Discussion Paper No. 13-096

Does Fragmented or Heterogeneous IP Ownership Stifle Investments in Innovation?

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Non-technical summary

The effectiveness of patents to stimulate R&D is often limited. If innovation is sequential and complementary, patent protection may even stifle technical advance (Bessen and Maskin, 2006). The surge of patenting in complex technologies suggests that firms accumulate large patent portfolios rather to secure freedom to operate (Grindley and Teece, 1997). This raises concerns that the increasing costs for securing IPR might “tax” innovation (Jaffe and Lerner, 2004; Bessen and Meurer, 2008).

Patents provide a right to exclude but not necessarily a right to use. Surging patent filings has resulted in thickets of overlapping patents (Hall et al., 2012). These mutual blocking relationships among multiple firms are difficult to resolve. IP ownership is fragmented which raises coordination costs and royalty stacks (von Graevenitz et al., 2011).

The uncertain scope of patent protection may furthermore result in inadvertent patent infringement (Reitzig et al., 2007, 2010). For capital-intensive innovators, this poses the risk of their high commitment level being exploited. Inadvertently infringed patent owners may capture part of their fruits from investment if infringed patent owners have invested less relationship-specifically (Farrell et al., 2007).

This study asks whether firms are less likely to invest in innovation if IP ownership is fragmented or if owners of overlapping patents are less capital intensive, respectively. Citations among German owners of European patents are used to identify owners of overlapping patents. It is usually difficult to identify relationship-specific investments directly. Fixed tangible assets appear, however, as feasible proxy (Antràs, 2003).

Using data from the Mannheim Innovation Panel, I find that fragmented IP reduces the investment propensity of firms with small patent portfolios. This suggests that market entry is difficult for firms lacking large patent portfolios as bargaining chips for licenses. Firms with large patent portfolios are less likely to invest in innovation if they cite owners of overlapping patents with smaller stocks of fixed capital. This suggests that large innovators incorporate the risk of held up application-specific capital in their investment decisions. Hence, the effects of patent thickets on innovation appear not uniform among firms.

Das Wichtigste in Kürze

Patente sind oft wenig effektiv als Anreizmechanismus für Forschung und Entwicklung. Falls sequentielle Innovationsaktivitäten komplementär sind, vermögen Patente den technischen Fortschritt sogar zu bremsen (Bessen und Maskin, 2006). Obwohl Patente in komplexen Technologien wenig effektiv sind, bauen Firmen große Patentportfolios auf (Grindley and Teece, 1997). Dies scheint der Sicherung ihrer freien Geschäftstätigkeit zu dienen und führte zu einer Patentexplosion. Dickichte sich überlappender Patente waren die Folge. Diese teure und defensive Sicherung intellektueller Eigentumsrechte wird oft als Innovationshemmnis betrachtet (Jaffe und Lerner, 2004; Bessen und Meurer, 2008).

Patente gewähren ein Ausschlussrecht aber nicht notwendigerweise ein Nutzungsrecht. Patentdickichte erzeugen also wechselseitige Blockaden unter einer Vielzahl von Patentinhabern. Diese Dickichte sind schwierig aufzulösen. Lizenzgebühren und Koordinierungskosten können sich auftürmen, wenn intellektuelles Eigentum fragmentiert ist (von Graevenitz et al., 2011).

Die Grenzen eines Patentrechtes sind darüber hinaus oft unklar, was zu ungewollten Patentverletzungen führen kann (Reitzig et al., 2007, 2010). Für kapitalintensive Innovatoren kann dies ein erhebliches Risiko darstellen. Eine blockierte kommerzielle Nutzung gebundenen Kapitals könnte durch Patentinhaber mit weniger gebundenem Kapital ausgenutzt werden (Farrell et al., 2007).

Dieses Papier untersucht, ob die Wahrscheinlichkeit in Innovation zu investieren sinkt, wenn intellektuelles Eigentum fragmentiert ist bzw. wenn die Eigentümer überlappender Patente weniger kapitalintensiv sind. Patentzitationen unter deutschen Inhabern europäischer Patente sollen dabei die Eigentümer sich überlappender Patentrechte identifizieren. Das tangible Anlagevermögen dient als Proxy für das gebundene Kapital (Antràs, 2003).

Daten des Mannheimer Innovationspanels zeigen, dass Firmen mit kleinen Patentportfolios seltener in Innovationen investieren wenn das intellektuelle Eigentum fragmentiert ist. Der Markteintritt ohne große Patentportfolios scheint also schwierig zu sein. Firmen mit großen Portfolios investieren demgegenüber seltener in Innovation wenn sie Patentinhaber mit kleinerem Anlagevermögen zitieren. Große Innovatoren scheinen das Risiko blockierten Kapitals in ihre Investitionsentscheidung miteinzubeziehen. Patentdickichte scheinen also die Innovationstätigkeit auf unterschiedliche Weise zu beeinflussen.

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Abstract

Thickets of partially overlapping patent rights raise costs to secure IPR for innovation. Fragmented IP ownership raises coordination costs to resolve mutual blockades. Inadvertent patent infringement poses the risk of fruits from investments to be exploited. A gap in economic commitment levels may be exploited if capital-intensive innovators have more invested application-specifically than inadvertently infringed IPR owners. I study whether fragmentation or heterogeneous capital-intensities among owners of overlapping patents affect propensities to invest in innovation. I find that firms with small patent portfolios are less likely to invest in innovation if IPR is fragmented. Firms with large patent portfolios are less likely to invest in innovation if cited patent owners have smaller stocks of fixed capital. This suggests that effects of patent thickets on innovation are not evenly spread among innovating firms.[1]

Keywords: Investment in innovation, Complementary assets, IP hazards

JEL classification: O31, O34

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1. Introduction

Markets for technologies and IP have become increasingly important for innovation in recent years (Arora et al., 2004; Chesbrough, 2003). Transactions for patent-protected technology have grown steadily in number and volume (Athreye and Cantwell, 2007). Trade in technology expands the division of innovative labor between upstream research and development (R&D) and downstream commercialization of innovation. This suggests efficiency gains due to specialization on comparative advantages and associated learning, scale and incentive economies.

Transactions for technological knowledge are subject to Arrow's disclosure problem (1962). Buyers can judge their valuation only if the technology is revealed. However, the potential buyer can hardly be excluded from utilizing the technological information after its disclosure. Patents serve as safeguards for technology suppliers as they provide a legal remedy against infringers. Patents appear, therefore, as prerequisite for technology markets to emerge. Strong intellectual property protection facilitates technology transactions (Anand and Khanna, 2000; Gans et al., 2008). They promote a vertical specialization and entry of specialized technology suppliers (Arora and Merges, 2004).

However, strengthening patent protection stimulates R&D only modestly (Kortum and Lerner, 1999; Sakakibara and Branstetter, 2001; Lerner, 2002). Furthermore, the escalating number of patent applications occurs predominantly in complex technologies. In complex technologies, patents are considered as little effective to protect innovation (Levin et al., 1987). This suggests that firms accumulate patent rights rather to secure their freedom to operate (Grindley and Teece, 1997; Cohen et al., 2000). Concerns have been raised that increasing costs for securing intellectual property rights might "tax" innovation (Jaffe and Lerner, 2004; Bessen and Meurer, 2008).

Transaction costs are an important part of these costs to secure IPR (Gambardella et al., 2007). Difficulties to trade technology are grounded in the imperfect property characteristics of patents. Patents provide a right to exclude but not necessarily a right to use the invention. Innovating firms have the right to use the invention for commercial exploitation if they secure all overlapping exclusion rights. However, escalating patent filings create thickets of partially overlapping patent rights which render this task difficult. For instance, IP ownership in thickets is usually fragmented which raises coordination costs and royalty stacks (Heller and Eisenberg, 1998; Shapiro, 2001, von Graevenitz et al., 2011).

The uncertain scope of patent rights increases the difficulty to trade technology even further (Lemley and Shapiro, 2005). Courts may confine fuzzy boundaries of overlapping patent rights but this is seldom the case. Hence, escalating patent filings pose the risk of inadvertent patent infringement for innovating firms (Reitzig et al., 2010). Patent citations might refer to such owners of partially overlapping patent rights as innovation is usually sequential and cumulative (Merges and Nelson, 1990; Scotchmer, 1991).

