Discussion Paper No. 12-015

Complementary Assets, Patent Thickets and Hold-up Threats – Do Transaction Costs Undermine Investments in Innovation?

Franz Schwiebacher

Zentrum für Europäische
Wirtschaftsforschung GmbH

Centre for European
Economic Research

Discussion Paper No. 12-015

Complementary Assets, Patent Thickets and Hold-up Threats – Do Transaction Costs Undermine Investments in Innovation?

Franz Schwiebacher

Non-Technical Summary

Patents are frequently viewed as major policy tool in order to stimulate R&D. In recent years however, doubts emerged whether this is the case for all technology areas. Theoretical research has shown that when research is sequential and cumulative, stronger patents may in fact discourage follow-on inventions. So called patent thickets are accused to stifle the commercialization of technology in innovations. These thickets refer to a multitude of overlapping patent rights that an innovating firm requires access to.

Recent empirical research provides evidence that firms facing patent thickets have lower innovation performance. By which mechanism patent thickets affect innovation activities remains, however, unclear. Two mechanisms could cause such a negative impact: royality stacking and hold-up threats. Using survey data of the Mannheim Innovation Panel for German manufacturing firms and balance sheet data from Creditreform's Dafne database, I investigate whether investments in innovations are affected by proxies for the pervasiveness of royality stacking and hold-up threats. The former is empirically characterized in terms of fragmented ownership of patent rights. The latter is characterized by differences in fixed tangible assets between the downstream innovating firm and upstream owners of relevant patents. This measure proxies for the maximum amount of accumulated sunk investments that holding-up patent owners could expropriate.

I find that both measures, ownership fragmentation and differences in non-current, tangibles assets, affect investments in innovation negatively. Ownership fragmentation reduces innovative investments for firms with small patent portfolios. Capital stock differences reduce investments in innovation for firms with large patent portfolios. Differences in fixed capital reduce investments in innovation irrespective whether they refer to blocking or non-blocking patent owners and irrespective to size characteristics of the cited patent owners.

These effects are specific to investments in innovation. There are no comparable effects on investments in R&D or residual physical investments. This evidence suggests that negative effects of patent thickets on innovation are not uniform and depend on characteristics of the innovating firm.

Das Wichtigste in Kürze

Die Vergabe von Patentrechten ist ein wichtiges Instrument zur staatlichen Förderung von Forschungs-und Entwicklungstätigkeiten (FuE). Allerdings hat die theoretische Forschung gezeigt, dass stärkere Patentrechte FuE-Anreize sogar mindern können, wenn Erfindungen sequenziell und kumulativ auf älteren FuE-Ergebnissen aufbauen. So genannte Patentdickichte sollen die Kommerzialisierung neuer Technologie in innovativen Produkten und Prozessen behindern. Diese Patentdickichte bestehen aus einer Vielzahl sich überlappender Patentrechte, zu denen ein Innovator Zugang benötigt.

Obwohl Evidenz vorliegt, dass Firmen die sich Patentdickichten gegenüber sehen weniger erfolgreich innovativ tätig sind ist weiterhin unklar woraus dieser negative Effekt resultiert. Zwei Eigenschaften von Patentdickichten könnten dies bewirken. Zum einen könnten zu viele Parteien Ansprüche anmelden. Zum anderen könnten Dritte unerwartet den Innovationsprozess blockieren und Innovationsrenten abschöpfen. Diese Arbeit untersucht, inwieweit Investitionen in Innovationen von diesen zwei Facetten von Patentdickichten beeinträchtigt werden. Dazu verwende ich Daten aus dem Mannheimer Innovationpanel sowie Bilanzinformationen aus der Dafnedatenbank über deutsche Firmen im verarbeitenden Gewerbe. Empirisch abgebildet werden die verschiedenen Facetten eines Patentdickichts zum Einen als Fragmentierungsindex der Patentinhaber, zum Anderen über Unterschiede in den Sachanlagevermögen zwischen Patentinhabern und nachgeordneten Firmen. Die Gefahr unerwarteter Blockaden kann gegeben sein, wenn die versunkenen Investitionen der Patentinhaber geringer sind als die der nachgeordneten Innovatoren. Letzteres Maß kann als Obergrenze für durch Blockaden abschöpfbare Renten angesehen werden.

Es zeigt sich, dass Innovationsinvestitionen mit steigender Fragmentierung seltener werden. Dies ist vor allem der Fall für Firmen mit kleinen Patentportfolios. Unterschiedliche Kapitalbestände zwischen Patentinhabern und nachgeordneten Firmen verringern die Neigung, in Innovation zu investieren. Letzters ist vor allem für Firmen mit großen Patentbeständen von Bedeutung. Dieser negative Effekt unterschiedlicher Kapitalbestände bleibt gegeben, auch wenn nur blockierende oder nicht-blockierende Patentinhaber betrachtet werden. Auch die Größe der Patentinhaber beeinflusst den negativen Effekt nicht.

Diese negativen Effekte der Charakteristika von Patentdickichten sind spezifisch für physische Investitionen in Innovationen. Es finden sich keine vergleichbaren Effekte auf sonstige physische Investitionen oder auf FuE-Tätigkeit. Der negative Einfluss von Patentdickichten auf die Innovationstätigkeit von Firmen kann nicht als gleichförmig angesehen werden und hängt von den Charakteristika des nachgeordneten Innovators ab.

Complementary Assets, Patent Thickets and Hold-up Threats - Do Transaction Costs Undermine Investments in Innovation?

Franz Schwiebacher*

November 2011

Abstract

Innovation is commercialization of technology. Imperfections in markets for technology should leave marks on physical investments for innovation. Two types of transaction costs could affect innovative investments: royality stacking and hold-up threats. Backward references in firm's patent portfolio indicate potential technology suppliers. I find a negative effect of ownership fragmentation on investments related to innovation for firms with small patent portfolios. Hold-up threats are credible when upstream patentees have less specific capital sunk than innovating firms. Differences in fixed capital stocks between downstream firms and upstream patentees negatively affect investments in innovation for firms with large patent portfolios. These effects are specific to investments in innovation. There are no comparable effects on investments in R&D or residual physical investments. The effects of patent thickets on innovation are thus not uniform. They depend on the characteristics of the downstream firm.†

JEL-classification: O31, O34

Keywords: Market for Technology, Complementary Assets, Transaction Costs, Patent Thickets

*ZEW Centre for European Economic Research, Mannheim and Department of Management, Strategy and Innovation, KU Leuven. Correspondence: ZEW, Industrial Economics and International Management, P.O. Box 103443, D–68034 Mannheim, email: schwiebacher@zew.de.

†I would like to thank Dirk Czarnitzki, Georg Licht, Bettina Peters, Bruno Cassiman, Reinhilde Veugelers, Katrin Hussinger, Bettina Peters, Salvatore Torrisi, Alberto Galasso, Simon Wakeman, Tom Magerman, Joel Stiebale and Sandrine Wolff for helpful comments. The usual disclaimer applies.

1 Introduction

Does access to complementary assets necessarily imply a privileged share in the distribution of innovation rents? At first glance, Teece's (1986) seminal work regarding the impact of appropriability regimes and complementary assets on the distribution of innovation rents seems to imply this conclusion. However, Teece (1986) and Gans and Stern (2003) focus their discussion on a unilateral dependence of technology suppliers on incumbent owners of complementary assets. These complementary assets thereby serve as gatekeepers to a successful commercialization of technologies. In this case, inventors are held up from commercializing their technology, because they lack complementary assets such as distribution networks, manufacturing equipment, or brand-name reputation.[1,2] On the other hand, imperfections in the market for technology (Gans and Stern 2010) may also lead to situations where the owner of complementary assets is held up by technology suppliers that own relevant patents. In this case, downstream innovators may find themselves unilaterally dependent on access to single intellectual property rights (e. g. Shapiro 2001). A prominent example is the case of the Blackberry producer Research in Motion (RIM). In the year 2000, when RIM was already producing its devices, the patent-holding company NTP (which was founded in 1992) sent notice of infringed patents to RIM. Although doubts have been raised on the validity of NTP's patents, the threat of shutting down their operations induced RIM to agree on a settlement payment of $ 612.5 mln. This study aims to investigate, whether firms perceive such hold up threats when deciding about investments that are targeted to the introduction of innovations.

During the last two decades, firms have increasingly been turning to external markets for technology developments (Arora et al. 2001, Chesbrough 2003). Whether there are transactional hazards in the market for technology that leave potential benefits unreaped is therefore an important research question. This literature on technology markets, however, has primarily focused on the expropriation risks that inventors face (Arrow 1962, Mowery 1983). Contrarily, this study investigates whether downstream innovators face such expropriation risks, too. The focus of the managerial literature on expropriation risks on technology market's supply side is surprising, since this literature usually regards complementary assets as co-specialized. In this case however, technology suppliers depend on access to complementary assets, as well as their downstream owners depend on

[1] In his original article, Teece (1986) already mentioned the possibility that the dependence may not be solely unilateral of the form that the technology supplier is dependent on access to complementary assets owned by incumbent innovators. He already indicated that the owner of specialized assets may equally well be dependent on technology of others. However, the discussion in the literature of mediating effects from access to specialized assets focuses to the best of my knowledge on the former case.

[2] A prominent example is the lost innovation race of EMI that developed the first tomographic scanner. Only after EMI lost its independence and incumbents took over the market with imitative innovations, they were granted damages for patent infringements.

access to the technology. Complementary assets are therefore co-specialized when there is a mutual dependence between technology supplier and downstream innovator. This mutual dependence implies that downstream innovators have to take expropriation risks into account in their decision to invest in complementary assets. This is the case because the innovator finds himself in a disadvantaged bargaining situation with residual patent-owning technology suppliers, while having already invested in complementary assets. In such ex post negotiations, failure of negotiations leaves downstream innovator with the incurred costs of adapting its equipment to specific technology. Residual patent owners can therefore expropriate innovation rents to the extent of these specific investments.[3] Firms perceiving such hold up threats should be less likely to invest in complementary assets.

This study contributes to a growing literature that analyzes the mediating role of complementary assets in boundaries of firm decisions.[4] The literature largely focuses on the effects of complementary assets on propensities to collaborate or license from the perspective of the technology supplier (e. g. Arora and Ceccagnoli 2006, Gans et al. 2002). Whether the demand-side for specialized technology is affected by expropriation risks is still an unanswered question. Ziedonis (2004) demonstrated that capital-intensive owners of complementary assets safeguard their access to the underlying technology more aggressively, when transaction costs in the market for technology are high. There is some evidence that imperfections in the market for technologies hinder the adoption of new technologies in innovative products and processes (Cockburn et al. 2010). Whether diffusion of technology is impeded by hold-up threats or by other transaction costs is, however, an open question.

This study integrates insights from managerial strategy literature of innovation with a transaction cost and property rights perspective of technology markets (cf. Madhok, 2002). I investigate whether innovative investments are affected by differences in sunk capital between potential technology suppliers and downstream innovators, since a lower amount of sunk investments by patentees is a necessary condition for their hold up threats to be credible. Section 2.1 discusses why and when investments in complementary assets could result in a risk of expropriation rather than create competitive advantage. Section 2.2 describes why a sequential and cumulative invention process that creates patent thickets could create transaction costs. Section 3 shows the empirical findings of this study.

[3] On the other hand, if licensing negotiations take place *before* the owner of complementary assets adapted it to a specific technology, we find ourselves in the classical case of an inventor facing the risk of expropriation by an incumbent owner of complementary assets.

[4] For a general overview of the empirical literature on the boundaries of the firm (i. e. whether parts of the value chain, like e. g. R&D, are organizationally independent or integrated) see Lafontaine and Slade (2007).

They reveal that patent thicket effects are not uniform. Firms with small patent portfolios reduce investments in innovation as a result of ownership fragmentation, whereas firms with large patent portfolio reduce innovative investments as a result of differences in sunk capital between them and upstream patentees.

2 Hypothesis development

The resource and competence based view of the firm in the strategic management literature largely regards downstream complementary assets as source of competitive advantage. Their adaptation to specific uses makes them hard to imitate for potential entrants (Wernerfelt 1984, Barney 1986, Dierickx and Cool 1989). Complementary assets are, however, only a source of competitive advantage when they are specialized, i. e. are not easily tradeable and are therefore associated with a certain amount of sunk, non-recoverable expenditures. Technology suppliers with their sunk R&D expenditures thus face expropriation risks when complementary assets are necessary to commercialize the technology. On the other hand, the resource based view of the firm takes complementary assets as already established. When deciding to invest in assets that are adapted to specific technology, however, the downstream innovator has to take the exclusion rights of patentees in the respective technology into account. So, at this point in time when the investment decision is made, there is a mutual dependence between technology suppliers and downstream innovators instead of a unilateral dependence when complementary assets are already established. Whether investments in complementary assets are affected by this dependence on technology suppliers, this study aims to investigate empirically.

