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Unraveling the Paradox of External Knowledge Sourcing in an Era of Open Innovation, Appropriation, and Organizational Learning

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D 83

Abstract (Deutsch)

Einleitung

Kontinuierliches Lernen aus Fehlern, strategische Veränderung, Fortschritt und Entwicklung durch Innovation sind notwendige Voraussetzungen für Unternehmen, um in Zeiten der zunehmenden Globalisierung und des Wettbewerbs zu wachsen, zu überleben und einen nachhaltigen Wettbewerbsvorteil zu erzielen. Kreativität, Ideen und neue Kombinationen von bereits bekannten Erfindungen sind entscheidende Bestandteile von Innovationen und neuen Produkten, die sich in so genanntem geistigem Eigentum (engl. Intellectual Property (IP)) manifestieren. Auf der einen Seite nutzen Unternehmen zunehmend Wissen und Ressourcen außerhalb ihrer eigenen Grenzen, um Innovationen hervorzubringen und neue Produkte zu vermarkten. Auf der anderen Seite sehen sich dieselben Unternehmen veranlasst ihr wertvolles technologisches Kapital und Knowhow zu sichern, was sich in der so genannten Patentierungswelle in den 1980er Jahren niedergeschlagen hat.

Um einerseits die hohen Investitionskosten, die bei der Erschaffung und Entwicklung von geistigem Eigentum und Innovationen getätigt werden, zu schützen und andererseits den Missbrauch durch Nachahmung zu bekämpfen, nutzen Firmen eine Palette an formalen Schutzmechanismen (IPR), wie z.B. Patente, Marken, Geschmacksmuster oder Copyright und informelle Schutzmechanismen, z.B. Lead Time und Geheimhaltung. Diese Arbeit beschäftigt sich mit dem Paradox der zunehmenden Öffnung der Unternehmen für Kooperationen mit anderen Partnern und der daraus resultierenden Schwierigkeit der Appropriationsmöglichkeiten. Darüber hinaus hat sich die strategische Nutzung von geistigem Eigentum zur Stärkung der Verhandlungsposition als wichtig erwiesen. Die gestiegene Nutzung von geistigem Eigentum ist ebenfalls ein Indikator für dessen Bedeutung als Abwehrmechanismus. Ein wertvolles und großes Patentportfolio kann für Firmen einer dieser wichtigen Abwehrmechanismen darstellen, um die Handlungs- und Vermarktungsfreiheit gegenüber anderen Firmen und Personen zu behaupten, insbesondere wenn diese möglicherweise Schutzrechte erwerben und gegen sie durchsetzen könnten.

Außerdem ist die Auswirkung von Produktfehlererfahrungen auf die Innovationsstrategie von Unternehmen bisher noch wenig erforscht. Vorhandene Forschungsergebnisse liefern widersprüchliche Aussagen über die Fähigkeit von Unternehmen aus Fehlern zu lernen. Zusätzlich zeigen frühere Studien Patente als wichtigen Anreiz für Innovation, verschiedene Motive für Patentierung (insbesondere von großen Firmen) und wie Unternehmen Gewinne ihrer Innovationsinvestitionen durch den Einsatz von formellen und informellen Schutzmethoden aneignen und sichern.

Basierend auf der bestehenden Literatur untersucht diese Dissertation den Einfluss der Innovationstrategie von Unternehmen (Forschungskooperation) auf Imitation von geistigem Eigentum und auf Appropriationsmechanismen. Zusätzlich fokussiert die vorliegende Arbeit die Auswirkungen des Lernens aus Fehlern auf das Verhalten und die Strategie von Unternehmen sowie die zugrunde liegenden Mechanismen, die die Nutzung von Abwehrstrategien beeinflussen. Damit trägt diese Dissertation zur Forschung in einem aufstrebenden und interdisziplinären Bereich bei.

Überblick

In meiner Dissertation konzentriere ich mich auf drei große Forschungsströmungen, die diese Arbeit in drei Teile gliedern. Dabei handelt es sich um organisationales Lernen, Open Innovation und Appropriation sowie defensive IP-Strategien. Zunächst gebe ich einen konzeptionellen Überblick über verschiedene Theorien zum Lernen aus Erfahrungen sowie die Auswirkungen dieses Lernprozesses auf die Innovationsstrategie von Unternehmen. Der zweite Teil analysiert die Zusammenhänge zwischen der Innovationstrategie von Unternehmen (Forschungskooperationen) und Appropriation. Der dritte Teil dieser Arbeit untersucht die Nutzung von defensiven IP-Strategien in Unternehmen. Somit beleuchtet diese Dissertation das Lernverhalten von Unternehmen in turbulenten Umgebungen, die komplexe Beziehung zwischen Öffnung und Appropriation sowie die Verbreitung defensiver IP-Strategien.

Methodik und Daten

In dieser Arbeit verwende ich hauptsächlich quantitative Daten aus verschiedenen Wellen des Mannheimer Innovationspanels (2005-2011), welche vom Zentrum für Europäische Wirtschaftsforschung (ZEW) zur Verfügung gestellt wurden. Diese Daten stellen die deutsche Version des bekannten Community Innovation Surveys dar. Ich wende ökonometrische Modelle und multivariate Methoden zur Analyse der Daten an. Die einzige Ausnahme hierbei bildet ein konzeptionelles Papier, das den aktuellen Stand der Literatur und Theorien im Bereich des organisationalen Lernens wiedergibt. Für die Analyse nutzen die Papiere zwei und drei logistische Regressionen. Zudem verwende ich im zweiten Papier Propensity Score Matching (PSM) als weitere Methode. Bayesian Averaging (BMA) komplementiert das Methodenspektrum und wird als Analyseerfahren im vierten Papier genutzt. Dabei erzeugt BMA alle möglichen Variablenkombinationen und wählt das Modell mit der besten Passform. Damit löst BMA das Problem der inhärent unsicheren Modellstruktur, die in der Regel bei normalen OLS Regressionen vorliegt und bietet somit eine wertvolle Alternative als empirische Methode für die Managementforschung. Das letzte Papier stützt sich auf deskriptive Analysen und die explorative Methodik der Multiple Correspondence Analysis (MCA). MCA ist bei der Identifizierung von Korrelationen zwischen dichotomen Variablen von Nutzen.

Ergebnisse

Das Reagieren von Unternehmen auf verschiedene Arten von Versagen (*legal copying* und *illegal infringement*) zeigt, dass sie in der Lage sind, aus Fehlern und insbesondere dem Scheitern ihrer Appropriationsstrategie zu lernen. Unternehmen mit *legal copying* Erfahrung sind weniger geneigt in Forschung und Entwicklung (F&E) mit anderen Partnern zusammenzuarbeiten, wohingegen Unternehmen, die *illegal infringement* erlebt haben eher zur F&E-Zusammenarbeit tendieren. Diese Dissertation kommt zu dem Ergebnis, dass eine zunehmende Öffnung der Unternehmen mit einem größeren Risiko der Imitation einhergeht. Artikel Nummer vier gibt Aufschluss über verschiedene Determinanten auf der Firmenebene für die Nutzung formeller und informeller Appropriationsstrategien. Der fünfte Artikel stellt dar, dass Firmen ihr IP-Arsenal auf- und ausbauen, indem Sie gleichzeitig unterschiedliche defensive IP-Strategien anwenden.

Implikationen

Die Ergebnisse dieser Doktorarbeit haben Konsequenzen sowohl für die Führung von Unternehmen als auch die Politik. Erstens müssen sich Unternehmen von einer leistungsorientierten Kultur zu einer lernbasierten Kultur weiterentwickeln und sich bewusst mit Fehlern, deren Ursachen und Auswirkungen auseinandersetzen und darüber reflektieren. Zweitens kann ein von Fehlern ausgelöster Lernprozess innerhalb der Organisation zu Anpassungen der IP- und Innovationsstrategien führen. Urheberrechtsverletzung (*illegal infringement of IPR*) stellt ein wichtiges Mittel für Unternehmen dar, Verhandlungen über die Zusammenarbeit mit externen Partnern zu initiieren. Nachahmung von geistigem Eigentum (*legal copying of IP*) und der damit verbundene Verzicht auf F&E-Kooperation kann dem Erfolg und der Innovationskraft von Unternehmen einen langfristigen Schaden zufügen. Des Weiteren sollten Unternehmen mit einer offenen Innovationsstrategie ihre IP- und Gesamtunternehmensstrategien entsprechend anpassen und unter kontrollierten Bedingungen (z.B. durch Verträge) mit anderen zusammenarbeiten.

Durch die Bereitstellung eines regulatorischen Umfeldes kann die Politik die Verbreitung von Informationen über Fehlerfahrungen anderer Firmen fördern und somit das Wissen im Umgang mit Fehlern für Unternehmen der gleichen Branche verbessern. Dadurch wird die Entwicklung neuer, verbesserter Vorschriften begünstigt, die das Auftreten von gleichen oder ähnlichen Fehlern verhindern.

Insbesondere der zunehmende strategische Einsatz von Schutzmechanismen und IPR zeigt Schwächen und Unzulänglichkeiten des Patentsystems, die für eine Reformierung desselben sprechen. Ein effizientes System zur Durchsetzung sowie moderate Transaktionskosten bei Anmeldung und Durchsetzung von Patenten bestimmen den Wert von Patenten als Exklusivrecht. Zudem ergänzen informelle Schutzmechanismen formelle Schutzmechanismen, was sich in der zunehmenden Tendenz von Unternehmen ihre eigenen komplexen IP- Strategien zu entwickeln, niederschlägt. Somit können Unternehmen besser mit der Ineffizienz und den Problemen im Zusammenhang mit der Offenlegung von Wissen in Patenten umgehen. Allerdings könnte eine leichtere Durchsetzung von Patentrechten für mehr Transparenz und Rechtssicherheit sorgen, welche im aktuellen System zu fehlen scheint.

Abstract

Introduction

Continuous learning from failure, strategic change, progress and development through innovation is a necessary requirement for firms to prosper, survive and develop a sustainable competitive advantage in times of increased globalization and competition. Creativity, new ideas and combinations of already known inventions are crucial elements of innovations and new products which manifest themselves in so-called Intellectual Property (IP). On the one hand, firms increasingly rely on external knowledge and resources to develop or commercialize innovations and new products. On the other hand, firms' need to secure their valuable technological capital has led to the so-called patent surge in the 1980s. In order to safeguard their investments into creating IP and innovation from imitation, firms employ a range of formal protection mechanisms (IPR), e.g., patents, trademarks, designs, or copyright and informal protection mechanisms, e.g., lead time and secrecy. Therefore, this thesis deals with the arising paradox of openness and the resulting appropriation concerns. Moreover, the strategic use of intellectual property has become tremendously important as a bargaining chip. Firms' increased strategic use of IP emphasizes the importance of defensive strategies. These are designed to respond to IP which can potentially be acquired and enforced against them by other firms and entities in a way which conserves the freedom of operating and commercializing.

Moreover, the impact of product failure experience on firms' innovation strategy is underexplored. Existing research provides conflicting evidence on firms' ability to learn from failure experience. Additionally, previous studies illustrate patents as an important incentive to innovate, identify different motives of patenting and clarify how firms appropriate their innovation investments by employing formal (IPR) and informal protection methods.

Based on this body of literature, my dissertation investigates the relevance of a firm's innovation (collaboration) strategy for imitation and for appropriation mechanisms. Additionally, it focuses on the influence of the process of learning from failure on company behavior and strategy and

the underlying mechanisms of firms' use of defensive strategies. In doing so, this dissertation contributes to research in an emerging and interdisciplinary area.

Overview

In my dissertation, I focus on three major research streams represented in three parts. These are organizational learning, open innovation and appropriation and defensive IP strategy. First, I give a conceptual overview of organizational learning from experience and its impact on innovation strategy. The second part analyzes the interrelationship between firms' innovation (collaboration) strategy and appropriation. The third part, reflected in the final paper of this thesis, focuses on firms' usage of defensive IP strategies. Thus, this dissertation sheds light onto firms' learning behavior in turbulent environments, the complex paradox of open innovation and appropriation and the prevalence of defensive strategies.

Methods and data

In this thesis, I mainly use quantitative data from different waves of the Mannheim Innovation Panel (2005-2011) which were generously provided by the Centre for European Economic Research (ZEW). These data represent the German equivalent of the well-known Community Innovation Survey. I employ econometric models and multivariate methods for analyzing the data. The only exception is the conceptual paper which is based on existing literature and theories in the field of organizational learning. For the analysis, papers two and three use logistic regression. Additionally, the second paper makes use of propensity score matching as a further method. Bayesian Model Averaging (BMA) serves as a complementary method in the fourth paper. BMA generates all possible combinations of variables and selects the model with the best fit. Thus, BMA tackles this inherent uncertain model structure which is usually the case in OLS regressions and offers a valuable alternative empirical method for management scholars. The last paper relies on descriptive analyses and the exploratory methodology of multiple correspondence analysis (MCA). MCA is useful in identifying underlying correlations between dichotomous variables.

Results

Firms' reactions to different kinds of failure experience (legal copying and illegal infringement) show that firms are able to learn from failure and in particular the failure of their appropriation strategy. Companies having experienced legal copying are less likely to cooperate on R&D with other partners whereas companies having experienced illegal infringement are more likely to enter into subsequent R&D collaboration. This thesis further finds indications that more openness is inseparable from a greater risk of imitation. Article number four disentangles different determinants for both formal and informal appropriation strategies. Article number five illustrates that firms build their IP arsenal by employing different defensive strategies simultaneously.

Implications

The results of this doctoral thesis have implications for management and policy. First, firms need to advance from a performance-based to a learning-based culture and consciously reflect upon failure experiences. Second, shifts in IP and innovation strategies can be triggered by a learning-from-failure process within the organization. Infringement of IPR is an important means for firms to initiate negotiations over collaboration with a range of external parties whereas the copying of IP and the associated withdrawal from R&D cooperation can harm firms' performance and innovativeness in the long-run. Moreover, companies with an open innovation strategy have to adjust their IP strategy accordingly and collaborate with others under controlled conditions (e.g., by contracts). Firms should cohesively align their IP and innovation strategy with their corporate strategy.

By providing a regulatory environment, policy can enhance the spread of knowledge and learning about other firms' failure across companies within the same sector. Thus, new, improved regulations to prevent the occurrence of the same or similar failures can be facilitated.

Particularly companies' increased strategic use of defensive strategies and IPR reveals weaknesses and inefficiencies which call for a reform of the patent system. An efficient enforcement system as well as moderate transaction costs associated with filing and enforcing patents determine the value of patents as an exclusion right. Informal mechanisms seem to complement formal appropriation mechanisms as firms increasingly develop their own complex IP strategy to deal with the inefficiency and disclosure problems related to patents. However, an economically viable enforcement of patents could create more transparency and legal certainty which seems to be missing in the current system.

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"It always seems impossible until it's done." – Nelson Mandela

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Annika Lorenz

Contents

Introduction

Context

Knowledge and intellectual property (IP)

As modern economies converge ever more towards a knowledge-based society, the role of intellectual property (IP) is steadily increasing. Creativity, new ideas and novel combinations of knowledge are crucial elements of innovations and new products which manifest themselves in so-called intellectual property. Moreover, scholars argue that innovation drives growth (Audretsch, 1995; Grossman and Helpman, 1990) which eventually enhances welfare. For the last decades, research has been investigating how IP rights (IPR), e.g., patents can provide enough incentives for innovation to stimulate growth (Somaya et al., 2011).

From a firm-level perspective, innovation is assumed to positively influence companies' long-term success and performance. Particularly, knowledge is an important strategic resource used by firms to generate these innovations, exceptional profits and competitive advantages (Grant, 1996). Thus, continuous learning from success and failure, creating new knowledge and capabilities as well as the persistent evolution and innovation of products and processes represent firms' endeavors in their pursuit of growth, survival and prosperity in a dynamic environment.

External knowledge sourcing, cooperation and open innovation

According to Nelson and Winter (1982), firms' search for knowledge is critical for our understanding of the innovation process. Particularly, innovation processes are characterized by firms' need to search for and carry out 'new combinations' of technologies, products, processes and markets (Schumpeter, 1912/1934).

Against this background, external knowledge search can be defined as 'an organization's problem-solving activities that involve the creation and recombination of technological ideas'

(Katila and Ahuja, 2002, p. 1184). Due to increasing complexity, accelerated technology life cycles, shortened time-to-market and the multi-disciplinarity of research and development (R&D) and innovation efforts, firms seek to access complementary assets and knowledge outside their boundaries (Miotti and Sachwald, 2003). The knowledge-based view predicts that firms engage in cooperation with external partners whenever they need to access knowledge and resources to reduce environmental as well as innovation-inherent risks (Cook, 1977; Galaskiewicz, 1985). Particularly, innovative companies are highly dependent on knowledge as an input factor and thus, collaboration is a critical means for these firms to sustain and thrive in the long-run (e.g., Grant, 1996; Kogut and Zander, 1992, 1996).

Furthermore, in the last decades, innovative firms have shifted from the 'closed innovation' paradigm where companies rely on internal capabilities, towards the 'open innovation' model (Chesbrough, 2003) using a wide range of inter-organizational ties and sources (Laursen and Salter, 2006). In addition to cooperation with competitors, open innovation stresses the integration of customers, suppliers, universities and other external knowledge sources in the innovation systems. Thus, it is a holistic innovation strategy where the company is constantly looking for innovation potential outside the company and eventually internalizes external knowledge.

Literature on open innovation takes a stand for a greater strategic use of external sources as inputs of innovation (von Hippel, 1988; Pavitt, 1984). In general, literature widely acknowledges the benefits and positive returns of search (Garriga et al., 2013; Katila and Ahuja, 2002; Laursen and Salter, 2006) and open R&D activities for firms' innovation performance (Ahuja, 2000; Belderbos et al., 2004; Cassiman and Veugelers, 2006; Powell et al., 1996).

Appropriation, imitation and infringement

Protection instruments provide important incentives to perform R&D and innovation activities (Somaya et al., 2011) because they create monopoly profits which are assumed to cover innovation-related costs and risks. In general, protection strategies can be divided into two groups of measures (e.g., Blind et al., 2006; Cohen et al., 2000; Cohen et al., 2002): *Formal appropriation instruments* which grant inventors and innovators an exclusive right to prevent others from the utilization of the protected subject matter (e.g., patents, trademarks, utility patents or copyright) and *informal appropriation instruments* that encompass various measures to avoid spillovers of own innovation efforts and to safeguard the appropriation of one's own innovation returns (e.g., secrecy, complex design of new products or services, lead time advantage). Thus, the industrial organization literature typically models appropriability as the extent to which firms can limit other firms from imitating their innovations and hence capture the profits generated from these innovations (Ceccagnoli, 2009; Teece, 1986). Teece (1986) shows that the 'lion's share' of profits created by innovation does not necessarily have to go to the owners of the underlying invention but to the owners of complementary technologies and/or assets instead. Therefore, patents and other appropriation instruments serve as isolating mechanisms that protect the firm's key technologies and resources from imitation (Lippman and Rumelt, 2003; Rumelt, 1984). In sum, research reveals that firms prevent imitation by building on a full portfolio of protection mechanisms available to them and thus secure or develop a competitive advantage (Somaya, 2012). A major stream of research has investigated symmetric industry-level appropriability (e.g., Cohen and Levinthal, 1989), but only more recently scholars have begun to consider the impact of asymmetric spillovers and analyze its impact on firm and industry innovation incentives and performance (Cassiman and Veugelers, 2002; Ceccagnoli, 2005). Greater appropriability and hence more market power for the innovator associates with lower spillovers from a high-quality, low-cost firm to less efficient competitors (Ceccagnoli, 2009).

Despite a long discussion of appropriability concerns mostly focusing on reverse engineering competitors' products, copying advertising strategies, and service innovations (McEvily and Chakravarthy, 2002), the limits and boundaries of appropriability regimes regarding IPR have not explicitly been addressed in the context of infringement, as yet. Despite some seminal works on trademark infringement and counterfeits in the marketing and trade literature (e.g., Bekir et al., 2012; Grossman and Shapiro, 1988a, 1988b; Olsen and Granzin, 1992; Wilcox et al., 2009), only recently have Berger et al. (2012) started to exploratorily detect drivers for the copying or infringement of patents and trademarks.

Indeed, there is a substantial amount of management literature around the topic of infringement and litigation of patents. Prior works have analyzed the determinants of patent litigation (Lanjouw and Schankerman, 2001) as well as the reasons not to settle patent litigations (Somaya, 2003). Furthermore, research reveals that firms' deliberately choose specific courts for patent litigation trials (Somaya and McDaniel, 2012). Shane and Somaya (2007) investigate the effect of patent litigation on university efforts to license technology. Other scholars study the business model of patent trolls (e.g., Reitzig et al., 2007), and ways to prevent litigation in complex markets (Lerner, 1995).

The tension between open innovation and appropriation

This dissertation combines different streams of literature investigating the paradox that arises when firms simultaneously share and protect their knowledge in an alliance with other organizations. In an era of open innovation, firms need to balance these emerging tensions related to knowledge sharing on the one hand and capturing value and protecting own IP on the other hand (Bogers, 2011).

The literature on cooperation with external actors highlights that firms need to reveal some parts of their own knowledge to obtain new knowledge in return (Laursen and Salter, 2013).

This phenomenon has been framed as the 'paradox of openness' (Laursen and Salter, 2013) based on Arrow's (1962) 'paradox of disclosure', because firms' engagement with a broad set of external actors may require them to pay more attention to protect their own knowledge from being copied.

Furthermore, being able to appropriate the benefits from an innovation requires substantial managerial attention and effort, such as applying formal and informal appropriation mechanisms (Arora and Ceccagnoli, 2006; Ceccagnoli, 2009; Teece, 1986; Ziedonis, 2004). At the same time, firms also face a severe attention problem regarding the simultaneous control of several collaboration partners (Love et al., 2013). Both mechanisms, thus, may exert a major influence on the firm's approach to dealing with conflicts and risks emerging from navigating through the external environment particularly regarding the partner choice, the knowledge sourcing strategy and the organization of own innovative activities (Chesbrough, 2006; Gans et al., 2008; Somaya, 2012).

The current literature on open innovation emphasizes that an overwhelming focus on protecting knowledge can also be harmful for a firm (Laursen and Salter, 2013) since it might miss out on valuable opportunities of knowledge exchange and new product development (Bessen and Maskin, 2009).

Nonetheless, in situations where property rights offer only limited protection, the value of the disclosure is offset by the increased threat of theft and spillovers (Laursen and Salter, 2013). The greatest fear of firms in external engagements relates to 'involuntary outgoing spillover', that is, the leakage of critical knowledge and resources to the firm's competitors. Accordingly, innovative firms must analyze the risk by balancing incoming against outgoing knowledge spillovers (Cassiman and Veugelers, 2002).

Despite the increase of firms engaging in external engagement and the tensions associated with it, research has rarely addressed how firms can deal with the emerging tensions between knowledge sharing and protection of their technological competencies (McEvily et al., 2004).

There are different strategies to overcome the mentioned risks and tensions. Firms strive to use relational as well as contractual governance mechanisms and increasingly rely on the strategic design of their relationships with external partners to create predictable environments (e.g., Gulati et al., 2000). Moreover, the characteristics of knowledge (e.g., teachability, complexity and specificity) determine how knowledge can be shared and protected and hence, have important implications for the relationship between the collaborating partners (Bogers, 2011; Kogut and Zander, 1992).

Selective revealing may be another strategy to deal with the tension between openness and appropriation. A firm will thus reveal only knowledge that is neither critical nor valuable for the firms' operations and competitive position and rather refrain from disclosing tacit or complex knowledge and resources that are of high competitive relevance (e.g., Polidoro and Toh, 2011). Furthermore, tacit and complex knowledge can be kept secret and provides promising high returns from excludability and inimitability (Rivkin, 2000; Teece, 1986).

In sum, the literature on external knowledge sourcing on the one hand and appropriation on the other hand provides five moderating factors that might influence the paradox of knowledge sharing and protection in the context of cooperation and open innovation. These are: (1) the characteristics and objectives of the collaboration, (2) the characteristics of the knowledge, (3) the role of IPRs, (4) the relationship between the collaborating partners, and (5) the environment in which the collaboration takes place (Bogers, 2011).

Overview

In this dissertation, I give an overview of the current state-of-the-art in each stream of literature presented above. Furthermore, I highlight the emerging debates and discussions in the innovation management, IP management, strategy and organizational learning literature and summarize the major findings for each field. I combine aspects, concepts and theories from different streams of research to advance our understanding because each field has the potential to inform the other. Taking an interdisciplinary approach offers me the opportunity to analyze relationships which have not been investigated before. In the first paper, I use different theories and frameworks from prior literature in organization theory and adapt and apply it to an innovation context. Here, I show how firms learn from product-related failure experience and adapt their innovation strategy accordingly. Based on the first part, the second paper analyzes whether firms learn from a failure of their appropriation strategy, particularly their legal copying or illegal infringement experience. Subsequently, I investigate whether following an open innovation strategy also associates with a greater risk of experiencing imitation. Article number four taps into the gap of how firm-level strategies determine a firm's choice of appropriation mechanisms. With the help of Bayesian Model Averaging, I am able to disentangle different determinants for both formal and informal appropriation strategies. Using an exploratory methodology shows that firms build their IP arsenal by employing and exercising different defensive strategies simultaneously. For the final two papers of this dissertation, I thus rather use an exploratory approach as both papers reflect first attempts to analyze the phenomena of interest with quantitative data.

Contribution of this dissertation

As this thesis follows an interdisciplinary approach, it addresses different audiences in the fields of innovation management, IP management, strategy and organizational learning.

The first two audiences benefit from insights into the paradox of cooperation and appropriation. This dissertation further informs strategy scholars about the connection between firm-level strategies and IP strategies. Organizational learning scholars get to explore that firms can also learn from own and others' product-related failure experiences such as product recalls and adapt their innovation strategy accordingly.

Learning from own and others' product-related failure is highly important.

This doctoral thesis investigates product-related failure as a further driver of organizations' decision making in innovation contexts. By providing a typology and a practical analysis tool for learning from product-related failure experience I show that product failure associates with different reactions in the short and long-run depending on whether the focal firm or other firms have made the initial failure experience. Thus, I contribute to the understanding of product failure as a further trigger of innovativeness and strategic change.

A differentiation between legal copying and illegal infringement is warranted.

The second paper of the dissertation makes a strong contribution regarding the change of company behavior due to experience with legal copying of IP or illegal infringement of IPR. I find opposite reactions for firms having experienced legal copying of their IP as compared to firms having experienced illegal infringement of their IPR which reinforces the conceptualization of two different independent variables for copying and infringement. Firms with unprotected IP will enter less R&D cooperation agreements while illegal infringement triggers more of such agreements. Hence, particularly the refraining from R&D cooperation after having their IP legally copied may decrease firms' performance and innovativeness in the long-run.

Imitation and IPR infringement can have severe consequences for both the infringed as well as the infringing firm.

Imitation and IPR infringement associate with severe reputation problems and litigation costs as well as high uncertainty about the success of the enforcement for the affected company. Firms may face a critical loss of sales caused if products are substituted with imitations, copies and counterfeits. Additionally, image and reputation damages often occur when the customer experiences uncertainties about the authenticity of a product which in turn weakens the customer's confidence in the well-known brand.

Moreover, an intensive and time-consuming search for imitations, copies and counterfeits on the market associates with high transaction costs in the form of search costs. Thus, the costs and benefits of such a strategic search can have an impact on the actual damage observed. Damage and costs frequently play a role regarding the investment budgets for the innovation or technology at stake. If a company A, for example, incurred high R&D costs for a new product or technology (which is quite common) and another company B 'invents around' or develops an extension to the existing technology of the company without any major problems, then A had greater costs than B and may even not be compensated with higher profits, especially if company B enters the market fast or could noticeably improve the technology compared to A.

In sum, there are three major damages a firm may experience caused by imitation, copying and infringement: financial, reputation and enforcement costs which emphasize the importance of research in this area. It is particularly important for firms to understand how to avoid infringement and imitation and how to deal with it once it has experienced legal copying or illegal infringement. This present dissertation provides some initial insights into these detected needs.

Moreover, firms can accidentally infringe upon other firms' IP due to obscure patent portfolios, thickets and fences. Therefore, firms need to be aware of the risks and costs associated with infringing other firms' IP. Otherwise initial R&D investments might be lost and further costs induced due to litigation and lawsuits by other entities. All these problems show and emphasize the importance to analyze and investigate firm behavior once having been affected by imitation and IPR infringement. This thesis provides insights into this phenomenon and provides strategies to cope with these incidences.