The intensive patenting of capital-intensive firms has resulted in surging patent filings in recent years (Hall and Ziedonis, 2001). This suggests that the risk of held-up business operations is an important concern for large, innovative firms (Ziedonis, 2004). There is evidence that large firms are increasingly targeted in patent litigation (Bessen and Meurer 2005, 2006; Hall and Ziedonis, 2007; Bessen et al., 2011). Their large investments appear to be partially sunk and committed to use specific technology. It is usually difficult to identify relationship-specific investments directly (see Tucker, 2012 for an exception). Fixed tangible assets appear, however, as feasible proxy for them (Caves and Bradburd, 1988; Antràs, 2003).

Hold-up risks originate particularly from small, capacity-constrained patent owners (Reitzig et al., 2007). Inadvertently infringed patent owners may capture part of the fruits from innovating firm's investment if relationship-specific investments of the innovating firm exceed their own relationship-specific investments (Farrell et al., 2007). Hence, the empirical approach will rely on the magnitude by which citing firm's fixed capital stocks exceed those of an average cited patent owner as proxy for their different commitment levels. This different commitment level may be exploited during inadvertent infringement of overlapping patents.

With the exception of Cockburn et al. (2010), evidence on the effects of patent thickets on product market innovation is rare. This study asks whether firms are less likely to invest in innovation if IP ownership is fragmented or if different commitment levels may be exploited during inadvertent patent infringement. The application-specificity of investments in innovation might render them susceptible to these transactional hazards. The empirical analysis will be based on firm-level information from the Mannheim Innovation Panel (MIP). In order to augment the available financial information for cited patent owners, the standardized names of German patent applicants at the European patent office are linked to the Mannheim Enterprise Panel (MUP).

I find that IP fragmentation and different commitment levels affect investments in innovation not uniformly for small and large firms. Fragmented intellectual property appears to reduce the investment propensity of in-licensing firms with small patent portfolios. This suggests that entry in innovative product markets is difficult for firms which lack large patent portfolios as bargaining chips for external licenses. Firms with large patent portfolios appear less likely to invest in innovation if they cite owners of overlapping patents with smaller stocks of fixed capital. This suggests that large innovators incorporate the risk of held up application-specific capital in their investment decisions.

This study proceeds in the following way. The next section discusses the susceptibility of investments in innovation for transactional IP hazards. Section 2.2 elaborates the risk of innovation-specific investments to be held up during inadvertent patent infringement. Section 2.3 discusses the innovation-hampering effect of fragmented IPR ownership. Section 3 describes the various data sources and the construction of variables. Section 4 presents the empirical findings and section 5 concludes.

2. Hypothesis development

2.1. Complementary assets

Strategy development for the commercialization of new technologies hinges on markets for technologies (Gans and Stern, 2003). Technology is commercialized in innovation. Innovation creates new value propositions or improves the cost-effectiveness of production. The translation of technology into innovation requires complementary assets, like manufacturing, marketing capabilities, etc. Innovation will refer subsequently to downstream commercialization of technology. Technology may be developed internally or provided by upstream suppliers.

Technology owners may access complementary assets over markets at competitive terms if these assets are generic. Generic assets are not adjusted to particular innovations (Teece, 1986). Complementary assets appear, however, often to be specialized and difficult to acquire over markets. The difficulty to access complementary assets for technology-intensive start-ups creates a competitive advantage for incumbent firms. Start-up entry into product markets for instance is less likely if it requires access to complementary assets (Shane, 2001). Start-up cooperation with incumbents (e. g. via licensing) is more likely if competitive entry is associated with sunk costs (Gans et al., 2002; Arora and Ceccagnoli, 2006). Hence, incumbent owners of complementary assets are more likely to survive and adapt to waves of radical technological change (Tripsas, 1997; Rothaermel, 2001).

Assets are valuable firm resources if they are firm-specific, rare and difficult to imitate (Wernerfelt, 1984; Barney, 1991, Amit and Schoemaker, 1993). Specialized complementary assets are built in a path-dependent and idiosyncratic process and can be considered as valuable resources (Dierickx and Cool, 1989; Teece et al., 1997). They appear to be a source of competitive advantage as they erect entry barriers to downstream product markets. This favors incumbents in the division of innovation rents with upstream technology providers.

When complementary assets are specialized, upstream technology owners are unilaterally dependent on access to them. Since these resources are difficult to substitute and subject to market failure, they generate economic rents for their owners. Resources which are specific to certain applications are particularly hard to substitute. This renders application-specific assets particularly valuable.

However, asset specificity constrains their owners at the same time to utilize them in a broader range of applications. Thus, the capacity of complementary assets to generate economic rents is inversely related to the range of market opportunities to which these resources could be applied with negligible switching costs (Montgomery and Wernerfelt, 1988; Silverman, 1999).

The importance of complementary assets for their incumbent owners suggests that they are, at least partially, application-specific (Ceccagnoli et al., 2010). Specialization and specificity are characteristic for co-specialized complementary assets (Jacobides et al., 2006). The application-specificity of co-specialized assets creates a bilateral dependence between technology providers and users. Application-specificity of complementary assets may, thus, deteriorate the favorable bargaining position of their owners when the division of value from innovation is negotiated with technology providers (Williamson, 1975; Pisano, 1990).

2.2. Different commitment levels during inadvertent patent infringement

This trade-off between asset specialization and asset specificity has to be taken into account for investment decisions in complementary assets. Asset specialization is a precondition for economic rents. However, specialized assets are usually also application- and technology-specific. Deploying these assets to alternative applications is associated with adjustment and switching costs. These switching costs create a lock-in situation which deteriorates the bargaining position when the division of value from innovation is negotiated with technology providers.

Such transactional hazards emerge when unprogrammed adaptation, lock-in and appropriable quasi-rents, i. e. rents which do not arise in other factor combinations, are present (Joskow, 1991). Innovation processes require ongoing mutually adjustments among technology and subsequent commercialization activities (Kline and Rosenberg, 1986). Hence, the value of innovation could be regarded as quasi-rent. Of course, innovating firms have strong incentives to secure the necessary technology rights before investing into application-specific assets. Contracting for technology is, however, notoriously incomplete. Ex-ante licenses might not eliminate the risk of inadvertent patent infringement entirely (Green and Scotchmer, 1995; Gallini, 2002; Bessen, 2004).

At the heart of this contractual imperfection lies the inability of intellectual property rights to transfer definite usage rights. Patents confer a right to exclude others from practicing the technology but do neither confer rights to use nor rights to its benefits. The right to use and benefit from technology is granted implicitly when no patentee owns further infringing exclusion rights. This distinction between usage and exclusion rights is important for complex technologies. Surging patent applications and the ineffectiveness of patents to protect complex technological knowledge create thickets of partially overlapping patent rights. von Graevenitz et al. (2011) provide evidence that overlapping patent portfolios among multiple patent owners are prevalent in complex technologies.

Hence, the scope of patent rights remains uncertain unless brought to court (Lemley and Shapiro, 2005).

Fuzzy boundaries of intellectual property rights leave contracts in technology transactions incomplete. Ballooning numbers of patent applications augment further the risk of inadvertently infringing prior art (Reitzig et al., 2010). If innovating firms face the risk of inadvertently infringing overlapping patents, propensities to invest in specialized assets diminish according to the diffuse entitlement theory (Heller and Eisenberg, 1998).

Specialized technology suppliers have become more important in recent years (Arora et al., 2004). This reflects partly a successful division of innovative labor. Quality advantages of external technology surely compensate transaction costs in many cases (Arora and Merges, 2004). Innovating firms rely more likely on external technology if the supplying industry is R&D-intensive (Acemoglu et al., 2010). However, some specialized technology suppliers may act opportunistically by maneuvering large, capital-intensive technology users into infringement (Reitzig et al., 2007, 2010). Whether technology suppliers act opportunistically or not, they should be able to negotiate surprisingly high licensing rewards if technology user's bargaining situation is deteriorated by high switching costs.