Naturally, downstream innovators have strong incentives to secure access to the necessary technology before investing into the adaptation of assets to this technology. However, recent evidence suggests that transaction costs restrict a broader market for technologies to emerge (Gambardella et al., 2007). These market imperfections should also be reflected in the propensity to invest in complementary assets. Patent rights are only imperfect property rights. They provide a right to exclude others solely, but do not (and cannot) confer rights to use and rights to its benefits. Thus, the downstream innovator may find herself in a position in which she licensed-in relevant technology, but still does not possess the right to use the technology, because other patentees have further exclusion rights. This may happen particullary in complex technologies in which it is difficult to protect technology by a limited number of patent rights (Levin et al. 1987). Complex technologies are susceptible to generate patent thickets in view an escalating number of patent applications (Hall and Ziedonis, 2001). Shapiro (2001) defines such thickets as ‚a dense web of overlapping intellectual property rights that a company must hack its way through in order to actually commercialize new technology‘. Patent thickets could thus create transaction costs in the market for technologies. Demand for technology then reduces according to the perceived probability to be held up and investments in complementary assets diminish accordingly.

2.1 Hold up Expectations

Transaction costs can emerge when unprogrammed adaptation, lock-in and appropriable quasi-rents, that could be haggled over are present (Joskow, 1991). In other words, preconditions for transaction costs are sequential and irreversible actions that are targeted to specific outcomes but cannot be fully contracted upon ex-ante. In the case of technology transactions, these sequential, irreversible actions refer to sunk investments of both market sides: The technology supplier sunk expenditures in R&D and the ‘commercializer of technology’ sunk expenditures in the adaption of assets to become complementary to a certain technology. These sunk investments create a lock-in situation. A successful transaction, however, creates quasi-rents, i. e. rents that do not arise in other factor combinations, but only in those when *specific* technology is matched with *specific* assets.

Specific investments in complementary assets pose the risk of expropriation, when the downstream innovator cannot contract upon the technology fully ex ante. Such an incomplete contract with regard to the necessary technology can be due to the fact that the downstream innovator herself does not anticipate all the necessary technological inputs at the outset of the innovation project (Rosenberg, 1998). Since the innovation process is a recursive one (Kline and Rosenberg 1986), new information regarding actual customer needs can emerge during the process. This is associated with altering the technical specifications of innovations and may require adaptations of downstream assets with the associated need to access further technology. Lacking technology access and the resulting risk of expropriation of the downstream innovator can just as well be due to the imperfect property characteristics of intellectual property. At the heart of this imperfection lies the inability of intellectual property to transfer usage rights of technology. Instead, only rights to exclude can be transferred. A downstream innovator has an implicit right to use the technology, when no patentee holds further exclusion rights. This distinction between usage and exclusion rights of technology is especially important in patent thickets, since there may patents that the innovator overlooked to license-in but that partly overlap with the technology underlying its investments in complementary assets. Lemley and Shapiro (2005) notice that complex technologies are susceptible to such an uncertainty regarding the scope of patent rights. When the innovator cannot be sure whether marginal patents juridically overlap with the core technology she adapted her assets to, the diffuse entitlement theory (Heller and Eisenberg, 1998) predicts that under-investing is the only feasible option.

When deciding to invest in the adaptation of assets to specific technology, the downstream innovator thus has to take the expropriation risk from technology suppliers into account. The magnitude of expropriation risks depend on innovator's *relative* dependence to residual patentee's technology. In other words, is the innovator more dependent on patentee's technology or is the patentee more dependent on complementary assets? To which market side the mutual dependence swings depends on each side's specific investments. The maximum amount that can be expropriated from downstream manufacturers are the expenses she incurred for adapting her assets to specific technology and expenses she would incur in case of switching to other technology suppliers.[5] Patentees of residual exclusion rights for which it is unclear whether they overlap with complementary asset's underlying technology, can expropriate this maximum amount only if they themselves have not sunk specific investments. The more the technology use is restricted to limited number of downstream innovators, the more dependent is the technology supplier, since the supplier cannot recover her sunk R&D expenditures. Despite innovator's specific investments in complementary assets, these are not subject to expropriation risks when the holding up patentee has incurred at least as much R&D expenditures. Differences in the amount of sunk investments therefore determine on which market side the expropriation risk lies (cf. Acemoglu et al., 2010).

The case of RIM being held up by NTP illustrates this point. RIM already invested in its capital-intensive production facilities and was already producing its devices when NTP claimed patent infringement. NTP's patent portfolio, however, was presumed to be of low technological value. Accordingly, associated R&D by NTP has been lower than investments in machinery and equipment incurred by RIM. This difference in threat points explains why RIM agreed to a licensing deal that presumably overvalued the intrinsic economic value of NTP's patents. Concerns regarding such hold-up threats have been growing in recent years (e. g. Lemley and Shapiro 2007).[6] Reitzig et al. (2007) show that current legal rules for determining damage awards overcompensate infringed patent holders. In this case, it is frequently more profitable to trap R&D intensive manaufactures in infringement situations than to negotiate licenses before production takes place. Such a systematic overcompensation especially prevails in jurisdictions (like Germany)

[5]The residual unspecifity of innovator's assets does not generate a competitive advantage. However, it can be freely traded and therefore liquidized. Consequently, unspecific assets are not subject to expropriation risks.

[6]Cf. also 'Patent Trolls: Fact or Fiction' (2006), Hearing before the Subcommittee on Courts, the Internet, & Intellectual Property of the Committee of the Judiciary, House of Representatives 109^{th} Congress, Serial no. 109-105.

that grant damage awards not only on the basis of lost profits or reasonable royality rates but also allow patentees to recover infringers' profits (based on the legal fiction that the infringer undertook business on behalf of the patentee).[7]

Successful R&D activities should result in patent rights, that cite the technological knowledge the firm developed further, also in technologies in which patents are not the most important appropriation mechanism (Cohen et al. 2000). These references refer to the most essential patents in the technology and therefore to those ones that are most likely to be in-licensend when commercializing the technology. When innovator's patents are not radical enough, she needs an agreement with the owners of cited patents (cf. next section). Grindley and Teece (1997) observe that firms manage their IP portfolios more proactively. Safeguarding their freedom to operate from hold-up threats drives this more proactive stance towards IP management. Nagaoka and Kwon (2006) show that cross-licensing is more prevalent between symmetric and large firms. The effectiveness of creating large patent portfolios to secure freedom to operate can therefore be limited. Accordingly, when the innovating firm has sunk more capital than the technology supplier (i. e. when market sides are asymmetric), threats to hold up the innovator are credible. The prevalent proactive stance towards IP managament should guarantee that patent portfolios nevertheless provide a reliable data source for the technological basis of firm's business activities. Therefore, I will test the following hypothesis:

H1: Investments in complementary assets decrease with increasing difference of capital stocks between innovator and patentees of relevant technology.

2.2 Royality Stacking

So far, we have considered imperfections in the market for technologies due to differences in sunk costs between technology suppliers and downstream innovators. However, the provision of patent rights does not only facilitate technology transactions. The associated disclosure of technology also serves as basis for other researchers. They can build upon this knowledge in cumulative way to further develop the technology and avoids them to bear duplicative R&D expenditures (Scotchmer 1991). This may lead to situations of having follow-on inventors been granted exclusion rights, who have at the same time not the right to use the follow-on technology, because the initial patent-holder blocks its usage. Blocking patent rights may therefore not only result from difficulties to codify the developments and discoveries into patented claims but may also reflect the division of labour with respect to inventive activity and its sequential and cumulative nature. In this case,

[7]See Reitzig et al. (2007) for an extensive discussion of different legislations for calculating patent damage awards.

transaction costs do not originate from coordination between the downstream innovating firm and a single residual IP-holder, but from coordination among the several patent owners of a distinct technology. When several parties have contributed to the development of the technology and therefore own exclusion rights, commercialization of such a technology requires access to the complete bundle of intellectual property. In the extreme case, single patent rights are perfectly complementary, when a single exclusion rights has no economic value in itself. The right to the benefits from technology is associated with the right to use it. This right to use is implicitly granted, when all patent owners jointly resign their exclusion rights. However, when the ownership to the technology is fragmented, each distinct IP holder has the incentive to skim off the complementarity gain. Each patent holder therefore induces a negative externality on other parties in the bargaining process. Compared to a situation when a single inventor developed the entire technology (Shapiro 2001, Lerner and Tirole 2004), the charged licensing fees increase with the number of parties that have exclusion rights to the technology. This specific reincarnation of double marginalization within vertical chains is called royality stacking.

Cockburn et al. (2010) find evidence for licensing expenditures of downstream innovators to be increasing with fragmentation of intellectual property. Nevertheless, there is still a heated debate to what degree the innovation process is actually affected by fragmented exclusion rights. Since the answer to this question depends on the size of arising transaction costs, quantifiable empirically evidence is warranted. Case-study evidence for the US Biotech sector suggests that these concerns may be exaggerated (Walsh et al., 2004). Murray and Stern (2005) find evidence for a modest anti-common effect for dual knowledge that diffuses within academia as well as within the commercial intellectual property sphere. Contrarily, Magerman et al. (2011) do not find such a anticommon effect for patent-paper pairs. Graff et al. (2003) document a dramatic restructuring of the plant breeding and seed industry (from a diffuse to a tightly vertically integrated industry structure) in order to exploit complementarities between intellectual property of breakthrough technologies. Noel and Schankerman (2007) find that firms active in more fragmented technologies have lower market valuations. When innovative firms anticipate potential transaction costs from fragmented technology ownership, the following hypothesis emerges:

H2: Investments in complementary assets decrease with the degree of fragmentation of the respective technology.

3 Empirical Section

3.1 Data and Variable Definitions

The data set is obtained from three different data sources: the Mannheim Innovation Panel (MIP), firm-level information from Creditreform (Germany's largest credit rating agency) and patent data from the EPO Worldwide Patent Statistical Database. My sample is based on the Mannheim Innovation Panel (MIP)[8], which is a stratified random sample of German firms. The survey is based on the concepts and definitions of OECD's Oslo Manual (2005) for collecting data on innovation processes and targets legally independent firms with at least five employees. My sample refers to information of German corporations in the manufacturing sector for the years 1993 to 2006. Due to lacking information on some explanatory variables, data referring to 1999 and 2000 does not enter the sample. The MIP asks firms about their additional gross investments in fixed assets. Separated thereof, investments associated to innovation projects is asked. The latter includes acquisition of advanced machinery, facilities, software and external knowledge (like in-licensed patents) in order to realize innovation projects. Information on investive innovation expenditures is separated from total innovation expenditures and expenditures for R&D. I investigate whether these innovation-related investments depend on characteristics of the patent landscape in which the firm is active. The effect of patent landscape characteristics on innovation-related investments is contrasted with their effects on residual investments, since they should only show an effect on the former if they represent a transaction cost phenomenon. This focus on characteristics of the patent landscape results in a sample in which only firms enter that had applied for patent protection at least once. One important characteristic of the patent landscape is the capital endowment of patent owners. Therefore, balance-sheet information from Creditreform is linked to patent applications at the European Patent Office (EPO). This provides information on patent applicant's non-current, tangible assets (like property, plant and equipments) and 'Other Shareholder Funds' available to them. The item 'Other Shareholder Funds' is the difference between total equity and shareholder deposits and reflects therefore company's accumulated cash-flows. Creditreform gathers this information from publications of annual balance sheets. Since only corporations are obliged to publish this information, I restrict my estimation sample to corporations, too.

Commercializations of innovations can be held up credibly when the patentee suffers less sunk costs and her exclusion right overlaps with the employed technology. Walsh et al. (2004) have documented that US biotech firms anticipate transaction costs and redirect their R&D efforts accordingly. However, biotechnology is an emerging market with many

[8]See Janz et al. (2001) or Rammer et al. (2005) for a more detailed description of the Mannheim Innovation Panel.

commercial applications yet unexploited. In more mature technologies, such a redirection of innovation activities may be more difficult (cf. Harhoff et al., 2008). According to the diffuse entitlement theory (Heller and Eisenberg, 1998), anticipated transaction costs should be reflected in reduced investments in innovations. In order to anticipate such transactional hazards, screening ex ante for owners of exclusion rights is necessary. The absorptive capacity literature (Cohen and Levinthal 1989, 1990) points out that internal R&D facilitates the identification of relevant external technology. Backward references in firm's patent portfolios show such patent rights that are essential for business activities. Access to these technology is necessary when firms aim to introduce innovations. Since EPO policy is to enumerate a minimum number of references (Michel and Bettels, 2001), cited patents are presumably valuable. Its economic value in conjunction with its overlap to firm's business activities makes in-licensing likely.