A further driver of imitation.

As seen by the costs of imitation above, it is particularly important for firms to understand the drivers of these damages. Furthermore, this thesis contributes to our neglected understanding of the determinants of imitation. It shows that firms' open innovation activities may be a further trigger of experiencing imitation.

Intellectual property rights increasingly serve strategic purposes.

A dense and obscure thicket of patents as well as the patent surge in the 1980s show that firms increasingly rely on patents and other IPR to use them as a bargaining chip for cross-licensing deals or collaborations. Thus, in particular industries such as in information and communication technologies (ICT) and semiconductors, IPR rather serve strategic purposes than as mere incentive for innovation or as a temporary monopoly to exclude others from using the invention.

Moreover, firms can accidentally infringe upon other firms‘ IP due to obscure patent portfolios, patent thickets and fences. Therefore, firms need to have a valid defensive IP strategy to deal with situations of mutual hold-up and to retain freedom to operate because otherwise initial R&D investments might be lost.

In sum, my dissertation thesis does not provide a comprehensive theoretical framework to explain all aspects of the relationship between open innovation and appropriation. It is rather a contribution to the broad realm of innovation management and strategy by advancing research in certain areas pointed out above.

At this point, I would like to acknowledge the comments and suggestions from anonymous reviewers, journal editors and conference participants. All papers of this thesis were read and commented by other researchers in the respective field and the improvements rest entirely on the shoulders of the voluntary reviews and feedback of great scholars. I am truly grateful to the scientific community and I would like to representatively thank those scholars whose names I know: Terry Amburguey, Ashish Arora, Mary Benner, Knut Blind, Xavier Castaner, Henry Chesbrough, Andy Cosh, Kristina Dahlin, Bernd Ebersberger, Henrich Greve, Christoph Grimpe, Anne-Marie Großmann, Marko Hekkert, Martin Kilduff, Mette Praest Knudsen, Tobias Kretschmer, Keld Laursen, Henry Lopez-Vega, Mark Lorenzen, Valeria Lorenzi, Orietta Marsili, Victor Meyer Jr., Peter Neuhäusler, Elena Novelli, Simone Ostermann, Fred Oswald, Joanne Oxley, Frank van Rijnsoever, Ammon Salter, Deepak Somaya, Juliane Teller, Bram Timmermans, Philip Ueno, Wim Vanhaverbeke, Theresa Veer, Ivanka Visnjic, Joel West, Ezra Zuckerberg. Furthermore, I would like to use this opportunity to thank all anonymous reviewers, the participants of the Colloquium on Innovation Research at TU Berlin and of the numerous conferences I had the honor to present my research at.

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Your Fault or Mine? The Impact of Organizational Learning from Product-related Failure on Innovation Strategy

Abstract

Organizational learning has been an important topic for the field of organization theory scholars but it is somewhat underexplored in the innovation management literature. I provide a typology and a practical framework to analyze organizational learning from product-related failure experience and its impact on strategic decision making.

I include and combine different theoretical approaches from organization theory literature focusing on learning from experience, learning from failure and learning from rare events. Although the literature review reveals that several barriers to effective learning from failure exist, I show that firms will learn more from others' product failure experience in the short-run than from their own product failure experience. This paper provides two insights. Firstly, firms incorporate own and others' product failure experience in their strategic decision making. Secondly, they will adapt their innovation strategy based on a preliminary conscious reflection, sensemaking and cause analysis of the failure. I also discuss a practical application of dealing with and avoiding failure. Furthermore, my findings have implications for practitioners and scholars in innovation management. Hence, the paper identifies promising future research directions in the field of organizational learning within the area of innovation management.

Contents

‘You can bet no one makes that mistake any more!’
(CEO of a mechanical contractor)[1]

1. Introduction

Organizations face many minor as well as major failure situations – whether externally or internally caused – in their daily operations. Furthermore, firms are continuously exposed to success and failure experiences right from the foundation and throughout their life cycle. Some of these experiences associate with more severe consequences for the organizations’ routines, employees and performance. A recent well-known example of product-related failure is the Boeing Dreamliner battery systems incident. The batteries caught fire and were the reason for a three months grounding of the 787 aircraft which caused severe security and reputation consequences for the Boeing company. Similar examples are product recalls of car manufacturers or consumer goods producers which – depending on the reason for the recall – can damage a good reputation and lead to a decline in the brand’s market share and the long-term sales on a larger scale. These prominent examples show how firms deal with and learn from such failure experiences can significantly influence whether they persist and succeed. Thus, for surviving or developing a competitive advantage, firms increasingly depend on improvement and change calling for a continuous learning process from any new and unfolding innovation journey (van de Ven et al., 1999).

Two questions arising from these examples are: How do firms effectively deal with product-related failure experience? Are there any long-term impacts, such as the change or new alignment of the firm’s innovation strategy? Because failure involves the alignment – or misalignment – of the organization and its environment, it is, by definition, about strategy (Sheppard and Chowdhury, 2005). Thus, failure and strategic change are inextricably linked.

Although there are various frameworks, concepts and theories on organizational learning, three major streams of literature have emerged from prior research dealing with learning from experience, learning from failure and learning from rare events. Extant research is mainly based on studies of particular industries (railroad, mining, airlines or banking industries) (e.g., Baum and Dahlin, 2007; Haunschild and Sullivan, 2002; Kim and Miner, 2007; Madsen, 2009) or links different aspects and dimensions of the experience concept such as learning from prior alliance experience, heterogeneity and recency of an experience to various performance or outcome indicators implicitly assuming that organizational learning occurs.

A growing amount of learning studies show that organizational failures, such as product-related accidents and incidents are an important promoter of organizational learning and change

1 Make no mistake, Inc. Magazine, June (1989), p. 105.

(Greve, 1998; Miner and Anderson, 1999; Sitkin, 1992). Some studies use rare and severe disastrous events to show that organizational learning is taking place (Christianson et al., 2009; Starbuck and Milliken, 1988).

Notwithstanding, extant research reveals that there are several barriers to effective learning from failure (Baumard and Starbuck, 2005; Cannon and Edmondson, 2005). Organizations may fail to learn from failure as a consequent failure analysis does not happen or is ineffective – even in complex organizations like hospitals, where human lives are at stake (Edmondson, 2011). This notion is supported by some scholars who are doubtful about whether companies (e.g., airlines) can learn from their prior product-related failure experiences (e.g., crashes and accidents) (Haunschild and Sullivan, 2002). Nonetheless, safety records show that accident rates have significantly reduced in the past decades (Haunschild and Sullivan, 2002). This suggests and underlines the ability of organizations to learn from product-related failure experience.

In sum, prior literature shows that failure may induce learning on the one hand but several barriers simultaneously impede learning to happen on the other hand. Organizations may even be prone to do the same mistake again if no learning has occurred or the failure is ignored (Cannon and Edmondson, 2005). Therefore, it is questionable whether companies adjust and improve their decision making processes and innovation strategies due to product-related failures. Furthermore, an important question remains regarding the conditions under which failure experience will be beneficial and lead to valuable learning outcomes. Particularly vicarious learning (i.e., learning from other firms' failure) and industry regulation play a major role in the context of learning from product failure.

In innovation management, these issues remain underexplored and in addition there is a lack of an analytical framework for this process of organizational learning from product-related failure in the context of innovation strategy.

In this paper, I investigate how organizations learn from prior product-related (product recall and product imitation) failure experiences and incorporate them into their decision making regarding their innovation strategy. I develop a typology and a practical framework to analyze the impact of product-related failure experience on company behavior and shed more light onto the black box of organizational learning reflected in firms' adaptation of their innovation strategies. This study informs innovation management scholars as it investigates product-related failure as further driver of organizations' decision making in innovation contexts. I would like to provoke reflection in researchers as well as practitioners. For the former, I would like to encourage and stimulate future work on organizational learning in the innovation management literature and for the latter, I will identify opportunities for managerial action regarding effective failure detection, cause analysis and adaptation. This framework can be used as an analysis tool to improve decision making processes and action plans after an organization has experienced a product failure situation.

The remainder of this article is structured as follows. First, I provide an overview of current and relevant concepts and frameworks in organizational learning to develop a typology and an analysis tool for analyzing the relationship between product failure experience, organizational learning and decision making in innovation settings. The article concludes by describing and discussing the results of the theoretical analysis and by providing implications for management and research.

2. Literature review

Organizational learning mechanisms inside organizations have become very well researched topics due to practical importance and the availability of better research methods (e.g., Argote and Todorova, 2007). Moreover, knowledge transfer, the ability to learn and be innovative is critical to the performance and long-term success of organizations (Argote and Miron-Spektor, 2011).

Prior work on learning from experience, e.g., learning from managerial experience (Holman et al., 1997; Kayes, 2002; Kolb et al., 1986), learning from alliance experience (Gulati, 1995; van de Vrande et al., 2009; Vanhaverbeke et al., 2002; Villalonga and McGahan, 2005; Wang and Zajac, 2007; Zollo and Reuer, 2010), learning from acquisition experience (Haleblian and Finkelstein, 1999; Hayward, 2002; Zollo, 2009), learning from contracting experience (Mayer and Argyres, 2004; Vanneste and Puranam, 2010), learning from entrepreneurial experience (Bruneel et al., 2010; Corbett, 2005; Holcomb et al., 2009) and learning from experience regarding organizational change (Hendry, 1996) has received considerable attention. These studies usually assume and find a positive relationship between learning from experience and various performance indicators.

Another stream of literature deals with learning from failure, e.g., business failure (Shepherd, 2003; Thornhill and Amit, 2003; Ucbasaran et al., 2011), alliance failure (Ariño and de la Torre, 1998), project failure (Shepherd et al., 2011), automotive product recalls (Haunschild and Rhee, 2004), aircraft incidences (Haunschild and Sullivan, 2002) and train crashes (Baum and Dahlin, 2007).

Researchers have investigated organizational learning from failure in diverse areas like the vehicle industry (Haunschild and Rhee, 2004; Madsen and Desai, 2010), natural disasters (Arslan and Korkmaz, 2007; Meyer, 2012), the bank industry (Kim and Miner, 2007), health care (Tucker and Edmondson, 2003), the newspaper industry (Muehlfeld et al., 2012) or mechanical engineering (Davidson and Labib, 2003). In contrast to the literature on learning curves and learning from experience, failures trigger more non-monotonic learning processes (Kim et al., 2009).

Learning from rare events has been a third major research concept – acknowledged by a special issue in Organization Science in 2009. Studies focusing on rare events demonstrate that rare events can initiate a learning process in various research settings such as the Fukushima nuclear power disaster, mining accidents and terrorism attacks. The actual effect however depends on the organization's perception of the rare event and its willingness and ability to incorporate this event into change. The potential relevance and impact of the rare event will drive the magnitude and scope of the learning process that follows from it (Lampel et al., 2009).

TABLES 1-3 summarize the key articles for each of the three streams highlighted in the literature.

Table 1. Overview organizational learning from experience by research setting and context[2]

Research Setting and Context	Key Citations
Contracting	Anand and Khanna, 2000; Mayer and Argyres, 2004; Vanneste and Puranam, 2010
Biotechnology	Jain, 2013
Banking	Kim et al., 2009
Education	Kolb and Kolb, 2005; McMullan and Cahoon, 1979
Strategic alliances, collaboration, interfirm exchanges	Anand and Khanna, 2000; Beckman and Haunschild, 2002; Dekker and van den Abbeele, 2010; Gulati, 1995; Hoang and Rothaermel, 2005; Holmqvist, 2004; Mulotte, 2013; Sampson, 2005; Simonin, 1997; van de Vrande et al., 2009; Vanhaverbeke et al., 2002; Villalonga and McGahan, 2005; Wang and Zajac, 2007; Zollo and Reuer, 2010
Hazardous, complex organizations	Carroll et al., 2002
Film industry	Miller and Shamsie, 2001
Administration	Nass, 1994
Aircraft	Mulotte, 2013
Shipbuilding	Thornton and Thompson, 2001
Extreme performance	Kim et al., 2009
Acquisition	Baum et al., 2000; Haleblian and Finkelstein, 1999; Hayward, 2002; Zollo, 2009
Entrepreneurship	Bruneel et al., 2010; Corbett, 2005; Deakins and Freel, 1998; Holcomb et al., 2009
Learning curves	Argote, 2013; Dorroh et al., 1994; Epple et al., 1991; Jain, 2013; Lieberman, 1987
Managerial experience	Holman et al., 1997; Kayes, 2002; Kolb et al., 1986; Miller and Shamsie, 2001; Ng et al., 2009
Industry experience	Ingram and Baum, 1997
Software development	Fong Boh et al., 2007; Holmqvist, 2004; Mulotte, 2013
Vicarious Learning	Argote et al., 2000; Baum et al., 2000; Bruneel et al., 2010; Offerman and Sonnemans, 1998; Thornton and Thompson, 2001
Business strategy	Starbuck, 1993
Product development capabilities	Eggers, 2012a
Organizational change	Fiol and Lyles, 1985; Hendry, 1996; March, 1981
Conceptual	Argote and Miron-Spektor, 2011; Baker, 2005; Crossan et al., 1999; Herriott et al., 1985; Huber, 1991; Kolb and Fry, 1974; Kolb, 1984; Kolb, 1981; Levitt and March, 1988; March and Olsen, 1975; March et al., 1991; Raelin, 1997

2 Search topics included 'learning from experience', 'experiential learning' and 'organizational learning + experience' on the ISI Web of Knowledge, Google Scholar and Ebscohost databases.

Table 2. Overview organizational learning from failure by industry and research setting[3]

Industry	Key Citations
Aviation	Arnaldo and Gómez, 2011; Catino and Patriotta, 2013; Choularton, 2001; Davidson and Labib, 2003; Dombrowsky, 1995; Haunschild and Sullivan, 2002
Automotive	Boyce and Geller, 1999; Haunschild and Rhee, 2004; Kim, 1998; Madsen and Desai, 2010; Wilson, 2010
Telecommunications	Baumard and Starbuck, 2005
Banking	Huang et al., 2003; Kim and Miner, 2007
Health care	Edmondson, 2004; Lu et al., 2005; Tucker and Edmondson, 2003; Tucker et al., 2007; Tucker and Spear, 2006; Walshe, 2003; Walshe and Shortell, 2004; Waters-Wood et al., 2012
Biotechnology	Katchalski-Katzir, 1993
Pharmaceuticals	Azoulay et al., 2010; Magazzini et al., 2012
Chemicals	Carroll, 1998; Myers et al., 2007
High-tech industry	Chiesa and Frattini, 2011; Eggers, 2012b; Ernst, 1998; Shrivastava et al., 1988
Trains	Baum and Dahlin, 2007
Tourism	Baum and Mezias, 1992; Baum and Ingram, 1998; Ritchie, 2004
Newspaper	Amburgey et al., 1993; Muehlfeld et al., 2012
Oil and natural gas	Choularton, 2001; Desai, 2010
Construction	Lourenço et al., 2007; Love et al., 2011; Yates and Lockley, 2002
Computer systems, software, internet	Collins and Bicknell, 1998; Spafford, 2003; Välikangas et al., 2009
Steel	Collinson, 1999
Services	Darr et al., 1995; DeWitt and Brady, 2003; McCollough et al., 2000; Smith et al., 1999; Tax and Brown, 1998
Research Setting and Context	Key Citations
New product development	Adams et al., 1998; Chiesa and Frattini, 2011; Collinson and Wilson, 2006; Eggers, 2012b; Griffin and Page, 1996; Hlavacek et al., 2009
Projects	Shepherd and Cardon, 2009; Shepherd et al., 2009; Shepherd et al., 2011; Williams et al., 2005
Joint ventures, inter-organizational	Ariño and de la Torre, 1998; Miner et al., 1999
M&A	Weber and Camerer, 2003
Nuclear repository and regulation	Carroll, 1998; Freudenburg, 2004

3 Search topics included 'learning from failure', 'learning from mistakes' and 'learning from errors' on the ISI Web of Knowledge, Google Scholar and Ebscohost databases.

Education and child protection service	Elliott, 2009; Knowles and Hoefler, 1989; Shepherd, 2004
Customer defection	Reichheld, 1996
Product recalls	Barber and Darrough, 1996; Chao et al., 2009; Chen et al., 2009; Dawar and Pillutla, 2000; Haunschild and Rhee, 2004; Kalaignanam et al., 2013; Marsh et al., 2004; Miller and Littlefield, 2010; Souiden and Pons, 2009; Thirumalai and Sinha, 2011; Zhao et al., 2011
Entrepreneurship and business failure	Cope, 2011; Gunther McGrath, 1999; Hoetker and Agarwal, 2007; Shepherd, 2003; Thornhill and Amit, 2003; Ucbasaran et al., 2011
Leadership	Carmeli and Sheaffer, 2008; Ford, 1981; Finkelstein, 2006; Hirak et al., 2012; Hodgkinson and Wright, 2002; Mellahi, 2005; Pearson and Clair, 1998; Spear, 2004
Strategy failure	Chuang and Baum, 2003
Workplace discrimination and diversity	James and Wooten, 2006; Wooten and James, 2004
Natural disasters	Arslan and Korkmaz, 2007; Hanson, 2005; Meyer, 2012; Yamamura, 2010
Policy failure	Judge, 2006; Liagouras, 2010; May, 1992
Football stadia disasters	Elliott and Smith, 1993; Elliott and Smith, 2006
Psychology, social capital and behavior	Carmeli, 2007; Carmeli and Gittell, 2009; Ivancic and Hesketh, 2000; Krohne and Hock, 1993; Niiya et al., 2004; Shepherd, 2004
Technology transfer	Zheng et al., 2013
Risk or crisis management	Carmeli and Schaubroeck, 2008; Labib and Read, 2013; Paltrinieri et al., 2013
Analyzing organizational learning from failure; barriers to learning	Baumard and Starbuck, 2005; Cannon and Edmondson, 2005; Carroll and Fahlbruch, 2011; Pidgeon and O'Leary, 2000; Smith and Elliott, 2007

Table 3. Organizational learning from rare events by research setting and context[4]

Research Setting and Context	Key Citations
Collapse of museum roof	Christianson et al., 2009
Mining accident	Madsen, 2009
Columbia and Challenger disasters	Starbuck, 1993; Starbuck and Farjoun, 2005; Starbuck and Milliken, 1988
Crisis at Nova Nordisk	Rerup, 2009
Terrorism	Dawes et al., 2004; Oetzel and Oh, 2013; Yechiam, 2005
Nuclear power disaster	Marcus and Nichols, 1999
Acquisition success	Zollo, 2009
Foreign entry and exit	Oetzel and Oh, 2013
Political learning from rare events	Carpenter, 2004; Kapucu, 2008
Risk estimation, forecasting	Barron and Yechiam, 2009; Camilleri and Newell, 2011; Erev et al., 2008; Goodwin and Wright, 2010
Middle managers' role	Beck and Plowman, 2009
Conceptual	Garud et al., 2011; Lampel et al., 2009; March et al., 1991; Starbuck, 2009

In sum, learning from experience rather associates with learning curves and as a result, organizations' performance improvements whereas learning from failure or rare events does not necessarily entail better or improved performance but for example changes in cognition, routines or processes.

Particularly, product failure is a major topic in management science (Chao et al., 2009; Thirumalai and Sinha, 2011) and marketing studies (Chen et al., 2009; Kalaignanam et al., 2013; Zhao et al., 2011) but has not, yet, attracted research in innovation management as another source of innovativeness and change. Furthermore, a few studies have investigated product recalls and product failure as a trigger for organizational learning (Haunschild and Rhee, 2004; Kalaignanam et al., 2013; Zhao et al., 2011). Learning from product failure is important as it associates with severe reputation and image consequences for the affected firm and can harm the firm in the long-run. Particularly product defects (e.g., in the automotive industry) can lead to serious harm or accidents. Moreover, product-related failures associate with substantial present and future costs for a company which necessitate a deeper understanding of how to deal with own and others' product failure experiences. Learning from other firms' failure (i.e., vicarious learning) and industry regulation play a major role in the context of learning from product failure.

As a result, firms may have the goal to learn from own as well as others' prior product-related

4 Search topics included 'learning from rare events', 'learning from unusual events', 'learning from unexpected events', 'learning from rare crises' and 'learning from infrequent events' on the ISI Web of Knowledge, Google Scholar and Ebscohost databases.

failure, adjust processes and routines accordingly to eventually prevent the recurrence of the failure. For the purpose of this paper, I explicitly focus on two types of product failures: product recalls and product imitation. Product recalls refers to the (in)voluntary process of firms to call back products due to (potentially) safety or health jeopardizing defects or missing compliance with mandatory or voluntary standards (Chen et al., 2009) whereas product imitation associates with a defect that unintentionally facilitates the unauthorized usage of product technology, brands, features or design.

A few studies emphasize the fact that organizations do learn from prior product failure experience (e.g., Haunschild and Rhee, 2004; Kalaignanam et al., 2013; Zhao et al., 2011). In the case of product-related failure successful learning thus implies the prevention of a similar failure experience (increased reliability) as well as the adaptation of the innovation strategy. In other words, a change of the innovation strategy in the case of product failure refers for example to a change in the cooperation strategy for imitation or an adaptation of product development processes for product recalls. The impact of product-related failure on firms' innovation strategy has not explicitly been investigated, yet.

However, anecdotal evidence reveals the opposite highlighting that barriers to effective learning from product failure may exist. In the U.S. market between 2005-2010, Toyota encountered several product recalls across a number of car models due to reoccurring problems with for example the floor mats or the accelerator pedals[5]. Particularly, the Toyota case shows that similar mistakes can reoccur. Although, the notion that organizations and individuals working in them should learn from failure has large support, yet, organizations that systematically learn from them are rare. Organizations frequently fail to transfer these failures into knowledge or behavior and hence, no learning occurs (Tucker and Edmondson, 2003). In the case of product-related failure, the causes of the failure may be ambiguous preventing a systematic failure analysis and rectification.

Not necessarily limited to product failure, the same is true for organizations in financial services, pharmaceutical, health care and aerospace which fail to learn from failure (Edmondson, 2011). In a well-publicized case of failed learning in a major hospital, two women died in quick succession due to a massive overdose of a chemotherapy drug in one of the world's most prestigious cancer hospitals. One patient died, and the other suffered permanent heart damage.[6]

Taking these examples, it is questionable whether companies adjust and improve their decision making processes and innovation strategies due to failure experience and particularly product-related failure experience.

5 http://pressroom.toyota.com/safety-recall, accessed on 01/22/2014.

6 http://webmm.ahrq.gov/perspective.aspx?perspectiveID=3, accessed on 12/29/2013. http://www.nytimes.com/1995/03/24/us/big-doses-of-chemotherapy-drug-killed-patient-hurt-2d.html?pagewanted=all&src=pm, accessed on 12/29/2013.

Edmondson (2011) argues that managers think about failure the wrong way ('as something bad') which is the reason that no learning takes place. Obviously, problems also arise if organizations ignore the experience or learn too late.

The literature review shows that on the one hand there is no clear evidence whether and how organizations learn from failure in general and product-related failure in particular. Moreover, the relationship between learning from product-related failure and decision making in an innovation context is underexplored. This paper tries to close this gap by developing a typology and a practical framework to analyze how learning from product-related failure transforms a firm's innovation strategy. I apply different frameworks and theories from organization theory and innovation management to shed more light onto the black box of organizational learning from product-related failure.

Despite conflicting evidence, I show that organizations – if they systematically and rationally analyze product failure experiences and ultimately learn from it – should be able to adapt their innovation strategy.

3. Theoretical background

The following paragraphs provide an overview of current concepts and frameworks adapted from organization theory which form the basis for the typology and the following practical decision making tool developed in the next paragraphs of this paper.[7]

3.1. Organizational learning

Organizational learning does not occur in a vacuum (Glynn et al., 1994); it takes place in an organization and the broad context the organization is embedded in. Although there is no overarching definition of organizational learning, yet, it is commonly understood as a 'process whereby knowledge is created through transformation of experience' (Kolb, 1984, p. 38). Taking a cognitive approach to learning, it has been defined as changes in knowledge (Fiol and Lyles, 1985) or changes in individuals' cognitive structures (Grant, 1996). In other approaches, learning is described as changes in the range of potential behaviors (Huber, 1991), as changes in organizational routines (Levitt and March, 1988; Nelson and Winter, 1982) or as changes in performance (Argote, 2013). Although these definitions share that some change in the organization occurs they differ regarding where the change manifests itself. According to Levitt and March (1988), organizations learn when they encode 'inferences from history into routines that guide behavior' (p. 319). Hence, organizational learning is a change in the organization that bases on experience.

Research on organizational learning does not directly measure any changes in cognition and behavior[8], but investigates whether experience systematically changes organizational routines, processes or outcomes (e.g., performance). Thus, in line with Zheng et al. (2013), I do not claim that all learning processes generally lead to beneficial results; superstitious or erroneous learning, for example, can lead to poor results (Levitt and March, 1988; Zollo, 2009). Nonetheless, in this study, I build on prior research examining the link between experience and valuable outcomes. In this context, 'learning' refers to performance improving learning (Zheng et al., 2013).

In general, prior literature on organizational learning reveals that there is a large amount of studies on learning curves which indicates that companies either improve efficiency and productivity or decrease costs due to repeated tasks, the development of routines and/or increasing (frequent) experience. Thus, learning curves usually associate with a positive monotonic relationship between

7 As the focus of this paper is on product-related failure, I explicitly concentrate on learning from experience, learning from failure and learning from rare events because these concepts are closely linked to each other as well as to the concept of product failure. Furthermore, I would like to further disentangle these different streams of research from a vast amount of literature on organizational learning in general.

8 Even knowledge in general is difficult to measure. Knowledge has been measured directly with the help of questionnaires, interviews, and verbal protocols or indirectly based on performance indicators. However, this approach cannot capture tacit aspects of knowledge. Therefore, there are many problems recording changes in knowledge, cognition or behavior (Argote and Todorova, 2007).

the sum of experience and performance outcomes (Argote et al., 1990; Kim et al., 2009). According to Kim et al. (2009), I focus more on learning from less linear experiences as these scholars also '[…] explicitly consider the specific features of success and failure and propose that this assumption [of monotonicity] does not necessarily apply to learning from experience' (Kim et al., 2009, p. 958).

Another debate in conceptualizing organizational learning relates to the level of analysis at which it happens. Individuals in organizations usually are the transmitters through which learning occurs however it does not necessarily imply that the organization as a whole has learned (Argote and Todorova, 2007). Thus, organizational learning additionally involves a multi-level spanning component (Levitt and March, 1988).

Because organizational learning begins with an event stimulating experience, organizational experience is discussed first.

3.2. The concept of organizational experience

There are different definitions and understandings of the concept of experience in the literature. In general, research discusses experience as something that is not visible a priori, something everybody is surrounded by, something that is always there (Kolb, 1984). Thus, experience rather comprises a novel observable event that just has to be discovered as such. I further define an experience as the state of having been affected by or gained knowledge through direct observation of facts or participation in events (Merriam Webster Dictionary)[9].

These events are consciously observed eventually leading to a shared understanding of them within the organization. This experience can be perceived as being positive or negative, and even positive deviations present opportunities for learning.

However, in the context of this paper, I explicitly focus on failure experiences because measured against a firm's whole product portfolio, product-related failures are relatively harmful events with severe consequences. Particularly, failures are assumed to impose a disruption of the organization's routines (Lampel et al., 2009). Thus, for this article, experience is reflected in events that are new to the firm, (partly) unknown or a deviation from expected or desired results since it would not be perceived or interpreted as an experience otherwise.[10] Hence, experience can be different for each context.

In line with Cannon and Edmondson (2001), this definition also comprises both avoidable mistakes and the inevitable negative consequences of R&D, daily business and risk taking. There

9 http://www.merriam-webster.com/dictionary/experience, accessed on 12/28/2013.
10 At least part of the experience event has to be new to the firm and the fact that it is new or a part of it is assumed to trigger a learning process.

are different forms and contexts in which an organization acts on and makes an experience. After an experience has been made, this experience has to be classified and categorized.

Prior research discusses different dimensions in the context of experiences (e.g., organizational, content, spatial and temporal) which can also interact (Argote et al., 2003; Argote and Todorova, 2007; Mayer and Argyres, 2004) (see TABLE 4).

Experiences can be acquired internally (directly) or externally (indirectly) from other units and firms whereas the latter type is termed 'Vicarious Learning' (Levitt and March, 1988).[11] Experience can also be acquired as a result of a systematic trial and error process or coincidence (Argote and Miron-Spektor, 2011). An experience can be made about tasks or about members of the organization. Experience can be ambiguous or straightforward. Routine tasks as well as new tasks can result in experience. Furthermore, an experience can be acquired within or from similar or different geographical contexts. Another dimension of experience refers to its frequency, pace and timing (prior versus concurrent versus after). Rarity is another dimension of experience, I will discuss in more detail in the last paragraph of this chapter.