Investments in fixed tangible assets appear as an important form of economic commitment. Caves and Bradburd (1988) report a positive cross-industry correlation between vertical integration and capital-labor intensities. Antràs (2003) shows that international trade is more likely intra-firm if the capital-labor intensity is high. Although situations of locked-in assets are not determined directly, this suggests that fixed capital stocks are partially sunk and application-specific.

Inadvertently infringing firms with large application-specific investments may find themselves in an unfavorable bargaining situation. Residual patent owners may exploit the high commitment level if there is a gap between their relationship-specific investments (Farrell et al. 2007).[2] They may be able to capture the fruits from held-up investments to the extent by which relationship-specific investments of the held-up firm

[2] Surprisingly high rewards for IP owners might result also from insufficient incentives to challenge weak patents among competing firms (Farrell and Shapiro, 2008). Patent challenges appear particularly seldom among multiple mutually blocking firms at the center of patent thickets (von Graevenitz et al., 2012b).

exceed those of the residual patent owner. This expropriation risk might diminish innovation-specific investments.

Hence, firms should be less likely to invest in innovation-specific assets if they have higher stocks of fixed capital, and thereby higher commitment levels, than owners of overlapping patents. Inadvertently infringed owners of overlapping patents might exploit this gap in economic commitment levels. This rationale is summarized in the following hypothesis:

H1a: Firms are less likely to invest in innovation if they are more capital-intensive than owners of overlapping IPR.

Large, innovative firms are increasingly targeted in patent litigation (Bessen and Meurer 2005, 2006; Hall and Ziedonis, 2007; Bessen et al., 2011). This suggests that concerns regarding operational freedom are not hypothetical. Ziedonis (2004) shows that semiconductor firms patent more intensively if they are capital-intensive and technology ownership is fragmented. This suggests that high patenting intensities reflect a defensive policy of firms with large application-specific investments (Hall and Ziedonis, 2001; Hegde et al., 2009). Their large patent portfolios are not intended to be asserted in the first place. They should rather pose the threat of countersuits when infringement is claimed. This shall induce cross-licensing agreements among owners of mutually infringing patent portfolios (Grindley and Teece, 1997).

Defensive patenting and cross-licenses might mitigate the risk from inadvertent patent infringement. Cross-licensing is frequent among symmetric and large firms (Nagaoka and Kwon, 2006; Siebert and von Graevenitz, 2010). The economic commitment level of both parties is similar here and expropriation risks appear limited among them. The increasing hazard rates of being targeted in patent litigation for large firms suggest, on the other hand, that defensive patenting is little effective to mitigate inadvertent patent infringement and expropriation risks from small, specialized technology vendors. Hence, firms with large patent portfolios appear particularly vulnerable to the exploitation of different commitment levels. This is summarized in the following hypothesis:

H1b: Firms with large patent portfolios are less likely to invest in innovation if they are more capital-intensive than owners of overlapping IPR.

2.3. Fragmented IPR ownership

Granting patent rights facilitates not only technology transactions. Inventors are awarded exclusion rights in return for disclosing the new technology. The revealed technological knowledge may then serve as starting point for other researchers. This facilitates further development of the technology (Scotchmer 1991). Duplicative R&D is avoided if technology is developed in this sequential and cumulative way. This is particularly important for technologies in which inventions tend to be incorporated into larger technical systems (Merges and Nelson, 1990).

Cumulative invention processes may lead to situations in which follow-on inventors possess exclusion rights but not the right to use the follow-on technology. Overlapping patents for basic inventions may block the use of follow-on inventions. The need to assemble multiple patents from various owners is, however, not a new phenomenon (Lampe and Moser, 2010). What has changed is the number of involved patent rights and technology owners (Somaya et al., 2011). Technical advance appears more cumulative today (Walsh et al., 2003; Greenstein, 2010). This causes concerns that fragmented patent rights may stifle R&D and innovation if technological advance is sequential and complementary (Graff et al. 2003; Bessen and Maskin, 2009; Bessen and Hunt, 2007).

Fragmented property rights may impose transaction costs for innovating firms even if ex-ante licenses are feasible. The right to use and commercialize an invention requires licenses from each owner of overlapping patent rights. Each of these patent owners might foreclose rents from technology commercialization in innovation. Resolving mutual blocking relationships between more than two parties is difficult. Optimal bargaining behavior in bilateral negotiations depends on other parties' actions. This raises coordination costs substantially compared to situations of bilateral ownership (von Graevenitz et al., 2011). Attempts to secure licenses from multiple owners of overlapping patents might furthermore result in stacking royalty payments (Shapiro, 2001). This suggests that usage rights are more costly to secure if IP ownership is fragmented.

Such difficulties to secure fragmented IPR appear to reduce R&D activities (Clark and Konrad, 2008; Noel and Schankerman, 2006). Evidence on stifled innovation activities is, however, rare. Cockburn et al. (2010) is an exception. They study the effects of fragmented upstream IPR on downstream innovation performance. They find that IPR fragmentation reduces product innovation performance for those firms which have to license-in patents.[3] On the other hand, the innovative performance of firms which do not license in appears to be positively affected by fragmentation. This suggests that the need to establish large patent portfolio as bargaining chip for securing IPR disadvantages entry of small firms if technology is complex and IPR is fragmented (Cockburn and MacGarvie, 2011; Graevenitz et al. 2012a). This is summarized in the following hypotheses:

H2a: The propensity to invest in innovation is lower if IPR ownership is fragmented.

H2b: The propensity of small firms to invest in innovation is lower if IPR ownership is fragmented.

3. Data and variables

3.1. Data

The data is obtained from three different 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) which is a stratified random sample of German firms with at least five employees.[4] The survey is based on the concepts and definitions of the OECD Oslo Manual (2005) for collecting innovation data. The sample refers to information on manufacturing corporations for the years 1993 to

[3] Evidence of Galasso and Schankerman (2010) on the duration of patent disputes suggests contrarily that technology has diffused more quickly during periods of weak patent protection if IP ownership is fragmented. This positive effect of IPR fragmentation on technology diffusion appears, however, much weaker after patent rights have been strengthened.

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

2006. The sample is restricted to firms which have, at least once, relied on external R&D or acquired external knowledge. Stifling effects of the patent landscape on innovation appear particularly important for those firms (Cockburn et al., 2010). Due to lacking information on some explanatory variables, data referring to 1999 and 2000 does not enter the sample. This results in an estimation sample of 968 observations.

The MIP asks firms about their annual gross investment in fixed assets. Separated thereof, investments associated to innovation projects is surveyed. This includes the acquisition of advanced machinery, facilities, software and other external knowledge for innovation purposes. Hence, surveyed investments in innovation consist in large parts of physical investments. I study whether patent landscape characteristics affect the propensity to invest in these innovation-related assets. As robustness check, the patent landscape effects on innovation-related investments are contrasted with their effects on residual investment and R&D propensities.[5]

Furthermore, EPO patent data has been linked to the Mannheim Enterprise Panel (MUP). This data match shall augment the available financial information on owners of cited patents. The MUP is a firm-level database collected by Creditreform, the largest credit rating agency in Germany. Creditreform gathers this financial information from publications of firm's annual balance sheets. 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 consists of Creditreform's entire firm-level data on newly established firms and a stratified random sample of established German firms.[6]

3.2. *The proxy for different commitment levels*

Ideal information would characterize the technologies used or built on by the firm and identify owners of overlapping rights. Patent citations provide indirect evidence on