Differences in sunk capital between technology suppliers and downstream innovators can cause transaction costs from hold up threats. Both market sides have incurred different kinds of non-recoverable investments. Downstream innovators invest in specific machinery and equipment whereas patent owners invest in R&D. The former is closest matched by tangible fixed assets (e. g. Antràs, 2003). R&D expenditures, on the other hand, consist of wages for scientists and engineers and the necessary research materials and equipment. German accounting rules prohibit to capitalize these expenditures. They have an immediate surplus effect. Although R&D expenditures resemble non-recoverable investments very closely, they are not treated as investments in the balance sheets. The irreversibility of R&D makes external funding difficult and expensive. Internal liquid funds are therefore usually the preferred mean to finance R&D (e. g. Hall, 2002). The accumulated cash-flows over time and therefore the capacity to finance R&D are reflected in balance sheets by the item 'Other shareholder funds', i. e. by the difference between total equity and invested equity from shareholders.

In order to obtain balance sheet information on the owners of cited patents, data on patent applications at the EPO is linked to data of the Mannheim Enterprise Panel (MUP). The MUP is a firm-level database collected by Creditreform, the largest credit rating agency in Germany.[9] Since 1999, the MUP reflects a full copy of Creditreform's data-warehouse. It can be assumed that this data covers nearly all firms economically active in Germany. In the preceding years, the MUP reflects Creditreform's entire firm-level data on firms active in Eastern Germany as well as newly established firms. The stock of Western German companies is included as stratified random sample.[10] The standardized applicant names

[9]See Almus et al. (2000) for a more detailed description of the Mannheim Enterprise Panel.

[10]Thus, capital stock characteristics of patent applicants from Western German firms before 1999 are subject to measurement error. However, these measures rely on a random sample of the company stock. Furthermore, since patenting activity is mainly explained by firm size (Hall and Ziedonis, 2001) and

of the Patstat database are used to account for varying subsidiaries that file for patent protection on behalf of a conglomerate.

Starting from the patent portfolio of the observation in the respective year, I determine the set of European patents that have been referenced to. From this set, I exclude all patents that are older than 20 years (which is the maximum duration of patent protection in Europe) and all self-owned patents. The applicants of this set of patents are assigned balance sheet information from Creditreform on their tangible fixed assets and the amount of 'Other Shareholder Funds'. This information is gathered from the MUP and Creditreform's balance-sheet database Dafne. Since the set of cited European patents issued during 30 years, year-specific balance-sheet information is not available for all patents and their applicants. Year-specific balance-sheet information is imputed on the basis of the closet available data. Then, I calculate the average stock of fixed tangible assets or the average stock of other shareholder funds, respectively, of patent owners that have been cited by the firm. This average is weighted according to the number of patent applications of each cited patent owner. The hold-up rationale predicts that with an increasing difference of capital stocks between innovating firm and cited patentees, the pressure the potential innovator suffers from a failure of licensing negotiations increases. Accordingly, specific investments in innovation should diminish with an increasing capital stock difference between innovator and patentee conditional on innovator's own capital endowment. Innovator's capital endowment is controlled for by fixed tangible assets per employee or by retained earnings (in other shareholder funds) per employee, respectively. For robustness checks, I further calculated the difference between innovator's turnover (number of employees) and average turnover (average number of employees) among the set of cited patent owners.

The set of cited European patents and their applicants is further differentiated according to citation type, citation frequency and size of the applicant. At the EPO, patent examiners classify patent citations according their blocking power (Harhoff et al. 2005, Webb et al. 2005). Citations classified as X- or Y-type threaten to render the application non-novel or non-inventive. For the sets of cited blocking and non-blocking patents, respectively, the differences in fixed tangible assets between citing firm and average stocks among cited firms are calculated separately. Hold-up threats also vary according to the size of the patentee. The difference in fixed tangible assets between the citing firm and the largest or the smallest cited patent owner, respectively, is therefore investigated. Hold-up occurs furthermore unexpectedly. The more patent examiners add citations from the same applicant, the more likely the citing firm is aware of this patent owner. Differences

pure R&D service companies are excluded from my estimation sample, the overrepresentation of newly established firms should not bias my capital stock characteristics.

in fixed tangible assets are therefore also calculated between the citing firm and the most cited patent owner, as well as between the citing firm and average stocks among the 10 per cent least cited firms.

These differences in fixed tangible assets refer to cited European patents only. However, cited patents can originate from other jurisdictions, too. In order to prevent systematic distortions, controls that characterize the set of cited patents are introduced. Therefore, the share of German, European, US and Japanese patents in this set of cited patents is calculated. Furthermore, balance sheet information on EPO applicants is only available for German companies. Accordingly, the share of German, European, US and Japanese applicants is calculated to control for this missing information.

Fragmented ownership to technologies is another characteristic of the patent landscape that reflects transactional burdens in markets for technologies (Ziedonis 2004). Since fragmentation of exclusion rights is a (time-specific)[11] feature of technologies, Cockburn et al. (2010) propose a technology-specific measure as weighted average of firm-specific fragmentations according to the formula:

$$\text{Fragmentation}_k = \frac{1}{N_k}\sum_{i=1}^{N_k}\{[1-\sum_{j=1}^{J}(\frac{\text{references}_{ikj}}{\text{references}_{ik}})^2(\frac{\text{references}_{ik}}{\text{references}_{ik}-1})]\} \tag{1}$$

In this formula, references_{ik} indicates the total number of backward citations in company i's portfolio of patent applications in technology k. references_{ikj} indicates the number of backward citations in company i's subportfolio of technology k that are held by company j ($j \neq i$). N_k refers to the total number of companies active in the respective technology and the last term within the summation refers to Hall's (2005) bias correction of Herfindahl-type measures. For my estimations, I will use a firm-level fragmentation index according to

$$\text{Fragmentation}_i = \sum_{k=1}^{K}\frac{n_k}{n}\text{Fragmentation}_k \tag{2}$$

that is generated as weighted average of technology-specific fragmentation indices. n refers to firm's patent portfolio size and n_k to the number of patents in a 4-digit IPC technology-class k.

[11]For clarity, the time index is omitted in the formula.

Subsequent sections investigate whether investments of varying degree of technological novelty are affected by patent landscape characteristics like ownership fragmentation and differences in sunk capital. Differences in sunk capital between technology suppliers and innovators can affect bargaining positions in licensing negotiations. However, cited patents need not to be in-licensed when they already expired. The share of cited patents that are older than 20 years (which is the maximum duration of patent protection in Europe) is shall control for technology's age. Furthermore, the more the innovating firm itself is active in R&D, the less she has to rely on in-licensing. Information on firm's stock of patent applications at the EPO, her R&D policy (whether she conducts R&D continuously or occasionally) and her labor costs per employee (as measure for employee's qualification) shall control the for varying dependence on licensing. Investment activities are furthermore affected by general firm characteristics. At first by firm's financial situation which is captured by the credit rating Creditreform assigns to the firm. Secondly, investments should be less likely the larger or older the company is already. Variables for firm age and size are included shall control for these general characteristics. Firm size is thereby included as number of employees and by a dummy variable whether it is part of a conglomerate.

Investments in innovations depend also on the economic value of technology in which the firm is active. The economic value of technology is, however, not directly observable to the econometrician. The applicant herself should have a more accurate view on the economic value of the technology. This assessment is revealed by applying the same technology for patent protection in several jurisdictions (Putnam 1996). Such a patent family is called triadic, when protection is sought at the three major patent offices; at the EPO, at the USPTO and the Japanese patent office. I calculate the share of triadic patents in the stock of new patent applications per year for each 4-digit technology class as an indicator for the economic value of the technology class. The value indicator for firm's patent portfolio is accordingly created as weighted average of triadic patents firm's technology classes.

3.2 Descriptive Statistics

Table 1 shows the descriptive statistics of the full sample of 1016 observations. Since having at least once applied for patent protection is a necessary prerequisite for observations to be included in the sample, average innovation-specific investment activity is very high: 87 per cent of observations invest in innovation-specific machinery and equipment. Observations with investments that are not related to innovative activity achieve a similar proportion by 90 per cent.[12] The prerequisite of having already generated new techno-

[12]Subsequent estimtation results should therefore be regarded as lower bounds for the effects of fragmentation (Cockburn et al. 2010). This is the case because firms that do not have applied for patent

logical knowledge reflects itself also in sample's R&D activity. 79 per cent of the sample is continuously engaged in R&D and only 8 per cent conduct R&D on an irregular basis. The requirement of being active in patenting is also reflected in the size descriptives of the sample. 79 per cent of the sample is part of a conglomerate. The mean number of employees is 3500 with a minimum at 6 employees and maximum at 426k employees. To take account for the skewness of the size distribution, firm size measured by number of employees enters the sample in logarithmized scale.[13]

The fragmentation index is constructed as inversed Herfindahl-index of ownership concentration. Correspondingly, a fragmentation measure of zero would indicate all cited patents are owned by the same applicant whereas a measure of one would indicate that all patents are owned by different applicants. Firms in my sample face technologies that are on average very fragmented. The mean fragmentation index lies at 88 per cent with a minimum at 81 per cent and a maximum at 91 per cent. Hold-up threats are operationalized as difference between sample firm's capital stock and the average capital stock of cited patent owners. Surveyed information shows an average stock of tangible assets of €320 mln. These sample firms report median tangible assets of €20.5 mln and a maximum amount of €36 bln. In contrast, German patent applicants at the EPO have reported mean tangible fixed assets of €174 mln in the same reference periods. The maximum amount of fixed assets reported by a patent applicant lies at €50 bln. The fact that large firms are more active in R&D and patenting will therefore reappear when calculating the difference of capital assets between sample firms and their cited patent owners, since the size distribution of German patent applicants is even more skewed than its sample counterpart. Sample firms have on average invested by €886 mln less than the average of cited patent owners. This negative difference in conjunction with the large extreme values (at the minimum, sample firms have €12 bln less tangible assets and at the maximum they have €10 bln more tangible assets reported than the respective owners of relevant patents) points to the important role large, global corporations play for patent applications at the EPO. This difference between own and potential technology suppliers' capital stocks can solely proxy for hold-up threats when own capital stocks is controlled

protection could be affected by fragmention even more severly, since they lack own patent rights as bargaining chips. In the extreme case, these firms could go out of business due to failure of obtainting licenses. Estimated effects for differences in sunk capital between patentees and innovators should be regarded as lower bounds, too. However not so much because of sample selection concerns, but because cited backward references are known to the innovator. Having relatively more sunk capital than the owners of cited patents operationalizes the hold-up pressure in licensing negotiations between them. However, unexpected patent owners could hold up, too (Reitzig et al. 2007). Hold-up threats from such entities are in fact more severe, since firm's unawareness of them could lead to situations in which they further invested in specific capital, which makes them even more susceptible to expropriation.

[13]Firm size could potentially introduce an endogeneity bias. Measuring firm size in number of employees should minimize these concerns in my opinion. The regulated labour market in Germany causes high adjustment costs. It can therefore be assumed that firms smooth their labour input over time. Unfortunately, the unbalancedness of the survey prohibits a direct econometric test of this presumption.

for. Sample firms have on average invested €80k per employee in tangible fixed assets and accumulated cash flows in the 'Other shareholder funds' item amount to €50k on average per employee.

Capital stock differences between sample firms and patentees that they cite in their patent portfolio are further differentiated by the size of the cited patentee, by the frequency she receives citations and the type of citations. At the EPO, citations to the state of the art are usually added by the patent examiner. Patent examiners classify them according to their blocking power. Patent applications are (threatened to be) non-novel or non-inventive if citations are classified as X- (or Y-) type (Harhoff et al. 2005).**?** Owners of blocking patents are on average by €557 mln larger than their citing sample counterpart. Owners of not blocking patents are larger on average than owners of blocking patents. Non-blocking patent owners are on average €816 mln larger than their citing sample firm (compared to €557 mln). Furthermore, capital stock differences to the largest and smallest patent owner among the set of cited patentees are investigated. Sample firms have on average €2.9 bln less fixed assets reported than the largest cited patent owner. Despite a shift of the range of sample values to the right, sample corporations still report on average by €300 mln less fixed assets than their smallest upstream patent owner. The high costs of receiving patent protection at the European level (e. g. van Pottelsberghe and Francois, 2006) refrain small firms and firms that are not active in the international market apparently from seeking patent protection at the EPO. A further differentiation criterion is the number of citations upstream patent owners receive from the sample firm. The most cited patent owner is interestingly comparatively small. Sample firms are only by €464 mln smaller than the respective patent owner.