Table 4. Dimensions of organizational experience

Success (positive) and failure (negative)			
Dimensions			
Spatial	*Temporal*	*Content*	*Organizational*
Geographicaly concentradet or dispersed	Frequent or **rare**	Tasks, members	Direct or indirect
	Before, during, after task performance	Ambiguous or easily interpretable	Internal or external
	Fast or slow	Novel or repeated tasks	Naturally occuring or through experiments

FIGURE 1 gives an overview of the concept of organizational experience, its occurrence across levels and different frameworks and concepts identified and used by prior research to explain the phenomenon of interest.

11 This form of learning is often referred to as 'knowledge transfer' (Argote and Todorova, 2007).

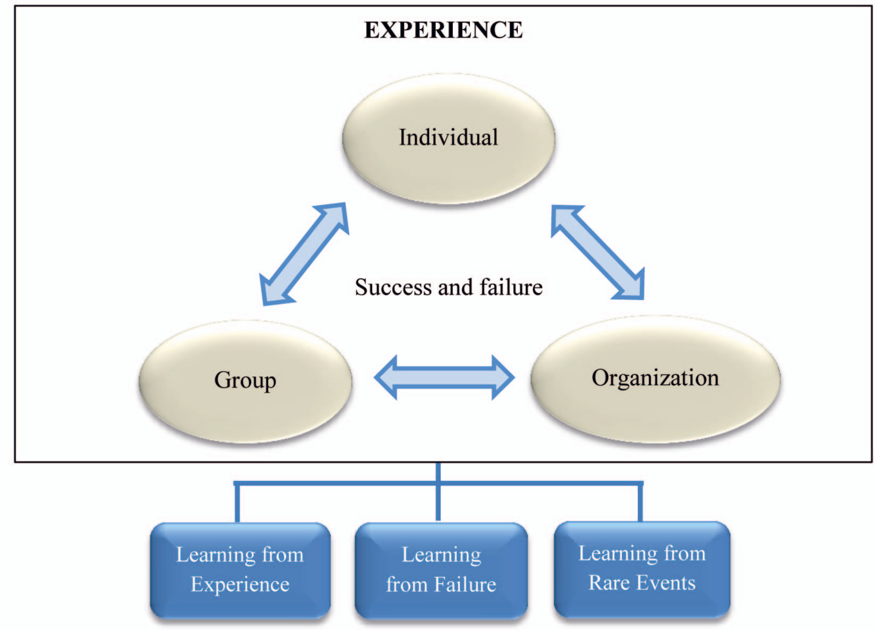

Figure 1. The concept of organizational experience

In the following paragraphs, I will provide an overview of these frameworks and concepts and show commonalities and differences between them.

3.3. Organizational learning from experience to knowledge framework

Another theoretical starting point for this article is Argote and Miron-Spektor's (2011) work linking organizational learning to an organization's context. These authors assert that organizational learning is a process that ultimately changes the organization's knowledge base over time as the organization acquires experience (Argote and Miron-Spektor, 2011). Hence, experience is converted into knowledge that in turn may affect future decision making.

The authors differentiate between an environmental context which comprises elements outside the boundaries of the organization such as competitors, clients, institutions, and regulators and an organizational context. According to the framework by Argote and Miron-Spektor (2011), an organization's context (e.g., structure, culture, technology, memory, goals, incentives, strategy, and interfirm relationships) influences the way an experience transforms into knowledge.

This context can be further distinguished into an *active* element (e.g., organizational members, tools and tasks) through which learning occurs and a *latent* element (e.g., trust between members, psychological safety or superordinate identity) that in turn shapes the active context (e.g., employees in an organization behave differently under flat hierarchies compared to strong hierarchies). The latent context influences individual members of the organization, their usage of different tools and their task choice. Thus, active and latent organizational contexts associate with different action patterns: members and tools actively execute and accomplish duties and functions (endeavors, tasks, purposes). Contrasting, the latent context refers to a passive component and thus does not associate with direct action steps but implicitly influences the activities within the active context of the organization.

The organization's latent context, on the one hand, shapes the learning process but knowledge acquired as a product of learning from experience, on the other hand, is integrated in the organizational context and in turn, modifies the context. The active context – organizational members, tools, and tasks and their networks – can store knowledge that thus becomes part of the organizational memory (Darr et al., 1995; Walsh and Ungson, 1991). Moreover, knowledge can also be embedded in the organizational culture or identity and hence, in the organization's latent context (Weber and Camerer, 2003). Hence, the relationship between experience and knowledge describes an interactive, circular process. Knowledge thereby represents the product of learning which is embedded in the organizational context and thus, affects future learning (FIGURE 2).

In sum, this framework predicts that organizational learning from experience manifests in the organization's context and interacts with the environmental context the organization is embedded in.

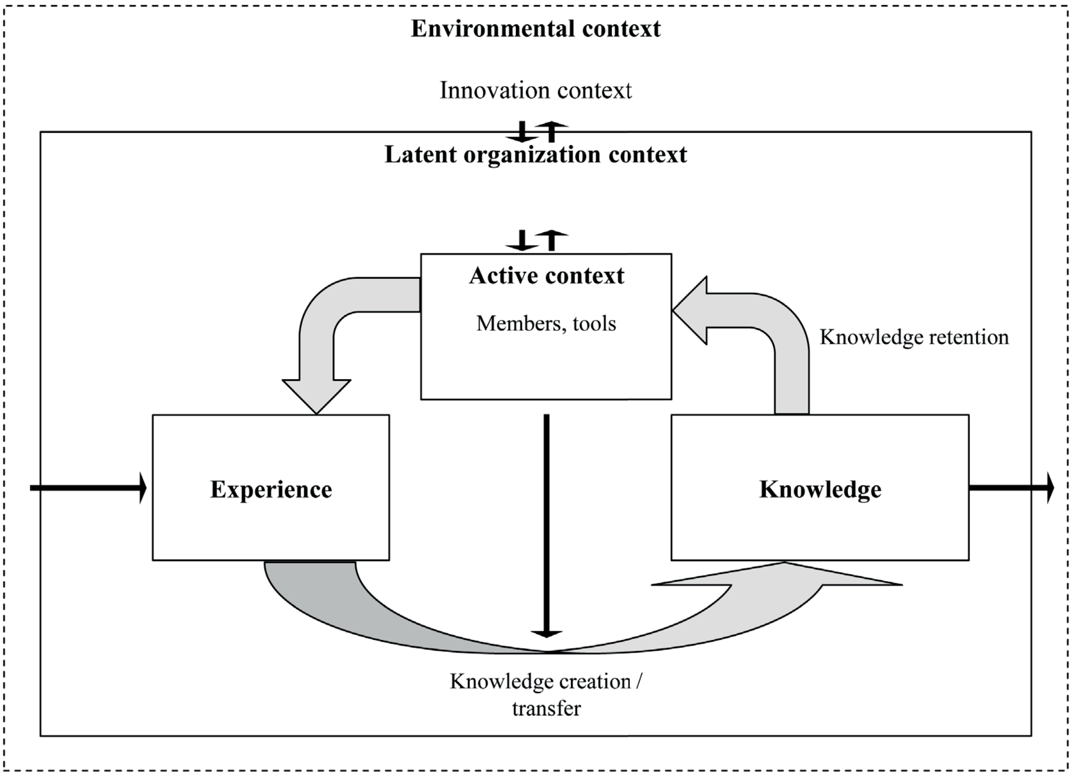

Figure 2. Learning from experience to knowledge framework
(Argote and Miron-Spektor, 2011, p. 1125)

3.4. Organizational learning from failure

An increase in large organizational failures such as the Columbia and Challenger Shuttle tragedies, the Concorde crash, the Fukushima nuclear disaster, and the Enron scandal justify the need of learning from failure (Cannon and Edmondson, 2001). Failure is a fact of life from which most organizations cannot escape, and the importance of understanding and learning from failure need hardly be stated (Wilkinson and Mellahi, 2005).

A special issue in Long Range Planning has acknowledged the importance of organizations' learning from failure. In general, failure, in organizations and elsewhere, is an outcome below the expected level or a deviation from expected and desired results (Greve, 2003). Deviations from expected results can be positive (success) or negative (failure), whereas both types provide occasions for learning. Yet, I explicitly focus on negative events because they present unique psychological and organizational challenges related with learning from them (Cannon and Edmondson, 2005). Furthermore, causes of organizational failure can be usefully split into two factors: external factors (e.g., catastrophic events and natural disasters such as fires, floods, earthquakes, hurricanes and wars) outside the control of management and organizational factors. However, given the aim and scope of this paper, I focus on organizational and individual-level factors and settings that can be influenced by the organization to avoid and/or learn from failure.

Organizational and management factors causing failure include a narrow management mindset or cognitive failure, protective mechanisms and delusional attitudes, information breakdowns and ineffective leadership practices (Finkelstein, 2006). Studies on learning from failure can broadly be differentiated into two groups: (1) roots of organizational failures and prevention of them and (2) effective learning from failures when they do occur.

A major stream of literature deals with companies learning from own prior failures (e.g., Baum and Dahlin, 2007; Shepherd et al., 2011) while another emphasizes learning from other organizations' failure experiences (vicarious learning) (Baum et al., 2000; Haunschild and Sullivan, 2002; Kim and Miner, 2007). In the context of airlines, Haunschild and Sullivan (2002) show that organizations acquire new knowledge from prior errors and incidents. A study that focuses on U.S. freight railroad industry leads to similar results (Baum and Dahlin, 2007). There are seminal works dealing with learning from failure in various industries such as automotive, health care, pharmaceuticals and services. Other studies highlight particular topics such as product recalls, business failure or new product development as important opportunities to learn from failure (e.g., Chao et al., 2009; Chiesa and Frattini, 2011; Eggers, 2012b; Haunschild and Rhee, 2004; Hlavacek et al., 2009; Hoetker and Agarwal, 2007; Miller and Littlefield, 2010; Shepherd, 2003; Ucbasaran et al., 2011).

In many disciplines such as sciences and engineering, it is widely accepted that organizations learn more and better from failures than from successes (Baum and Dahlin, 2007; Madsen and Desai, 2010; Shepherd et al., 2011). Nonetheless, Sitkin (1992) argues learning from failure is more effective than learning from success because failure motivates deeper search and richer understandings than success.

Additionally, there is evidence that many organizations fail to systematically learn from failure (Cannon and Edmondson, 2001). Depending on the size or the timing of identification of the failure it could already be too late to learn from it. Prior research of individual learning proposes that painful or poor outcomes usually stop present behaviors but at the same time do not cause change either, which challenges the assumption that failure necessarily entails behavioral change. Particularly, poorly performing companies generally do not alter their strategic orientations and have a poor habit of communication and hence do not learn from failures (Husted and Michailova, 2002; Starbuck, 2009).

Especially small failures can disclose early or initial weaknesses of a system and thus may point to or even prevent more severe incidences (Cannon and Edmondson, 2001). However, these are often not recognized. Moreover, there are several social as well as technical barriers limiting or even preventing an effective organizational learning process. Social barriers to organizational learning refer to strong psychological reactions, expectations and inherited instincts to blame others, deny or avoid disclosing mistakes. Technical barriers refer to an inadequate understanding of complex systems or technologies or a lack of the basic scientific 'know-how' and a resulting inability to thoroughly and systematically draw inferences from failures (Cannon and Edmondson, 2001).

In sum, literature emphasizes that organizations may learn from failure events but there are various barriers that impede an effective recognition, analysis and thus the opportunity to learn from failures.

3.5. Organizational learning from rare events

Some studies use rare and severe disastrous events with major consequences to show that organizational learning is taking place (Lampel et al., 2009) such as, e.g., the collapse of the roof of the Baltimore & Ohio Railroad Museum Roundhouse (Christianson et al., 2009), U.S. coal mining accidents (Madsen, 2009), and prior corporate acquisition success (Zollo, 2009). However, as these events are so unusual they pose challenges for interpretation (Argote and Miron-Spektor, 2011). Rare events are discontinuities assumed to disrupt current routines, thus expose weaknesses and strengths of an organization and eventually lead to new practices, structures and change (Lampel et al., 2009). As a result, rare events can also reveal unrealized behavioral potential. A rare event is often referred to as a disruptive intervention that unfreezes established patterns and reshapes organizational routines or transforms the organization's structure and strategy (Christianson et al., 2009). Broadly speaking, previous history as well as cognitive heuristics that are adapted to more routine events influence learning from rare events. As rare events happen per definition unpredictably, they also produce unexpected insights (Meyer, 1982). Therefore, learning from rare events associates with an emergent process of realizing useful lessons from experiences that could not have been predicted. Organizations invest a lot of limited resources and attention investigating disasters to derive 'lessons learnt' from these events which can have complex, ambiguous causes and are additionally shaped by selective and biased interpretation of outcomes. Learning from rare events comprises a higher level of uncertainty than learning from more frequent events because organizations have fewer relevant observations to compare them to (Starbuck, 2009). Thus, lessons learnt are highly dependent on how decision makers in different hierarchies of the firm make sense of these rare events (Weick, 1988). Learning from rare events is different from conventional approaches to organizational learning because the experience has not been encountered before, and hence does not fit into a recognized category of experience (Garud et al., 2011). These prominent approaches however define learning as a continuous improvement of knowledge based on enhanced reactions to already known categories of experiences (Argote, 2013; Argote and Todorova, 2007) which in turn renders learning from these unrecognized experience categories ambiguous and difficult.

Rare events are highly context-dependent suggesting that it is the organization or the individual that differentiate and define whether an event is 'rare' or not. Thus, they observe or directly experience an event as unusual – being something unique without a close equivalent or a deviation from common experience with a similar type of event. Therefore, an event that is rare for one organization can be ordinary for another (Lampel et al., 2009). Additionally, similar events can generate various lessons for different organizations. Based on the potential impact and the potential relevance of a rare event for an organization Lampel et al. (2009) propose a taxonomy identifying four types of learning; *transformative*, *reinterpretative*, *focusing*, and *transitory*.

Furthermore, prior literature reveals two views of rare events. The first view defines rare events as probability estimates, usually calculated from the frequency of the event. In this view, learning from such events is driven by the desire to prevent these events from recurring which in turn is contingent on developing an understanding of the causes of the rare event (Lampel et al., 2009). The second view defines rare events as opportunities for unique sensemaking based on the enacted salience of specific features of the rare events (Daft and Weick, 1984). This view emphasizes the importance for experiencing a single event 'richly' (March, 1991), i.e., as a unique experience with no reference to any estimates of probability that the event will recur. Research reveals that firms are prone to experience unusual, rare events when they fail to notice or ignore to act on weak cues that signal potential threats (Ansoff, 1975; Weick and Sutcliffe, 2013) which might be either due to that these weak cues are not recognized as signals of potential problems (Weick, 1995) or because firms do not possess enough capacity of the limited resource of attention to do so (Argote and Greve, 2007; Ocasio, 1997). Moreover, there might be observant individuals who have the capacity to understand the meaning of weak cues, but they do not have the influence, resources, or motivation to either raise their voice or take action themselves (Edmondson et al., 2001; Rerup, 2009).

Consequently, evaluating rare events creates opportunities to learn by transforming this experience into knowledge that can be stored in the organizational memory for future purposes (Garud et al., 2011; Zander and Kogut, 1995; Zollo and Reuer, 2010; Zollo and Winter, 2002). According to Lampel et al. (2009), learning from rare events triggers two reactions of companies: they either focus on forecasting, improvement and prevention of consequences when the event has a negative impact, and on repetition when the event has a positive impact.

4. Typology of learning from product failure experience in innovation contexts

The literature review and the theoretical background presented above reveal that firms face obstacles preventing them to effectively learn from product failure experience.

Therefore, two research questions arise: How do firms effectively deal with and hence learn from product-related failure experience?[12] Are there any long-term impacts, such as the change or new alignment of the firm's innovation strategy? I will particularly investigate these questions in the context of product failure and a firm's connected innovation strategy because such an event may have severe consequences for the firm's reputation, its competitive advantage and hence, long-term performance (Haunschild and Rhee, 2004; Zhao et al., 2011). In the worst case, product recalls may impact the stock market value of publicly traded firms due to a decline in investor confidence and their resulting unwillingness to continue financing the affected firm. Thus, the firm's fundamental existence may be at risk (Chen et al., 2009). Moreover, I assume that firms experiencing a product defect (followed by a product recall) will be more likely to re-evaluate their production processes and try to improve the product at stake resulting in new and better products and processes reflected in a change of innovation strategy. In this section, I therefore address how product failure experience may be reflected in a firm's innovation strategy. To do so, I build on the established distinction between learning from own failure experience and learning from other firms' failure experiences (Baum et al., 2000; Haunschild and Sullivan, 2002; Kim and Miner, 2007; Thornton and Thompson, 2001). In addition, I consider a strategic component in light of short-term versus long-term impact of product failure experience.

Combining these two dimensions results in the matrix depicted in FIGURE 3. Below, I explain the resulting four archetypes of learning from product failure experience and how they influence a firm's innovation strategy. I analyze firms' technological trajectories by focusing on whether a firm intends to create or change to a new path or rely and extend a current one. This typology shows the plurality of learning from product failure scenarios and refers to the perspective of the focal firm.

12 For the purpose of this paper, learning is understood as a change of the organizational knowledge base as reflected in an alignment of the firm's innovation strategy.

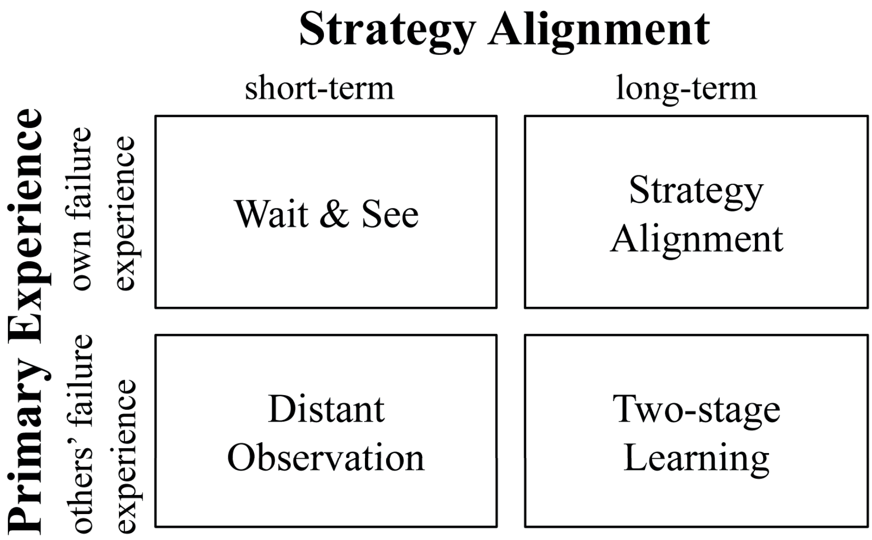

Figure 3. Typology with archetypes of strategic learning from failure experience

4.1. Wait and see (deferral or delay of trajectory change)

As per definition, a product failure event is a deviation from expectation[13], a firm will not act with precipitation after having experienced such an event. Firstly, the firm will have to perceive, classify and categorize the product failure experience.[14] Thus, the organization will wait before analyzing causes which led to the event. As the categorization and investigations will take time, the firm will not change its technological trajectory on short notice and without concrete proof whether the product failure can be attributed to the firm's current trajectory. Particularly, as failure is usually seen as something exceptional and as firms might expect that the same event will most likely not happen again in the near future, it will not change its current technological trajectory, instantly. Thus, the firm may decide to take a 'wait and see' approach while carefully monitoring the incidence and its consequences.

According to Cyert and March (1963), failure can stimulate behavioral innovation but this takes time and resources. Firms usually have a limited capacity of both which explains why product failure analysis can take up to several months. Depending on the size and causes of the product failure event, firms might want to investigate the reasons for this event for themselves and do not want to attract too much attention. Therefore, they will defer any change in their current strategy on the one hand to mislead competitors or other stakeholders and on the other hand, to disguise the product failure as the actual reason for the alignment of the innovation strategy.

13 Nonetheless, in some industries (e.g., automotive) the occurrence of product recalls may already be embedded in the organizations' expectations due to vigorous safety regulations.

14 A product recall will only be announced after concrete proof of the defect and its consequences. Moreover, a firm may adopt passive strategy in managing product recalls by trying to delay the announcement of a product recall as long as possible (Chen et al., 2009; Dawar and Pillutla, 2000; Laufer and Coombs, 2006).

Furthermore, decision makers' personal dissociation from failures and their association with successful innovation strategies and practices (correct or not) to their own abilities, further prevent initiation of change of their current trajectory. In extreme cases, especially when the product failure only had few negative results, any of these false or superstitious beliefs or biases that decision makers hold will be reinforced and that their learning will be influenced toward validation (Levinthal and March, 1993; Miller, 1999). Besides, depending on the strategic decision maker in charge, their personal biases might lead them to interpret the product failure not as a questioning to their chosen strategy but as an indication that they need to pursue it with greater resolve. In sum, in the short-run, this deferral strategy is easier to execute, cost-neutral and gives firms more time to conduct a proper cause-event analysis. Path dependence theory (Sydow et al., 2009) as well as empirical studies provide vigorous evidence that organizations tend to persist in strategies and courses of action they employed in the past (Amburgey and Miner, 1992; Kelly and Amburgey, 1991). As a result, the organization suffers from the so-called competency trap which describes organizations experienced with a given strategy holding on to that strategy, despite proof (e.g., product failure) that they should not (Chuang and Baum, 2003; Levitt and March, 1988).

4.2. Strategic alignment (change of trajectory)

Some failure events such as product defects (followed by a product recall) usually reveal weaknesses in the firm's current business or innovation strategies as described above. Thus, these product failures point out room for improvement and hence induce the firm to develop new strategies (Starbuck, 2009). After having analyzed and attributed causes for the failure, the organization can then implement new strategic actions leading to the creation of a new trajectory. As a result, product failure experiences can also lead to a competitive advantage especially if a firm is able to learn more effectively from their own failure events than its competitors. When these product failures have a major impact on the firm, there is clear motivation for the affected firm to draw lessons and make the necessary operational and cognitive adjustments.

The firm's decision makers will increasingly react to own product failure events, which they take not only as evidence of the inefficacy of the common strategy but also as proof (rightly or wrongly) of the correctness of their chosen strategy (Chuang and Baum, 2003). Chuang and Baum (2003) for example find support that the failure of a firm's naming strategy is a sign of poor performance that can motivate the firm to reevaluate its strategy.

Consequently, a firm's product failure should lead managers to reexamine the current innovation strategy stimulating exploratory search and leading the company to advance from the old trajectory in favor of new and improved technologies, components and products (Chuang and Baum, 2003).

Hence, prior research suggests that organizational learning from failures yields short-run handicaps but creates long-run benefits as in the long-run failure can be investigated more effectively, causes analyzed and attributed. Causes of product failure can be diverse but taking the Toyota example, defects can usually be traced back to particular parts, components, products, processes or suppliers. Avoiding a reoccurrence of the same or similar failure events requires the long-term effective analysis of causes, learning from them and the adaptation of the current innovation strategy. Depending on the cause of the product failure, Toyota may want to switch suppliers, initiate new external collaborations, invest in R&D to develop new and improved technologies and components which could even lead to patent applications. Sometimes a product failure can have severe consequences for the firm affected especially when it involves the firm's core or cash cow product. In extreme cases, the concerned firm may not have anything to loose anymore. Thus, a complete turnaround and adaptation of its innovation strategy can be seen as the last chance or resort.

4.3. Distant observation (adaptation of trajectory)

Another firm's product failure experience resulting in a product recall presents the opportunity for the focal firm to observe the affected company and its behavior from the distance.[15] By observing, managers can potentially learn a range of strategies, practices, and technologies produced by the ongoing explorations and failures of others in their industry (Levinthal and March, 1993; Levitt and March, 1988). To minimize the resulting negative impact and avoid high costs associated with product failure companies can actively reduce their chances of having a recall (Berman, 1999) by observing and learning from others' failure experience. Furthermore, firms are more likely to become aware of highly visible and salient product failures experienced by other organizations, and are consequently able to purposefully learn from them (Ocasio, 1997). Thus, high visibility of others' product failures creates attention and implies that it must have been a major failure event.

When examining accidents on U.S. railroads, Cyert and March (1963) find that organizations benefited less from their own direct experience and more from the indirect experience of other firms in the industry. Firms increasingly refer to other firms' experiences and actions for clues about how to interpret their own situation to reduce inherent uncertainty.

Furthermore, it should be emphasized that a firm can learn from external observation of others (maybe even about the causes of others' product failures) but a direct application and transfer to own processes and products as well as how to prevent its own demise is rather complex and thus, doubtful (Kim and Miner, 2007). Learning from self-derived inferences of observed product failure gives hypothetical but untried solutions and may lead firms to derive irrational assumptions about the causes and contexts of the observed failures (Huber, 1991). However, observing others' product failure may increase a firm's likelihood to engage in search activities and to actively interpret their

15 It should be notes that a firm will compare itself to those firms that it classifies as competing or operating in the same industry.

observations (Sitkin, 1992). Others' product failure experiences provide a hands-on example to evaluate origins and contexts of failures which in turn give a hint whether the focal firm might be subject to a similar fate (Kim and Miner, 2007). Consequently, a product failure by others can stimulate firms to apply the insights and lessons drawn from their observations assuming to lead to a focus on prevention of the same experience. Of course, this highly depends on the visibility of the event, the size of the firm experiencing the failure, the regulatory environment, the relevance of the failure for the focal firm and other factors.

Therefore, this will lead to minor changes of the innovation strategy or an adaptation strategy without major changes of the current technological trajectory in the short-run. Particularly, in cases of major failures government regulations may further impose the adaptation of a firm's current trajectory. Furthermore, these unaffected firms can also stimulate own trial and error learning or search processes to optimize own processes and products and to avoid similar product defects. However, these will take time and will not be initiated in the short run. Moreover, once the focal firm has full information whether the affected firm was able to successfully cope with the product defect, it will be able to adapt its innovation strategy in the long run. Thus, short-term learning will inform and influence long-term decision making.

Observing other firms, the focal firm focuses on avoiding those experiences and actions that appear harmful, imitating those actions that appear beneficial for other organizations and developing novel activities based on its interpretations of the observed experiences (Chuang and Baum, 2003; Haunschild and Miner, 1997; Kim and Miner, 2000; Levitt and March, 1988; Miner et al., 1999).

Firms that completely fail due to major product defects provide other firms in their industry with a valuable opportunity to observe and learn and consequently improve their chances of survival by resisting potential threats or by adjusting their current strategy (Haunschild and Miner, 1997; Levinthal and March, 1993). Furthermore, assuming that in the extreme case, firms experiencing product failure are permanently removed from an industry, along with the possibly valuable information associated with their failures, this can increase the difficulty for others to learn from the failures (Huber, 1991; Levinthal and March, 1993).

In sum, theories that stress limited organizational attention or the importance of visibility suggest that others' product failure experience is a better source of learning in the short-run than own product failure experience.

4.4. Two-stage learning (change of trajectory)

Prior research reveals how other firms' product failures served as wake-up calls not only for the firms directly involved but also for the ones indirectly affected leading both involved parties to search for new actions or to develop new routines or craft new long-term strategies (Miner et al., 1999).

A large number of near-failures[16] in an industry provide firms with an occasion to observe others' approach to product failure, indicating situations that can risk their own survival (Miner et al., 1999). From a learning perspective, near-failure experience offers the advantage of rich, complex information embedded in an aggregate set of events from product failure to turnaround. Show case examples of other firms who managed to cope with near-failure render this experience an important source of outcome-based learning in the long-run. Furthermore, the accumulated experience by others provides tried and tested successful reactions that a firm can use to deal with potentially similar situations in the future. In this regard, near-failure experience is more likely to provide lessons to be adopted by observing firms than other types of failure-related experiences (Kim and Miner, 2007). Firms and managers that successfully recovered from product failure may even actively describe their turnarounds in light of managerial pride and organizational prestige (D'Aveni, 1990). This notion may qualify others' product failure experiences as a useful source of knowledge but may at the same time be inflated with misleading, not proven or not validated solutions.

Notwithstanding, companies may try to hide their near-failure experience to create an image of healthy operations which renders these near-failures not as visible as 'fully-fledged' failures because they are not widely publicized which makes it more difficult to observe them in the first place (Elsbach and Kramer, 1996; Kim and Miner, 2007). Moreover, other firms may only share information long after the crisis is overcome (Sutton and Callahan, 1987).