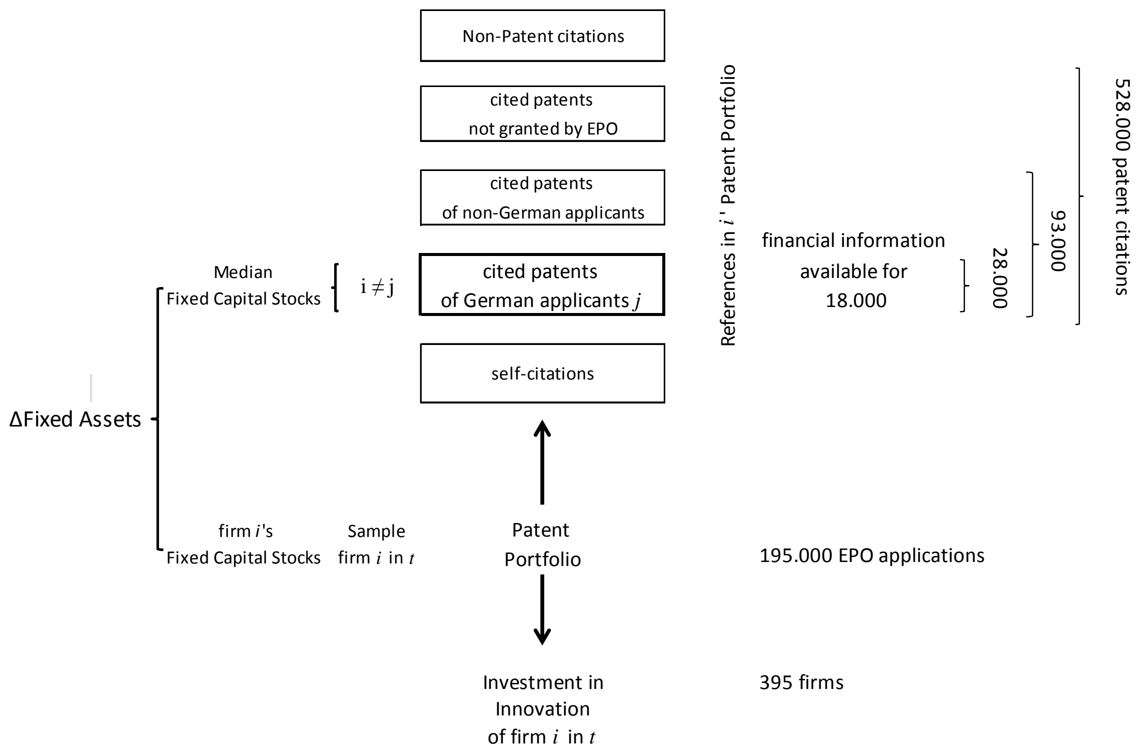
[5] Investments in innovation might be R&D-related. However, R&D expenditures are usually considered to consist mainly of salaries for research personnel and ongoing expenditures for equipment and materials.

[6] Not all patents are renewed to full term (Pakes, 1986; Schankerman and Pakes, 1986). However, cited patents should be more important and longer valid than an average one as EPO examiners are encouraged to describe the state of prior art within a minimum of citations (Michel and Bettels, 2001).

overlapping patent rights only. The eligibility of applications for patent protection is evaluated against a list of citations which describe the state of prior art. Patent examiners assemble this list at the EPO (Michel and Bettels, 2001; Harhoff et al. 2006). Patent citations reveal, thus, technological linkages across generations of inventions (Jaffe and Trajtenberg 2002). The scope of individual patent rights within this sequence of inventions remains uncertain unless brought to court. Hence, the set of cited patents in firm's patent portfolio may pose the risk of inadvertent patent infringement for the citing firm.

If cited patents are infringed inadvertently, their owners may be able to capture part of the fruits from infringing firm's investments. This requires an exploitable gap in their economic commitment levels. Fixed tangible assets should, at least partially, reflect an economic commitment. The difference in fixed capital stocks *ΔFixed Assets* between the citing and the median of cited patent owner appears as a reasonable proxy for different commitment levels between citing and cited firms. Median fixed capital stocks shall proxy the commitment level of an average cited patent owner. Figure 1 illustrates this empirical approach.

Figure 1 Capital stock difference to an average cited patent owner



The estimation sample consists of 395 firms which have filed 195 thousand patent applications at the EPO. The eligibility of these applications for patent protection is evaluated against a list of 528 thousand patents. 68 thousand citations are self-citations. 69 thousand cited patents have been filed 20 years before the citing patent and are expired.[7] Among the remaining set of backward citations, 24 percent are patents granted by the EPO. 28 thousand thereof are filed by German applicants. Patent applicants could be matched with MUP data for 20 thousand observations. Financial information for cited applicants is available for 18 thousand applications from which median fixed capital stocks are calculated. These 1400 standardized applicant names, for which financial information is available, refer to three-quarter of cited EPO patents with German applicants. Financial information appears to be available for patenting-intensive firms, in particular.

3.3. The fragmentation index

Fragmented IP ownership is another characteristic of the patent landscape which might hamper technology commercialization. Ziedonis (2004) introduces a Herfindahl-type measure for fragmented ownership of cited patents according to

$$frag_i = 1 - \sum_j \left(\frac{references_{ij}}{references_i} \right)^2 \left(\frac{references_i}{references_i - 1} \right)$$

Referencesi refers here to the number of backward citations in firm *i*'s patent portfolio. Referencesij indicates the number of patents of company *j* which are cited in the stock of patent applications of firm *i* in year *t*.[8] The second product term within the summation refers to Hall's (2005) bias correction of Herfindahl-type measures.

Cockburn et al. (2010) propose to measure fragmented IP ownership on the technology level. The fragmentation index for technology *k*, $frag_k$, refers to the set of backwards citations listed in all MIP firms' patent applications in technology *k*. The

[7] Not all patents are renewed to full term (Pakes, 1986; Schankerman and Pakes, 1986). However, cited patents should be more important and longer valid than an average one as EPO examiners are encouraged to describe the state of prior art within a minimum of citations (Michel and Bettels, 2001).

[8] The formula omits the time index for simplicity.

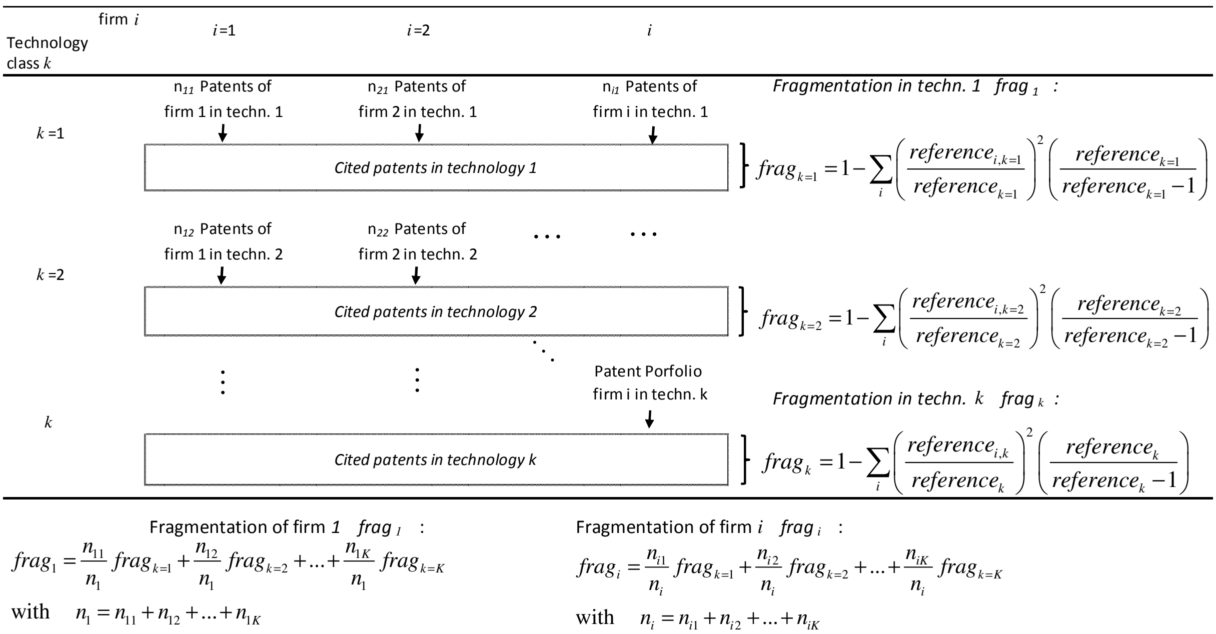
technology area k corresponds to the OST-INPI/FhG-ISI technology classification (OECD, 1994). Figure 2 illustrates this approach.