Besides investments in the adaptation of fixed tangible assets, differences of sunk investments between innovators and patentees can also be due to unequal R&D expenditures. R&D expenditures are usually funded internally. Therefore, I calculate the difference between observation's and average patentee's 'Other shareholder funds'. This balance sheet item reflects equity that has not been invested by shareholders. It reflects therefore the accumulated cash flows over time. Unfortunately, information on this item is rare. Regressions on this item have to rely on a reduced sample of 508 observations. Table 3 in the appendix shows its descriptive statistics. Besides losing extreme value observations in residual investment intensity and invested equity intensity, the reduced and full sample are qualitatively similar. The same is true for a subsample of firms that reported in previous MIP waves that they acquired external knowledge and/or conducted external R&D. The qualitatively similar descriptive statistics of the latter sample are shown in table 2.

Besides external technology, firms can employ internally generated technology in innovations. The more technology is available internally, the less the necessity to rely on external technology markets with its associated transactional hazards. The size of firm's patent portfolio is therefore introduced as control in my estimations. Sample firms have on average applied for 424 patents. Since the maximum lies at more than 28k patent applications, the variable is introduced in logarithmic scale. Differences in sunk capital between cited patent owners and citing innovators can affect bargaining positions in licensing negotiations. However, not all cited patents need to be in-licensed nor is balance sheet information available for all citations. In-licensing is not necessary when the respective patent protection already expired. On average, 32 per cent of the citations refer to patents that were applied for more than 20 years ago. Balance sheet information on applicants' capital stocks is obtained from matching patent data with firm-level data from Creditreform. This data refers to the stock of firms in Germany. Thus, there will be no capital information for foreign firms that have no German subsidiary. In order to prevent these missing observations to create systematic distortions, the authority that granted patent protection and the inventor origin of backward citations are included as control variables. The European patent office refers overwhelmingly to patents granted by the EPO herself in order to define the state of the art, against which the patent application is evaluated. 74 per cent of patent citations refer to European patents. Application language has apparently an impact on cited references, too, since the second largest group are German patents.[14] A similar picture is revealed when investigating inventor location of the technology that is referenced to. European and German inventors are the largest groups among backward citations in EPO patents.

Large parts of my sample are companies from the chemical industry and from electrical and mechanical engineering. Cross-sectional econometric studies suffer the drawback of unobserved firm heterogeneity. Subsequent explanatory variables are attempts to reduce this heterogeneity. The capacity to invest depends on the extent of shareholders' invested equity and accumulated cash-flows. In order to control for the extent to which firms are financially constraint (Kaplan and Zingales 1997) information on their rating from Creditreform is introduced. This rating scale ranges from 100 to 500 of which the former constitutes the best rating and the latter the worst one. Firms in my sample are financially sound, since they hold a mean rating of 182 with a standard deviation of only 52. Refrained investments due to financial constraints is therefore unlikely to introduce heterogeneity biases in my estimations. Investments into innovation aim ultimately to increase expected productivity. Investment activity is cyclical in firm age (Cooper et al. 1999). Logarithmized age and its square shall capture these dynamics in the 12 reference periods. Since firm's technology and factor endowments determine productivity, firm's

[14]Patent families count as patents for each jurisdiction. Therefore, the sum of shares does not equal 1.

factor endowments have to be controlled for in regressions on investments. Besides information on physical fixed assets and available liquid funds, labour input is therefore included. Doms et al. (1997) find evidence that 'that the most technologically advanced plants paid their workers higher wages *prior* to adopting new technologies' (see also Chennels and van Reenen, 1998). Endogeneity biases from simultaneously determined factor inputs should be limited, consequently. My sample shows a high dispersion of labour costs per employee and year which could reflect such heterogeneity in technological capacity. The mean of €50k is accompanied by a minimum of €4k and a maximum of €170k. Instead of productivity or productivity growth (which is virtually not related to investments), heterogeneity of this kind drives investment behavior (Power 1998). Furthermore, an indicator for Eastern German firms is introduced, since economic conditions and firm performances still differ markedly between the Western and Eastern part of Germany (e. g. Czarnitzki 2005).

3.3 Econometric Results

Specifity of investments and contractual uncertainty are the main prerequisites for transaction costs to be relevant. We have discussed the prevalence of the latter in section 2. Despite the fact that transaction costs should not arise in the absence of specific investments, this is rarely taken into account in empirical investigations of transaction cost phenomena (Lafontaine and Slade, 2007). In order to discern transaction costs phenomena from other spurious effects, the influence of the patent landscape on innovation-specific investments is contrasted with its impact on non-specific, non-innovation-related investments. Investments in innovation are further distinguished according to their degree of technological novelty. Specific investments in innovation comprise R&D expenditures that shall generate new technological knowledge as well as investments that aim at commercializing given new technologies in innovative products or processes. Probit frameworks estimate correspondingly the probability to conduct R&D, innovation-specific or residual investments.[15]

Table 5 reports mean marginal effects from Probit estimations on investment probabilities.[16] Specific, innovation-related investments are separated from residual, non-specific investment activities and from investments in R&D. This is done for three different sample sizes. Besides the full sample of 1016 observations, a further subsample of 876 observations includes solely firms for which is known from pre-sample information that they have experience in acquiring external knowledge and/or in external R&D. Transaction cost concerns

[15]See section A in the appendix for further details on the employed estimation technique.

[16]Heteroscedastic Probit regressions for innovative and residual investments cannot reject the hypothesis of no heteroscedasticity in the full sample when the stratification criteria size and industry sector are introduced as heterogeneity explaining variables. This is not the case for the R&D regressions. R&D Probit regresssions are therefore clustered according to the stratification criteria.

should be especially relevant for these observations. Introducing the balance sheet item 'Other Shareholder funds' as further capital stock characteristic reduces the available sample to 508 observations. Explanatory power is highest for explaining innovation-related investment probabilities when the full sample is used. Decreasing sample size is associated with declining χ^2 statistics that test against the null of only a constant regressor. The same is true when residual investment or R&D probabilities are explained, although on a much lower level. Explanatory power of residual investment regressions is weak in view of a majority of innovation-related explanatory variables. Their primary purpose is, however, to validate that the effects of the former regressions are indeed innovation-specific. Explanatory power of R&D regressions is low because of fewer explanatory variables. Potential endogeneity concerns lead me to omit explanatory variables from the R&D regressions. For instance, whether financial constraints (expressed by firm's credit rating) cause a reduction in R&D or whether firm's rating is low because it conducts risky R&D is unclear. Furthermore, firms usually smooth R&D activities whereas physical investments are lumpy and cyclical. Firm age is introduced to control for these dynamics and is consequently omitted in the R&D regressions.

Firm's R&D policy have the largest impact on explaining innovation-related investments followed by firm age and firm size, whereby the positive effect of age decreases quadratically. The prevalence of references to expired patents and the prevalence of triadic patents do not exhibit significant effects on propensities to invest in innovation. Firms active in more valuable technologies do, however, R&D with significantly higher probability. Control variables for the authorities granting the referenced patents and for their inventor locations are not reported in the regression tables to improve clarity, but are nevertheless included in the regressions. The share of references to patents granted by the German, by the Japanese and by the European authority have significant negative impacts on investment in innovation. References to US patents positively affect investment in innovation. Inventor location of referenced patents has minor effects on investment. Solely referenced patents of European inventors affect investments in innovation regularly negatively. In order to empirically capture hold-up threat's impact on specific investments, the effect of differences in capital stocks between observations and relevant patent owners has to be conditional on observation's own capital stocks. Fixed capital stocks per employee and 'Other Shareholder Funds' per employee do not show up significant effects´on probabilities of physical investments. Larger physical capital stocks per employees do, however, negatively affect the probability to conduct R&D.

Fragmentation negatively affects the probability to invest in innovation-specific assets on a 10 per cent level of significance for the reduced and in-licensor sample and on 5 per cent level for the full sample. Increasing the fragmentation index by one percentage point decreases the mean probability of specific investments by 1.2 to 2.2 percentage points. Difference between own and average patentee's fixed capital stocks shows highly significant effects in the full and in-licensor sample. Including furthermore differences in 'Other Shareholder Funds' diminishes this effect. Approximating the marginal effect of changing from the worst to the best bargaining position reveals that capital stock differences tend to have larger quantitative effects on the probability to invest in innovation than fragmentation. The fragmentation index shows a range of 10 percentage points from 0.81 to 0.91. Such change from the least to the highest fragmentation changes the probability to observe innovation-specific investments approximately by 12 to 22 percentage points. The difference between own and an average patentee's fixed capital stocks has a range of €22 bln. Estimated marginal effects range from 7×10^{-6} to 2×10^{-5}. In the worst bargaining situation, innovators report fixed tangible assets that exceed the one of an average patent owner by €10 bln. In their best bargaining situation, cited patentees report fixed assets that exceed their own by €12 bln. Switching from the best to the worst bargaining situation reduces the investment probability by approximately 15 to 44 percentage points. These changes in probability do not indicate a complete breakdown of technology adoption as postulated by the tragedy of anticommons (Heller 1998).

Capital stock differences between upstream patentees and downstream firms affect only physical, innovation-related investments. Non-specific investments and investments in R&D are not affected. Fragmentation exhibits a negative effect on firm investments also for innovation-specific, physical investments only. Residual, physical investments are not significantly affected by fragmentation in all three samples. Investments in R&D are, however, positively correlated with technology fragmentation at a 10 per cent significance level for in-licensing firms. If the impact of single firm's patent policy on fragmentation can be neglected (what is likely the case since the measure is created on the technology level), this positive effect is inconsistent with a transaction cost rationale (e. g. Clark and Konrad, 2008). The disappearing effect of the technological value indicator suggests that fragmentation reflects partly competition in valuable technologies which in turn stimulates R&D. A certain degree of ownership dispersion may thus be necessary in order to ensure technology competition. On the other extreme, Lichtman (2006) challenges the anti-common view of patent thickets by noting that the expropriation potential of single patentees diminishes with the number of other patent holders in the thicket. Whether such non-linear fragmentation effects are present with respect to innovation-related, physical investments is investigated in Table 6. Introducing fragmentation further non-linearly renders its effects on investments in innovation insignificant in the full and in the in-licensor sample. Only in the reduced sample, in which there are no significant effects of capital stock differences, the linear and non-linear fragmentation effects are weakly significant. The negative linear fragmentation effect diminishes non-linearly, whereby former's coefficient quantitatively dominates the non-linear effect.

Cockburn et al. (2010) have shown that the effect of upstream fragmentation on downstream innovation depends on downstream firm characteristics. They provide evidence that fragmentation affects primarily in-licensing firms and firms with small patent portfolios. Table 7 presents estimation results on samples differentiated by patent portfolio size.[17] The median number of 28 patent applications is used to divide the full and the licensee sample into firms with small and large patent portfolios. This excercise furthermore serves to validate the operationalization of ownership fragmentation, since fragmenation measures following Ziedonis (2004) frequently work well for large firms with large patent portfolios, but perform poor with regard to small firms. I find that only firms with small patent portfolios are affected by upstream fragmentation. Fragmentation negatively affects their propensity to invest in innovation whereas there is no such an effect for firms with large portfolios. Especially firms with small patent portfolios should be affected by IP fragmentation, since their small portfolios are minor bargaining chips in licensing negotiations between various IP owners (cf. Hall and Ziedonis 2001). Firms with large patent portfolios are, however, not left unaffected by patent landscape characteristics. Hold-up threats should be especially relevant for firms with large patent portfolios since larger patent portfolios should exhibit larger overlap with other patents and since large patent portfolios are usually owned by larger firms with corresponding higher expropriation potential. If there are such hold-up concerns present in the innovation process, the larger the downstream innovator compared to upstream patent owners the higher the expropriation risk and the lower, ceteris paribus, the probability to invest specifically in innovation. Indeed, I find highly significant effects of capital stock differences for firms with large patent patent portfolios, whereas there are no such effect for firms with small patent portfolios. Patent thickets effects are thus not uniform and depend on downstream firm characteristics.