In fact, there is a two-stage (simultaneous) learning process taking place. In the first learning process, the directly affected firm, will effectively observe, interpret and derive the lessons learnt and based on its evaluation change its current strategy. The whole turnaround process and its subsequent evaluation (whether it was successful) will take time. The second learning process relates to the firm not directly affected by the near-failure event. Assuming that the focal firm is able to derive *correct* lessons learnt from the near-failure of others' it will most likely change its current trajectory to avoid similar failure events in the long-run. In sum, theories emphasizing the importance of rich, comprehensive information suggest that near-failure experience has greater impact for firms to learn from in the long-run based on two different but simultaneous learning cycles of directly and indirectly involved firms. Combining the arguments from above lead to the conceptual model depicted in FIGURE 4.

16 A near-failure in this context refers to a product recall causing severe consequences but not a complete going-out-of-business or a product defect that was discovered and fixed before the announcement of a product recall.

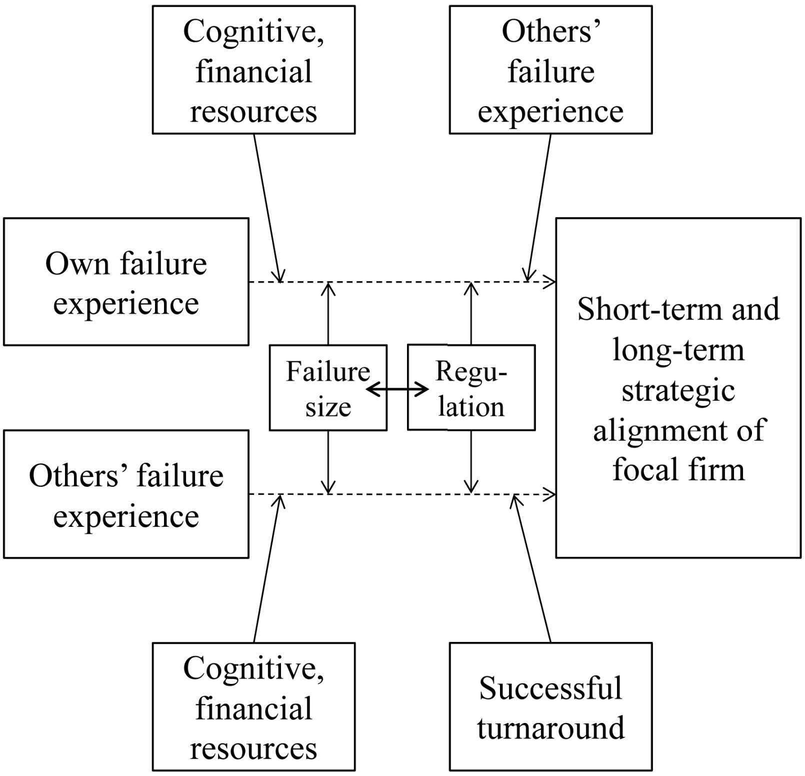

Figure 4. Conceptual framework for analyzing learning from own and others' failure and strategic behavior (learning processes are indicated by a dotted line)

5. Practical implication

'Organizational learning from experience is as much a process as an outcome' (Cannon and Edmondson, 2001, p. 303). In this vein, I will break this organizational learning process into narrower steps that starts with the process of identifying a failure event and builds up to the more challenging one of translating it into action (e.g., strategy alignment). In this section, I develop a hands-on learning process framework based on already extant frameworks and concepts. I will further describe the different components of the model which can serve as a basis for empirical testing and validation and as a practical tool for managers. A research design for testing this framework would be in the context of organizations having encountered product-related failure, that is the imitation of their products. According to their (negative) experience, I would expect them to adjust and put a process forward to be more cautious with regards to collaboration in the future as it associates with certain risks of a repeated imitation experience. Moreover, this framework is based on the perspective of the focal firm. For reasons of simplicity, vicarious learning is left out here.

This basic framework can serve as a source for organizations to effectively deal with product-related failure experience which can translate to improved (decision making, strategic) processes and performance or innovativeness.

The framework in FIGURE 5 shows that an organization's context (e.g., structure, culture, technology, memory, goals, incentives, strategy, and interfirm relationships) influences the way experience creates knowledge (Argote and Miron-Spektor, 2011). The context, on the one hand, shapes the learning process but knowledge acquired as a product of learning from experience, on the other hand, is integrated in the organizational context and in turn, modifies the context. Hence, the relationship between experience and knowledge is an interactive, bi-directional process. The learning process that takes place relates to the actual imitation experience, its translation to new knowledge and its impact on strategic behavior. FIGURE 5 visualizes this dynamic learning process and the interdependencies between failure experience, learning, organizational memory and an organization's decision making.

During all steps of the framework knowledge is constantly created and re-created which is indicated by the double arrows in the lower part of the figure. Hence, new knowledge obtained from each stage is saved in the organizational memory or knowledge stock. The knowledge stock in turn can also inform each stage as the organization and its members are able to use previous experiences, knowledge, procedures etc. to deal with new experiences.

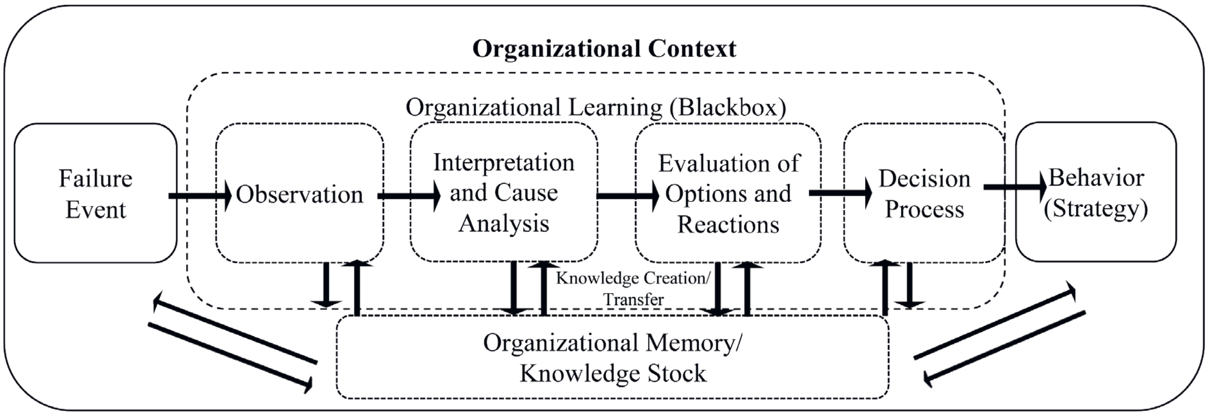

Figure 5. Practical framework for analyzing learning from imitation experience, knowledge and strategic behavior (not yet observable aspects are indicated by a dotted line; arrows indicate knowledge flows)

5.1. Failure event

Learning begins with an initial failure event, e.g., product-related failure (product imitation). The event per definition has to represent a deviation from expectation or desired results. An organization consists of individual members who either make the experience alone or in a group.

I take a multi-level approach to analyze organizational learning. Extending prior theories on multi-level learning which posit different processes at different levels (Crossan et al., 1995), I propose in line with Argote and Todorova (2007) similar processes (antecedents, learning, processes, and outcomes of learning) take place at all three levels: individual, group, and organizational. FIGURE 6 explains this interactive circular process between individual members and the organization itself.

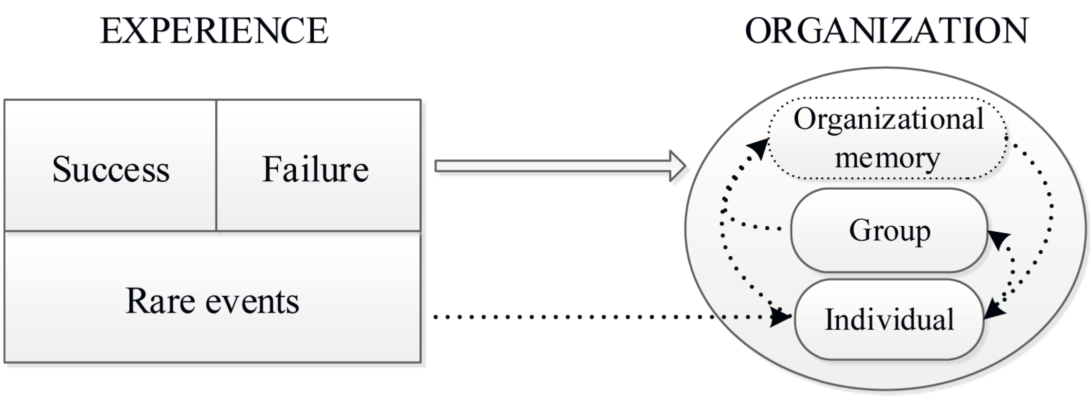

Figure 6. Organizational learning from experience (not yet observable aspects are indicated by a dotted line)

5.2. Observation

The organization has to observe the failure experience (e.g., product imitation) to start the learning process. Customers might e.g. draw the organization's attention to a false or copied product they purchased on the market. Furthermore, product imitation can lead to a decrease in customers and sales or lead to complaints. Many organizations already face severe difficulties at this early stage as experiences, especially mistakes, are regarded as personal failures and people have an inherited instinct to deny, distort, ignore, or disassociate themselves from their own mistakes. An organizational culture that is low in tolerating failures further promotes ignoring and thus, not 'observing', especially with regards to smaller experiences and failures (Cannon and Edmondson, 2005; Edmondson, 2011).

5.3. Interpretation, sensemaking and cause analysis

Moreover, the recognition and evaluation of an experience as failure exposes an organization's weaknesses, and may reveal improvement potential that transform the organization to a better and more effective one. I assume that the organizations exposed to imitation will engage in mindful learning (Weick and Sutcliffe, 2006) and develop common narratives. Hence, actors within organizations can summarize and communicate their observations to each other and, in the process, collectively generate shared understanding of a failure experience (Garud et al., 2011).

A mindful learning process consists of two groups of activities: first, the dialogic practice (Tsoukas, 2009), and, second, the analogical reasoning (Gentner, 1983; Gick and Holyoak, 1983). These activities do not necessarily take place in a specific order; instead they iterate and influence each other. Engaging in this dialogic practice, e.g., discussing the imitation experience with others, organizational members are able to establish a distance between them and the product imitation experience, and, hence, to evaluate the experience from different angles. This includes comparing the incidence to other cases, to find commonalities, differences, to thoroughly analyze it and, eventually, to derive conclusions. At the end of this stage, an organization should have reached a clear understanding of the origins of the experience or failure and also should have developed a clear categorization of whether this product imitation experience harms or benefits the organization and its members. Furthermore, the organization will start looking for causes of the failure experience and derive a course of action from them. According to these principles, the organization will then interpret the product imitation experience as being negative because product imitations can harm the organization's reputation and brand value especially if the imitation is of lower quality. Thus, the experience will be categorized as harmful to the focal organization. I expect that an organization's concrete experience with imitation will be stored in the organizational memory.

Furthermore, looking for causes of the imitation may lead to the conclusion that weak IP protection, a risky internalization strategy or other loopholes caused the damage. Another source of that failure experience resulting from dialogic practices and analogical reasoning result in principles and heuristics which may e.g., include that collaborative R&D in inter-organizational relationships has been associated with an unintended and undesirable knowledge drain, which can result in the loss of an organization's critical IP to a partner without receiving any reimbursement in return.

5.4. Evaluation of opinions and reactions

Having developed narratives triggers an action process that starts responding to failure experiences (Garud et al., 2011). The next step comprises to evaluate different potential coping strategies and reactions on how to deal with the imitation experience. There are always different ways and options on how to solve or cope with a failure experience. Sometimes, organizations have to come up with a quick reaction and thus, they do not have enough time to thoroughly analyze all available options and reactions. Nonetheless, an organization potentially looks at as many alternatives as possible to be able to exploit the evaluations for future (similar) purposes. Usually, it is a combination of both strategies: short-term reaction and long-term strategic (prevention) management. Moreover, the evaluation of options and reactions is valuable as it may serve on more than one single occasion and thus, will not just be a waste of time. Therefore, it is important to list all options and their respective ratings on risk, time and resources needed to perform them. Finally, the conclusions obtained from the previous stage will be abstracted to (decision making) principles and then stored in the organizational memory as acquired knowledge.

In the practical example of having experienced product imitation, the risk of repeated imitation, knowledge spillover or opportunism depends on particular characteristics, such as the transferability (tacit vs. explicit knowledge) (Grant, 1996) the partner's absorptive capacity (Cohen and Levinthal, 1990), and appropriability regime (Teece, 1986). Furthermore, prior literature suggests that R&D cooperation is indeed a potential source of imitation. Consequently, companies must analyze the risk of outgoing spillovers depending on the type of research partnership, on their own absorptive capacity (Cassiman and Veugelers, 2002) and on the value of the resources in question. Organizations engaging in a thorough analogical reasoning will eventually derive this conclusion and store this abstract principle as knowledge. This means, the firm's knowledge base (e.g., processes, databases or computer systems) grows as the transfer of employees' failure experiences results in learning (Argyris, 1999; Kim, 2004; Simon, 1991). The organizational memory also serves as knowledge repository[17] and thus through the accumulation of knowledge about failure experiences, an organization builds a memory of such events that in turn informs individuals about procedures, decision making guidelines or similar cases from the past which might help them to derive solutions for dealing with emerging failure experiences (Garud et al., 2011).

17 Furthermore, previous research defines organizations as knowledge repositories with an organizational memory storing past experiences and information (Moorman and Miner, 1998; Olivera, 2000; Simon, 1991; Walsh, 1995; Walsh and Ungson, 1991).

5.5. Decision making process

Firms do not create, implement, exert or renew strategies. Individuals within these firms do (Mantere, 2007). Sometimes firms need to decide and develop new strategies due to government regulations especially in cases of major product failures. The decision will be made based on an accurate problem definition which in this case will be a concrete failure experience. Decision makers of the organization should accurately calculate and choose the alternative with the highest perceived value. In reality, however, the decision taken often is a political one: firms will not decide for the optimal strategy but rather the one that is advocated by the most powerful stakeholders, the one that is common sense or the one that is based on the least common denominator.

In the case of product imitation experience, an organization needs to observe changes in the environment (e.g., stakeholder behavior) thoroughly, evaluate all potential alternatives and adapt the cooperation strategy accordingly as it is a potential source of imitation (Harrigan, 1985).

5.6. Behavior

A firm's actual behavior to the precedent process will be observable again. Organizations use formal and relational governance mechanisms to control and manage the above mentioned hazards of opportunism and spillovers (Somaya et al., 2011). As a result, firms with negative experience may either choose not to cooperate at all or to set tight contractual guidelines to protect their interests especially when their technological knowledge capital is very valuable. Trust can also help overcome appropriation concerns (imitation of IP) (Barney and Hansen, 1994). In sum, there are three coping mechanisms after having experiences product imitation and thus, potential reactions: a detailed contract, trust or refraining from cooperating.

A more long-term and severe change of behavior is a completely new alignment of an organization's innovation strategy (e.g., R&D cooperation strategy) due to product imitation.

Based on the framework, I hypothesize that a negative experience decreases the probability that strategies (in this case the decision to cooperate on R&D) probably resulting in an unwanted repetition of that experience will be chosen in the future. Hence, organizations exhibit a natural learning tendency to avoid alternatives that produce poor outcomes (Denrell and March, 2001). Ultimately, it will change or adapt its current strategy.

I argue that companies might be able to learn from failure experience and will thus improve performance as well as their strategic decisions regarding innovation to reduce and avoid the recurrence of the failure experience.

6. Discussion and implications

Failure can typically be attributed to either the environment or the organization. To be more exact, as failure is the misalignment of the organization and its environment, it is, by definition, about strategy (Sheppard and Chowdhury, 2005).

The typology developed in this paper emphasizes that the primary source of the failure experience can trigger different learning process in the short and long-run. Firms own product failure experience will for example most likely lead to a change of the current trajectory in the long-run whereas other companies' product failure experience will cause the focal firm to observe the failure and quickly draw lessons from the other companies' behavior to adapt minor aspects of their innovation strategy in the short-run. Depending on the cause of the product-related failure, firms should always see it as a learning opportunity. In the case of a product defects, firms need to have a viable product recall strategy at hand which can reduce costs and minimize a recall's severe consequences for the firm substantially. This can also be valuable when fast reactions need to be executed. Firms can restore their reputations by aspiring to prevent a future recall on the same safety hazard, and by differentiating their new products from those that were recalled (Berman, 1999). In contrast, other firm managers view a recall program as an inconvenience, as a sign of defeat or they take a defensive approach by denying that a problem even exists, or by blaming others as the cause of the product defect. Managers may underestimate or play down the consequences of a recall (Berman, 1999). Firms differ considerably in terms of when they announce a recall and how they handle a recall incident (Laufer and Coombs, 2006). Some proactively announce product recalls whereas others take a defensive approach and wait until they are forced to recall their defected product (Chen et al., 2009). Companies may follow this defensive strategy assuming that others will observe their behavior and even profit or learn from their product failure experience. Moreover, product-related failures are costly and thus, should be accepted if happened, not ignored in the short-run and rather prevented in the long-run. Firms should also carefully observe others and how they manage failure experiences as these provide very valuable learning occasions where the focal firm can learn more than from own experiences.

The findings of this theoretical analysis have implications for managers and researchers. The literature review shows that there is no clear evidence whether and how organizations learn from failure in general and product-related failure in particular because of several barriers preventing firms to learn from failure. There is a large body of literature on learning curves which suggests that learning in deed is taking place. With the help of the typology and the framework developed in this paper, I emphasize that organizations can also learn from non-routine tasks or product-related failure experiences when they consciously reflect, make sense and analyze the causes of the failure. These experiences will be replicated in the organizations' strategic decision making or their innovation and R&D investments and hence, their innovativeness or performance. Of course, further empirical investigations are needed to verify these theoretical predictions. Although, as emphasized before, quantitative evidence is hard to obtain, I at first encourage further in depth case research to open up the black box of organizational learning and decision making processes in innovation management.

In reality, firms usually get stuck in the early stages of the process introduced and never reach a learning outcome as they might want to forget about the failure or do not consider the failure important enough to learn from.

While their firms remain prosperous, many managers believe that nothing bad can happen and thus, too often overlook cues of a potential dangerous or failure situation. In a case study of a telecommunication firm, Baumard and Starbuck (2005) identify further problems impeding effective learning such as perceptions of idiosyncrasy and external influence, reluctance to foreclose experiments prematurely, employee turnover, and poor communication. Furthermore, organizations tend to look for external causes when failure events have a significant impact and thus it is questionable whether they will learn anything from these experiences (Starbuck, 2009).

Organizations further inhibit the learning from failure process by rewarding success and punishing failure. With the help of a failure accepting culture, organizations can adjust and improve decision making processes to avoid the negative and repeat the positive experience which ultimately leads to a successful, prosperous organization. Thus, a transition from a performance-based culture[18] to a learning-based culture may be necessary. Small steps to be taken in this direction are the installment of systematic failure reporting and analyses tools that clearly describe steps and tasks on how to proceed with any kind of failure experience. Organizations can e.g., set up a special task force and or teams that are specifically prepared to deal with and react to any unforeseen (major) experiences. With the help of a so called failure mode and effect analysis (FMEA)[19] tool, potential sources of failure can be analyzed ex-ante as the failure introduced and discussed in this paper are only detected ex-post. A good pre-failure analysis helps firms to more efficiently deal with these potentially relevant errors and any other (similar) failure experiences after they happen. However, an effective way to detect, deal with and analyze failure is still not a common practice in many organizations (Edmondson, 2011). Therefore, there is a growing need for context-specific and highly effective learning strategies. Another problem why learning is underrepresented in so many organizations is due to the fact that there is no failure acceptance culture which leads people to avoid admitting or even publicly acknowledging failure. Hence, a sophisticated analysis of failures and their contexts is necessary to avoid the blame game as Edmondson (2011) calls it.

18 In general, failures may have consequences for individuals' or teams' performance evaluations. Therefore, people have a deeply rooted and inherited instinct to deny, distort, ignore, or disassociate themselves from their own mistakes (Cannon and Edmondson, 2001).

19 FMEA comprises a risk analysis and optimization process based on the potential failure, the potential cause of failure, the recommended corrective action and the designated preventive measure.

The most important undertaking for firms to deal with failure is to accept and embrace it in the first place. However, a fundamental change of the deeply in the organization rooted cultural principles is a difficult, painful and time consuming undertaking – if possible at all. A good manager is a necessary condition to establish and reinforce a learning culture where people are not discouraged and feel responsible to report mistakes, small and large which is the basis to learn from failures (Cannon and Edmondson, 2001). Once a failure has been detected, it is necessary to examine the failures but at the same time avoid shortsighted or a scapegoat search for causes though it can be painful or emotional. Tolerance, patience, openness, time and communication are essential as are diverse teams from different backgrounds, organizational levels and departments with different perspectives that engage in problem search regarding more complex failures. Organizations can only learn from experiences, understand what happened and how to prevent it from happening again if individuals within these organizations discuss and analyze these error and failure experiences, honestly and openly.

Once having dealt with any product-related failure experience, the coping and problem solving strategies and the solution found can be recorded and serve for future purposes. Later on, the solution, strategy or the decision should also be looked at again to see if the measures undertaken were successful in that matter (feedback loop). Usually, major product failure experiences require a really quick decision. This short-term reaction should also inform and be aligned with the long-term innovation strategy.

While this work has many interesting implications, several limitations exist. This paper gives some intuitive reasons; however, I am not able to empirically test my argumentation. Still, such research is very valuable as it reveals information about the organization's potential reactions. As the typology and the practical framework mainly bases on and provides theoretical assumptions, further empirical works on organizational learning are needed to test and verify this framework. Thus, it might be beneficial to use the techniques shadowing or long-term observation of a firm over a longer period of time to see what caused the experience though most of the time this might not even be that obvious for the organizations themselves. Longitudinal investigations might be necessary to gain a full picture to what led to the experience. Taking into consideration the conceptual ideas I have developed, I argue that the source of the experience is not of major importance as the reflection about the experience reveals a call for action.

7. Conclusion and further research

The question whether and how organizations learn from product failure remains unclear as several barriers to effective learning from failure exist. Moreover, the impact of product-related failure on a firm's innovation strategy has not been explored, yet. Therefore, in this article, I provide a typology and a practical analysis tool for learning from product-related failure experience. In doing so, I integrate and combine extant concepts and frameworks to explore how learning from product-related failure experience influences an organization's strategic decision making in innovation contexts.

Furthermore, previous studies mainly analyze learning from failure within a single industry such as railroad, mining, airlines or banking industries. I provide a framework that applies to firms from various industries. In the typology I explain the interdependency of different types of experience (own versus others' failure experience) with organizations' strategic decision making. Adopting the typology or the practical application for managers reveals that product failure associates with different reactions in the short and long-run depending on whether the focal firm or other firms have made the initial failure experience. I further identify current and emerging themes in research on organizational learning from failure experience.

Whether firms learn from product-related failure and change their behavior (to repeat or avoid a certain experience) depends on a systematic and conscious analysis process. I have described a research design to further test and explore the ideas I developed.

The initial theoretical assumptions derived from the framework have clear implications for management and future research. I have pointed out promising future avenues of research to stimulate further work on organizational learning from experience and to raise the discussion among scholars about this topic. While I must take care generalizing the findings here, the evidence presented is a step towards understanding the importance of product-related failure experience as a concept in innovation management (literature), here captured via learning, on strategic decision making in an innovation context. Product-related failure events are to some degree unavoidable in a turbulent world. Being able to cope and manage them to some extent, is a necessary prerequisite for firms in their struggle to prosper and survive. In order to better understand internal microchanges of behavior once failure hits a complex system such as an organization, we still have a lot to learn.

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Once Bitten, Less Shy? – The Impact of Legal Copying and Illegal Infringement Experience on R&D Cooperation

Abstract

In this article, we investigate how a company's experience with *legal copying* of non-protected intellectual property (IP) and, contrasting, *illegal infringement* of intellectual property rights (IPR) influences its decision to cooperate on research and development (R&D). We base our argument on literature that focuses on learning from failure and rare events and we empirically test our hypotheses using data from the German Community Innovation Survey.

We find that firms with experience regarding the legal copying of their IP are less willing to engage in research collaboration, while in contrast, firms with experience regarding the illegal infringement of their IPR are more likely to cooperate on R&D.

Our results provide humble contributions to the organizational learning literature in pointing out that failure events of firm strategies can trigger learning processes. Furthermore, we inform strategic management literature in shedding light on the complex interdependencies of IP, appropriation and firms' innovation strategies. Innovation management literature benefits from this study as it provides insight into the connection between legal copying, illegal infringement and R&D cooperation, thus, offering two new determinants of firms' R&D cooperation behavior.

Contents

'There are many arts among mankind which are experimental, and have their origin in experience. For experience makes the days of men to proceed according to art, and inexperience according to chance' (Gorgias by Plato, Translated by Benjamin Jowett)

1. Introduction

While research has analyzed experiences stemming from previous alliances and, even more detailed, partner-specific alliance experience, anecdotal evidence shows that experiences a company makes outside of these bonds also affect their strategic decision making. A good example is the German company Stihl, one of the world's best-selling brands of chainsaws. According to the company's website, Stihl suffers from severe plagiarism of their products. Stihl does not engage in any form of cooperation with these manufacturers and still, they have decided to deal with the external event of counterfeits by addressing the possibly fatal consequences for customers when using a counterfeit chain saw. This means that Stihl reacts to this external threat and takes it into account for their actions and behavior on the market.

The OECD (2009, p. 1) estimates the worldwide damage counterfeits to reach ~2% of worldwide sales. Moreover, recent estimations show that around 17% of all German imports are counterfeits (Cuntz, 2012). Even if the last figure seems overwhelmingly high, we assume that counterfeits trigger a learning process for companies eventually resulting in a change of their strategy. We analyze this reaction in the context of formal research and development (R&D) cooperation[1] by empirically investigating the relationship between a firm's experience with being affected by legal copying of intellectual property (IP) or illegal infringement of intellectual property rights (IPR), respectively, and the likelihood to collaborate in R&D.

IP is often defined in the narrow sense of a legal construct. Notwithstanding, we separate the inherent explicit and implicit knowledge, competence and creativity materialized in the product, which we take as a definition for IP, from the legal constructs (e.g., patents, trademarks, designs; i.e., protection mechanisms for the underlying IP), which we define as IPR. Even after the patent's expiration, the formerly patented technology is still IP. The same can be said about a design for which the legal protection is expired or about a technology for which the inventor never had sought for a patent.

We define *legal* copying of IP as the use of another party's IP which is not protected by a legal exclusion right (e.g., a new technical idea that is not protected by a patent or for which the patent has expired) and, contrasting, illegal infringement of IPR as the *unauthorized* use of another

1 In line with Laursen and Salter (2013), we focus on formal collaboration agreements which require both partners to comply with an agreed structure of the cooperation.

party's IP that is protected by a legal exclusion right (e.g., patents, trademarks, etc.) as displayed in FIGURE 1. For our research question, we distinguish an organization that passively experiences the legal copying of their IP or the illegal infringement of their IPR from an organization that actively engages in copying or infringing other firms.

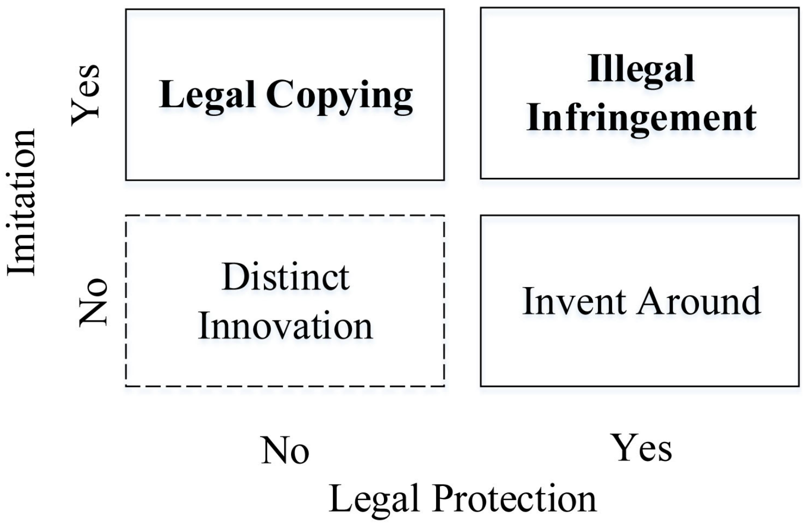

Figure 1. Definition of legal copying and illegal infringement by level of imitation and legal protection

Our research question is as follows: Do firms learn from the failure of their appropriation strategy – in terms of having experienced legal copying of IP or illegal infringement of IPR – and, consequently, adjust their innovation strategy by refraining from R&D cooperation? This question is important as the myopic reaction to withdraw from or reduce R&D cooperation after a company has experienced legal copying or illegal infringement, can have severe consequences for a company in the long run. Extant research shows that companies engaging in R&D cooperation are more successful in their innovative endeavors, attain the same output of innovations with fewer resources and are more successful in bringing the innovation to the market (Hagedoorn, 1993; Powell et al., 1996; Tether, 2002). Moreover, R&D cooperation is an important means to avoid double R&D spending on the same innovation, eventually resulting in an increase in welfare (Hagedoorn et al., 2000).