I will use subsequently a firm-level fragmentation index according to

$$frag_i = \frac{n_{i1}}{n_i} frag_{k=1} + \frac{n_{i2}}{n_i} frag_{k=2} + ... + \frac{n_{iK}}{n_i} frag_{k=K}$$
$$\text{with} \quad n_i = n_{i1} + n_{i2} + ... + n_{iK} \quad .$$

This is calculated as weighted average of technology-specific fragmentation indices $frag_k$. n_i refers here to the size of firm i's patent portfolio and n_{ik} refers to portfolio size in technology k.

Figure 2 Fragmentation indices



3.4. Further control variables

Financial information on cited patent owners is only available for German applicants of EPO patents. This raises validity concerns regarding the capital stock measure for an average cited patent owner. Figure 1 shows that financial information on cited patent owners is not available for patents granted by other patent offices or for cited non-German applicants. As long as patents from various origins pose similar risks of inadvertent infringement and expropriation, the share of citations to non-German applicants as well as the share of cited non-EPO patents might control for missing information.

Investments in innovation should be more likely if technological opportunity is high (Klevorick et al., 1995). The share of triadic patent applications in a 4-digit technology class is calculated in order to proxy for technological opportunities. Triadic patents are inventions for which patent protection is sought at three major patent offices; the European Patent Office (EPO), the US Patent and Trademark Office and the Japanese patent office. The protected invention appears, thus, important to their applicants (Putnam, 1996). The technological opportunity for firm i is proxied as weighted average of triadic patent shares.

Further control variables include qualitative information on firm's R&D policy, patent portfolio and firm size as well as firm's credit rating.[9] Logarithmized age and its square shall control for the dynamics of investment activity (Cooper et al. 1999). Furthermore, the stock of fixed tangible capital as well as labor input is included.

3.5. Descriptive Statistics

My sample includes manufacturing corporations in Germany which have applied for patent protection at the EPO. It is further restricted to firms which have at least once relied on external technology. Table 1 shows the descriptive statistics of the 968 observations. The sample includes overwhelmingly large companies. The mean number of employees is 3800 with a minimum of 8 and maximum of 426 thousand employees. Investments in innovation are very frequent among them. 90 percent invest in innovation-specific machinery and equipment. This extraordinarily high proportion reflects the sample restriction to patenting firms. Non-innovation related investments appear similarly frequent. R&D activity of sample firms is also very high. 83 percent is continuously engaged in R&D.

[9] Firm size might eventually introduce an endogeneity bias. Measuring firm size in number of employees might minimize these concerns. The regulated labor market in Germany causes high adjustment costs. This should lead firms to smooth labor input over time.

Ownership of cited patents appears dispersed. The fragmentation indices range from 94 to 98 percent. Matched financial information indicates a very skew distribution of fixed tangible assets among cited patent owners. The median lies at EUR 415 million and the maximum value amounts to EUR 11 billion. Sample firms have invested less than the average cited patent owner in most cases. These have invested EUR 346 million in fixed tangible assets on average. The mean capital stock differential *ΔFixed Assets* is negative and lies at EUR -800 million, i. e. sample firms have invested EUR 800 million less on average than an average cited patent owner. Differences in number of employees also show that citing sample firms are mostly smaller than an average cited firm. Differences in number of employees are additionally calculated in order to verify whether capital stock differences reflect size effects.

Table 1 about here

Sample firms appear financially sound. Creditreform assigns credit ratings of a scale from 100 to 500 in which the former indicates the best rating. The mean rating is 180 and the standard deviation is 50. This does not suggest that financing difficulties constrain sample firm's investments.

In order to avoid biases due to missing financial information for cited patent owners, the share of cited patents which are not granted by the EPO and the share of cited non-German patent applicants are included in the estimations. Citations included in EPO patents refer frequently to EPO patents. This is the case for 40 percent of cited patents. Application language appears also important. 62 percent of cited patents have German applicants.

Table 2 about here

4. Econometric evidence

Table 3 reports the average marginal effects on investment propensities from Probit estimations. It reports marginal effects on the propensity to invest in R&D, in innovation-related machinery and equipment and in other assets which are not innovation-related. It is expected that negative effects of heterogeneous or fragmented IP ownership are most pronounced for innovation-specific investments if they reflect IP-related hazards.

Propensities to invest in innovation are largely explained by R&D policies, firm age and size. The marginal effects of fixed capital stock differentials *ΔFixed Assets* are negative at a 5 percent level of significance. This effect appears specific to investments in innovation. R&D propensities and residual investments are not significantly correlated with *ΔFixed Assets*. This negative effect could refer to IP hazards due to different commitment levels. However, it could also show that large patent owners invest less in further innovation than smaller patent owners. If this is the case, *ΔNo. of Employees* should exhibit a similar negative effect on innovative investment propensities. Table 3 shows that this seems not to be the case. It could not be confirmed that the negative effect is due to size differentials between citing and cited patentees.

If the effect of *ΔFixed Assets* reflects hazards due to different commitment levels, the negative effect should be, furthermore, particularly pronounced for firms with large patent portfolios. Table 4 presents estimations for firms with large or small patent portfolios. The median number of 27 patent applications is used to divide the samples. *ΔFixed Assets* shows no significant effects on innovative investments for firms with small patent portfolios. Small firms are not more likely to invest in innovation with increasingly large cited patent owners. The marginal effect of *ΔFixed Assets* on innovation propensities is significant at the 5 percent level for firms with large patent portfolios. Hence, large corporations appear less inclined to invest in application-specific assets when the average cited patent owner is less capital-intensive. This suggests different commitment level between large citing corporations and cited patent owners which might be susceptible to exploitation during inadvertent patent infringement.

Fragmented ownership of cited patents does not appear to affect investments in innovation if *ΔFixed Assets* is controlled for. Fragmentation diminishes innovation propensities on a low level of significance if the estimation equation excludes *ΔFixed Assets.* Adding a non-linear fragmentation term improves the level of significance for fragmentation to a 5 percent level. The marginal effect appears to diminish slightly with increasing fragmentation. This might indicate that highly fragmented IP ownership diminishes the value at stake in bilateral patent disputes which might speed up settlement to some low extent (Gallasso and Schankerman, 2010).

Table 3 about here

Fragmented ownership of backward citations does not show significant effects on innovative investments of large firms. Innovation activities of firms with small patent portfolios appear weakly affected by fragmented IP. IP fragmentation reduces their propensity to invest in innovation at a 10 percent level of significance. This suggests that entry into innovative markets is difficult in the absence of large patent portfolios if IPR ownership is fragmented (Cockburn et al., 2010; von Graevenitz et al., 2012a).

Table 4 to Table 7 about here

Table 5 to Table 7 present estimation results which refine the proxy for different commitment levels *ΔFixed Assets*. These measures refer to different subsets of cited patent owners. Capital stock differences to the smallest and largest cited patent owner, to owners of blocking and not blocking patents as well as to owners of highly or seldom cited patents are, thereby, considered. With exception of ΔFixed Assets to the most cited patentee, all these measures significantly reduce the propensity to invest in innovation. Their effects on residual investment propensities and R&D propensities are either insignificant or positive. Hence, the negative effects of *ΔFixed Assets* on investment propensities appear innovation-specific.

Subsequently, the marginal effects of changing from the worst to the best bargaining position are approximated. The fragmentation index ranges from 0.94 to 0.98. A change from the least to the highest fragmentation reduces the propensity to invest in innovation by approximately 19 percentage points for firms with small patent portfolios. With regard to capital stock differences, the worst bargaining situation is given by EUR 10 billion for *ΔFixed Assets*. In their best bargaining situation, *ΔFixed Assets* is EUR -10 billion. The estimated marginal effects range is 1.3×10^{-5}. Hence, switching from the best to the worst bargaining situation reduces investment propensities by roughly 26 percentage points.