Capital stock differences between upstream and downstream firms are necessary but not sufficient for hold-up threats. It has to be investigated whether presented evidence is due to specific capital and that it does not reflect pure size effects. Large firms may, for instance, be less inclined to invest in innovation because they suffer opportunity costs from replacing own business with non-innovative goods. (Arrow, 1962). In such a case, firms that are larger than patent-owning firms would refrain from innovating not because of vertical transactional considerations but because of horizontal size effects. Table 8 investigates whether size differences (measured in number of employees) to upstream patent

[17] Small size of the reduced sample hinders me to conduct regressions on this sample for firms with large patent portfolios. Results for firms with small patent portfolios in this sample nevertheless confirm the results in other samples.

owners affect firm investments. Differences in size do not show significant effects on specific R&D or innovation-related investments. Solely residual, physical investments are less likely in the reduced sample with increasing firm size relative to upstream patent owners. Table 9 presents regressions when size differences are measured in terms of sales.[18] Here, investments in innovation are negatively affected with increasing relative firm size. This could indicate that previous capital stock effects are spurious size effects. Including capital stock differences renders this size effect, however, insignificant. Negative effects of increasing relative firm size should thus be a capital stock effect and not a size effect.

Tables 10-12 differentiate capital stock effects according to characteristics of the upstream patent or patentee. Patent examiners classify references to prior art according to their power to block the patent applications. References classified as X or Y can render the application non-novel or non-inventive. Owners of such prior art patents can thus block usage of technology in which the sample firm is interested in apparently. Differences in sunk capital between the sample firm and the patentee should be especially relevant in this case. Remaining non-X and non-Y references, on the other hand, indicate patents that are not capable to block the patent application. They rather indicate prior art technology that is built upon and further developed in cumulative and sequential way. Table 11 shows that the difference to the average capital stock of blocking and non-blocking patent owners, both, significantly reduce the probability of innovative investments to quantitatively similar degrees. Although owners of cited non-X or non-Y patents could not block the patent application, technology usage could still be blocked when technologies are cumulative and sequential. R&D and residual physical investments are still not affected by capital stock differences to blocking and non-blocking patent owners.

Instead of relying on the average capital stock of cited patent owners solely, the effects of capital stock differences to the smallest and largest cited patent owners are clarified. These effects should be more pronounced for differences to the smallest firm than to the largest firm. Both differences significantly reduce investments in innovation whereby the marginal effect of the latter is indeed smaller than the former. There are no negative effects on R&D or residual, physical investments. On the contrary, the larger the sample firm compared to the largest cited patent owner the higher its R&D propensity on a 10 per cent level of significance. This increased R&D propensity of already large firms could reflect first-mover advantages in evolving technologies. Small patent owners pose in particular hold-up threats (Reitzig et al., 2007). The increasing propensity to invest in non-specific, physical assets with increasing capital stock difference to the smallest cited

[18] In order to have consistent size measures, labor cost and capital intensity are introduced as normalized to sales-variables. Furthermore, sales regresssions exhibit heterogeneity in industry and size. Standard errors are clusters according to these stratification criteria.

patent owner could reflect substitution patterns towards non-expropriable assets.

In addition to measures of sunk capital according to citation type and size of cited patent owner, they are further differentiated according to the number of citations upstream patent owners receive from the sample firm. One measure includes only the 10 per cent citations-quantile of cited patent owners in the calculation of the average capital stock of upstream patentees. The other capital stock measure is restricted to the difference to the most cited patent owner. Hold-up threats can affect innovation only when there is uncertainty about the distribution of intellectual property rights. Capital stocks of seldom cited patent owners proxy for the sunk capital of such residual patent owners. On the other hand, downstream firms should be well aware of frequently cited patent owners and therefore adjust their investment policies accordingly. Differences in capital stock to seldom cited patent owners reduce highly significantly innovative investments but not R&D or residual physical investments. On the other hand, capital stock differences to the most cited firm do not affect investments in R&D and innovation. Only residual physical investments are positively affected by differences in capital stocks compared to the most cited patent owner. This should reflect the technological exclusivity that the upstream patentee enjoys and an according adjustment of downstream's business policy.

These effects could be driven by unobserved heterogeneity that is correlated with explanatory variables. Hausman tests are carried out for the subsamples for which fixed-effects estimations are feasible. Fixed-effects estimations 'difference away' time-invariable unobserved heterogeneity at the cost of losing observations that are not observed adjacently. Hausman tests on regressions on investments in R&D, innovation and residual investments, respectively, cannot reject the hypothesis that fixed effects logit and random effects logit estimators yield equal coefficients on a 10 per cent significance level. Thus, there is no evidence that endogeneity biases the results.

4 Conclusion

Patent's ability to foster innovation can be limited when sequential and cumulative R&D results in so-called patent thickets. This study investigates by which mechanism patent thickets could stifle innovation. It searches for evidence whether such patent landscape characteristics affect specific investments in R&D and innovation.

Possessing complementary assets (e. g. production facilities for innovative goods) is frequently regarded as advantageous for innovating firms in technology transactions, since technology suppliers face expropriation risks when these assets serve as gatekeepers to the commercialization of technology (Teece 1986, Gans et al. 2002). However, when deciding to invest in such specialized assets (Wernerfelt 1984), the innovating firm has to take market imperfections in the market for technology into account, too. Two kinds of transaction costs could hinder adoptions of technology in innovations: royality stacking and hold-up threats. The former stems from fragmented ownership to technology whereas the latter originates from differences in sunk capital of the market sides. Having a higher amount of sunk capital than a holding-up patent owner worsens the bargaining situation of the downstream firm and increases her expropriation risk. Backward citations in firm's patent portfolio are used to identify upstream patentees of business-relevant technologies. This set of business-relevant patents is used to construct empirical proxies for ownership fragmentation and differences in sunk capital between upstream patentees and the downstream firm. Fixed capital stocks shall thereby act as (imperfect) proxy for the amount of sunk investments (e. g. Antràs, 2003).

I find evidence for both, ownership fragmentation and capital stock differences, to affect the probability to invest in innovation negatively. These effects on innovation-specific, physical investments are contrasted with effects of ownership fragmentation and capital stock differences on innovation-specific, intangible investments (i. e. R&D) and residual, physical investments. For these investments, I do not find comparable effects. The effect of differing capital stocks on innovative investments seems also not to be a size effect. Capital stock differences affect innovative investments negatively irrespective whether they refer to blocking or non-blocking patent owners or to large or small patent owners (although the marginal effect of being larger compared to the largest cited patent owners is the smallest). Capital stock differences to seldom cited patent owners affect innovative investments also negatively, whereas there is no such an effect for capital stock differences to the most cited patent owner, which is consistent with a downstream adjustment of business policies according to available technology.

The negative effects of upstream patent thickets on downstream innovation are not uniform. Firms with small patent portfolios reduce investments in innovation as a result of ownership fragmentation. Capital stock differences do not play a significant role for them. Building large patent portfolios is a defensive measure to insure business's freedom to operate (Grindley and Teece 1997). Large patent portfolios can serve as bargaining chips in multilateral licensing negotiations when ownership is fragmented and lacking them makes firms more vulnerable to exclusion (Cockburn et al. 2010). Firms with large patent portfolios appear, however, not to be entirely shielded from the negative effects of patent thickets. Differences in capital stocks have a strong negative impact on their propensity to invest in innovation. Large patent portfolios offer more overlap possibilities for residual patent owners. Furthermore, establishing large patent portfolios reveals that a certain expropriation risk is conceived that can be leveraged when the excluding patent owner has less sunk capital. Despite these negative effects of patent thickets on downstream innovation, the evidence does not suggest a complete breakdown of technology markets due to market imperfections as suggested by the tragedy of anticommons (Heller and Eisenberg 1998). Patent thicket characteristics change investment probabilities in the worst case by approx. 15% to 45%.

Although I find no evidence that these effects are driven by spurious correlation, this study is surely not without limitations. At first, I am able to identify solely owners of relevant technology, that the firm developed further in a cumulative and sequential way. So called patent trolls (see e. g. Reitzig et al. 2007) are accused to deliberately hide their exclusion rights in patent thickets. These entities pose further hold-up threats which are not incorporated in my empirical study. Further research has to show whether their presence significantly affects adoptions of technologies in innovation. Uncertainty in intellectual property does not rely necessarily on the presence of opportunistic parties. Therefore, future research has to verify the role of uncertainty regarding validity and scope of patent rights on hold-up threats and technology diffusion. Furthermore, this study suffers a frequent drawback that the parties in licensing negotiations are not directly observable. Information on technology licensors would allow to investigate, for instance, whether repeated interactions are able to mitigate hold-up threats.

The importance of intellectual property not only to refund R&D investments but furthermore to secure usage rights to basic business technology has been emphasized in the literature since Grindley and Teece (1997). Such threats to exclude competitors also fostered views to unlock hidden value in intellectual property (Rivette and Kline, 2000). However, when all participants are aware of this game, the escalating patent portfolio race in complex technologies ends up to be purely defensive. The resulting mutual blockades leave all participants worse off. The negative effects of ownership fragmentation could indicate that the majority of market participants is indeed aware of this game. Besides being aware of IP's importance for own freedom to operate, firms and policymakers should support coordination efforts among various owners of technologies. Patent pools and standard-setting organization provide such a forum for coordination. Future research has to show whether these fora actually promote innovation.

References

Acemoglu, D., P. Aghion, R. Griffith, and F. Zilibotti (2010): "Vertical Integration and Technology: Theory and Evidence," *Journal of the European Economic Association*, 8(5), 989–1033.

Almus, M., D. Engel, and S. Prantl (2000): "The ZEW Foundation Panels and the Mannheim Enterprise Panel (MUP) of the Centre for European Economic Research (ZEW)," in *Schmollers Jahrbuch*, vol. 120, pp. 301–308.

Arora, A., and M. Ceccagnoli (2006): "Patent Protection, Complementary Assets, and Firms' Incentives for Technology Licensing.," *Management Science*, 52(2), 293 – 308.

Arora, A., A. Fosfuri, and A. Gambardella (2004): *Markets for Technology: The Economics of Innovation and Corporate Strategy*, vol. 1 of *MIT Press Books*. The MIT Press.

Arrow, K. (1962): "Economic Welfare and the Allocation of Resources for Invention," in *The Rate and Direction of Inventive Activity: Economic and Social Factors*, NBER Chapters, pp. 609–626. National Bureau of Economic Research, Inc.

Barney, J. B. (1986): "Strategic Factor Markets: Expectations, Luck, and Business Strategy," *Management Science*, 32(10), 1231 – 1241.

Chennells, L., and J. V. Reenen (1998): "Establishment Level Earnings, Technology And The Growth Of Inequality: Evidence From Britain," *Economics of Innovation and New Technology*, 5(2-4), 139–164.

Chesbrough, H. W. (2003): *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Harvard Business Press.

Clark, D. J., and K. A. Konrad (2008): "Fragmented Property Rights and Incentives for R&D," *Management Science*, 54(5), 969–981.

Cockburn, I. M., M. J. MacGarvie, and E. Müller (2010): "Patent thickets, licensing and innovative performance," *Industrial and Corporate Change*, 19(3), 899–925.

Cohen, W. M., and D. A. Levinthal (1989): "Innovation and Learning: The Two Faces of R&D," *Economic Journal*, 99(397), 569–96.

Cohen, W. M., and D. A. Levinthal (1990): "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administrative Science Quarterly*, 35(1), 128–152.

Cohen, W. M., R. R. Nelson, and J. P. Walsh (2000): "Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)," *SSRN Working Paper Series*.

Cooper, R., J. Haltiwanger, and L. Power (1999): "Machine Replacement and the Business Cycle: Lumps and Bumps," *American Economic Review*, 89(4), 921–946.

Czarnitzki, D. (2005): "The Extent and Evolution of Productivity Deficiency in Eastern Germany," *Journal of Productivity Analysis*, 24, 211–231, 10.1007/s11123-005-4706-0.

Dierickx, I., and K. Cool (1989): "Asset stock accumulation and sustainability of competitive advantage," *Management Science*, 35, 1504–1511.

Doms, M., T. Dunne, and K. R. Troske (1997): "Workers, Wages, and Technology," *The Quarterly Journal of Economics*, 112(1), 253–90.

Francois, D., and B. van Pottelsberghe (2006): "The Cost Factor in Patent Systems," CEPR Discussion Papers 5944, C.E.P.R. Discussion Papers.

Gambardella, A., P. Giuri, and A. Luzzi (2007): "The market for patents in Europe," *Research Policy*, 36(8), 1163–1183.

Gans, J. S., D. H. Hsu, and S. Stern (2002): "When Does Start-Up Innovation Spur the Gale of Creative Destruction?," *RAND Journal of Economics*, 33(4), 571–586.

Gans, J. S., and S. Stern (2003): "The product market and the market for 'ideas': commercialization strategies for technology entrepreneurs," *Research Policy*, 32(2), 333–350.

——— (2010): "Is there a market for ideas?," *Industrial and Corporate Change*, 19(3), 805–837.

Graff, G. D., G. C. Rausser, and A. A. Small (2003): "Agricultural Biotechnology's Complementary Intellectual Assets," *The Review of Economics and Statistics*, 85(2), 349–363.