Our article complements and adds to the body of work that emphasizes learning from failure and rare events (Baum and Dahlin, 2007; Haunschild and Sullivan, 2002; Lampel et al., 2009). In general, more research is needed on how these unusual experiences influence companies' decision making as prior research is mainly based on case studies of particular industries and focuses on different aspects of the experience concept (Argote and Miron-Spektor, 2011).

These aspects include, as determinants for companies' learning outcomes, learning from prior alliance experience (Kale et al., 2002; Sampson, 2005; Zollo et al., 2002), learning from acquisition experience (Haleblian and Finkelstein, 1999; Hayward, 2002; Muehlfeld et al., 2012; Zollo, 2009), learning from start-up failure (Cope, 2011; Shepherd, 2003) and learning from contracting experience (Mayer and Argyres, 2004; Vanneste and Puranam, 2010). Literature further investigates different dimensions of the experience concepts such as heterogeneity (Haunschild and Sullivan, 2002; Schilling et al., 2003), rarity (Christianson et al., 2009; Lampel et al., 2009) and the recency (Baum and Ingram, 1998; Benkard, 2000) of the experience as well as vicarious learning (Baum and Dahlin, 2007; Denrell, 2003; Kim and Miner, 2007) from other firms' experiences. Furthermore, extant literature mainly emphasizes learning from and within R&D cooperation.

We theoretically build on the literature on learning from failure and rare events. However, rather than using indicators of cooperation such as e.g., alliance capability (derived from general and partner-specific alliance experience), spillovers or firm size, we focus on the failure of a firm's appropriation strategy indicated by a legal copying or illegal infringement experience.

We derive our hypotheses in the decision context of formal inter-firm research partnerships, i.e., R&D cooperation, which have become increasingly important as firms seek to access new knowledge, to increase the pace of innovation and to quickly respond to market needs (Hagedoorn et al., 2000). Despite the advantages of R&D alliances, prior literature also analyzes general obstacles and risks associated with cooperating on R&D including, but not limited to, knowledge spillover, distrust, sunk costs, opportunism, adverse selection, moral hazard and hold-up (Dess and Beard, 1984; Somaya et al., 2011).

This article reports the findings of empirical investigations of experience with legal copying and illegal infringement. The data we use stem from the German version of the Eurostat Community Innovation Survey (CIS). We connect different data waves to investigate the effect of legal copying and illegal infringement experience on a company's likelihood to engage in R&D cooperation. We find that firms with experience regarding the legal copying of IP are less willing to engage in research collaboration, while in contrast, firms with experience regarding the illegal infringement of IPR are more likely to cooperate on R&D. In doing so, we provide a humble contribution to the organizational learning literature by giving a first example of companies learning from the failure of their strategy. Furthermore, we inform strategy literature by showing that firms adjust their appropriation strategy not only due to external factors (changes in the market) but also according to the performance of the appropriation strategy. Finally, innovation management scholars benefit from our findings that a failure in appropriation influences the likelihood of companies to engage in R&D cooperation in two different ways: positively in case the imitated IP was legally protected (illegal infringement) or negatively if the IP was not legally protected (legal copying).

The remainder of this article is organized as follows. First, we provide an overview of the most relevant research regarding the phenomena of legal copying of IP and illegal infringement of IPR and of common drivers as well as inhibiting factors for R&D cooperation. Next, we give an overview of the learning from failure and rare events literature to explain the influence of experience on company decisions. We then demonstrate whether a firm with experience in legal copying of IP or illegal infringement of IPR will engage in R&D cooperation by deriving our hypotheses. The subsequent section describes the data, explains the methodology and tests the hypotheses on the likelihood of R&D cooperation depending on legal copying or illegal infringement experience. The article concludes by describing and discussing the results of the empirical investigation and by providing implications for management and research.

2. Literature review

In this chapter, we provide an overview of the most relevant research on the two critical phenomena we investigate: legal copying of IP and illegal infringement of IPR on the one hand, as well as drivers for R&D cooperation on the other hand. In addition, we note the contribution of our research to both literature streams. The last part of this chapter considers relevant findings of organizational learning literature from which we draw to derive our hypotheses.

2.1. Legal copying of IP and illegal infringement of IPR

Imitation of innovation (e.g., due to limited appropriation mechanisms) can reduce the innovation endeavors of organizations (Teece, 1986). In other words, without appropriate protection, a firm's innovation effort may be diluted if there is a serious threat of imitation. Strategic management and more specifically, literature on appropriation strategies offers a long track record of research investigating how firms capture value from their innovations given the risk of imitation. The recent article by James et al. (2013) gives a comprehensive overview on the most influential papers in this line of research and points out the mechanisms predominantly researched to mitigate imitation risks: patents, secrecy, lead-time advantage, complementary assets, and their combinations. These mechanisms are often grouped into legal (i.e., formal) protection methods such as patents, trademarks, utility models, copyrights, registered designs, etc. (European Commission, 2011), and informal protection methods such as lead time, secrecy, use of complementary assets, etc. (Cohen et al., 2000; Cohen et al., 2002; James et al., 2013; Teece, 1986).

Prior literature in management research suggests that a firm should focus on the inimitability of its products to sustain a competitive advantage (for a recent literature overview, please refer to Polidoro and Toh, 2011). Thus, IP as an important, valuable and intangible resource of the organization (Wernerfelt, 1984) is crucial to ensure inimitability. While management literature, as pointed out, shows interest in the inimitability of valuable resources guaranteeing the competitive advantage, only recently the role of legal copying of IP and illegal infringement of IPR has become of interest. Especially, patent infringement in terms of patent litigation has evolved as an influential topic in strategic and innovation management literature.[2] Factors influencing patent litigation are the choice of courts (Somaya and McDaniel, 2012) and the value of the respective patents (Lanjouw and Schankerman, 2001). Ongoing patent litigation, on the other hand, triggers strategic reactions of firms (diversification to markets with weaker IP protection (Paik and Zhu, 2013)), and negatively impacts the licensing activities of litigating universities (Shane and Somaya, 2007). According to Lerner (1995), the costs of litigation influence the patenting behavior of companies. Moreover, Marco (2005) finds that enforceability of patents is an important value determinant for

2 Another line of extant literature focuses on the phenomenon of patent trolls (e.g., Reitzig et al., 2007), non-practicing entities merely focusing on generating value from patent litigation, which lies outside the focus of this paper.

patents and Somaya (2003) shows that firms' likelihood to settle patent litigation depends, inter alia, on the strategic stakes of the involved patents. More recently, factors triggering legal copying and illegal infringement are investigated by innovation management scholars (Berger et al., 2012) as well as consequences of illegal IPR infringement on firms' patenting activities. Usually, when a firm experiences illegal infringement of its IPR, then the course of action is to patent more. Indeed, it has been established in a number of studies that firms like Texas Instruments, IBM and others were awakened to patenting in the late-1980s by issues of illegal infringement (Bhaskarabhatla and Hegde, 2012; Hall and Ziedonis, 2001). In general, patenting may precede, accompany, or follow R&D collaboration efforts of firms (Iversen, 2012). Most studies focus on the latter scenario (Ahuja, 2000; Brouwer and Kleinknecht, 1999; Hoang and Rothaermel, 2005; Sampson, 2007; Sampson, 2005; Schilling and Phelps, 2007) or the co-ownership of patents (Belderbos et al., 2013; Hagedoorn, 2003). In contrast to investigating the impact of patenting on subsequent collaboration, we aim at analyzing the connection between legal copying of IP and illegal infringement of IPR as a constraining factor for future R&D cooperation.

A further stream of literature investigating legal copying of IP and illegal infringement of IPR focusses on the economics of counterfeiting (e.g., Grossman and Shapiro, 1988a, 1988b), including literature on marketing topics (e.g., Qian, forthcoming) and on software piracy (e.g., Conner and Rumelt, 1991; Givon et al., 1995).

The work closest to our research question is on firms' reputation for rigorousness in patent enforcement and its impact on spillover effects in terms of inventor mobility (Agarwal et al., 2009). Agarwal et al. (2009) find that companies in the semiconductor market build up reputation for being tough in patent litigation to diminish the spillover effects of inventors leaving their former employer to join a competing company. Our approach differs from Agarwal et al.'s (2009) as we specifically look at how companies factor in previous experience with legal copying or illegal infringement when deciding to cooperate on R&D, i.e., deciding on engaging in a cooperation that might facilitate spillovers. Another recent article deals with appropriation concerns in open innovation settings and argues that the strength of firms' appropriability strategies has a concave relation with firms' external innovation engagements (Laursen and Salter, 2013). Contrasting, we focus on a particular failure experience of a firm's appropriation strategy and its impact on the firm's innovation decisions regarding R&D cooperation. Hence, our work complements previous research in this field.

2.2. Drivers of R&D cooperation

Due to increasing complexity and the multi-disciplinarity of R&D and innovation efforts, firms seek to access complementary assets and knowledge outside their boundaries (Miotti and Sachwald, 2003).

Thus, a growing amount of literature has analyzed companies' motivations to collaborate on R&D, and this literature finds an elaborate set of determinants of R&D cooperation.

Amongst others, Bayona et al. (2001) find technological complexity, firm size, risk and costs of innovation (also refer to e.g., López, 2008; Miotti and Sachwald, 2003; Tether, 2002) to be important drivers for cooperating with another firm. Although the resource-based view proposes that firms conducting expensive, risky or complex research or innovation projects will collaborate on R&D with external partners, Miotti and Sachwald (2003) do not find that the obstacles to innovate, e.g., costs and risks of innovation, have a significant effect on R&D cooperation. In turn, high-tech and mid-high-tech sector affiliation stimulates horizontal cooperation. Moreover, conducting R&D close to the technological frontier, having a strong research orientation and receiving public funding substantially increase a company's propensity to cooperate on R&D (Miotti and Sachwald, 2003). In addition to the size effect, firms with a high market share also exhibit a greater likelihood to cooperate (Miotti and Sachwald, 2003). In a sample of Dutch manufacturing firms, Kleinknecht and Reijnen (1992) do not find firm size to be significantly related to the propensity to cooperate. In contrast, the existence of an R&D department, granted patents, licensing and sectorial affiliation have a significant impact on a company's likelihood to cooperate in R&D. Kaiser (2002a) shows a positive link between an increase in research productivity as well as the generality of a firm's R&D approach and the likelihood to form research joint ventures. However, Kaiser (2002a) does not find significant evidence for a positive relationship between market demand and research cooperation.

According to Tether (2002), other indicators for R&D cooperation could be age, sector and ownership as well as the type of innovation being developed such as product, process, new-to-the-world or new-to-the-market innovations. For large samples of German and Spanish manufacturing firms, scholars find support for the importance of R&D intensity on the propensity to cooperate (Bayona et al., 2001; Fritsch and Lukas, 2001). Moreover, theoretical models and studies also incorporate absorptive capacity as an indicator for benefiting from R&D cooperation. These models insist on the need for companies to conduct their own R&D (Cassiman and Veugelers, 2002; Kaiser, 2002b; Kamien and Zang, 2000). Moreover, empirical studies demonstrate that firms' absorptive capacity depends on their own R&D intensity (i.e., the relation between R&D expenditures and turnover) (Cohen and Levinthal, 1990). Hence, the greater a firm's absorptive capacity, the more likely it is that the firm is able to recognize what it does not know, yet. Thus, the firm's benefits from cooperation will increase as the firm realizes incoming spillovers and targets external knowledge resources more systematically.

In the management literature, empirical studies predominantly address prior general alliance experience (Kale et al., 2002; Sampson, 2005; Zollo et al., 2002) as predictors for repeated cooperation. Moreover, real option theory suggests that companies with a history of prior alliances are more likely to subsequently engage in alliances as prior alliances create valuable options

(Chi, 2000; Folta and Miller, 2002) and the partnering companies may eventually develop an alliance management capability (Kale et al., 2002) from repeated interactions. In the literature on open innovation, a recent study shows that firms with previous experience of 'openness' or external collaborations derive better innovation output from current levels of openness (Love et al., 2013). In sum, previous (positive) experiences to cooperate on R&D with the same or other partners is positively associated with future R&D collaboration.

2.3. Research question and contribution

Our literature review reveals that research lacks an empirical study that investigates a company's experience with legal copying of IP or illegal infringement of IPR as determinants for R&D cooperation. We also find that the impact of imitation on R&D cooperation remains relatively unclear and has not, as yet, been empirically validated.

Nonetheless, Cassiman and Veugelers (2002) present empirical evidence for a positive relationship between complementary knowhow, complementary assets and appropriability as indicators for R&D cooperation. In this sense, the more control a company has over outgoing information and knowledge spillovers (through strategic protection methods), the greater the probability of cooperation with any type of partner. Particularly, López (2008) finds that the degree of legal protection mechanisms employed in an industry negatively influences R&D cooperation. Moreover, incoming (horizontal) spillovers (Cassiman and Veugelers, 2002; Kaiser, 2002a; López, 2008) positively relate to a firm's likelihood to cooperate on R&D.

However, the aforementioned studies neglect the impact of outgoing spillovers due to measurement problems. Theoretically, however, knowledge outflows are associated with a lower propensity to cooperate on R&D (Cassiman and Veugelers, 2002). Further, Arora and Merges (2004) demonstrate the importance of IPR as it relates to the efficiency of firm investments in highly innovative suppliers with strong research capabilities. In their qualitative work, Gassmann and Han (2004) find that weak appropriability regimes and failure to protect IP are barriers to cooperate on R&D.

Accordingly, we analyze the phenomenon regarding how a company's experience with legal copying of IP or illegal infringement of IPR influences its tendency to cooperate on R&D. Thus, we contribute to the existing research by taking a different approach to explain and predict R&D cooperation. Furthermore, we find evidence that legal copying of IP and illegal infringement of IPR influence a firm's (strategic) behavior.

2.4. Organizational learning from failure and rare events

A growing number of learning studies show that organizational failures, such as accidents and incidents, are important promoters of organizational learning and change (Greve, 1998; Miner and Anderson, 1999). Extant studies in this literature domain use rare and severe disastrous events to show that organizational learning does, in fact, occur. Rare events are discontinuities assumed to disrupt current routines, and therefore expose weaknesses and strengths of a company and eventually lead to new practices, structures and change (Lampel et al., 2009). Consequently, learning from rare events relates to an emergent process of discovering useful lessons from experiences that otherwise would not have been obtained. Furthermore, rare events create opportunities to capture these lessons and then transform them into knowledge which in turn improves skills, expands capabilities and affects decision making (Argote and Miron-Spektor, 2011; Zollo and Reuer, 2010; Zollo and Winter, 2002). According to Lampel et al. (2009), learning from rare events triggers two reactions of companies: they either focus on forecasting, improvement and prevention of consequences when the event has a negative impact, or on repetition when the event has a positive impact. The literature on learning from rare events can be divided in the larger part of learning from failure and the comparatively smaller part of learning from success. A major stream of literature suggests that learning processes differ for failure and success experiences (March, 1991; Muehlfeld et al., 2012; Sitkin, 1992). In many disciplines, such as sciences and engineering, it is widely accepted that companies learn more and learn better from failures than from successes (Baum and Dahlin, 2007; Shepherd et al., 2011). Furthermore, failure usually generates more novel, unexpected types of information than does success, thus stimulating a problem-oriented search for superior solutions (Cyert and March, 1963).

Further, Lampel et al. (2009) conceptualize experiences in four different categories according to their potential impact and relevance. An overarching theory combining established learning frameworks with learning from prior failure and rare events, however, has yet to be developed. Moreover, we emphasize learning from failure, however in a less linear way than other papers in the field dealing with learning curve effects (Argote et al., 1990; Baum and Dahlin, 2007; Haunschild and Sullivan, 2002).[3] Hence, we consider learning from IP(R) experience as learning in a non-routine way.

We build our paper on this body of literature assuming that companies also learn from the failure of their strategy, more specifically, their appropriation strategy. Thus, we complement extant research for firms' failure to capture all the benefits from their innovation investments. In particular, we examine if firms learn from the negative or problematic experience that occurs when a company moves into another company's IP space without authorization.[4]

3 The strict 'assumption [of monotonicity in the literature on learning curves] does not necessarily apply to learning from success and failure experience' (Kim et al., 2009, p. 958).

4 There is an increasing interest in experiential learning from those incidents that occur more frequently than rare events (Argote and Miron-Spektor, 2011), and it is this specific phenomenon that is the focus of our study.

3. Hypotheses

Collaborative learning in inter-organizational relationships has often been described as a double-edged sword. On the one hand, R&D partnerships are often suggested to be an appropriate way to acquire new knowledge, skills, and expertise (Hamel, 1991). Despite their advantages, however, R&D or innovation alliances may also lead to an unintended and undesirable knowledge drain, which can result in the loss of a firm's critical capabilities or skills to a partner without receiving any reimbursement in return and thus, also result in the potential dilution of a competitive advantage. As both partners can opportunistically take advantage of the cooperation, there is a potential for conflict and tensions between the collaboration parties.

Moreover, the partners may anticipate potential legal copying and illegal infringement due to knowledge spillovers, especially if they possess valuable resources or technologies (i.e., IP or IPR). In sum, companies must analyze the risk by balancing incoming against outgoing spillovers depending on the type of research partner, on their own absorptive capacity (Cassiman and Veugelers, 2002) and on the value of the resources in question.

The risk of spillover and opportunism depends on particular characteristics, such as the transferability (tacit vs. explicit knowledge) (Grant, 1996), the partner's absorptive capacity (Cohen and Levinthal, 1990), and the appropriability regime (Teece, 1986). At the same time, collaboration also induces risk to create new competitors and to strengthen existing competitors (Wang and Zajac, 2007). Referring to Harrigan (1985), a firm must thoroughly observe changes in the environment and adapt the cooperation strategy accordingly.

Companies use formal and relational governance mechanisms to control and manage the above-mentioned hazards (Somaya et al., 2011). As a result, firms with negative experiences may either choose not to cooperate at all or decide to establish tight contractual guidelines to protect their interests, especially when their IP is exceptionally valuable (Wernerfelt, 1984). Trust can also help overcome transaction costs (Dyer and Singh, 1998; Poppo and Zenger, 2002) and appropriation concerns (legal copying of IP and illegal infringement of IPR) (Barney and Hansen, 1994), and it also facilitates the assessment of each other's likely behavior and the enforcement of property rights (Gulati and Singh, 1998). In sum, there are three mechanisms to cope with the identified hazard: a detailed contract, trust or the refraining from cooperation.

Our hypotheses base on two main assumptions. The first assumption is that companies can learn from the failure of their appropriation strategy and adapt their general innovation strategy accordingly, thereby resting on the body of literature on organizational learning from failure. The second assumption is that legal copying and illegal infringement both are indicators for the failure of a firm's appropriation strategy. Consequently, we refer to the learning from failure and rare events literature to analyze the experience with legal copying of IP or illegal infringement of IPR as a barrier to R&D cooperation. FIGURE 2 shows the interdependencies among experience (i.e., legal copying, illegal infringement), learning, and firms' innovation strategy (i.e., R&D cooperation).

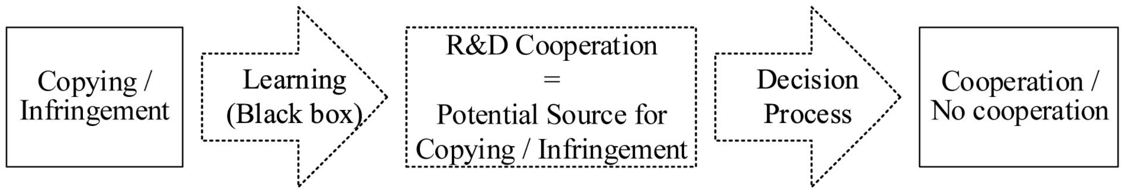

Figure 2: Learning from legal copying and infringement experience and company behavior in cooperation decisions (non-observable aspects are indicated by a dotted line)

A company whose IP has been legally copied or whose IPR has been illegally infringed has experienced the failure of their appropriation strategy as the legal copying or the illegal infringement constitutes the imitation of one of the company's innovations leading to the expropriation of parts of the innovation's rents. The framework by Argote and Miron-Spektor; 2011) (FIGURE 3) predicts that this experience is directly made by the focal organization, hence, and stems from the environmental context of the firm. Moreover, it interacts with the members and tasks of the organization. After this experience, the firm will engage in reflecting about it, search for causes and develop theories about its origin and the action steps necessary to cope with this experience.

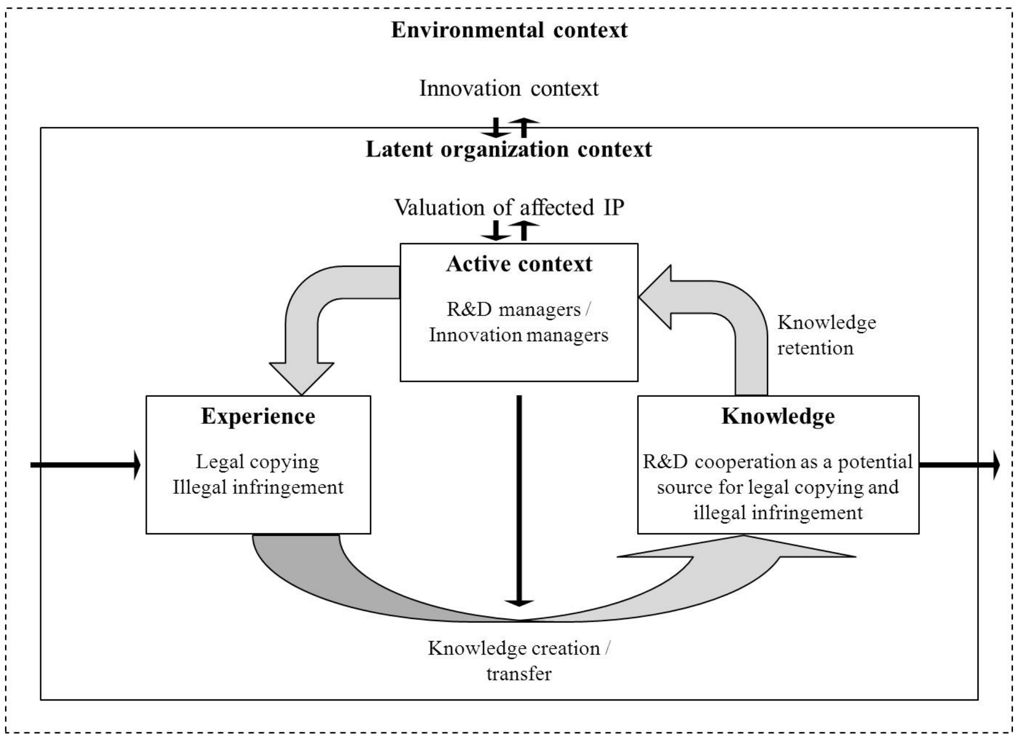

Figure 3. Theoretical framework for analyzing organizational learning (Argote and Miron-Spektor, 2011), adapted to the empirical context of legal copying and illegal infringement

In other words, the company will adapt its innovation strategy in a way to cope with the insufficient appropriation mechanisms employed. Consequently, companies with legal copying or illegal infringement experience could refrain from future R&D cooperation as this form of external engagement constitutes a threat of expropriation (Cassiman and Veugelers, 2002). This knowledge will manifest itself in the actions the company takes in the environmental context after the learning process for which we expect to observe a decline in R&D cooperation. Firms that have experienced legal copying of IP or illegal infringement of IPR should be risk-averse and should prefer in-house R&D over external R&D with a partner. Thus, firms will engage in less R&D cooperation when associated with the risk of knowledge spillover, opportunism or imitation.

In conclusion, depending on the innovation capabilities of the firm and the potential cooperation partner, the firm will compare potential gains (e.g., incoming spillover) with the risks, costs and downsides of a collaboration and thus, will decide for or against cooperation. This leads to our hypothesis 1:

Hypothesis 1. A company's likelihood to cooperate in R&D decreases if the company has experienced legal copying of IP.

At this point, we differentiate between legal copying and illegal infringement as the reasoning for both hypotheses is the same, however, the intensity of the influence of illegal infringement on R&D cooperation might differ. This is due to the fact that illegal infringement constitutes the possibility for the affected company to impose a credible threat and launch a legal counter strike. However, the company might be more cautious towards R&D cooperation as even legal protection did not deter opportunistic behavior or prevent the expropriation.

The literature in open innovation highlights that a firm's application of overly restrictive legal protection mechanisms can have significant negative consequences for the possibilities for external engagements (Alexy et al., 2009; Chesbrough, 2006; Reitzig and Puranam, 2009). Significant barriers to working with new external partners can arise from complex negotiations prior to the collaboration and due to legal departments that require individual employees to sign non-disclosure agreements or obtain permission to set up collaboration talks and thus, prevent knowledge exchange across the firm boundary (Alexy et al., 2009). Furthermore, tough legal protection signals that conflicts over control and ownership of knowledge might follow from the collaboration (Laursen and Salter, 2013).

Beyond the legal aspects, in R&D cooperation non-tacit and tacit knowledge is transferred. Tacit knowledge might, however, work as a complementary asset for the non-tacit knowledge codified, disclosed in and protected by a patent. Consequently, R&D cooperation might ease the illegal infringement of IPR for the partner and induce further expropriation based on tacit knowledge obtained from the collaboration. As the arguments for legal copying and illegal infringement point into different directions, we disentangle the mechanisms into two separate hypotheses. Notwithstanding, we also predict a negative relation between legal copying and R&D cooperation.

Hypothesis 2. *A company's likelihood to cooperate in R&D decreases if the company has experienced illegal infringement of IPR.*

4. Empirical analysis

4.1. Sample

For our study, we use the Germany Community Innovation Survey (CIS)[5], which includes the core Eurostat CIS and additional topics for firms in Germany. The study is conducted every year and contains a random sample that is stratified by region, size, and sector. The CIS survey includes questions on IP, innovation performance, R&D cooperation, and innovation expenditures, and it follows the recommendations contained in the OECD's Oslo manual on innovation data collection (OECD and Eurostat, 2005). The German CIS is a panel sample that is updated by adding new companies (observations) every second year to address panel mortality. European as well as international scholars (e.g., Belderbos et al., 2004; Cassiman and Veugelers, 2002; Leiponen and Helfat, 2011; Miotti and Sachwald, 2003; Tether, 2002) have begun using CIS data for two reasons. First, CIS data measure innovation performance, and second, CIS data complement conventional patent data (Kaiser, 2002b; Leiponen and Helfat, 2011), thus existing patent data drawbacks can be overcome. We merge two waves containing information regarding the legal copying of IP and the illegal infringement of IPR (CIS 2008), the firm-level variables (CIS 2011) and information about R&D cooperation (CIS 2011).

Moreover, information from the EPO regarding patent stock, trademark stock and utility model stock is added to the data set. The matching of the three waves is conducted on a 1:1 basis by a variable (ID) identifying each company throughout the German CIS waves with a distinctive number. The same holds true for the matching of the numbers of patents, trademarks and utility models. The merged data set contains 2,001 randomly chosen, innovative German companies[6] of various sizes. The resulting data set is suitable for cross-section analyses regarding our employed dependent and independent variables as they are either contained in CIS 2008 (independent) or in CIS 2011 (dependent).

4.2. Measures

Recent experience is known to be more relevant for the organizational learning process as compared to experience acquired a long time ago (Argote and Miron-Spektor, 2011; Argote et al., 1990; Baum and Ingram, 1998; Benkard, 2000). Consequently, we choose the period in which the legal copying or illegal infringement experience (2005-2007) is made in a way that it is closely followed by the period in which the organization's learning outcome can manifest itself with regard to R&D cooperation (2008-2010). For our empirical analyses, we limit the time in which

5 Mannheim Innovation Panel (MIP), ZEW, Mannheim.

6 Due to our research design, we restrict the sample to firms that are active in innovation as we tentatively assume that only innovative companies care about the appropriation of innovation rents and, hence, are able to experience the failure of their appropriation strategy.

the firm has acquired the experience but do not limit the frequency of the experience, for which we do not possess information.