These magnitudes do not suggest collapsing technology adoptions due to imperfect intellectual property rights as it is postulated by the tragedy of anti-commons (Heller and Eisenberg, 1998). However, the estimated marginal effects should be considered as lower bounds. The estimation sample includes only patenting firms. Excluded firms lack patent portfolios that might serve as bargaining chip if IP ownership is fragmented. The measure for differential commitment levels refers to fixed assets of cited German patent owners only. There might be further marginal overlapping patent rights which are not listed as state of the art references by patent examiners. These marginal rights might pose additional risks of inadvertent infringement (Reitzig et al., 2007, 2010).

5. Conclusion

Innovation combines often multiple technological components (Somaya et al., 2011). In view of escalating patent numbers, each of these components is frequently protected by multiple patents. Innovation requires access to thickets of partially overlapping patent rights then. This increases the costs for securing intellectual property rights which might stifle innovation (Jaffe and Lerner, 2004; Bessen and Meurer, 2008).

Patent thickets can be characterized by mutual blocking rights among multiple parties (von Graevenitz et al., 2011). These constellations are difficult to resolve. Fragmented IP ownership raises coordination costs (Shapiro, 2001; Ziedonis, 2004). The uncertain scope of patent rights poses further the risk of inadvertently infringing overlapping rights (Lemley and Shapiro, 2005; Reitzig et al., 2010). Sunk investments in application-specific assets may leave innovating firms in an unfavorable bargaining position with residual patent owners (Reitzig et al., 2007, Farrell et al., 2007)

Innovation-related assets are frequently considered as source of competitive advantage. However, their application-specificity might render them also vulnerable to IP-related hazards (Jacobides et al., 2006). This study asks whether propensities to invest in innovation are lower when ownership of cited patents is fragmented or when owners of cited patents are less capital-intensive.

Evidence on the effects of patent thickets on product market innovation is rare (Cockburn et al., 2010). The effects of fragmented or heterogeneous IP ownership appear not uniform among innovators. Firms with small patent portfolios have lower propensities to invest in innovation if IPR ownership is fragmented. In contrast, firms with large patent portfolios appear not to be affected by fragmented IP ownership. This suggests that entry into innovative markets is difficult without large patent portfolios if IPR ownership is fragmented.

Overlapping patent rights pose the risk of inadvertent infringement. This may allow residual patent owners to exploit different economic commitment levels if the residual patent owner has invested less relationship-specifically than the infringed firm (Farrell et al., 2007). Relationship investments are difficult to identify. Fixed tangible assets appear, at least partially, application-specific (Hall and Ziedonis, 2001; Antràs, 2003). Different magnitudes of fixed tangible assets between citing and an average cited firm shall, therefore, proxy for the exploitable gap of application-specific investments between citing firms and residual owners of overlapping patents.

Innovation propensities of firms with large patent portfolios are significantly lower if they are more capital-intensive than an average cited patent owner. I do not find evidence for higher investment propensities of firms with small patent portfolios if they are not less capital-intensive than an average cited patent owner. I do further not find evidence for lower innovation propensities if the citing firm has more employees than an average cited patent owner. This suggests a high commitment level of capital-intensive firms which is susceptible to exploitation by less committed residual patent owners. Large corporations appear to take these exploitation risks into account in their decision on investments in innovation. However, the evidence does not suggest technology commercialization to be collapsing due to imperfect IPR. In the worst case, investment propensities in innovation appear to be reduced by a range of 19 to 26 percentage points.

Fragmented or heterogeneous IP ownership might also be reflected in lower investment volumes in innovation. This could provide further explanatory variation in addition to qualitative information on the decision to invest in innovation. However, I do not find investment intensities to be affected by these patent landscape characteristics.

This might be due to the veiled selection of innovation projects in total investment figures (Walsh et al., 2003; Chan et al., 2007).

A limitation of this study is surely that financial information on cited patent owners is available for German applicants at the EPO only. The share of cited non-German applicants and other cited authorities should control for the limited information. This assumes that cited patents of non-German applicants and cited patents from other jurisdictions pose similar exploitation risks. Furthermore, this study identifies those overlapping patents only by which EPO examiners describe prior art. Prior art shall be described within a minimum number of documents there. This excludes likely marginal overlapping patents. These might pose further risks of inadvertent infringement and increase fragmentation further. This study does also not address whether tendencies to accumulate weak patents distort innovation incentives. This might be an interested avenue for future research.

Appendix

Table 1 Descriptive statistics

	Mean	Std.dev.	Min.	Max.
Investments in Innovation	0.91	0.29	0	1
Residual Investments	0.89	0.31	0	1
Fragmentation Index	96.84	0.88	93.76	98.23
ΔFixed Assets§	-800	1565	-12827	10459
Δ(No. of Employees)§	1621	18699	-52544	425998
Share Patents filed more than 20 years ago	0.31	0.15	0	0.82
Share Triadic Patents	0.82	0.14	0.00	1
ln (Patent stock)	3.58	1.67	0	10.25
Occasional R&D activities	0.09	0.29	0	1
Continuous R&D activities	0.83	0.37	0	1
Share of cited GPTO patents	0.24	0.10	0	0.63
Share of cited EPO patents	0.39	0.10	0.17	1
Share of cited USPTO patents	0.18	0.08	0	0.50
Share of cited JPO patents	0.03	0.05	0	0.50
Share of cited German Applicants	0.62	0.12	0.27	1
Share of cited European Applicants	0.34	0.12	0	0.86
Share of cited US Applicants	0.16	0.10	0	0.67
Share of cited Japanese Applicants	0.06	0.06	0	0.43
Credit rating	180	50.10	100	500
Fixed Asset Intensity‡	0.06	0.11	0.00	2.16
ln (No. of Employees)	6.66	1.51	2.08	12.96
ln (Age)	3.65	1.18	0	5.86
Part of Conglomerate	0.77	0.42	0	1
Labour Cost Intensity‡	0.05	0.01	0.00	0.17
Location in Eastern Germany	0.03	0.18	0	1
Low-Tech Manufacturing	0.33	0.47	0	1
Medium High-Tech Manufacturing	0.48	0.50	0	1
High-Tech Manufacturing	0.19	0.40	0	1
No. of. Observations		968		

§ in €mln

‡ per no. of employees

Table 2 Correlation matrix

		(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	0.03	-0.01	1															
(4)	ΔFixed Assets	-0.04	0.00	0.13	1														
(5)	ΔNo. of Elmployees	0.03	0.00	0.13	0.20	1													
(6)	Share Patents filed > 20y	0.06	0.07	0.08	0.03	-0.04	1												
(7)	Share Triadic Patents	0.04	-0.03	-0.02	-0.10	0.01	-0.16	1											
(8)	ln(Patent stock)	0.12	0.01	0.28	0.02	0.37	0.03	0.17	1										
(9)	Occasional R&D	0.04	-0.04	0.02	0.06	-0.02	0.09	-0.02	-0.09	1									
(10)	Continuous r6d	0.31	0.01	-0.01	-0.04	0.04	-0.05	0.09	0.11	-0.72	1								
(11)	Boone Index	0.01	-0.06	0.08	0.05	-0.08	0.03	-0.07	-0.17	0.01	-0.07	1							
(12)	Credit rating	-0.06	0.02	0.07	0.03	0.06	0.00	-0.03	0.00	0.00	-0.09	-0.06	1						
(13)	Fixed Asset Intensity	0.10	0.12	0.12	-0.02	0.43	0.00	0.07	0.62	-0.12	0.15	-0.32	0.12	1					
(14)	ln(No. of Elmployees)	-0.03	0.08	-0.01	0.00	0.08	0.19	-0.04	0.16	0.06	-0.04	-0.34	0.04	0.26	1				
(15)	ln(Age)	0.02	-0.03	0.31	0.00	0.07	0.12	0.18	0.29	-0.04	0.06	0.00	0.25	0.13	-0.04	1			
(16)	Labour Cost Intensity	0.09	0.00	0.10	-0.02	0.07	0.01	0.05	0.24	-0.01	0.08	0.03	0.02	0.18	-0.11	0.13	1		
(17)	Med. Tech. Manuf.	0.02	-0.01	0.10	0.03	0.05	0.16	0.04	0.19	0.03	0.02	0.04	-0.08	0.06	-0.03	0.17	-0.01	1	
(18)	High Tech Manuf.	0.06	-0.11	-0.04	-0.06	-0.01	-0.24	0.24	-0.01	-0.09	0.11	-0.02	-0.02	-0.06	-0.14	0.01	0.01	-0.47	1