Greene, W. H. (2007): *Econometric Analysis*. Pearson Prentice Hall, Upper Saddle River, NJ.

Grindley, P. C., and D. J. Teece (1997): "Managing Intellectual Capital: Licensing and Cross-Licensing in Semiconductors and Electronics," *California Management Review*, 39(2), 8–41.

Hall, B. H. (2002): "The Financing of Research and Development," *Oxford Review of Economic Policy*, 18(1), 35–51.

——— (2005): "A Note on the Bias in Herfindahl-Type Measures Based on Count Data," *Revue d'Économie Industrielle*, 110(1), 149–156.

Hall, B. H., and R. H. Ziedonis (2001): "The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995," *RAND Journal of Economics*, 32(1), 101–28.

Harhoff, D., K. Hoisl, and C. Webb (2005): “European Patent Citations: How to Count and how to Interpret them,” mimeo. Munich.

Harhoff, D., G. von Graevenitz, and S. Wagner (2008): “Incidence and Growth of Patent Thickets - The Impact of Technological Opportunities and Complexity,” CEPR Discussion Papers 6900, C.E.P.R. Discussion Papers.

Heller, M. A. . (1998): “The Tragedy of the Anticommons: Property in the Transition from Marx to Markets,” *Harvard Law Review*, 111, 621–688.

Heller, M. A., and R. S. Eisenberg (1998): “Can Patents Deter Innovation? The Anticommons in Biomedical Research,” *Science*, 280(5364), 698–701.

Hsiao, C. (2003): *Analysis of panel data*. Cambridge University Press, Cambridge, MA.

Janz, N., G. Ebling, S. Gottschalk, and H. Niggemann (2001): “The Mannheim Innovation Panels (MIP and MIP-S) of the Centre for European Economic Research,” *Journal of Applied Social Science Studies*, 121(1), 123–129.

Joskow, P. L. (1991): “The Role of Transaction Cost Economics in Antitrust and Public Utility Regulatory Policies,” *Journal of Law, Economics and Organization*, 7(0), 53–83.

Kaplan, S. N., and L. Zingales (1997): “Do Investment-Cash Flow Sensitivities Provide Useful Measures of Financing Constraints,” *The Quarterly Journal of Economics*, 112(1), 169–215.

Kline, S. J., and N. Rosenberg (1986): “An overview of innovation,” in *The Positive sum strategy: harnessing technology for economic growth*, ed. by R. Landau, and Rosenberg. Nathan National Academy of Engineering, Washington D.C.

Lafontaine, F., and M. Slade (2007): “Vertical Integration and Firm Boundaries: The Evidence,” *Journal of Economic Literature*, 45(3), 629–685.

Lemley, M. A., and C. Shapiro (2005): “Probabilistic Patents,” *Journal of Economic Perspectives*, 19(2), 75–98.

——— (2007): “Patent Holdup and Royalty Stacking,” *Texas Law Review*, 85, 1991–2049.

Lerner, J., and J. Tirole (2004): “Efficient Patent Pools,” *American Economic Review*, 94(3), 691–711.

Levin, R. C., A. K. Klevorick, R. R. Nelson, and S. G. Winter (1987): “Appropriating the Returns from Industrial Research and Development.,” *Brookings Papers on Economic Activity*, (3), 783.

Lichtman, D. (2006): “Patent holdouts in the standard-setting process,” Academic Advisory Council Bulletin 1.3, Progress and Freedom Foundation.

Madhok, A. (2002): “Reassessing the fundamentals and beyond: Ronald Coase, the transaction cost and resource-based theories of the firm and the institutional structure of production,” *Strategic Management Journal*, 23(6), 535–550.

Magerman, T., B. van Looy, and K. Debackere (2011): “In search of anti-commons: patent-paper pairs in biotechnology. An analysis of citation flows.,” Discussion paper, Paper presented at the DRUID conference 2011.

Michel, J., and B. Bettels (2001): “Patent citation analysis.A closer look at the basic input data from patent search reports,” *Scientometrics*, 51, 185–201, 10.1023/A:1010577030871.

Mowery, D. C. (1983): “The relationship between intrafirm and contractual forms of industrial research in American manufacturing, 1900-1940,” *Explorations in Economic History*, 20(4), 351–374.

Murray, F., and S. Stern (2005): “Do Formal Intellectual Property Rights Hinder the Free Flow of Scientific Knowledge? An Empirical Test of the Anti-Commons Hypothesis,” Working Paper 11465, National Bureau of Economic Research.

Nagaoka, S., and H. U. Kwon (2006): “The incidence of cross-licensing: A theory and new evidence on the firm and contract level determinants,” *Research Policy*, 35(9), 1347–1361.

Noel, M., and M. Schankerman (2006): “Strategic Patenting and Software Innovation,” Discussion paper, LSE STICERD Research Paper No. EI43.

OECD, and Eurostat (2005): *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*Paris, 3rd edition edn.

Power, L. (1998): “The Missing Link: Technology, Investment, and Productivity,” *Review of Economics and Statistics*, 80(2), 300–313.

Putnam, J. (1996): “The value of international patent rights,” Phd thesis, Yale University.

Rammer, C., B. Peters, T. Schmidt, B. Aschhoff, T. Doherr, and H. Niggemann (eds.) (2005): *Innovationen in Deutschland - Ergebnisse der Innovationserhebung 2003 in der deutschen Wirtschaft*vol. 78 of *ZEW Wirtschaftsanalysen*, Baden-Baden. Nomos Verlagsgesellschaft.

Reitzig, M., J. Henkel, and C. Heath (2007): “On sharks, trolls, and their patent prey–Unrealistic damage awards and firms’ strategies of "being infringed",” *Research Policy*, 36(1), 134–154.

Rivette, K. G., and D. Kline (2000): *Rembrandts in the Attic -Unlocking the Hidden Values of Patents*. Harvard Business Press, Cambridge, MA.

Rosenberg, N. (1998): "Uncertainty and Technological Change," in *The Economic Impact of Knowledge*, ed. by D. Neef, G. A. Siesfeld, and J. Cefola. Butterworth-Heinemann, Boston ; Oxford.

Scotchmer, S. (1991): "Standing on the Shoulders of Giants: Cumulative Research and the Patent Law," *Journal of Economic Perspectives*, 5(1), 29–41.

Shapiro, C. (2001): "Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting," in *Innovation Policy and the Economy, Volume 1*, NBER Chapters, pp. 119–150. National Bureau of Economic Research, Inc.

Teece, D. J. (1986): "Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy," *Research Policy*, 15(6), 285 – 305.

Walsh, J. P., A. Arora, and W. M. Cohen (2004): *Patents in the Knowledge-Based Economy*chap. Effects of Research Tool Patents and Licensing on Biomedical Innovation, pp. 285–340. National Academies Press.

Webb, C., D. Dernis, D. Harhoff, and K. Hoisl (2005): "Analyzing European and International Patent Citations: A Set of EPO Database Building Blocks," STI Working Paper 2005/9, OECD.

Wernerfelt, B. (1984): "A Resource-Based View of the Firm," *Strategic Management Journal*, 5(2), 171–180.

Wooldridge, J. M. (2002): *Econometric analysis of cross section and panel data.* Cambridge University Press, Cambridge, MA.

Ziedonis, R. H. (2004): "Don't Fence Me In: Fragmented Markets for Technology and the Patent Acquisition Strategies of Firms," *Management Science*, 50(6), 804–820.

A Estimation Technique

Propensities to invest are estimated by the Probit discrete-choice framework (see e. g. Greene 2005). The latent net-benefit from investing y^* is estimated as linear function of the explanatory variables $\mathbf{x}$ and an error term ν that is independent of $\mathbf{x}$:

$$y^* = \boldsymbol{\beta'x} + \nu.$$

Since we cannot observe the latent net-benefit y^*, the estimation equation has to be re-formulated in terms of the observable investment decision y.

$$y = \begin{cases} 1 & \text{if } y^* > 0 \\ 0 & \text{if } y^* \leq 0 \end{cases}$$

When $F(\quad)$ denotes the cumulative distriubtion of the error term ν, the conditional probability that observation i has decided to invest is given by $P(y^*_{it} > 0) = P(\nu > -\boldsymbol{\beta'x_{it}} = F(\boldsymbol{\beta'x_{it}}))$. The estimatated likelihood function for a sample of N individuals is then given by:

$$L = \prod_{it=1}^{N} F(\boldsymbol{\beta'x_{it}}))^{y_{it}}[1 - F(\boldsymbol{\beta'x_{it}})]^{1-y_{it}}$$

Since estimated coefficients from this likelihood are not easily interpretable, my estimation results provide the sample average of marginal effects. According to

$$\frac{\partial E(y|\boldsymbol{x})}{\partial x_j} = \frac{P(y^* > 0)}{\partial x_j} = F(\boldsymbol{\beta'x})\beta_j$$

the marginal effect of an explanatory variable x_j is the marginal change of the expected probability to observe a positive outcome, when the respective explanatory variable x_j is changed by a marginal unit.

A frequent problem in econometric panel studies is the assumption of unobserved effects to be random noise. Systematic differences between the units of observations could, however, be subsumed under this random noise, too. It is therefore reasonable to decompose the overall error term ν into a cross-sectional, time-invariant component u_i and a remainder η_{it}: $\nu_{it} = u_i + \eta_{it}$. Conditional on this unobserved heterogeneity, the probability to invest is then given by:

$$P(y^*_i > 0) = P(\eta_{it} > -\boldsymbol{\beta'x_i} - u_i = F(\boldsymbol{\beta'x_i} - u_i)).$$

Under the assumption that u_i is strictly exogeneous to the explanatory variables $\mathbf{x}$ and is distributed according to $G(\quad)$, the log-likelihood can be expressed in its marginal form by:

$$logL = \sum_{i=1}^{N} \int \prod_{T}^{t=1} F(\boldsymbol{\beta'}\boldsymbol{x_{it}} - u_i)^{y_{it}} [1 - F(\boldsymbol{\beta'}\boldsymbol{x_{it}} - u_i)]^{1-y_{it}} dG(u|\sigma_u)$$

When $G(\quad)$ and $F(\quad)$ are normally distributed, the above equation shows the estimation of the random-effects probit model. This random-effects likelihood is unconditional on unobserved heterogeneity and depends on the (normalized) parameters $\boldsymbol{\beta}$ and the variation parameter σ_u of $G(\quad)$. This estimator relies on the strong strict exogeneity assumption. Fixed effects expressions of the likelihood (conditional on u_i) may be more appropriate, when there are doubts on this assumption.

In linear econometric models, fixed-effects transformations can eliminate this unobserved heterogeneity and circumvent thereby the resulting incidental parameter problem when the likelihood is conditional on u_i and the time-dimension is asymptiotically fixed. However, for non-linear models, usually no such transformations exit. Fortunately, a consistent fixed-effects estimator exits for the panel-logit model, when $G(\quad)$ is normally distributed and $F(\quad)$ logistically distributed (see Hsiao, 2002 for more details). Wheter the assumptions of the random effects specification are met will be tested using the Hausman test (see e. g. Wooldridge, 2002). When the hypothesis of an unbiased random effects specification is correct, estimated coefficients from the fixed-effects- and random-effects-approach should not differ significantly.

Since the Hausman tests cannot reject the hypothesis that estimated coefficients from the fixed-effects and random-effects framework are asymptotically equal in the discrete choice models, I do not further discuss the difficulties encountered in truncated regressions from spurious correlations between individual heterogeneity and explanatory variables (see Hsiao, 2002 for a discussion of alternative approaches).