Dependent variable

We operationalize R&D cooperation with the binary variable 'Cooperation'. This variable comprises cooperation in R&D with all types of external actors, including suppliers, customers, competitors, etc. The related question is present in the CIS 2011 questionnaire, refers to the years 2008 to 2010, and includes all types of cooperation in R&D.[7]

Independent variables

As determinants for legal copying and illegal infringement of IP(R), we employ the following two binary variables: 'Legal copying' and 'Illegal infringement'. *Legal* copying, in this context, refers to incidences in which no IPR has been granted for the respective IP. *Illegal infringement* refers to the *unauthorized* usage of IP, which is protected by a legal exclusion right such as patents, trademarks, etc. Hence, legal copying does not violate any IPR. This information is taken from the CIS 2008. The questionnaire refers to different types of IP (technical IP, products or business models, names or brands and designs), and it differentiates between unprotected IP without and protected IP with legal exclusion right (i.e., IPR). The distinction makes it possible to operationalize legal copying of non-protected IP and illegal infringement of IPR in two different variables. Both variables are mutually exclusive; hence, an organization has either experienced legal copying or illegal infringement. The question refers to the years 2005 to 2007.[8]

Control variables

In our estimations, we control for company size using the number of employees as a natural logarithm (employees (ln)). Moreover, we control for R&D intensity (R&D intensity (‰)), measured as a ratio of turnover. Furthermore, we include the natural logarithm of IPR stocks (No. of patents (ln); No. of utility models (ln); No. of trademarks (ln)) in our models. Finally, we control for sector influence by employing the OECD classification of manufacturing industries based on R&D intensities (High-tech; Medium-high-tech; Medium-low-tech; Low-tech) and of knowledge-intensive service (KIS) industries and less knowledge-intensive service

7 The exact question is "Hat Ihr Unternehmen in den Jahren 2008 bis 2010 FuE-/Innovationskooperationen durchgeführt?" – English translation: "Did your company conduct any R&D/innovation cooperation in the years 2008-2010?" Hence, we do not possess data on a dyad-level.

8 The exact question is "Ist intellektuelles Eigentum Ihres Unternehmens in den Jahren 2005-2007 durch andere Unternehmen beeinträchtigt worden (…) und hatte Ihr Unternehmen dieses intellektuelle Eigentum rechtlich geschützt" – English translation: „Has IP of your company been interfered with by other companies in the years 2005-2007 (…) and had your company protected the respective IP legally?"

(LKIS) industries.[9] The information on sectors is provided by NACE codes (European industry classification) and is translated into the OECD classification based on Eurostat (2009). We choose the control variables on the basis of previously conducted studies regarding influencing factors on R&D cooperation (Becker and Dietz, 2004; Fritsch and Lukas, 2001; Tether, 2002). Moreover, we add the ordinal variable product life cycle indicating how fast products are replaced in the market which might have an influence on the harm done by legal copying or illegal infringement. The rating scale goes from 0 meaning 'slow' to 3 coding 'very fast'.

Different IP strategies could influence the likelihood of companies experiencing legal copying or illegal infringement as well as influencing the propensity to cooperate on R&D. However, prior research has shown that there are no prominent IPR strategies among the companies in our sample (Mueller et al., 2013). Hence, we do not expect endogeneity in this context. It is not obvious why an IPR strategy should simultaneously influence cooperation, legal copying and illegal infringement if there are no prominent IPR strategies.

All employed control variables, with the exception of the IPR stocks, are directly taken from the CIS 2011 questionnaire; the operationalization is straightforward. For an overview of the employed variables, please refer to TABLE 1.

9 LKIS is the reference category in the estimations.

Table 1. Overview variables

Dependent Variable	Measurement	Mean	S.D.	Min	Max
Cooperation	Dummy	0.33	0.47	0	1
Independent Variables					
Legal copying	Dummy	0.11	0.31	0	1
Illegal infringement	Dummy	0.09	0.29	0	1
Control Variables					
Product life cycle	Categorical	0.95	0.83	0	3
No. of patents (ln)	Continuous	2.16	30.06	0	1008.18
No. of trademarks (ln)	Continuous	0.14	0.49	0	4.95
Employees (ln)	Continuous	4.07	1.68	0.69	10.67
R&D intensity (‰)	Continuous	0.35	1.22	0	13.37
Sector Types					
High-tech	Dummy	0.05	0.21	0	1
Medium-high-tech	Dummy	0.18	0.38	0	1
Medium-low-tech	Dummy	0.17	0.38	0	1
Low-tech	Dummy	0.12	0.33	0	1
KIS	Dummy	0.39	0.49	0	1
LKIS	Dummy	0.02	0.14	0	1
Propensity Score					
Employees (ln)	Continuous	4.07	1.68	0	10.67
Export intensity (%)	Continuous	0.18	0.27	0	1.00
R&D intensity (‰)	Continuous	0.04	0.12	0	1.34
Innovation expenditure intensity (%)	Continuous	0.07	0.23	0	5.32
High-tech	Dummy	0.05	0.21	0	1
Low-tech	Dummy	0.12	0.33	0	1

4.3. Statistical method

In this paper, we analyze the influence of legal copying of IP and illegal infringement of IPR on a firm's likelihood to cooperate on R&D. As our dependent variable (cooperation) is binary, we use logistic regressions. By employing the odds-ratios, we can determine the strength of the influence (in percentage) in lowering or increasing the likelihood of cooperation, thus enabling us to derive interpretable and comprehensive evidence for economic implications and for management recommendations.

However, the effect we aim to estimate is a classic treatment effect. The fact that an organization has been legally copied or illegally infringed upon can be interpreted as a treatment that influences the likelihood of cooperation. As our sample may be imbalanced regarding certain unobservable variables, endogeneity becomes an issue (Guo and Fraser, 2010). Such a bias would exist if, e.g., companies that cooperated before a legal copying or illegal infringement incident are systematically more or less likely to cooperate afterwards. This also applies to firms within a certain sector where firms there is more cooperation in general and firms are also more likely to experience legal copying and illegal infringement.

One possibility to correct for such bias is to use a Heckman-type selection approach (Heckman, 1979). However, this approach tackles sample selection bias, which is not present in our sample as it was randomly selected and contains treated and untreated subjects. The bias for which we must correct stems from the fact that becoming part of the treatment group versus not becoming part of the group may be induced by certain observable characteristics of the firms and may, as a consequence, not be random. Therefore, we apply a propensity score instead of a Heckman-type analysis to correct for this bias.

A further alternative to tackle the discussed bias is to construct a panel and analyze the effect of legal copying and illegal infringement on R&D cooperation over time. However, a panel analysis demands strict exogeneity of the independent variable (Greene, 2008). Therefore, even if we relax this assumption and adopt the premise of conditional exogeneity (Wooldridge, 2010), our independent variables, legal copying and illegal infringement, do not fulfill this criterion. Thus, as the endogeneity issue present in our sample stems from the fact that legal copying and illegal infringement may well be induced by past cooperation in R&D, we cannot directly control for that or disentangle the origin of the legal copying or illegal infringement occurrences. Consequently, a panel analysis does not solve the endogeneity problem. However, an instrumental variable approach could solve the problem of endogeneity by employing instruments endogenous to legal copying and illegal infringement but exogenous to R&D cooperation. In a two-step analysis, the endogeneity of legal copying and illegal infringement is accounted and corrected for in the final regression. While this approach solves the endogeneity issue, we are not able to make use of it since all variables suitable as instruments (exogenous) are too weak: their F statistics (between 1 and 4) are far below the threshold of 9.08 suggested by Stock and Yogo (2002). Even from a theoretical perspective, it is difficult to argue for a strong instrument. Very convincing instruments are policy shifts resulting in a change of one variable and not affecting the other. However, they are suitable for panel data only. As we are not able to employ panel data, nor an instrumental variable approach, we encourage further research to do so.

Moreover, the perfect design for our study would comprise two observations for one company: the cooperation behavior after a legal copying or illegal infringement incidence and the cooperation behavior if the incidence had not occurred. However, if we observe a legal copying or illegal infringement incidence, we cannot observe the latter case which is often called the counterfactual outcome. In our case, we compare firms having experienced legal copying or legal infringement to those who did not in separate estimations. The average treatment effect on the treated (ATT, in our research design the average shift in the cooperation behavior caused by experienced legal copying or illegal infringement for companies with such an experience) can be formally expressed as:

$$ATT = E(ATT \mid D = 1) = E[Y^1 \mid D = 1] - E[Y^0 \mid D = 1]$$

where Y^1 refers to the cooperation behavior of a company which experienced illegal infringement or the illegal copying while Y^0 codes the cooperation behavior of companies without such an incidence and D equals 1 if there was indeed a case of legal copying or illegal infringement, 0 otherwise.[10] As we lack the counterfactual outcome ($E[Y^0 \mid D = 1]$), we tackle the endogeneity issue using propensity score analysis (Rosenbaum and Rubin, 1983) aiming at matching non-treated firms (without legal copying or illegal infringement experience, i.e., control group) which are similar to the treated firms (with such an experience) in the relevant pretreatment characteristics. After this matching, the difference between the R&D cooperation behavior of the treated group and the control group can be attributed to the legal copying or the illegal infringement experience. We use a three step approach for this analysis.[11] First, we identify variables with influence on legal copying and illegal infringement (pretreatment characteristics) and choose those variables with a significant influence (at least at the 10% level) to estimate the propensity score. We derive these variables from stepwise logistic regressions (TABLE 2). For both legal copying and illegal infringement, we use 'Number of employees (ln)', thereby including information about the company size, and the 'Export intensity (%)' of the company, thereby reflecting the regional scope of the products. With regard to legal copying, we further include the 'Innovation expenditure intensity (%)', as legal copying occurs at the product as well as at the technology level. R&D intensity would solely account for the technology level. Moreover, we account for the sector type 'Low-tech' as we expect legal copying to have a greater effect on the less technical aspects of a product where legal copying occurs. Regarding illegal infringement, we further account for the 'R&D intensity (‰)', as companies heavily investing in R&D attract relatively more illegal infringement, and the sector type 'High tech', because high-tech sectors are innovating at the technological frontier and patents provide the necessary information for imitating, and hence, illegally infringing, the respective technology.

Next, we use the propensity score to execute a nearest neighbor matching with caliper (0.25*SD) of the propensity score; compare (Rosenbaum and Rubin, 1985) without replacement[12], as suggested by extant literature (Guo and Fraser, 2010), thus resulting in a balanced sample with 50% treated and 50% untreated items.[13] This reduces the size of our dataset to 227 observations for legal copying[14] and 196 for illegal infringement, respectively. These observations meet the

10 Compare Rubin (1974).

11 For a concise overview on propensity score and matching analysis, their advantages and drawbacks, please refer to Guo and Fraser (2010).

12 As our sample comprises relatively many untreated companies, we choose this method to ensure a higher reliability of the findings.

13 The nearest neighbor matching is executed with the user written Stata command psmatch 2 by Leuven and Sianesi (2003).

14 Stata drops one observation in the regression. Therefore, the number is uneven.

common support assumption; while all treated observations for legal copying are confirmed, three observations of illegal infringement are dropped due to missing support. In the third and final step, we run logistic regressions on the balanced sample, leading to fairly unbiased results regarding unobservable variables (Rosenbaum and Rubin, 1983). We estimate propensity scores for both variables legal copying and illegal infringement, and run independent logistic regressions on the balanced sample afterwards.

4.4. Results

The analyses and hence the results are based on innovative firms. As we strive to estimate the influence of legal copying of IP and illegal infringement of IPR, it is worthwhile to analyze descriptive statistics to determine the extent to which companies affected by those incidences tend to cooperate in R&D (FIGURE 4), because many innovative companies cooperate in R&D and most of these companies have not experienced legal copying or illegal infringement. Less than half of the firms affected by illegal infringement cooperate, whereas the opposite is true for legal copying. Accordingly, the descriptive analysis provides a first overview of firms' R&D cooperation behavior, legal copying of IP and illegal infringement of IPR. Notwithstanding, the results are ambiguous and a straight interpretation is not possible, the multivariate analyses explained above form a clearer picture. The results are reported herein.

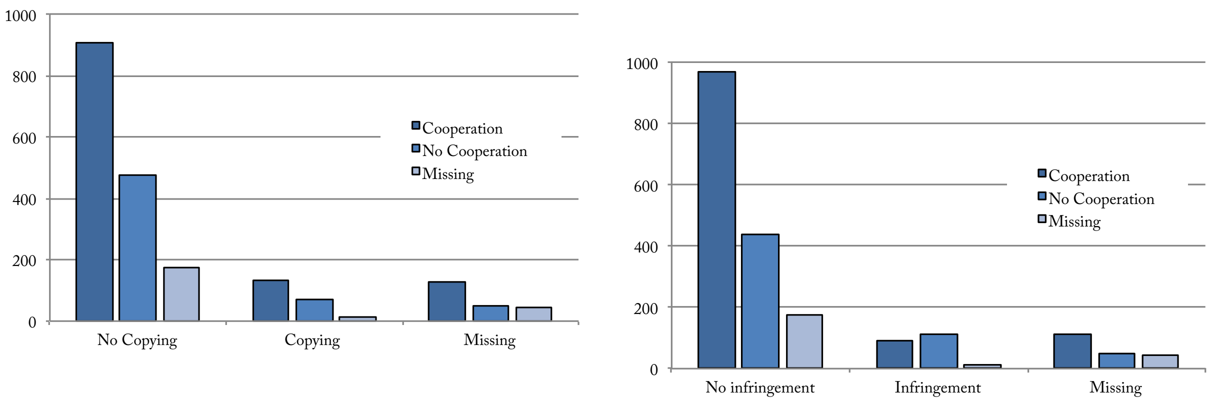

Figure 4. Descriptive analyses - cooperation and legal copying/illegal infringement

For the purpose of our research, we estimate four different logistic estimation models (TABLE 2) with cooperation as the dependent variable. The first model (M1) is a simple logistic regression, whereas the third model (M3) is a logistic regression on a balanced sample regarding legal copying and the fourth (M4) is a logistic regression on a balanced sample regarding illegal infringement. The balancing is achieved by propensity score analysis.[15]

15 We run the same regressions with R&D cooperation data taken from the CIS 2009, covering the years 2006-2008 and we find the same effects indicating that our results are robust. The results for these regressions are available upon request.

The results of M1 indicate a significant influence of both legal copying and illegal infringement experiences. While the influence of legal copying is negative, the influence of illegal infringement is positive. In other words, if a firm has experienced legal copying of IP it is approximately 35% less likely to engage in R&D cooperation, whereas experience with illegal infringement of IPR increases the likelihood of cooperation by approximately 76%. Other influences are, as expected, contained in the control variables. Especially, R&D intensity draws the attention towards its odds-ratio. The odds-ratio means that with each 1‰ increase of R&D expenditures, the likelihood of engaging in cooperation increases by roughly 500%, which seems quite high. However, TABLE 1 reveals a mean of 0.4‰ and a maximum value of 13.4‰, which indicates that an increase of 1‰ is rather substantial and the high odds-ratio is consistent. However, this substantial influence of R&D intensity may dilute any other influence, including that of legal copying and illegal infringement. Therefore, we run a second regression (M2) without legal copying and illegal infringement to calculate the BIC and AIC measures. While the BIC measure indicates that M1 has a slightly higher explanation value, the AIC indicates the opposite. Hence, these measures do not reveal a clear picture. Legal copying and illegal infringement together contribute by 0.68% to the R^2, which equals an improvement of 3.7%. Further, we run regressions without R&D intensity and find that R&D intensity contributes to roughly 50% of the estimated R^2. However, we must bear in mind that the calculated R^2 is only a pseudo R^2 and, hence, even more limited in its explanation value when compared to the R^2 of an OLS regression. Finally, the sector variables do not reveal a systematic influence on the likelihood to cooperate on R&D, and neither does the product life cycle.

Table 2: Logistic regression – dependent variable always cooperation

	M1		M2		M3		M4	
	Coeff.	Odds-Ratio	Coeff.	Odds-Ratio	Coeff.	Odds-Ratio	Coeff.	Odds-Ratio
Legal copying	-0.43*	0.65*			-0.55*	0.58*		
	(0.24)	(0.16)			(0.33)	(0.19)		
Illegal infringement	0.57**	1.76**					0.64*	1.89*
	(0.24)	(0.42)					(0.34)	(0.64)
Product life cycle	0.10	1.10	0.11	1.12	-0.14	0.87	-0.01	0.99
	(0.08)	(0.09)	(0.08)	(0.09)	(0.19)	(0.16)	(0.19)	(0.19)
No. of patents (ln)	-0.00***	1.00***	-0.00**	1.00**	-0.01***	0.99***	-0.00**	1.00**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
No. of trademarks (ln)	-0.01	0.99	0.06	1.06	0.25	1.29	-0.29	0.75
	(0.15)	(0.15)	(0.14)	(0.15)	(0.39)	(0.50)	(0.24)	(0.18)
Employees (ln)	0.38***	1.46***	0.39***	1.47***	0.43***	1.53***	0.45***	1.57***
	(0.05)	(0.07)	(0.05)	(0.07)	(0.11)	(0.17)	(0.12)	(0.19)
R&D expenditures (‰)	1.79***	6.01***	1.75***	5.75***	1.02**	2.78**	1.91***	6.73***
	(0.36)	(2.15)	(0.34)	(1.97)	(0.40)	(1.11)	(0.55)	(3.67)
High-tech	0.61**	1.84**	0.70**	2.00**	2.31***	10.04***	1.22*	3.37*
	(0.30)	(0.56)	(0.30)	(0.61)	(0.65)	(6.52)	(0.64)	(2.16)
Medium-high-tech	0.56***	1.74***	0.56***	1.75***	1.11***	3.03***	0.26	1.30
	(0.19)	(0.33)	(0.19)	(0.33)	(0.41)	(1.24)	(0.43)	(0.56)
Medium-low-tech	0.60***	1.82***	0.63***	1.88***	1.52***	4.58***	0.63	1.88
	(0.20)	(0.36)	(0.20)	(0.37)	(0.47)	(2.13)	(0.47)	(0.87)
Low-tech	0.42*	1.52*	0.41*	1.50*	1.36***	3.90***	0.18	1.19
	(0.23)	(0.35)	(0.23)	(0.34)	(0.52)	(2.02)	(0.61)	(0.73)
LKIS	-0.92	0.40	-0.86	0.42	(omitted)		(omitted)	
	(0.76)	(0.30)	(0.72)	(0.31)				
Constant	-3.15***	0.04***	-3.20***	0.04***	-3.21***	0.04***	-3.39***	0.03***
	(0.25)	(0.01)	(0.25)	(0.01)	(0.62)	(0.02)	(0.78)	(0.03)
Observations	1,201		1,201		227	227	196	196
Log Likelihood	-613.04		-618.22		-119.37	-119.37	-111.33	-111.33
Chi^2	126.90		120.15		40.40	40.40	31.75	31.75
Pseudo R^2	0.19		0.19		0.21	0.21	0.18	0.18
Prob > Chi^2	0.00		0.00		0.00	0.00	0.00	0.00
BIC	1318.254		1314.436		-		-	
AIC	1252.072		1258.436		-		-	

Robust Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

As the results of M1 could be influenced by certain variables that we do not observe, our sample may not be balanced regarding our explanatory variables, legal copying and illegal infringement. Therefore, we estimate two models with balanced samples regarding legal copying (M3) and illegal infringement (M4) based on a propensity score analysis. Both models support the findings of M1. For both explanatory variables, the coefficients remain significant and consistent, although the degree of influence is slightly more pronounced. All models are highly significant and have a satisfying degree of explanation. For reasons of simplicity, we only refer to the coefficients of the regression model M1, as all results indicate that these findings are robust. The following chapter explains and discusses our results for innovative firms with implications for management and research.

5. Discussion and implications

The research question we set out to answer in the beginning of this paper was whether companies learn from weaknesses of their IP and, more specifically, their appropriation strategy as reflected in their R&D cooperation behavior. Our results confirm our assumption that companies learn from failure in shaping their appropriation strategy and mitigate their exposure to risks of expropriation by adapting their R&D cooperation behavior accordingly. However, the firms in our sample only partially show a behavior consistent with our predictions. Hypothesis 1 which posits a decrease in the likelihood of R&D cooperation in case of prior experience with legal copying of IP is confirmed by our findings. On the other hand, Hypothesis 2 is not verified, thus leaving us rather puzzled as the influence of illegal IPR infringement experience is significant, but it reveals a positive influence on the likelihood of cooperating in R&D. Nonetheless, our findings altogether show that firms are able to learn from failure in a more varied manner as shown by extant literature. While previous research has shed light on companies learning from product failures (e.g., Haunschild and Sullivan, 2002 on airplane accidents), insufficient safety regulations (e.g., Baum and Dahlin, 2007 on U.S. Class 1 freight railroads' accident costs), (e.g., Madsen, 2009 on coal mining accidents in the US), or external shocks (e.g., Christianson et al., 2009), our results imply that companies also learn from failure in crafting and exerting their strategy, specifically their appropriation strategy. Our results, hence, compliment the body of learning from failure literature in proposing a new source of learning experience.

The implication that firms learn from mistakes in their strategy is especially relevant for strategic management scholars in general, while the empirical setting of our work is specifically interesting for innovation management scholars and practitioners. Shifts in (IP) strategies can be triggered by a learning-from-failure process within the organization. This enhances our understanding about factors shaping firms' strategies.

However, the question why legal copying of IP has a negative (as predicted) influence while illegal infringement of IPR has a positive influence is difficult to answer within the limits of our data. We expected a similar result for illegal infringement as we did for legal copying, assuming firms to be more cautious towards R&D cooperation as even ex-ante legal protection did not deter opportunistic behavior or prevent the expropriation. The aforementioned limits of the survey data do not allow us to investigate factors that might possibly explain the positive relationship between illegal infringement and R&D cooperation. Still, this result merits a further analysis. Hence, we triangulate our survey data with qualitative data which we gained in semi-structured interviews with experts in IP strategy, IPR infringement, and innovation management. The first results of these interviews, which are still in progress, shed light on this interesting result.

Apparently, illegally infringed companies take this experience as justification for reciprocating with illegal infringement within R&D collaboration. In other words, an illegally infringed company feels entitled to strike back by illegally infringing themselves or might use this opportunity to enter into negotiations with the alleged infringer. R&D partnerships provide a setting in which the company can collect information about the IPR portfolio of the partner and find valuable IP suitable to infringe them back. Furthermore, infringement of IPR is an important means for firms to initiate negotiations over collaboration with a range of external parties (Cohen et al., 2000; Laursen and Salter, 2013). In reality, this might lead to a cross-licensing deal in which the initially infringed company has an advantaged position as it can threaten the infringer with litigation.

Further possible explanations that have not been supported by the interview data, yet, are the following. In line with the first, already supported argument, firms might use the reciprocal infringement to broaden their product portfolio in areas where they do not possess technological competencies. This strategic step could induce future R&D cooperation as the company needs to acquire additional (tacit) knowledge to leverage the IP gained by illegal infringement. Furthermore, the dynamics between infringer and infringed company can play an interesting role. Assuming for example, a large firm unintentionally committed the illegal infringement of IPR held by a small-medium sized enterprise (SME), it might initiate an R&D cooperation between the SME and the large company. Still, the SME might be more interested in a valuable partnership than trying to litigate its IPR against a large corporation because it will be able to obtain valuable knowhow from the collaboration. A further possibility is that the illegally infringed company successfully litigated the IPR and gained valuable knowledge in IPR enforcement. The positive experience of being able to enforce the IPR successfully plays an important role in R&D cooperation in terms of the ability to appropriate innovation rents (Alexy et al., 2009; Cassiman and Veugelers, 2002; Gassmann and Han, 2004; Teece, 1986). This knowledge could possibly influence the likelihood to enter settings which induce an increased expropriation risk as the company feels well protected and prepared to combat illegal infringement and involuntary knowledge spillover induced by R&D cooperation (Denrell and March, 2001).

While we do not have conclusive evidence for the last ideas as of yet, we feel confident that our research contributes to the emerging area of literature on the interrelation of general company strategy, IP strategy and appropriation strategy (Laursen and Salter, 2013; Somaya, 2012). It allows us to get a glimpse of the complex relations between these strategic elements and shows that these connections justify further investigation to understand how strategic decision making, innovation management, and long-term company strategies work together in economies which rely evermore on knowledge as an integral asset.

Notwithstanding, the results for legal copying negatively influencing the likelihood to cooperate on R&D could give reason for concern. Extant research has shown that inter-firm cooperation is positively related to innovative output (Hagedoorn, 1993; Powell et al., 1996; Tether, 2002). However, experience with the legal copying of IP may jeopardize incentives established for entering into R&D cooperation, as the results of our research suggest. Thus, a shortsighted reaction to withdraw from or reduce R&D cooperation after experiencing legal copying can harm a company in the long run regarding its innovativeness and competitiveness. However, the long-term implications from this learning process are yet to be investigated. A short-term drawback from R&D cooperation to gain time for adapting the appropriation strategy of the company combined with a long-term strategy to cooperate on R&D with an improved appropriation strategy would be a rational choice for companies affected by legal copying.

If this explanation is valid, the connection between illegal infringement and successful enforcement experience could be interpreted as learning from success. As the odds-ratio of illegal infringement is greater than that of legal copying, one could even argue that organizations learn more intensely from success than they do from failure. However, we have to be careful to draw these conclusions as we cannot provide conclusive proof for this relationship since we lack data for IPR enforcement. Accordingly, this gives room for further research on IPR enforcement.

6. Conclusion and limitations

In this article, we provide first extensions to the organizational learning from failure and rare events literature (e.g., Lampel et al., 2009) by investigating if firms learn from the failure of their appropriation strategy. Indeed, our results suggest that companies are able to reflect on the failure of their strategy and adapt their behavior accordingly. Furthermore, our results inform strategic management literature in general by providing first evidence that firms change their innovation strategy according to the performance of their appropriation strategy. These results shed light on the complex relations between IP, appropriation, and innovation strategy of a firm and call for further research in this area. Moreover, our article contributes to innovation management literature by drawing attention to the expropriation risks of R&D cooperation and adding legal copying and illegal infringement experience as further driving factors.

The different influences of legal copying and illegal infringement experience on R&D cooperation provide an interesting and a bit puzzling picture reflected in the title of this article 'Once bitten, less shy' alluding to the proverb 'Once bitten, twice shy' which would only reflect part of our findings.

Our research provides first insights into this phenomenon. While we must take care when generalizing the findings, the evidence presented is a step towards understanding the importance of experience with legal copying of IP and illegal infringement of IPR, as captured herein via learning from failure and its impact on inter-organizational R&D cooperation.

While this work has interesting implications, several limitations exist. First, it is not possible to draw any conclusions about the prevalent IPR regime the firms in the sample face. Furthermore, we do not possess quantitative data about legal enforcement, and we cannot draw inferences about the origins for the legal copying of IP and the illegal infringement of IPR experience. The employed quantitative data informs us if a firm has had experience with legal copying of IP or with illegal infringement of IPR but not about the extent to which the company was affected meaning a quantifiable number of legal copying and illegal infringement incidences. However, the fact that firms do show a reaction suggests that an organization's collaborative efforts are to a certain degree independent of its experience intensity.

A further concern about our findings is the possibility of endogeneity as discussed in the section *Statistical Method* stemming from the fact that previous R&D cooperation influences the likelihood that an organization cooperates and simultaneously impacts the probability of a firm making a legal copying or illegal infringement experience. We suggest further research to solve this problem with an instrumental variable approach employing a policy shock (e.g., changes in the prosecution of patent infringements, changes in the patent law, etc.) in a panel data set. We try to tackle this shortcoming of our study by controlling for previous alliances using data on collaboration for the years 2006-2008[16]. The results of these robustness checks suggest that our measured effect is not random.