Table 3 Marginal effects on R&D, innovative and non-innovative investment propensities

	R&D		Invest. in Innovation				Residual Invest.	
Fragmentation Index	0.019	0.019	- 0.299*	- 84.031**	- 0.032	- 0.032	0.012	0.012
	(0.021)	(0.021)	(0.176)	(34.022)	(0.020)	(0.020)	(0.018)	(0.018)
Fragmentation Index^2				0.432**				
				(0.175)				
ΔFixed Assets[§]	0.000				- 0.000013**		0.000	
	(0.000)				(0.000006)		(0.000)	
Δ(No. of Employees)[§]		0.000				0.000		0.000
		(0.000)				(0.000)		(0.000)
Share Patents filed >20y	0.077	0.075	1.027*	1.058*	0.047	0.057	0.093	0.089
	(0.122)	(0.121)	(0.557)	(0.558)	(0.082)	(0.083)	(0.066)	(0.062)
Share Triadic Patents	0.103	0.101	- 0.212	- 0.227	0.000	0.004	0.119	0.109
	(0.076)	(0.075)	(0.537)	(0.538)	(0.064)	(0.065)	(0.079)	(0.078)
ln(Patent stock)	- 0.004	- 0.004	0.163***	0.158***	0.017**	0.017**	- 0.016	- 0.015
	(0.012)	(0.012)	(0.06)	(0.061)	(0.007)	(0.007)	(0.011)	(0.011)
Occasional R&D activities			2.334***	2.369***	0.259***	0.258***	- 0.083	- 0.080
			(0.319)	(0.325)	(0.035)	(0.035)	(0.074)	(0.072)
Continuous R&D activities			2.156***	2.201***	0.228***	0.227***	- 0.040	- 0.040
			(0.202)	(0.207)	(0.021)	(0.021)	(0.044)	(0.044)
Credit rating			0.003**	0.003**	0.000**	0.000*	0.000	0.000
			(0.002)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
Fixed Asset Intensity[‡]	- 0.162***	- 0.159***	- 0.005	0.194	0.042	0.037	0.074	0.070
	(0.061)	(0.057)	(0.627)	(0.684)	(0.069)	(0.075)	(0.131)	(0.126)
ln(No. of Employees)	0.009	0.009	0.143**	0.142**	0.019**	0.020**	0.032***	0.033***
	(0.011)	(0.011)	(0.070)	(0.070)	(0.008)	(0.008)	(0.012)	(0.01)
ln(Age)	0.047*	0.047*	0.691***	0.669***	0.066***	0.069***	0.063	0.062
	(0.028)	(0.028)	(0.219)	(0.221)	(0.025)	(0.025)	(0.042)	(0.041)
ln(Age)^2	0.975	0.983	- 0.129***	- 0.124***	- 0.013***	- 0.014***	- 0.010	- 0.010
	(0.659)	(0.67)	(0.035)	(0.035)	(0.004)	(0.004)	(0.007)	(0.007)
Part of Conglomerate			0.086	0.124	0.021	0.019	- 0.004	- 0.006
			(0.167)	(0.168)	(0.019)	(0.019)	(0.028)	(0.028)
Labour Cost Intensity[‡]			- 6.391	- 5.736	- 0.631	- 0.655	- 0.782	- 0.789
			(5.068)	(5.174)	(0.569)	(0.576)	(0.936)	(0.937)
Location in Eastern Germany	0.036	0.035	- 0.066	- 0.035	0.006	0.006	- 0.083**	- 0.079*
	(0.065)	(0.066)	(0.338)	(0.344)	(0.039)	(0.04)	(0.038)	(0.039)
Medium High-Tech Manuf.	0.042	0.042	- 0.154	- 0.125	- 0.016	- 0.016	- 0.034	- 0.033
	(0.029)	(0.042)	(0.165)	(0.167)	(0.018)	(0.018)	(0.033)	(0.033)
High-Tech Manufacturing	0.063*	0.062*	0.24	0.245	0.022	0.026	0.092**	0.091**
	(0.035)	(0.042)	(0.225)	(0.226)	(0.025)	(0.026)	(0.039)	(0.039)
Citation shares to authorities and applicant residence included								
Year dummies included								
No. of Observations				968				

[§] in million EUR

[‡] per no. of employees

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

Table 4 Marginal effects by patent portfolio size

	Invest. in Innovation			
	Frms with small patent portfolios		Frms with large patent portfolios	
Fragmentation Index	- 0.045*	- 0.033	- 0.035	- 0.037
	(0.027)	(0.030)	(0.040)	(0.04)
ΔFixed Assets[§]	0.000		- 0.000013**	
	(0.000)		(0.000005)	
Δ(No. of Employees)[§]		0.000		0.000
		(0.000)		(0.000)
Share Patents filed >20y	- 0.049	- 0.057	0.088	0.108
	(0.126)	(0.127)	(0.126)	(0.130)
Share Triadic Patents	- 0.097	- 0.099	0.059	0.09
	(0.103)	(0.101)	(0.095)	(0.097)
ln(Patent stock)	0.022	0.02	0.008	0.01
	(0.022)	(0.022)	(0.009)	(0.01)
Occasional R&D activities	0.356***	0.356***	0.189***	0.173***
	(0.054)	(0.053)	(0.056)	(0.055)
Continuous R&D activities	0.303***	0.304***	0.152***	0.149***
	(0.033)	(0.034)	(0.028)	(0.029)
Credit rating	0.001*	0.001**	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Fixed Asset Intensity[‡]	- 0.006	0.018	0.104	0.170
	(0.128)	(0.127)	(0.152)	(0.18)
ln(No. of Employees)	0.019	0.024	0.012	0.009
	(0.014)	(0.015)	(0.010)	(0.012)
ln(Age)	0.031	0.037	0.104***	0.103***
	(0.050)	(0.050)	(0.034)	(0.034)
$\ln(Age)^2$	- 0.010	- 0.011	- 0.017***	- 0.016***
	(0.008)	(0.008)	(0.005)	(0.005)
Part of Conglomerate	0.019	0.017	0.01	0.007
	(0.029)	(0.029)	(0.025)	(0.026)
Labour Cost Intensity[‡]	0.243	0.291	- 1.269*	- 1.448*
	(1.038)	(1.043)	(0.69)	(0.754)
Medium High-Tech Manuf.	- 0.078**	- 0.078**	0.023	0.026
	(0.033)	(0.032)	(0.023)	(0.023)
High-Tech Manufacturing	- 0.014	- 0.015	0.041	0.062
	(0.043)	(0.042)	(0.037)	(0.041)
Citation shares to authorities and applicant residence included				
Year dummies included				
LR	127.03***	128.16***	108.14***	101.66***
No. of Observations	484		484	

[§] in million EUR

[‡] per no. of employees

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

Table 5 Marginal R&D effect of capital stock gaps to subsets of cited patent owners