B Data

Table 1: Descriptive Statistics - Full Sample

	Mean	Std.dev.	Minimum	Maximum
Investments in Innovation	0.87	0.34	0	1
Residual Investments	0.90	0.30	0	1
Fragmentation Index	87.98	1.43	81.34	90.91
Δ Fixed Assets§	-886	1460	-12213	10184
Δ Other Funds§	-227	934	-10196	5804
Δ No. of Employees	-512	17627	-47180	422627
Δ Sales§	-772	4953	-22379	82656
Δ Fixed Assets ...				
... to X or Y-References	-557	1471	-23920	10162
... not to X or Y-References	-816	1387	-10752	10193
... to largest cited patentee	-2948	5867	-59821	7698
... to smallest cited patentee	-300	1364	-10752	13640
... to seldom cited patentees	-510	1243	-10752	12764
... to most cited patentee	-474	1377	-10752	4087
Share Expired Patents	0.32	0.15	0	0.82
Share Triadic Patents	0.82	0.13	0.27	1
ln(Patent stock)	3.54	1.67	0	10.25
Occasional R&D activities	0.08	0.28	0	1
Continuous R&D activities	0.79	0.41	0	1
Share of Citations from DE Authority	0.24	0.10	0	0.63
Share of Citations from EU Authority	0.74	0.10	0.38	1
Share of Citations from US Authority	0.18	0.08	0	0.50
Share of Citations from JP Authority	0.03	0.05	0	0.50
Share of Citations to DE Applicant	0.63	0.12	0.27	1
Share of Citations to EU Applicant	0.33	0.12	0	0.86
Share of Citations to US Applicant	0.16	0.10	0	0.75
Share of Citations to JP Applicant	0.06	0.05	0	0.42
Credit rating	182	52.04	100	500
Other Funds Intensity‡	0.08	0.18	0.00	2.36
Fixed Asset Intensity‡	0.06	0.12	0.00	2.16
ln(No. of Employees)	6.54	1.53	1.79	12.96
ln(Age)	3.63	1.14	0	6.03
Part of Conglomerate	0.78	0.42	0	1
Labour Cost Intensity‡	0.05	0.01	0.004	0.17
Location in Eastern Germany	0.06	0.23	0	1
Low-Tech Manufacturing	0.35	0.48	0	1
Medium High-Tech Manufacturing	0.46	0.50	0	1
High-Tech Manufacturing	0.19	0.39	0	1
No. of Observations		1016		

‡ in €mln per employee
§ in €mln

Table 2: Descriptive Statistics - In-Licensors

	Mean	Std.dev.	Minimum	Maximum
Investments in Innovation	0.91	0.29	0	1
Residual Investments	0.90	0.30	0	1
Fragmentation Index	87.97	1.43	81.34	90.91
Δ Fixed Assets§	-894	1500	-12213	10184
Δ Other Funds§	-200	856	-10184	5804
Δ No. of Employees	-113	18731	-47180	422627
Δ Sales§	-636	5126	-22379	82656
Share Expired Patents	0.31	0.15	0	0.82
Share Triadic Patents	0.82	0.13	0.27	1
ln(Patent stock)	3.60	1.70	0	10.25
Occasional R&D activities	0.09	0.28	0	1
Continuous R&D activities	0.83	0.37	0	1
Share of Citations from DE Authority	0.25	0.10	0	0.63
Share of Citations from EU Authority	0.74	0.10	0.38	1
Share of Citations from US Authority	0.18	0.08	0	0.50
Share of Citations from JP Authority	0.03	0.05	0	0.50
Share of Citations to DE Applicant	0.63	0.12	0.27	1
Share of Citations to EU Applicant	0.33	0.12	0	0.86
Share of Citations to US Applicant	0.16	0.10	0	0.67
Share of Citations to JP Applicant	0.06	0.05	0	0.40
Credit rating	179	50.56	100	500
Other Funds Intensity‡	0.08	0.17	0.00	2.36
Fixed Asset Intensity‡	0.06	0.11	0.00	2.16
ln(No. of Employees)	6.66	1.50	2.08	12.96
ln(Age)	3.70	1.10	0	5.86
$ln(\text{Age})^2$	14.92	7.43	0	34.28
Part of Conglomerate	0.78	0.42	0	1
Labour Cost Intensity‡	0.05	0.01	0.008	0.17
Location in Eastern Germany	0.03	0.18	0	1
Low-Tech Manufacturing	0.34	0.47	0	1
Medium High-Tech Manufacturing	0.47	0.50	0	1
High-Tech Manufacturing	0.20	0.40	0	1
No. of Observations			876	

‡ in €mln per employee
§ in €mln

Table 3: Descriptive Statistics - Reduced Sample

	Mean	Std.dev.	Minimum	Maximum
Investments in Innovation	0.87	0.34	0	1
Residual Investments	0.90	0.30	0	1
Fragmentation Index	88.08	1.41	81.34	90.84
Δ Fixed Assets§	-828	1300	-10752	6160
Δ Other Funds§	-442	1267	-10196	5804
Δ No. of Employees	-461	13020	-47180	141908
Δ Sales§	-749	4228	-22379	30804
Share Expired Patents	0.32	0.15	0	0.82
Share Triadic Patents	0.82	0.13	0.36	1
ln(Patent stock)	3.59	1.66	0	9.59
Occasional R&D activities	0.09	0.28	0	1
Continuous R&D activities	0.80	0.40	0	1
Share of Citations from DE Authority	0.24	0.10	0	0.63
Share of Citations from EU Authority	0.74	0.10	0.38	1
Share of Citations from US Authority	0.19	0.09	0	0.50
Share of Citations from JP Authority	0.03	0.05	0	0.50
Share of Citations to DE Applicant	0.63	0.12	0.27	1
Share of Citations to EU Applicant	0.34	0.12	0	0.85
Share of Citations to US Applicant	0.17	0.10	0	0.50
Share of Citations to JP Applicant	0.05	0.05	0	0.22
Credit rating	176	50.20	100	500
Other Funds Intensity‡	0.08	0.19	0.00	2.36
Fixed Asset Intensity‡	0.06	0.12	0.00	2.16
ln(No. of Employees)	6.67	1.64	2.08	11.90
ln(Age)	3.74	1.09	0	6.03
$ln(\text{Age})^2$	15.15	7.48	0	36.40
Part of Conglomerate	0.72	0.45	0	1
Labour Cost Intensity‡	0.05	0.01	0.01	0.17
Location in Eastern Germany	0.05	0.21	0	1
Low-Tech Manufacturing	0.32	0.47	0	1
Medium High-Tech Manufacturing	0.49	0.50	0	1
High-Tech Manufacturing	0.19	0.39	0	1
No. of Observations			508	

‡ in €mln per employee
§ in €mln

Table 4: Correlation Matrix of Full Sample

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1) Innovation Invest.	1																	
(2) Non-Innovation Invest.	-0.11	1																
(3) Fragmentation Index	-0.04	-0.03	1															
(4) Δ Fixed Assets	-0.03	-0.01	0.09	1														
(5) Δ Other Funds	0.04	-0.05	0.08	0.42	1													
(6) Share Expired Citations	0.05	0.06	0.11	0.02	-0.04	1												
(7) Share Triadic Patents	0.03	-0.04	-0.08	-0.13	-0.03	-0.15	1											
(8) ln(Patent stock)	0.12	-0.01	0.14	0.02	0.21	0.01	0.20	1										
(9) Occasional R&D	0.04	-0.01	-0.01	0.08	0.02	0.11	-0.04	-0.07	1									
(10) Continuous R&D	0.47	-0.03	0.01	-0.05	0.03	-0.07	0.13	0.14	-0.59	1								
(11) Credit rating	-0.01	-0.07	0.04	0.06	-0.06	0.02	-0.17	-0.21	0.01	-0.08	1							
(12) Other Funds Intensity	-0.04	-0.01	-0.21	0.07	0.11	-0.01	0.07	0.12	0.00	-0.06	-0.11	1						
(13) Fixed Asset Intensity	-0.08	0.04	0.07	0.03	0.02	0.01	0.04	0.02	0.02	-0.09	-0.07	0.37	1					
(14) ln(No. of Employees)	0.16	0.11	0.06	-0.03	0.12	-0.01	0.13	0.62	-0.08	0.21	-0.33	-0.03	0.11	1				
(15) ln(Age)	0.03	0.04	-0.03	-0.01	-0.01	0.19	0.03	0.16	0.09	0.00	-0.33	-0.02	0.02	0.28	1			
(16) Labour Cost Intensity‡	0.00	-0.04	0.22	0.01	0.07	0.10	0.18	0.28	-0.04	0.05	-0.04	0.15	0.25	0.12	-0.03	1		
(17) Med. High-Tech Manuf.	0.06	0.01	0.04	0.00	-0.03	0.14	0.05	0.18	0.02	0.06	0.01	0.01	-0.06	0.09	0.03	0.16	1	
(18) High-Tech Manuf.	0.06	-0.10	-0.03	-0.03	0.05	-0.25	0.25	0.01	-0.09	0.10	-0.05	-0.04	-0.02	-0.05	-0.13	0.00	-0.44	1

Table 5: Probit marginal effects

	All firms			In-Licensors			Reduced sample		
	R&D	Inno. Invest.	Res. Invest.	R&D	Inno. Invest.	Res. Invest.	R&D	Inno. Invest.	Res. Invest.
Fragmentation Index	0.011	-0.013*	-0.005	0.013*	-0.012*	-0.006	-0.009	-0.024**	-0.008
Δ Fixed Assets	0.000	-0.00002***	0.000	0.000	-0.00002***	0.000	0.000	-0.000	-0.000
Δ Other Funds							0.000	0.000	-0.000
Share Expired Patents	0.047	0.084	0.033	0.091	0.075	0.063	0.058	0.092	0.163
Share Triadic Patents	0.188**	-0.009	0.078	0.121	0.038	0.072	0.381***	0.020	0.076
ln(Patent stock)	-0.008	0.011*	-0.016**	-0.004	0.011	-0.016*	0.018	0.005	-0.017
Occasional R&D activities		0.273***	-0.074		0.228***	-0.035		0.263***	-0.046
Continuous R&D activities		0.283***	-0.061*		0.222***	-0.037		0.279***	-0.080
Credit rating		0.001***	-0.000		0.000	-0.000		0.001**	-0.000
Fixed Asset Intensity	-0.177***	0.008	0.272	-0.164***	0.042	0.253	-0.167	0.152	0.446
Other Funds Intensity							-0.124	-0.038	-0.029
ln(No. of Employees)	0.038***	0.020***	0.034***	0.006	0.018**	0.032***	-0.006	0.038***	0.030**
ln(Age)		0.098***	0.019		0.085***	0.039		0.063	-0.102
ln(Age)^2		-0.016***	-0.005		-0.015***	-0.008		-0.012	0.011
Part of Conglomerate	0.025	0.028	-0.013	0.040	0.040**	-0.020	0.022	0.035	-0.002
Labour Cost Intensity	0.619	-0.266	-1.133*	0.777	-0.192	-1.109	2.858**	1.195	-2.373**
Location in Eastern Germany	-0.037	0.043	-0.048	0.003	0.008	-0.088	-0.000	0.088	-0.004
Med. High-Tech Manuf.	0.073***	-0.007	-0.011	0.037*	-0.013	-0.015	0.066**	-0.032	-0.070*
High-Tech Manuf.	0.078*	0.047*	-0.070**	0.050	0.058**	-0.081***	0.040	0.127**	-0.106**
	Authority and Inventor location of citations as well as Periods controlled for								
LR χ^2( )	82.13***	359.78***	71.72***	49.86**	211.18***	63.85***	68.66***	204.16***	51.24***
No. of Observations		1016			876			508	

***, ***, * indicate significance of 1%, 5% or 10%

Table 6: Non-linear Fragmentation model

	All firms	In-Licensors	Reduced sample
	Coef.	Coef.	Coef.
Dependent: Investments in Innovation			
Fragmentation Index	-5.709	-3.998	-37.005*
Fragmentation Index^2	0.032	0.022	0.209*
Δ Fixed Assets	-0.000***	-0.000***	-0.000
Δ Other Funds			0.000
Share Expired Patents	0.727	0.702	0.865
Share Triadic Patents	-0.056	0.381	0.418
ln(Patent stock)	0.093	0.100	0.039
Occasional R&D activities	2.311***	2.168***	2.572***
Continuous R&D activities	2.408***	2.108***	2.762***
Credit rating	0.005***	0.003	0.008**
Other Funds Intensity			-0.879
Fixed Asset Intensity	0.022	0.372	1.663
ln(No. of Employees)	0.172***	0.174**	0.370***
ln(Age)	0.827***	0.802***	0.612
ln(Age)^2	-0.133***	-0.139***	-0.115
Part of Conglomerate	0.248	0.388**	0.423
Labour Cost Intensity	-1.756	-1.536	15.750
Location in Eastern Germany	0.403	0.096	1.205*
Med. High-Tech Manuf.	-0.082	-0.133	-0.385
High-Tech Manuf.	0.410*	0.555**	1.363**
Authority and Inventor location of citations as well as Periods controlled for			
LR χ^2( )	361.28***	211.79***	209.52***
No. of Observations	1016	876	508

***, ***, * indicate significance of 1%, 5% or 10%

Table 7: Probit marginal effects by Patent Portfolio Size

	All firms		In-Licensors	
	Small Patenters	Large Patenters	Small Patenters	Large Patenters
Dependent Variable	*Investments in Innovation*			
Fragmentation Index	-0.021*	-0.004	-0.022*	-0.007
Δ Fixed Assets	-0.000	-0.00002***	-0.000	-0.00002***
Share Expired Patents	0.067	0.159	0.022	0.127
Share Triadic Patents	-0.065	-0.010	-0.055	0.067
ln(Patent stock)	0.010	0.014	0.022	0.009
Occasional R&D activities	0.358***	0.199***	0.301***	0.184***
Continuous R&D activities	0.341***	0.228***	0.277***	0.176***
Credit rating	0.001**	0.000	0.000	0.000
Fixed Asset Intensity	0.082	0.006	0.045	0.094
ln(No. of Employees)	0.022	0.014	0.016	0.009
ln(Age)	0.038	0.134***	-0.010	0.133***
ln(Age)^2	-0.009	-0.020***	-0.004	-0.020***
Part of Conglomerate	0.032	0.003	0.053	0.004
Labour Cost Intensity	0.967	-0.940	1.375	-1.493**
Location in Eastern Germany	0.027	0.054	0.010	§
Med. High-Tech Manuf.	-0.057*	0.025	-0.073**	0.023
High-Tech Manuf.	0.063	0.053	0.047	0.078*
Authority and Inventor location of citations as well as Periods controlled for				
LR χ^2( )	186.18***	198.69***	131.81***	104.61***
No. of Observations	514	502	442	434

***, ***, * indicate significance of 1%, 5% or 10%

§ Collinearity of the limited sample size hinders identification of the Location dummy.