A further possible bias stems from a missing variable (omitted variable bias), namely from the IP value. As we use the actual R&D cooperation (instead of a variable measuring the willingness to enter an R&D cooperation) as dependent variable, the value of the company's IP influences the fact that it collaborates. If a firm has something valuable to offer the likelihood of cooperation is greater. At the same time, the IP value influences the probability that an organization has experienced legal copying or illegal infringement. For this reason, we added the IPR portfolio of companies as a control variable. However, scholars have used oppositions to and litigations of patents as an indicator for the patent value (Crampes and Langinier, 2002; Lanjouw, 1998) indicating that the mere number of patents is an insufficient measure. The fact that legal copying and illegal infringement influence the likelihood to cooperate on R&D in opposite ways indicates that our results are worthwhile being discussed. Further, to correct for the omitted variable bias is a great challenge. The assumption that the whole IP portfolio a firm owns is more valuable because it cooperates or because it experienced legal copying or illegal infringement might seem farfetched. Besides, firms might cooperate on R&D to gain access to new knowhow instead of offering IP or other benefits, e.g., capital, distribution networks, etc.

We encourage further research to examine other reactions to legal copying and illegal infringement as we focus on a very specific part of the innovation strategy of the company: the decision to engage in R&D cooperation. This leaves room for future research investigating shifts in the appropriation strategy (e.g., usage of patents vs. secrecy) which further leverages the large body of research in this area (James et al., 2013).

16 Results are available on request.

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How Open is Too Open? The 'Dark Side' of Openness Along the Innovation Value Chain

Abstract

In this article, we aim at establishing a link between open innovation and the imitation of intellectual property (IP). Bivariate analyses of survey data concerning the open innovation orientation of 3,956 German firms reveal that companies engaged in open innovation face imitation. Further, we find significant positive relations between imitation and every single innovation phase with the exception of the testing and marketing phase. Moreover, we show that all potential open innovation partner types are connected to the risk of imitation with the exception of competitors, which is a surprising result. While our results show these relationships, we are not able to test for a causal direction. However, the results of our work point at an interesting avenue in research quantitatively analyzing the influence of open innovation on imitation of IP. Furthermore, our findings suggest that companies engaging in open innovation should be careful about an increased risk of imitation possibly induced by their openness.

Contents

1. Introduction

Due to increasing complexity and the multi-disciplinarity of research and development (R&D) and innovation efforts, firms seek to access complementary assets and knowledge outside their boundaries (Miotti and Sachwald, 2003). Open innovation has increased awareness and aroused interest in the current management literature. Prior research associates an open innovation strategy with benefits and positive returns for companies organizing their R&D activities in an open framework. In general, literature emphasizes a positive relationship between openness and innovation (Laursen and Salter, 2006), while we currently have a limited understanding of the downsides and tensions associated with openness (Dahlander and Gann, 2010; Knudsen and Mortensen, 2011). This study helps to extend our knowledge for how firms' engaging in open innovation settings simultaneously need to source external knowledge and also share and protect their own knowledge in order to appropriate the returns from innovative activities. This tension between collaboration (i.e., external knowledge sourcing) and protection of own knowhow and IP has recently been framed as the 'paradox of openness' (Bogers, 2011; Laursen and Salter, 2013).[1] Moreover, an open innovation strategy is assumed to decrease the risk which is inherent to the innovation process. At the same time, however, it may increase the risk and costs inherent to collaboration with different partners. The current study helps to extend our understanding of how firms' openness decisions are related to their need to protect their knowledge in order to appropriate the returns from innovative activities (Laursen and Salter, 2013).

According to Huizingh (2011), more quantitative research is needed to test for context dependencies of open innovation. Consistent with prior research that calls for more research on the costs and risks of openness (Vanhaverbeke et al., 2008), our study contributes to the understanding of possible drawbacks and paradoxes of open innovation.

Research neglects the risks of an open innovation framework, i.e., knowledge spillovers and imitation. We define imitation as the unauthorized usage of products or business models of companies, including technology, brands, and designs.[2]

This, we believe, may cause further drawbacks of an open innovation strategy which is the topic of this paper. Open innovation has, as yet, not been analyzed in the context of imitation and in particular, along the innovation value chain. The concept of an innovation value chain is part of a broader evolutionary dynamic perspective in which knowledge, ideas, and technologies are constantly redefined (Roper et al., 2008). In this paper, we show how the firms' choice of

1 Based on Arrow's (1962) 'paradox of disclosure', Laursen and Salter (2013) have adapted this concept as openness (i.e., engaging with a broad set of external actors) may require firms as well as managers to pay more attention to protect their own knowledge form being copied.

2 Hence, depending on the appropriabilty, a firm experiences imitation if it is not able to capture all the profits generated from its innovation investment (Ceccagnoli, 2009; Teece, 1986).

the cooperation partner type as well as the firms' cooperation behavior along the innovation value chain connect with imitation. Exploring the particular case of "high-risk" openness (i.e., competitor collaboration) (Laursen and Salter, 2013), we argue that the threat of experiencing imitation is greater due to similar knowledge bases and compatibility of content exchanged. We analyze survey data consisting of 3,956 German firms and identify the relationship of a company's open innovation strategy and the imitation of its intellectual property (IP). These results shed light on some new limitations of openness than the literature on the open innovation paradigm currently suggests.

In this article, we do not challenge the benefits of openness with regards to reducing the innovation inherent risks but we raise awareness for the correlation between open innovation and imitation.

Next, we give an overview on open innovation literature to explain the influence of openness on imitation. We exemplify whether a company that is open along the innovation value chain is experiencing imitation of its intellectual property (IP). The subsequent section describes the data, explains the methodology and looks at the link between imitation and the firm's openness along the value chain. We are not able to precisely identify the direction of causality since our dependent and important independent variables are choice variables (see methods section). The article concludes by describing and discussing the results of the empirical investigation and provides implications for management and policy.

2. Literature review

2.1. Open innovation

Open innovation has aroused enormous interest and has become an en vogue topic for both research and management. In the last decades, innovative firms have shifted from the 'closed innovation' paradigm where companies rely on internal capabilities, towards the 'open innovation' model (Chesbrough, 2003) using a wide range of inter-organizational ties and sources (Laursen and Salter, 2006). According to Chesbrough et al. (2006, p.1), 'open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation'. In that sense, we understand open innovation as an interactive innovation process where firms rely on innovation collaboration with external partners (Hippel, 1986; Szulanski, 1996; Dahlander and Gann, 2010), but at the same time acknowledge that the concept of open innovation comprises a wider range of mechanisms. Thus, internal processes need to be aligned to the external environment to enable successful absorption of knowledge from partners (Cohen and Levinthal, 1990; Laursen and Salter, 2013).

A large amount of literature on strategic alliances addresses the impact of inter-firm cooperation on innovation performance (for a review see de Man and Duysters, 2005). Some scholars, argue that the impact on innovative performance depends on the nature of the partner(s) involved (Belderbos et al., 2004; Chen et al., 2011; Faems et al., 2005; Miotti and Sachwald, 2003), the intended type of innovation to be developed (radical vs. incremental) (Tether, 2002), the knowledge overlap (Mowery et al., 1996), or the absorptive capacity of the partnering companies, (Lane and Lubatkin, 1998; Lane et al., 2001; Zahra and George, 2002) and the sector (Tether and Tajar, 2008a, 2008b). In sum, a growing number of R&D alliances have been formed during the past decades since R&D partnerships are an important strategic tool for organizational learning (Inkpen, 1998; Inkpen and Dinur, 1998).

Against this background, we focus on formal collaboration agreements which Laursen and Salter (2013) refer to as the 'hard' form of openness[3] as it requires both partners to comply with an agreed structure of the cooperation. Further, scholars have analyzed how the degree of openness affects companies. They differentiate between two dimensions: breadth and depth (Katila and Ahuja, 2002; Laursen and Salter, 2004, 2006). Breadth refers to the number of formal collaboration relationships or external knowledge sources firms use in their search for innovative opportunities (Laursen and Salter, 2013); depth means the extent to which firms use these external partners, search channels (Laursen and Salter, 2006; Leiponen, 2012; Leiponen and Helfat, 2010), or existing knowledge (Katila and Ahuja, 2002; Laursen and Salter, 2004).

3 This is in contrast to external knowledge sourcing defined as the 'soft' form of openness as it does not necessarily involve legally binding agreements.

In general, literature emphasizes a positive relationship between openness and innovation (Laursen and Salter, 2006), while potential drawbacks and tensions of openness are yet to be examined (Dahlander and Gann, 2010; Knudsen and Mortensen, 2011).

The 'bright side' of open innovation

To successfully develop and commercialize at least one innovation, a company diversifies risks and R&D investments across different knowledge sources or cooperation partners resulting in a portfolio strategy which aims at hedging the innovation inherent risk. Thus, innovators rarely innovate alone as they can benefit from access to a broad base of complementary ideas, knowledge, skills, and expertise when cooperating (Dyer and Singh, 1998; Hamel, 1991; Laursen and Salter, 2006).

Usually studies find a positive relationship between cooperation and innovation activities (e.g., Belderbos et al., 2004; Hagedoorn, 2002; Sampson, 2007; Stuart, 2000). In a meta-analytic study, Wijk et al. (2008) discover that inter-organizational knowledge transfer positively influences company performance (also: Lane et al., 2001; Szulanski, 1996) as well as innovativeness (also: Jansen et al., 2005; Powell et al., 1996).

In general, prior research associates essential positive returns with an open innovation strategy as well as with the breadth and depth of external information sources and the cooperation objectives (Chen et al., 2011; Katila and Ahuja, 2002; Leiponen and Helfat, 2010; Tomlinson, 2010).

Lee et al. (2010) (also: van de Vrande et al., 2009a) prove open innovation to be beneficial for small and medium-sized enterprises (SMEs). Another stream of literature addresses the advantages of open innovation practices in corporate venturing (Vanhaverbeke et al., 2008; van de Vrande et al., 2009b). Chesbrough and Rosenbloom (2002) and Dahlander and Gann (2010) suggest that companies may benefit from outside partners when commercializing inventions.

The 'dark side' of open innovation

An open innovation strategy aims at decreasing the risk inherent to the innovation process but at the same time it may increase the risk inherent to collaboration with different partners. According to Vanhaverbeke (2006), most companies do not feel at ease in open innovation settings because this process redefines and blurs the boundaries between the own firm and its environment (Laursen and Salter, 2006; McEvily et al., 2003).

An emerging stream of literature suggests that there are drawbacks associated with an open innovation strategy. Openness induces costs which are caused by coordination, management, and control (Enkel et al., 2009). Eventually, these costs may also become a burden for an open company. Using too many sources simultaneously generates an attention and a maintenance problem (Ahuja, 2000; Love et al., 2013). This means, implementing an open innovation strategy can be associated with high transaction costs (Christensen et al., 2005). Enkel et al. (2009) show that difficulty in finding the right partner (also: Chesbrough and Appleyard, 2007), interference with the daily business, and insufficient time and financial resources are risks of carrying out open innovation activities.

Open innovation is usually associated with the risk of involuntary knowledge spillover (Cassiman and Veugelers, 2002), leakage of critical internal resources, and disclosure of core competencies to cooperation partners. In a first empirical study, Laursen and Salter (2013) make a case for a concave relation of appropriability and openness. Additionally, Knudsen and Mortensen (2011) find that openness relates to slower product development projects with greater costs than usual. Furthermore, Lokshin et al. (2011) acknowledge that firms with negative collaboration experiences may also encounter negative innovative performance.

In general, the literature has emphasized a positive relationship between openness, but the downsides of openness can be detrimental in terms of imitation and performance (Dahlander and Gann, 2010; Knudsen and Mortensen, 2011). Hence, our study contributes to the understanding of possible drawbacks of open innovation.

2.2. Imitation

According to Teece (1986), innovators are likely to lose parts of their profit share to imitators if imitation is relatively easy. The ease of imitation is especially influenced by the degree of codification of the relevant knowledge (e.g., the imitation enabling effect of patents (Anton and Yao, 2004; Horstmann et al., 1985)) and the way the knowledge is transmitted. Consequently, weak appropriability regimes or the failure to protect knowledge or IP can induce imitation. Teece (1986) points out different cases in which the 'lion's share' of the innovation's profits eventually was reaped by imitators. In other words, without appropriate protection, a firm's innovation effort can be diluted if there is a serious threat of imitation.[4]

Especially, open innovation is often referred to as a double-edged sword. On the one hand, firms enter an open innovation setting to gain new insights, knowhow, capabilities and innovative output. On the other hand, firms are aware that open innovation is a reciprocal process that requires the disclosure of some knowledge to obtain new knowledge from external partners outside the firm boundaries. This process, however, can also lead to involuntary and unanticipated spillover of sensitive tacit knowledge and IP.[5] Consequently, appropriating all the rents from IP and knowledge

4 For an overview on legal and informal protection measures please refer to Teece (1986) and Cohen et al. (2002).

5 From a rational point of view, firms cooperate if the expected benefits outweigh the risks and costs of openness.

put into the open innovation partnership may be difficult as imitation may occur. Managers can employ an appropriability strategy which comprises formal methods such as patents and trademarks as well as informal methods such secrecy and lead time. Firms may deem application of protection mechanisms necessary to make sure their technology or knowhow is not copied by others, as a signal of valuable technological knowledge or to enter into negotiation over collaboration with a wide range of partners (Cohen et al., 2000; Laursen and Salter, 2013). Nonetheless, these formal mechanisms only provide partial protection as rivals may be able to invent around a patent (Mansfield et al., 1981) which is why firms employ a complex bundle of formal and informal mechanisms to prevent imitation and knowledge spillover (Arora and Gambardella, 2010). Even informal measures such as secrecy do not guarantee a 100% protection against imitation as direct competitors can entice skilled employees from firms in the same market or reverse engineer their products (Laursen and Salter, 2013).

As prior literature in strategic management (Wernerfelt, 1984) suggests, firms must focus on the inimitability of their products to sustain a competitive advantage (for a recent literature overview, refer to Polidoro and Toh, 2011). Thus, firms engaging in open innovation contexts should be especially aware of the imitation threat open innovation poses.

Extant studies analyze factors that influence the likelihood of being imitated such as export intensity, company size, IP right stocks, etc. (Berger et al., 2012; Gulati and Singh, 1998). Furthermore, scholars find that cooperation intensity reduces patent infringement while other IPR types are not affected (Berger et al., 2012).

In addition, we aim to analyze open innovation along the value chain as a further driver for imitation of IP.

2.3. Research question and contribution

Our literature review reveals that research lacks an empirical study that investigates the relationship between following an open innovation strategy and imitation of IP. The current study helps to extend our understanding for how firms' openness decisions are related to their need to protect their knowledge in order to appropriate the returns from innovative activities (Laursen and Salter, 2013). Despite the advantages of open innovation, it may also lead to an unintended and undesirable knowledge drain, without receiving any benefits in return. This knowledge drain may result in the imitation of the own technology, products or services. We define imitation as the unauthorized usage of products or business models of companies, including technology, brands, and designs.

In this paper, we emphasize open innovation as a threat of appropriability of IP as imitation imposes a risk to capture the benefits from innovation investments (Teece, 1986). This is a potential drawback of an open innovation strategy.

To address the risk of imitation, firms usually use combinations of different means of protection using both formal methods (such as patent, trademark or copyright protection, etc.) and informal methods (lead time, first mover advantage, lock-in, complementary assets, etc.) within their appropriability strategies (Arora and Ceccagnoli, 2006; López and Roberts, 2002; Pisano, 2006; Pisano and Teece, 2007). Especially in the context of informal protection measures, open innovation is a risky strategy as critical (unprotected) knowledge may spill over to external actors. Therefore, cooperation with a wide number of external partners and managing these different sources involves huge information asymmetries which can be mitigated by negotiating formal contracts or at least informal agreements based on a degree of mutual understanding.

We also find that the impact of openness along the innovation value chain on imitation remains relatively unclear. In this paper, we show how companies' cooperation along the innovation value chain relates to imitation.

We thereby focus on these typical phases of the innovation value chain: (1) idea generation, (2) R&D, (3) design and configuration, (4) testing and marketing/ product preparation, and (5) market introduction/ implementation.[6] Hansen and Birkinshaw (2007) argue that especially in the idea generation phase many companies miss opportunities as they do not source knowledge from outside. Notwithstanding, Hansen and Birkinshaw (2007) do not find cooperation in the idea conversion phase as important, but argue that in the idea diffusion phase support from external partners (and not only customers) may be more beneficial.

Consistent with Roper et al. (2008), we are especially interested in the process through which firms generate ideas, transform and exploit new knowledge into inventions to capture value. The concept of an innovation value chain is part of a broader evolutionary dynamic perspective in which knowledge, ideas, and technologies are constantly redefined (Roper et al., 2008). There is evidence for a positive relationship between the idea generation phase and innovation outcome (Roper et al., 2008). However, the innovation value chain has, as yet, not been investigated in the context of open innovation and imitation.

In this paper, we answer how open innovation along the value chain connects to the imitation of IP and, thus, may nurture an obsessiveness with ownership as pointed out by Dahlander and Gann (2010). In doing so, we contribute to literature investigating hybrid strategies between the purely open or purely proprietary extremes (West, 2003).

Furthermore, we aim to shed light on the relationship between a firm's orientation of openness (Chen et al., 2011), openness along the innovation value chain and the firm's appropriability of

6 We further focus on these particular phases as every single one of them comprises certain collaboration opportunities as well as spillover risks.

its innovation investments. Therefore, we focus on specific dimensions of open innovation. We do not claim causal relationships between the mentioned variables but try to establish a link between them. Hence, we refrain from hypothesizing causal links but instead focus on possible connections between the different variables as indicated by previous research.

First, we take a look at the breadth of open innovation by considering specific types of cooperation partners (i.e., competitors, B2B customers, B2C customers, suppliers, and universities). This is consistent with current research which defines breadth of open innovation as the number of external partners a company has (Laursen and Salter, 2006).[7] Second, we define scope of open innovation as the extent to which firms cooperate in different phases along the innovation value chain. Third, we investigate how breadth and scope connect to imitation and establish a non-causal link between the two. Fourth, we focus on open innovation along the value chain (i.e., idea generation; R&D; design and configuration; testing, marketing, and production preparations; market introduction and implementation) and investigate which phases jointly occur with imitation.

In the following, we derive rationales for correlations between imitation and the mentioned concepts of breadth and scope, and the different phases along the innovation value chain.

Open innovation enables the partners to make use of the IP brought into the cooperation. Therefore, a company operating in an open innovation setting might also experience imitation. A company shares knowledge more intensely across the innovation value chain if it openly cooperates in many different phases, i.e., if the scope of open innovation is high. Therefore, critical knowledge is shared more deeply. Furthermore, a company sharing knowledge with many different partners in a broader open innovation setting creates more potential imitators. We assume that the breadth and scope both positively correlate with imitation.

Furthermore, companies cooperating with competitors might also be more affected by imitation. If a firm enters an open innovation setting with a competitor, the product portfolio of both partners is very similar. This extant overlap in knowhow and absorptive capacity among the partner firms might facilitate imitation as potential knowledge gaps and learning opportunities are revealed and recognized regarding IP or knowledge exposed within the open setting.

As aforementioned, we assume that a greater risk of imitation is associated with an open innovation

7 Cooperation with competitors is less common since the risk of involuntary outward spillover is particularly greater than with any other actor in the firm's portfolio of innovation collaboration. Thus, only firms with a strong appropriability strategy will engage in collaborations with competitors (Laursen and Salter, 2013). Typical examples for collaboration with competitors are the development of pre-competitive research projects (Spencer, 2003), in the standards setting process (Leiponen, 2008) or in licensing agreements (Leone and Reichstein, 2012).

strategy. We further take a look at the different phases along the innovation value chain which might be more prone to imitation of *certain* IP. We focus on the imitation of technology and design as these are typical and crucial IP for innovation. In contrast, brands and copyrighted material do not necessarily represent core parts of an innovation and are, consequently, no integral part of open innovation activities. The only exception to this is copyrighted software which we cannot disentangle from other copyrighted material (such as technical manuals, photographs, pictures, etc.).

During the idea generation and R&D phases, the company mainly reveals its critical technological capabilities to its open innovation partner(s). Hence, we especially expect imitation of technology to be correlated with these phases of the innovation value chain. Moreover, we expect imitation of technology to be connected with the implementation phase of the innovation value chain. During this phase, the companies exchange complex IP and knowledge on the optimal production process of the innovation. For the production process, internal technological knowledge needs to be shared to ensure an optimal outcome of the cooperation.

Contrasting, in the design phase of the innovation value chain, the close-to-optimal design of the innovation is developed and critical design components are shared within the open innovation setting. Hence, imitation of design should be correlated with companies that open up within the design and configuration phase of their innovation value chain.

3. Empirical analyses

3.1. Sample

We use data from the Mannheim Innovation Panel (MIP), ZEW, Mannheim, which is the German version of the Eurostat Community Innovation Survey (CIS). The MIP is sent out every year to a random sample (stratified by size, region, and sector) of German companies. Moreover, it includes additional alternating questions covering topics such as IP, innovation performance, cooperation, etc. To deal with mortality, new companies (observations) are added every other year. Among scholars (e.g., Belderbos et al., 2004; Cassiman and Veugelers, 2002; Leiponen and Helfat, 2011; Miotti and Sachwald, 2003; Tether, 2002), the interest in CIS data has risen for two reasons. First, the data provide indicators for innovation performance, and second, CIS data are used as a supplement to traditionally used patent data (Kaiser, 2002; Leiponen and Helfat, 2011). Thus, downsides of patent data can be tackled. We analyze data from the MIP 2008, containing information about imitation and about open innovation activities along the value chain. Furthermore, we match EPO patent and trademark stock data on a 1:1 basis using an ID variable unique to each company throughout the MIP. The final data set contains 3,956 observations and is cross-sectional.

3.2. Measures

The focal variable in our analyses is 'Imitation'. The operationalization derives from the question 'Has IP of your company been negatively affected by other companies in the years 2005-2007?[8] Hence, the dependent variable is binary, 1 coding imitation, and 0 coding no imitation. We further differentiate between imitation of technology and imitation of design. Both technology and design are in contrast to – brands, trademarks, and copyrights – typical and crucial IP for innovation while the latter are not necessarily related to innovations. Both variables 'Imitation of Technology' and 'Imitation of Design' are binary and their coding resembles the one of imitation.

The other variables in focus are 'Breadth of Open Innovation' and 'Scope of Open Innovation'. Both are categorical variables with a scale from 0 to 5.

Breadth codes 0 for open innovation with no partner type and, hence, codes a company not engaging in open innovation at all. A value of 5 represents open innovation with all five possible partner types. Scope is coded 0 if the company does not conduct open innovation in any phase along the innovation value chain and, hence, does not engage in open innovation at all. Contrasting, 5 codes open innovation within all phases along the innovation value chain.

8 Original question in German: "Ist intellektuelles Eigentum Ihres Unternehmens in den Jahren 2005-2007 durch andere Unternehmen beeinträchtigt worden?" Hence, we do not have any information whether this form of imitation is 'real' or just perceived by the firm informant.

Further variables capture the open innovation activities regarding the different phases of the value chain and the different open innovation partners. The operationalization is straightforward: if the company has conducted cooperation with *any partner* within a *certain phase* of the value chain, we code this phase 1 and 0 if otherwise. The same is true for the cooperation partners: if the company has cooperated with a *certain cooperation partner* in *any phase* of the value chain, we code this partner 1 and 0 if otherwise.

In our estimations, we control for variables which scholars have found to influence the likelihood of imitation. Hence, we include the size of the company (Employees (ln)), the intensity of exports (Export Intensity (%)) and of R&D (R&D Intensity (%)), both measured as a ratio of sales. Furthermore, we control for sectorial differences[9] and the influence of patent and trademarks stock (Patent Stock (ln); Trademark Stock (ln)).

9 The information on sectors is provided by NACE codes and is translated into the OECD classification based on Eurostat (2009).

For an overview of all employed variables, please refer to TABLE 1.

Table 1. Overview of variables

Dependent Variable	**Measurement**	**Mean**	**S.D.**	**Min**	**Max**
Imitation	Dummy	0.20	0.40	0	1
Imitation of Technology	Dummy	0.10	0.30	0	1
Imitation of Design	Dummy	0.09	0.28	0	1
Independent Variables					
Breadth of Open Innovation	Categorical	1.71	1.45	0	5
Scope of Open Innovation	Categorical	2.50	2.03	0	5
Idea generation	Dummy	0.58	0.49	0	1
R&D	Dummy	0.53	0.50	0	1
Design and configuration	Dummy	0.45	0.50	0	1
Testing and marketing/ production preparations	Dummy	0.50	0.50	0	1
Market introduction/ implementation	Dummy	0.45	0.50	0	1
B2B Customer	Dummy	0.54	0.50	0	1
B2C customer	Dummy	0.19	0.39	0	1
Supplier/ service provider	Dummy	0.55	0.50	0	1
Competitor	Dummy	0.12	0.33	0	1
University	Dummy	0.31	0.46	0	1
Control Variables					
Employess (ln)	Continuous	3.88	1.72	0	12.16
R&D intensity (%)	Continuous	0.02	0.09	0	1.34
Exports intensity (%)	Continuous	0.17	0.25	0	1.00
Patent stock (ln)	Continuous	0.25	0.64	0	6.92
Trademark stock (ln)	Continuous	0.11	0.42	0	4.98
High-technology	Dummy	0.05	0.21	0	1.00
Medium-high-technology	Dummy	0.18	0.38	0	1
Medium-low-technology	Dummy	0.17	0.38	0	1
Low-technology	Dummy	0.13	0.33	0	1
Knowledge-intensive services	Dummy	0.35	0.48	0	1
Less-knowledge-intensive services	Dummy	0.03	0.17	0	1

3.3. Statistical method

We cannot directly investigate whether the company faced infringement within an open innovation setting. However, we argue that the decision to open up the innovation process is a conscious, long-term decision that emphasizes a firm's engagement in openness on a general scale, making it more prone to imitation. The exact wording of the question ('In which phases of the innovation process does your company cooperate with innovation partners?') reflects this viewpoint. However, we do not claim causality for any of these regressions but rather use them as controlled correlations.

We use logistic regression analysis computing coefficients and odds-ratios as the dependent variable is binary. The odds-ratio enables us to interpret the strength of the explaining variables' connection with imitation.

As the estimated regressions miss out on roughly 35% of observations contained in the data set, we also conduct a non-response analysis (t-tests) to make sure that companies that did not give particulars about their imitation experience or open innovation behavior significantly differ from the ones that did. The t-tests do not reveal any significant differences.

3.4. Results

The descriptive statistics in FIGURES 1-4 reveal some interesting results. Imitation is connected to all phases of the innovation value chain, most frequently in the idea generation phase and least frequently in the market introduction phase. Particularly, the R&D phase is prone to imitation of technology. Additionally, imitation of design occurs together with the idea generation, R&D, and design and configuration phases.

Imitation coincides in open innovation settings with all partner types but most frequently with B2B customers and suppliers while less frequent regarding cooperation with competitors.

While the descriptive statistics already shed some light on the incidences of imitation along the value chain, only the bivariate analyses reveal significant correlations between the variables. The results of these analyses are reported herein. As stated beforehand, we make use of logistic regressions and will report these results. However, we do not claim causality but rather interpret them as correlations while controlling for other factors.