	R&D					
Fragmentation Index	0.019 (0.021)	0.019 (0.021)	0.019 (0.021)	0.018 (0.021)	0.019 (0.021)	0.019 (0.020)
ΔFixed Assets to...[§]						
…X- or Y-citations	0.000 (0.000)					
…non-X- and non-Y-citations		0.000 (0.000)				
…to smallest cited patentee			0.000 (0.000)			
…to largest cited patentee				0.000 (0.000)		
…to seldom cited patentees					0.000 (0.000)	
…to most cited patentee						0.000 (0.000)
Credit rating	0.074 (0.121)	0.080 (0.121)	0.074 (0.120)	0.079 (0.118)	0.074 (0.121)	0.077 (0.123)
Fixed Asset Intensity[‡]	0.100 (0.074)	0.103 (0.075)	0.103 (0.077)	0.105 (0.071)	0.098 (0.073)	0.103 (0.076)
ln(No. of Employees)	- 0.004 (0.011)	- 0.004 (0.012)	- 0.005 (0.013)	0.002 (0.01)	- 0.004 (0.013)	- 0.004 (0.012)
ln(Age)	- 0.159*** (0.06)	- 0.165*** (0.062)	- 0.164*** (0.064)	- 0.157*** (0.055)	- 0.164*** (0.062)	- 0.163*** (0.06)
$\ln(Age)^2$	0.009 (0.011)	0.010 (0.011)	0.009 (0.011)	0.009 (0.011)	0.009 (0.011)	0.009 (0.011)
Part of Conglomerate	0.047* (0.028)	0.047* (0.028)	0.047* (0.028)	0.045 (0.029)	0.046* (0.028)	0.046* (0.028)
Labour Cost Intensity[‡]	0.982 (0.669)	0.974 (0.661)	0.987 (0.672)	0.926 (0.667)	0.975 (0.661)	0.983 (0.672)
Location in Eastern Germany	0.036 (0.065)	0.035 (0.065)	0.036 (0.066)	0.038 (0.065)	0.035 (0.066)	0.036 (0.065)
Medium High-Tech Manuf.	0.042 (0.029)	0.042 (0.029)	0.042 (0.028)	0.042 (0.028)	0.041 (0.028)	0.043 (0.029)
High-Tech Manufacturing	0.062* (0.036)	0.063* (0.034)	0.062* (0.035)	0.060* (0.036)	0.062* (0.036)	0.063* (0.036)
Citation shares to authorities and applicant residence included *Year dummies included*						
No. of Observations	968					

[§] in million EUR

Table 6 Marginal innovation effect of capital stock gaps to subsets of cited patent owners

	Invest. in Innovation					
Fragmentation Index	- 0.034*	- 0.032	- 0.030	- 0.034*	- 0.034*	- 0.032*
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)
ΔFixed Assets to...[§]						
...X- or Y-citations	- 0.00001**					
	(0.000007)					
...non-X- and non-Y-citations		- 0.00001**				
		(0.000006)				
...to smallest cited patentee			- 0.00002***			
			(0.000007)			
...to largest cited patentee				- 0.000007**		
				(0.000003)		
...to seldom cited patentees					- 0.00002***	
					(0.000006)	
...to most cited patentee						0.000006
						(0.000007)
Share Patents filed >20y	0.062	0.050	0.066	0.039	0.073	0.055
	(0.083)	(0.082)	(0.082)	(0.082)	(0.082)	(0.083)
Share Triadic Patents	- 0.003	0.002	- 0.005	- 0.016	0.008	0.003
	(0.065)	(0.064)	(0.065)	(0.065)	(0.064)	(0.065)
ln(Patent stock)	0.015**	0.017**	0.020***	0.009	0.019***	0.017**
	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)
Occasional R&D activities	0.255***	0.260***	0.257***	0.266***	0.264***	0.258***
	(0.035)	(0.035)	(0.035)	(0.036)	(0.035)	(0.035)
Continuous R&D activities	0.229***	0.229***	0.225***	0.234***	0.230***	0.229***
	(0.021)	(0.021)	(0.021)	(0.022)	(0.021)	(0.021)
Credit rating	0.000*	0.000**	0.000*	0.000**	0.000**	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Fixed Asset Intensity[‡]	0.042	0.040	0.046	0.028	0.043	0.039
	(0.069)	(0.068)	(0.065)	(0.066)	(0.063)	(0.073)
ln(No. of Employees)	0.020**	0.019**	0.021***	0.020**	0.021***	0.019**
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
ln(Age)	0.065***	0.069***	0.069***	0.071***	0.075***	0.070***
	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
$\ln(\text{Age})^2$	- 0.013***	- 0.014***	- 0.014***	- 0.014***	- 0.014***	- 0.014***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Part of Conglomerate	0.023	0.020	0.021	0.021	0.020	0.021
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
Labour Cost Intensity[‡]	- 0.636	- 0.621	0.671	0.596	- 0.549	- 0.675
	(0.57)	(0.572)	(0.571)	(0.576)	(0.583)	(0.574)
Location in Eastern Germany	0.005	0.006	0.009	0.002	0.010	0.005
	(0.039)	(0.039)	(0.039)	(0.039)	(0.038)	(0.039)
Medium High-Tech Manuf.	- 0.018	- 0.017	- 0.014	- 0.018		- 0.018
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.019)
High-Tech Manufacturing	0.022	0.022	0.026	0.029	0.026	0.022
	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.026)
Citation shares to authorities and applicant residence included						
Year dummies included						
No. of Observations			968			

[§] in million EUR

Table 7 Marginal investment effect of capital stock gaps to subsets of cited patent owners

	Residual Invest.					
Fragmentation Index	0.011 (0.022)	0.012 (0.022)	0.011 (0.022)	0.012 (0.022)	0.013 (0.022)	0.011 (0.022)
ΔFixed Assets to...[§]						
...X- or Y-citations	0.000 (0.000)					
...non-X- and non-Y-citations		0.000 (0.000)				
...to smallest cited patentee			0.000 (0.000)			
...to largest cited patentee				0.000 (0.000)		
...to seldom cited patentees					0.000 (0.000)	
...to most cited patentee						0.00002** (0.000006)
Share Patents filed >20y	0.095 (0.103)	0.087 (0.103)	0.094 (0.103)	0.090 (0.103)	0.097 (0.103)	0.107 (0.103)
Share Triadic Patents	0.120 (0.086)	0.109 (0.086)	0.129 (0.087)	0.113 (0.086)	0.115 (0.086)	0.138 (0.086)
ln(Patent stock)	- 0.015* (0.009)	- 0.015* (0.009)	- 0.018** (0.009)	- 0.015 (0.01)	- 0.017* (0.009)	- 0.016* (0.008)
Occasional R&D activities	- 0.079 (0.052)	- 0.080 (0.052)	- 0.084 (0.052)	- 0.082 (0.052)	- 0.085 (0.052)	- 0.086* (0.052)
Continuous R&D activities	- 0.040 (0.044)	- 0.040 (0.044)	- 0.039 (0.044)	0.041 (0.044)	- 0.041 (0.044)	- 0.041 (0.044)
Credit rating	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Fixed Asset Intensity[‡]	0.083 (0.155)	0.070 (0.146)	0.075 (0.156)	0.072 (0.15)	0.081 (0.156)	0.097 (0.162)
ln(No. of Employees)	0.031*** (0.009)	0.031*** (0.009)	0.031*** (0.009)	0.031*** (0.009)	0.031*** (0.009)	0.032*** (0.009)
ln(Age)	0.066** (0.032)	0.061* (0.032)	0.063** (0.032)	0.062* (0.032)	0.061* (0.032)	0.062** (0.032)
$\ln(Age)^2$	- 0.011** (0.005)	- 0.010** (0.005)	- 0.010** (0.005)	- 0.010** (0.005)	- 0.010** (0.005)	- 0.010** (0.005)
Part of Conglomerate	- 0.005 (0.025)	- 0.005 (0.025)	- 0.003 (0.025)	- 0.005 (0.025)	- 0.003 (0.025)	- 0.005 (0.025)
Labour Cost Intensity[‡]	- 0.801 (0.734)	- 0.792 (0.733)	- 0.773 (0.733)	- 0.793 (0.733)	- 0.809 (0.733)	- 0.83 (0.732)
Location in Eastern Germany	- 0.084 (0.052)	- 0.082 (0.052)	- 0.086* (0.051)	- 0.082 (0.052)	- 0.086* (0.052)	- 0.087* (0.051)
Medium High-Tech Manuf.	- 0.033 (0.026)	- 0.033 (0.026)	- 0.037 (0.026)	- 0.033 (0.026)	- 0.036 (0.026)	- 0.034 (0.026)
High-Tech Manufacturing	- 0.094*** (0.030)	- 0.092*** (0.030)	- 0.094*** (0.030)	- 0.092*** (0.030)	- 0.094*** (0.030)	- 0.089*** (0.030)
Citation shares to authorities and applicant residence included						
Year dummies included						
No. of Observations	968					

[§] in million EUR

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