Table 8: Marginal effects due to firm size

	All firms			In-Licensors			Reduced sample		
	R&D	Inno. Invest.	Res. Invest.	R&D	Inno. Invest.	Res. Invest.	R&D	Inno. Invest.	Res. Invest.
Fragmentation Index	0.011	-0.014**	-0.005	0.013*	-0.013*	-0.005	-0.001	-0.024**	-0.008
Δ No. of Employees	-0.000	-0.000	-0.000	0.000	-0.000	-0.000	-0.000	-0.000	-0.000**
Share Expired Patents	0.045	0.093	0.032	0.091	0.089	0.060	0.051	0.109	0.166
Share Triadic Patents	0.181**	0.001	0.067	0.122*	0.046	0.058	0.357***	0.019	0.069
ln(Patent stock)	-0.008	0.012*	-0.015*	-0.005	0.012	-0.015*	0.017	0.004	-0.018
Occasional R&D activities		0.269***	-0.072		0.223***	-0.029		0.259***	-0.046
Continuous R&D activities		0.280***	-0.062*		0.218***	-0.035		0.277***	-0.079
Credit rating		0.000**	-0.000		0.000	-0.000		0.001**	-0.000
Fixed Asset Intensity	-0.173***	-0.004	0.262	-0.161***	0.036	0.240	-0.227*	0.155	0.470
ln(No. of Employees)	0.038***	0.022***	0.036***	0.004	0.020**	0.033***	-0.002	0.040***	0.040***
ln(Age)		0.096***	0.018		0.084***	0.038		0.059	-0.104
$ln(\text{Age})^2$		-0.015***	-0.005		-0.015***	-0.008		-0.012	0.011
Part of Conglomerate	0.025	0.024	-0.014	0.040	0.037*	-0.022	0.016	0.031	-0.009
Labour Cost Intensity	0.619	-0.304	-1.128*	0.790	-0.265	-1.095	2.836**	1.126	-2.334**
Location in Eastern Germany	-0.035	0.044	-0.045	-0.000	0.000	-0.083	-0.011	0.077	0.003
Med. High-Tech Manuf.	0.074***	-0.008	-0.011	0.038*	-0.014	-0.014	0.070**	-0.031	-0.070*
High-Tech Manuf.	0.078	0.049*	-0.068**	0.049	0.061**	-0.079***	0.047	0.133**	-0.094**
	Authority and Inventor location of citations as well as Periods controlled for								
LR $\chi^2(\ )$	81.98***	335.81***	72.32***	49.99**	201.88***	63.88***	65.79***	202.70***	54.19***
No. of Observations		1016			876			508	

***, ***, * indicate significance of 1%, 5% or 10%

Table 9: Marginal effects due to sale size

	All firms			In-Licensors				Reduced sample		
	R&D	Inno. Invest.	Res. Invest.	R&D	Inno. Invest.		Res. Invest.	R&D	Inno. Invest.	Res. Invest.
Fragmentation Index	0.009	-0.014*	-0.004	0.013*	-0.012*	-0.011	-0.004	-0.004	-0.022***	-0.002
Δ Sales	0.000	-0.000	-0.000	0.000	-0.000*	-0.000	0.000	0.000	-0.000	-0.000**
Δ Fixed Assets						-0.000*				
Share Expired Patents	0.040	0.076	0.039	0.079	0.066	0.065	0.067	0.050	0.101*	0.140
Share Triadic Patents	0.205**	-0.004	0.070	0.144*	0.044	0.039	0.063	0.352***	0.035	0.102
ln(Patent stock)	-0.006	0.017*	-0.002	-0.005	0.013**	0.014**	-0.003	0.015	0.007	-0.007
Occasional R&D activities		0.270***	-0.053		0.224***	0.225***	-0.034		0.259***	-0.053
Continuous R&D activities		0.289***	-0.031		0.222***	0.223***	-0.021		0.278***	-0.070
Credit rating		0.000*	-0.000***		0.000	0.000	-0.000**		0.000	-0.000
Fixed Asset Intensity	-0.253**	0.011	0.072	-0.299**	0.013	0.012	0.081	-0.726***	0.034	0.228***
ln(Sales)	-0.000***	0.000	0.000	-0.000***	0.000	0.000	0.000	-0.000***	0.000**	0.000
$ln(\text{Sales})^2$	0.000***	0.000	0.000	0.000***	0.000	-0.000	0.000	0.000***	-0.000*	-0.000
ln(No. of Employees)	0.061***			0.022*				0.017		
ln(Age)		0.089***	0.015		0.079**	0.081***	0.039		0.057	-0.064
$ln(\text{Age})^2$		-0.014***	-0.003		-0.014***	-0.014***	-0.007		-0.011*	0.007
Part of Conglomerate	0.025	0.024	-0.016	0.040	0.036	0.039*	-0.018	0.025	0.042	-0.003
Labour Cost Intensity	1.068	-0.022	-0.199**	1.064	-0.054	-0.051	-0.092	3.499***	0.101	-0.201
Location in East. Ger.	-0.002	0.029	-0.051	0.043	-0.015	-0.010	-0.106**	0.046	0.030	-0.013
Med. High-Tech Manuf.	0.071***	-0.013	-0.020	0.037*	-0.023	-0.021	-0.026	0.065***	-0.036	-0.086**
High-Tech Manuf.	0.075*	0.041	-0.070**	0.047	0.048	0.048	-0.092**	0.036	0.101***	-0.117**
Authority and Inventor location of citations as well as Periods controlled for										
LR $\chi^2(\quad)$	100.80***	347.29***	57.22**	62.76***	205.12***	209.74***	52.30**	82.01***	199.69***	45.60
No. of Observations		1016			876				508	

***, ***, * indicate significance of 1%, 5% or 10%

Table 10: Verification of Capital stock effect on R&D

Dependent: R&D						
Fragmentation Index	0.011	0.011	0.011	0.010	0.011	0.011
Δ Fixed Assets ...						
... to X or Y-References	0.000					
... not to X or Y-References		0.000				
... to smallest cited patentee			0.000			
... to largest cited patentee				0.000003*		
... to seldom cited patentees					0.000	
... to most cited patentee						0.000
Share Expired Patents	0.045	0.045	0.047	0.047	0.047	0.048
Share Triadic Patents	0.183**	0.185**	0.189**	0.190**	0.188**	0.192**
ln(Patent stock)	-0.008	-0.008	-0.009	-0.002	-0.008	-0.008
Fixed Asset Intensity	-0.174***	-0.175***	-0.178***	-0.173***	-0.177***	-0.176***
ln(No. of Employees)	0.037***	0.038***	0.037***	0.038***	0.038***	0.038***
Part of Conglomerate	0.025	0.025	0.025	0.024	0.025	0.025
Labour Cost Intensity	0.623	0.621	0.629	0.574	0.619	0.623
Location in Eastern Germany	-0.036	-0.036	-0.037	-0.034	-0.037	-0.035
Med. High-Tech Manuf.	0.074***	0.074***	0.073***	0.074***	0.073***	0.073***
High-Tech Manuf.	0.078	0.078*	0.078*	0.076	0.078*	0.080*
	Authority and Inventor location of citations as well as Periods controlled for					
LR $\chi^2(\quad)$	81.95***	81.97***	82.18***	83.46***	82.13***	82.45***
No. of Observations	1016					

***, ***, * indicate significance of 1%, 5% or 10%

Table 11: Verification of Capital stock effect on innovation investments

Dependent: Investments in Innovation						
Fragmentation Index	-0.013*	-0.014*	-0.013*	-0.013*	-0.013*	-0.015**
Δ Fixed Assets ...						
... to X or Y-References	-0.00002**					
... not to X or Y-References		-0.00002**				
... to smallest cited patentee			-0.00002***			
... to largest cited patentee				-0.00001***		
... to seldom cited patentees					-0.00002***	
... to most cited patentee						-0.000
Share Expired Patents	0.095	0.094	0.093	0.085	0.084	0.090
Share Triadic Patents	-0.002	-0.006	-0.011	-0.015	-0.009	-0.001
ln(Patent stock)	0.010	0.011	0.015**	0.001	0.011*	0.012*
Occasional R&D activities	0.269***	0.269***	0.269***	0.276***	0.273***	0.269***
Continuous R&D activities	0.283***	0.281***	0.281***	0.287***	0.283***	0.281***
Credit rating	0.001**	0.001***	0.001**	0.001***	0.001***	0.000**
Fixed Asset Intensity	0.009	0.003	0.006	-0.007	0.008	-0.002
ln(No. of Employees)	0.020***	0.020***	0.022***	0.019**	0.020***	0.020***
ln(Age)	0.096***	0.096***	0.098***	0.094***	0.098***	0.097***
ln(Age)^2	-0.015***	-0.015***	-0.016***	-0.015***	-0.016***	-0.016***
Part of Conglomerate	0.027	0.026	0.027	0.027	0.028	0.025
Labour Cost Intensity	-0.300	-0.270	-0.322	-0.197	-0.266	-0.312
Location in Eastern Germany	0.043	0.041	0.044	0.035	0.043	0.041
Med. High-Tech Manuf.	-0.009	-0.008	-0.006	-0.010	-0.007	-0.008
High-Tech Manuf.	0.047*	0.046*	0.049*	0.049*	0.047*	0.046*
	Authority and Inventor location of citations as well as Periods controlled for					
LR χ^2( )	357.71***	356.80***	358.67***	359.33***	359.78	351.65***
No. of Observations			1016			

***, ***, * indicate significance of 1%, 5% or 10%

Table 12: Verification of Capital stock effect on residual investments

Dependent: Residual investments						
Fragmentation Index	-0.005	-0.005	-0.005	-0.004	-0.005	-0.004
Δ Fixed Assets ...						
... to X or Y-References	0.000					
... not to X or Y-References		-0.000				
... to smallest cited patentee			0.00001*			
... to largest cited patentee				-0.000		
... to seldom cited patentees					0.000	
... to most cited patentee						0.000*
Share Expired Patents	0.032	0.032	0.038	0.032	0.033	0.037
Share Triadic Patents	0.073	0.064	0.095	0.066	0.078	0.093
ln(Patent stock)	-0.016**	-0.016**	-0.019**	-0.019**	-0.016**	-0.017**
Occasional R&D activities	-0.073	-0.071	-0.077*	-0.070	-0.074	-0.077*
Continuous R&D activities	-0.061*	-0.061*	-0.061*	-0.059*	-0.061*	-0.062*
Credit rating	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
Fixed Asset Intensity	0.270	0.262	0.277	0.259	0.272	0.305*
ln(No. of Employees)	0.034***	0.034***	0.034***	0.034***	0.034***	0.035***
ln(Age)	0.019	0.019	0.017	0.018	0.019	0.017
ln(Age)^2	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005
Part of Conglomerate	-0.013	-0.013	-0.012	-0.012	-0.013	-0.014
Labour Cost Intensity	-1.130*	-1.127*	-1.127*	-1.119*	-1.133*	-1.179*
Location in Eastern Germany	-0.048	-0.048	-0.050	-0.048	-0.048	-0.048
Med. High-Tech Manuf.	-0.011	-0.011	-0.014	-0.011	-0.011	-0.012
High-Tech Manuf.	-0.070**	-0.070**	-0.070**	-0.068**	-0.070**	-0.066**
	Authority and Inventor location of citations as well as Periods controlled for					
LR χ^2( )	71.55***	72.08***	74.71***	71.84***	71.72***	74.79***
No. of Observations			1016			

***, ***, * indicate significance of 1%, 5% or 10%