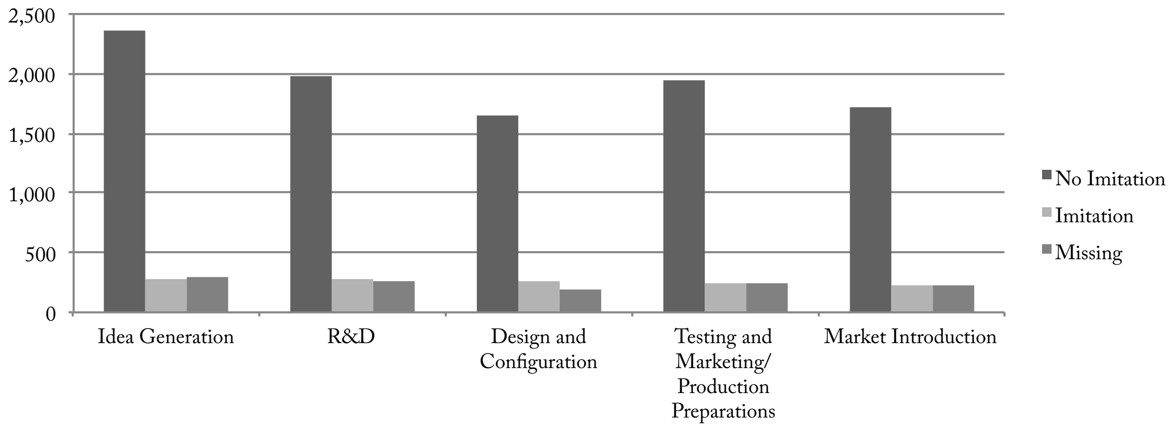

Figure 1. Frequency of imitation across the innovation value chain

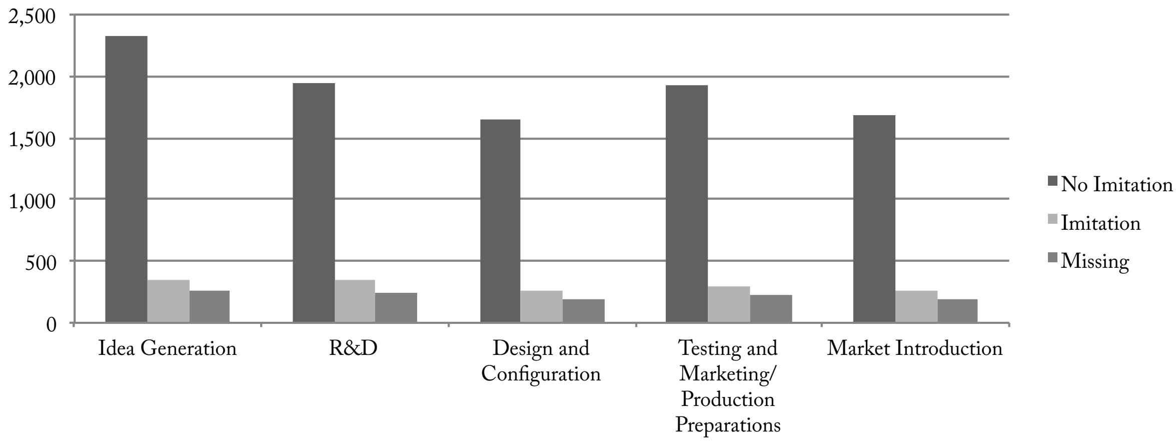

Figure 2. Frequency of imitation of technology across the innovation value chain

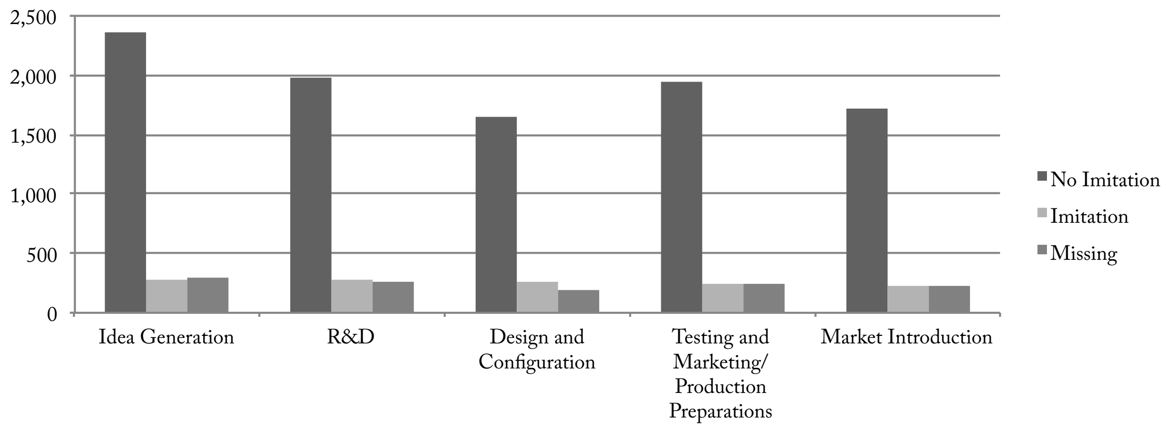

Figure 3. Frequency of imitation of design across the innovation value chain

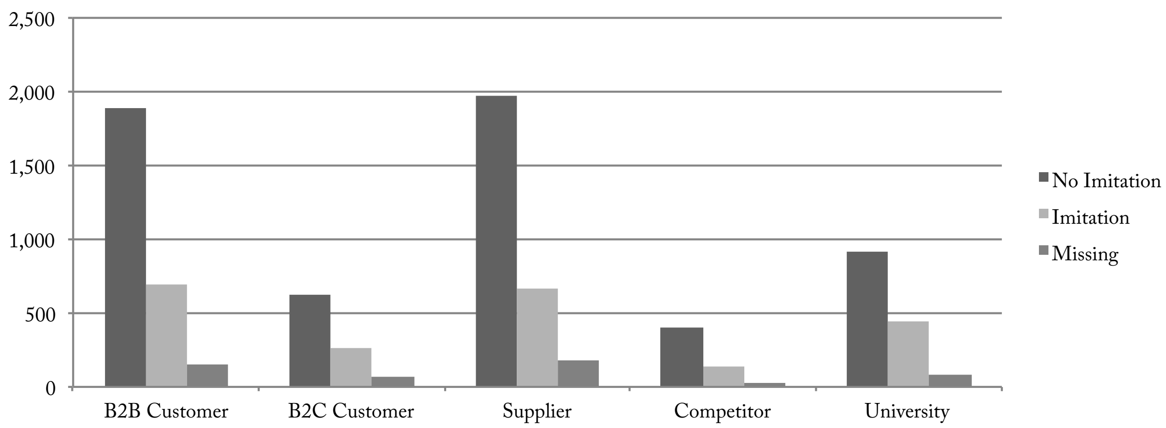

Figure 4. Frequency of imitation for different partner types

With regard to the base model (TABLE 2), our results show a strong correlation between the breadth and scope of open innovation and imitation. Both positively and significantly correlate with imitation. If the open innovation breadth increases by one category (i.e., one additional partner type), then the likelihood of the same company facing imitation at the same time rises by 66%. Likewise (i.e., one additional innovation phase), it rises by 45% with regard to scope. Both effects remain stable if we include both variables into the regression.

Table 2. Base model: logistic regression – breadth and scope of open innovation

	Imitation		Imitation		Imitation	
	Coeff	Odds ratio	Coeff	Odds ratio	Coeff	Odds ratio
Breadth of Open Innovation	0.51***	1.66***			0.32***	1.37***
	(0.04)	(0.07)			-0,06	-0,08
Scope of Open Innovation			0.37***	1.45***	0.22***	1.25***
			(0.03)	(0.04)	-0,05	-0,06
Employees (ln)	0.04	1.04	0.04	1.04	0,02	1,02
	(0.04)	(0.04)	(0.04)	(0.04)	-0,04	-0,04
R&D intensity (%)	-0.76	0.47	-0.38	0.69	-0,91	0,4
	(0.67)	(0.31)	(0.61)	(0.42)	-0,69	-0,28
Exports intensity (%)	1.37***	3.92***	1.29***	3.65***	1.33***	3.77***
	(0.22)	(0.87)	(0.21)	(0.75)	-0,22	-0,83
Patent stock (ln)	0.56***	1.75***	0.54***	1.71***	0.55***	1.73***
	(0.10)	(0.18)	(0.09)	(0.16)	-0,1	-0,17
Trademark stock (ln)	-0.04	0.96	0.01	1.01	-0,03	0,97
	(0.15)	(0.14)	(0.13)	(0.13)	-0,14	-0,14
High-technology	-0.18	0.84	-0.35	0.71	-0,23	0,8
	(0.30)	(0.25)	(0.29)	(0.21)	-0,3	-0,24
Medium-high-technology	-0.06	0.94	-0.04	0.96	-0,05	0,95
	(0.21)	(0.20)	(0.20)	(0.19)	-0,21	-0,2
Medium-low-technology	0.19	1.21	0.28	1.32	0,2	1,22
	(0.21)	(0.25)	(0.20)	(0.26)	-0,21	-0,25
Low-technology	0.00	1.00	0.02	1.02	-0,02	0,98
	(0.22)	(0.22)	(0.21)	(0.21)	-0,22	-0,21
Knowledge-intensive services	-0.23	0.80	-0.21	0.81	-0,19	0,83
	(0.20)	(0.16)	(0.19)	(0.15)	-0,2	-0,16
Constant	-3.00***	0.05***	-3.13***	0.04***	-3.21***	0.04***
	(0.23)	(0.01)	(0.23)	(0.01)	-0,24	-0,01
Observations	2,616	2,616	2,892	2,892	2615	2615
Loglikelihood	-1071.82	-1071.82	-1183.81	-1183.81	-1059,89	-1059,89
Chi^2	403.13	403.13	432.49	432.49	405,78	405,78
Pseudo R^2	0.19	0.19	0.18	0.18	0,2	0,2
Prob > Chi^2	0.00	0.00	0.00	0.00	0.00	0.00

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The further models differentiate between imitation types (imitation of technology, imitation of design), phases along the value chain (TABLE 3), and partner types (TABLE 4).

The estimations show that imitation is connected to different phases along the innovation value chain. Collaboration in the idea generation phase (94%), the R&D phase (59%), the design and configuration phase (65%), and the market introduction and implementation phase (40%) significantly and positively correlate with imitation. The only phase not correlating with imitation is the testing and marketing phase. The imitation of technology is significantly and highly correlated with open innovation in the idea generation (161%) and R&D phases (171%), while the market introduction and implementation phase (41%) correlates to a lesser degree with imitation. The imitation of design is predominantly coinciding with open innovation in the design and configuration phase (214%).

Regarding the influence of different open innovation partners, all partner types are significantly and positively related to imitation. The only exception is competitors, which is the only partner type that is not significantly connected to imitation. Furthermore, we controlled for interaction effects between phases and partners. However, these effects did not reveal any interesting results and are not reported herein.

The employed control variables export intensity and patent stock both reveal a positive and significant connection with imitation as expected and also predicted by literature. We do not find any sectorial influence on imitation, nor does the R&D intensity or the number of employees correlate with imitation.

Table 3. Logistic regression – innovation phases

	Imitation		Imitation of technology		Imitation of designs	
	Coeff	Odds ratio	Coeff	Odds ratio	Coeff	Odds ratio
Idea generation	0.66***	1.94***	0.96***	2.61***	0.33	1.39
	(0.18)	(0.35)	(0.30)	(0.78)	(0.26)	(0.36)
R&D	0.47***	1.59***	1.00***	2.71***	0.33	1.39
	(0.17)	(0.28)	(0.30)	(0.82)	(0.25)	(0.35)
Design and configuration	0.50***	1.65***	0.12	1.13	1.14***	3.14***
	(0.14)	(0.22)	(0.18)	(0.20)	(0.21)	(0.66)
Testing and marketing/	-0.03	0.97	0.13	1.14	0.01	1.01
production preparations	(0.15)	(0.15)	(0.21)	(0.24)	(0.21)	(0.22)
Market introduction/	0.33**	1.40**	0.34*	1.41*	0.05	1.06
implemenation	(0.14)	(0.20)	(0.19)	(0.26)	(0.19)	(0.20)
Employess (ln)	0.04	1.04	-0.04	0.96	0.05	1.05
	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)
R&D intensity (%)	-0.36	0.69	0.59	1.80	-1.86	0.16
	(0.62)	(0.43)	(0.70)	(1.25)	(1.14)	(0.18)
Exports intensity (%)	1.28***	3.59***	1.77***	5.88***	1.86***	6.44***
	(0.21)	(0.74)	(0.26)	(1.53)	(0.26)	(1.65)
Patent stock (ln)	0.52***	1.68***	0.68***	1.98***		
	(0.09)	(0.16)	(0.10)	(0.20)		
Trademark stock (ln)	0.01	1.01				
	(0.13)	(0.13)				
High-technology	-0.34	0.71	-0.41	0.67	-0.54	0.58
	(0.29)	(0.21)	(0.38)	(0.25)	(0.40)	(0.23)
Medium-high-technology	-0.04	0.97	-0.08	0.92	-0.31	0.73
	(0.20)	(0.19)	(0.25)	(0.23)	(0.25)	(0.18)
Medium-low-technology	0.28	1.32	-0.45*	0.64*	0.00	1.00
	(0.20)	(0.26)	(0.26)	(0.17)	(0.24)	(0.24)
Low-technology	0.03	1.03	-0.43	0.65	-0.15	0.86
	(0.21)	(0.21)	(0.28)	(0.18)	(0.26)	(0.22)
Knowledge-intensive services	-0.22	0.80	-0.76***	0.47***	-0.79***	0.45***
	(0.19)	(0.15)	(0.28)	(0.13)	(0.26)	(0.12)
Constant	-3.20***	0.04***	-4.36***	0.01***	-3.90***	0.02***
	(0.23)	(0.01)	(0.37)	(0.00)	(0.29)	(0.01)
Observations	2,892		2,836		2,811	
Loglikelihood	-1177.88		-678.90		-701.60	
Chi^2	436.88		359.97		246.34	
Pseudo R^2	0.19		0.26		0.16	
Prob > Chi^2	0.00		0.00		0.00	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4. Logistic regression – partner types

	Imitation	
	Coeff	Odds ratio
B2B Customer	1.02***	2.77***
	(0.16)	(0.44)
B2C customer	0.29**	1.34**
	(0.13)	(0.17)
Supplier/service provider	0.60***	1.83***
	(0.15)	(0.27)
Competitor	0.22	1.24
	(0.16)	(0.19)
University	0.28**	1.33**
	(0.12)	(0.16)
Employess (ln)	0.04	1.04
	(0.04)	(0.04)
R&D intensity (%)	-0.77	0.46
	(0.67)	(0.31)
Exports intensity (%)	1.27***	3.55***
	(0.22)	(0.80)
Patent stock (ln)	0.57***	1.76***
	(0.10)	(0.18)
Trademark stock (ln)	-0.01	0.99
	(0.15)	(0.15)
High-technology	-0.27	0.76
	(0.30)	(0.23)
Medium-high-technology	-0.11	0.89
	(0.21)	(0.19)
Medium-low-technology	0.16	1.17
	(0.21)	(0.25)
Low-technology	-0.05	0.95
	(0.22)	(0.21)
Knowledge-intensive services	-0.22	0.80
	(0.20)	(0.16)
Constant	-3.21***	0.04***
	(0.24)	(0.01)
Observations	2,616	
Loglikelihood	-1061.41	
Chi^2	407.00	
Pseudo R^2	0.20	
Prob > Chi^2	0.00	

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

4. Discussion and implications

The findings of our empirical analyses partly correspond to our expectations. Our expectation that imitation correlates with breadth and scope of an open innovation strategy is confirmed by our findings. Thus, our theoretical prediction holds in this case, suggesting that imitation is closely linked to the firm's level of openness. Our results regarding correlations between partner types and imitation are counterintuitive in that the cooperation with competitors is not significant while all other partner types reveal a positive correlation with imitation. The question, why competitors are not correlated with imitation while all other partner types or external sources do is difficult to answer as we do not possess information about the contract regimes companies active in open innovation employ. We assume that companies cooperating with competitors are more aware of the potential risks of knowledge spillover and imitation. Thus, they cooperate less with competitors in general (cf., FIGURE 4 suggesting that cooperation with competitors is less common), set tight contractual guidelines before entering collaboration with competitors or require formal IPR in place before working together (Dahlander and Gann, 2010). Firms rather apply indirect learning methods (e.g., reverse engineering of competitors' products or increasing own R&D speed while observing competitors' activities) (Slater and Narver, 1995) as opposed to direct cooperation with competitors.

Although appropriability in general sends a positive signal to potential partner firms, prior literature suggests that an over-emphasis may deter external partners who expect conflicts over control and ownership of knowledge (Laursen and Salter, 2005; Reitzig and Puranam, 2009). Strict firm-internal legal requirements (e.g., non-disclosure agreements for employees) may be further barriers to external cooperation (Alexy et al., 2009). Our data indicate that all partner types but competitors are connected to imitation. This is a major risk firms need to be aware of when entering an open innovation strategy. We suggest firms to be prudent and expect an imitation risk across all sources they use and, thus, establish stronger and standard contractual guidelines. In sum, firms need to balance open and proprietary innovation strategies. IP can thereby serve as a source of revenue through licensing while also promoting cooperation and innovation (Alexy et al., 2009).

A company engaging in an open innovation setting with a lot of partner types should focus on certain critical external actors or have a clear idea about the different partners' behavior and intentions. Another problem that arises is the capacity of managers to manage, maintain and control all their open innovation partners at the same time. It might be more difficult to handle two partners of different types (e.g., a university and a competitor) than just more than two partners of one type (e.g., three competitors).

With regard to the scope of the open innovation setting, our data suggest firms to evaluate a priori in which phase of the innovation value chain they want to cooperate. We find evidence that imitation of technology correlates with all phases of the innovation value chain but the testing as well as the design phase. We find that the R&D phase is strongly correlated with imitation, which is why we propose to enter the R&D phase with a clear idea about IP ownership (e.g., update the patent portfolio beforehand) and to draft clear contracts. The empirical analyses reveal that design imitation correlates with open innovation in the design phase. Therefore, design protection is important when entering this kind of open innovation collaboration.

Open innovation is associated with the idea to jointly develop new IP at the cost of revealing firm-internal critical IP to partners who may use that IP for imitation of products and services not necessarily related to the cooperation. We suggest that it is critical for firms to align their appropriability strategy with their open innovation strategy. This can be achieved when firms rely on a strategy that involves only partial disclosure of some essential aspect of the exchanged knowledge while controlling access to strategically important aspects of the knowledge (Laursen and Salter, 2013). Consequently, a firm's awareness of its core competencies and capabilities and which of these are critical for its performance and competitive advantage is the prerequisite for appropriate protection decisions. These are the ones that deem worthy to be kept secret, or be protected by formal IP rights and not be disclosed while cooperating in a phase where these may be revealed. Alexy et al. (2013) refer to this strategy as 'selective revealing' (see also Henkel, 2006). Hence, firms ideally would choose a suitable partner and an innovation phase in which they can offer less critical resources and capabilities that are still valuable for the partner. Simultaneously these partner firms provide opportunities to gain valuable capabilities in return. As a result, we expect companies to analyze the innovation process with regard to the most beneficial phase and partner to cooperate in and with and, hence, to optimize their open innovation strategy, accordingly. Among the collaboration partners each party can also license the knowledge needed for the collaboration in a cross-licensing agreement prior to the cooperation to prevent any tensions associated with external innovation engagement (Bogers, 2011).

Moreover, it can prove a reckless strategy for firms to overestimate the benefits and underestimate the risk induced by breadth and scope of the open innovation setting.

In sum, this study shows that there is a tradeoff between risk hedging (a lot of partners and phases enable a lot of different innovations and increase the probability of at least one successful innovation) and risk inducing effects (breadth and scope relate to imitation).

5. Conclusion and further research

In this article, we provide extensions to previous open innovation studies by showing a potential 'dark side' of an open innovation strategy, which has, as yet, not been in the focus of research (Dahlander and Gann, 2010; Knudsen and Mortensen, 2011). The theoretical background and the derived results have significant implications for the literature on open innovation and appropriability. Current studies on open innovation highlight the benefits of openness in general (Laursen and Salter, 2006) but the first few studies have started to investigate the so called 'paradox of openness' (Bogers, 2011; Laursen and Salter, 2013) targeting the conflicting evidence on the relationship between external innovation cooperation and appropriability. Our results relate to the literature discussed above, and highlight the negative aspect of appropriability for open innovation. We therefore contribute to this discussion. We explain the interdependency between open innovation and imitation of IP and provide first empirical evidence of the relation between openness along the innovation value chain and imitation. We disentangle open innovation along the different phases of the innovation value chain and give recommendations for managers on how to leverage an open innovation strategy. In sum, our results give first indications that open innovation exposes companies to the risk of imitation.

Particularly, open innovation relies on mutual sharing of resources, releasing some IP (e.g., by licensing) to receive some in return. There is no access to new knowledge sources without being regarded a potential source of knowledge. However, these sources might be accessed and used outside the open innovation collaboration without permission. As a result, firms may need to be open to a wider range of external partners to be innovative but they also need to be able to appropriate the profits from their innovations which emphasizes the importance of protection mechanisms in place. Thus, openness comes along with appropriability: openness is a reciprocal process that requires the disclosure of knowledge in order to gain new knowledge from collaboration partners. At the same time, firms also need to protect crucial aspects of their knowhow and technology if they are to profit from the exchange (Laursen and Salter, 2013).

Some firms may even purposefully enter open innovation settings to acquire new IP or knowledge not in the focus of the collaboration from suppliers or customers to diversify vertically. This may not only increase the risk of imitation but also breed future competitors. We raise awareness for the fact that managers should be as cautious about other partners as they are about direct competitors and should therefore consider the aforementioned risk of imitation which might seem farfetched in the first place.

This study highlights the tradeoff between transaction and protection costs and the benefits of open innovation: transaction costs decrease if contracts are less tight; however, the risk of imitation increases at the same time. Although we cannot measure the transaction costs of open innovation, our results show that companies engage in a significant number of open innovation partnerships while they experience imitation at the same time. This result suggests a lack of protection against imitation.

Addressing potential pitfalls in contracts in advance may limit the possibility of a rude awakening. Moreover, IPR might mitigate the effects we detect; however, we find evidence that IPR might even enable them (i.e., patents enable imitation). We discover a positive relationship between patent stock and imitation which leaves room for further research. We further encourage research on how companies cope with imitation and how this affects further collaboration in the future.

In general, we raise the question whether open innovation is a win-win or more a win-lose game assuming that one firm wins the IP another firms 'looses' and vice versa. Hence, the questions of how strong the effect of imitation directly induced by open innovation is (which we cannot control for) and how this is out-weighted by the benefits (new IP and innovation, etc.) remain and offer an interesting avenue for further research.

Concluding, we do not challenge the benefits of openness but we raise awareness for the risks of imitation companies face simultaneously.

Our contribution has clear limitations. The causal relationship between imitation and open innovation is not entirely transparent as we lack information about who imitates. This may not necessarily be the open innovation partner. Consequently, the measured imitation could be caused by other factors which are yet to be found by scholars. Future research may reveal further insights.

Furthermore, we did not include IP value in our analyses as there is no clear and convincing concept on how to capture the real IP value as existing concepts (e.g., patent citations, IP transactions, etc.) are very limited in their explanation power. Hence, IP value is difficult to control for and represents a classic limitation in this context.

Our results find tentative evidence for a negative relationship between open innovation and imitation. Imitation, however, might also induce positive effects such as increasing the diffusion of innovations (e.g., in network goods). This opens up an interesting area for further research disentangling the effects of imitation on companies. We also lack information regarding perceived versus real imitation which is due to the survey data approach. A matching with litigation data may mitigate this problem.

The relationship we assume and provide evidence for is based on a sample of German companies, only. Thus, we may encounter a country bias here. Hence, we encourage further research in a more international context to check for robustness of these results.

We lack data with regard to the quality of cooperation which might moderate the imitation effect. Hence, we suggest further research to test this effect. Prior research reveals that roughly 60% of alliances and inter-firm cooperation fail (Hoang and Rothaermel, 2005; Sampson, 2005). Moreover, we argue that negative experience within the collaboration or open innovation setting might increase the likelihood of termination of the same. Therefore, companies that experience imitation of their IP caused by an open innovation strategy are also more likely to resolve these ties. This leaves room for further research as we are unable to test this relationship within the limits of our data.

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Determinants of Appropriation Strategies: A Three Step Guide to Bayesian Model Averaging

Abstract

In this article, we investigate and disentangle cooperation in general and coopetition (collaboration with competitors) in particular as further determinants for a firm's choice to utilize formal or informal appropriation strategies to capture innovation benefits. Previous studies have mainly analyzed firm characteristics and sector variables as predictors for appropriation mechanisms but the impact of firm level innovation strategies is underexplored. We employ Bayesian Model Averaging (BMA) to address two general problems of empirical research: (1) Which parameters should be estimated and included in the model? and (2) What is the relative importance of predictors in a model? BMA generates all possible combinations of variables and selects the model with the best fit. Thus, BMA tackles this inherent uncertain model structure and offers a valuable alternative empirical method for management scholars. We analyze firm-level survey data of 1,879 German firms to illustrate the application of BMA by providing a three step guide to BMA. Furthermore, we hope that this guide will stimulate future work on BMA in the management literature.

Contents

1. Introduction

Firms differ in their innovation performance because they vary in their initial resource endowments, because they make different innovation related investment decisions, and because they employ various value capture or appropriation mechanisms. This paper explores how the choices of firms to cooperate on innovation with different external actors are linked to the choices they make about protecting their knowledge in order to appropriate the returns from their innovative activities.

In general, research on appropriability deals with the central question of how, whether and to what extent value capture instruments such as patents, lead time advantages, and secrecy help firms to create value when they introduce innovations (Cohen et al., 2000; Levin et al., 1987; Teece, 1986). Recent examples in the smart phone industry indicate that firms use both patents and trade secrets complementarily to protect innovations. Contrary to common believe, patents do not always protect a firm's most valuable innovations (Arora, 1997; Thomä and Bizer, 2013). Research highlights the importance of intellectual property (IP) appropriation strategies for companies and calls for more work to identify further drivers for the usage of value capture instruments (James et al., 2013; Rivette and Kline, 2000). Previous research has mainly analyzed firm characteristics and industry variables as predictors for appropriation methods. At the same time, however, scholars emphasize the need for empirical studies investigating the effect of firm-level strategies as determinants of appropriation mechanisms, because theoretical models suggest that these should affect the choice of the value capture instruments (Hall et al., 2012). Cooperation in general and coopetition in particular have increasingly received awareness as strategic options in the context of open innovation. Thereby, coopetition refers to the specific case of firms' collaboration with competitors.

Particularly, openness and appropriability have been shown to go hand-in-hand (Laursen and Salter, 2013). Thus, we quantitatively analyze the impact of R&D cooperation and coopetition strategies as determinants of a firm's choice to utilize formal or informal appropriation mechanisms to protect and exploit innovation. We differentiate between *formal* and *informal* instruments of appropriation, and consistent with Cohen et al. (2000), we define *formal* appropriation instruments as legally protected IP rights (e.g., patents, trademarks) and *informal* appropriation instruments as methods to prevent involuntary spillovers (e.g., secrecy, lead time).

For the empirical analysis, we estimate the effects of cooperation and coopetition on the implementation of appropriation strategies. In our methodological approach, we acknowledge that the structure of the regression model is essentially uncertain. This model uncertainty means that from the outset, it is unclear which predictors should be included in the regression model. Bayesian Model Averaging (BMA) allows us to deal with model uncertainty (Hoeting et al., 1999;

Raftery, 1995). The most striking feature of BMA is that inference is not based on a single model. Rather, BMA enables the researcher to base the inference on averages across several models. Additionally, we highlight that BMA can be helpful to elicit the relative importance of predictors.

We show that BMA is a relevant empirical approach that represents a valuable addition to the empirical tool kit of researchers in management or organization sciences by providing an introduction for scholars who want to employ BMA in management research. Finally, we illustrate the application of BMA by investigating the determinants for a firm's use of appropriation mechanisms. We find cooperation depth to be a robust determinant of informal appropriation strategies and coopetition a robust determinant for formal appropriation strategies. However, our results do not confirm cooperation breadth as a robust determinant for either appropriation strategy.

2. Conceptual background

2.1. Appropriation strategies

Strategic management and more specifically, literature on appropriation strategies offers a long track record of research investigating how firms capture value from their innovations given the risk of imitation (David and Hall, 2006). Appropriability refers to the degree to which a firm captures the profits generated when it introduces innovations (Ceccagnoli, 2009; Teece, 1986). Furthermore, in an increasingly dynamic business environment, the ownership of the critical pieces of intellectual property (IP) is an important strategic source of competitive advantage (Granstrand, 2000). Thus, in the industrial organization literature, appropriability is often modeled as an isolating mechanism that firms employ to prevent other firms from imitation (Mahoney and Pandian, 1992; Rumelt, 1984). Appropriation of innovation investments entails considerable managerial attention and transaction costs such as applying for patents, maintaining patents, establishing lead time, keeping key technologies secret from competitors and gaining access to complementary assets (Arora and Ceccagnoli, 2006; Ceccagnoli, 2009; Teece, 1986; Ziedonis, 2004).

Much of the existing work emphasizes patents as the single value capture mechanism or discusses the tradeoffs between patents vs. secrecy or patents vs. complementary assets in the firm's attempt to create barriers to imitation. However, patenting is not the only instrument for appropriation of innovation returns, as in practice firms rather choose from the entire set of isolating mechanisms available to them (Arora, 1997; Brouwer and Kleinknecht, 1999). In general, strategies typically used to increase appropriability can be divided into two groups (e.g., Cohen et al., 2000; Levin et al., 1987):

- *Formal appropriation instruments*, such as patents, utility patents, trademarks, or copyright, are state guaranteed legal instruments, which grant inventors and innovators an exclusive right to exclude others from the utilization of the protected subject matter.

- *Informal appropriation instruments* encompass various measures on the part of companies to prevent spillovers of own innovation efforts and thus to safeguard the appropriation of one‘s own innovation returns. