behavioral Economics (IMEBE)", Barcelona (Spanien)
14 - 16 Februar 2011	"European Meeting on Applied Evolutionary Economics (EMAEE), Pisa (Italien),
4 Februar 2011	Doctoral Colloquium "Innovation, Industrial Dynamics, Entrepreneurship, Organisation and Space", Marburg
05 - 07 November 2009	DIME Conference "Experimental methods and Innovation: Broadening and challenging existing knowledge", Jena

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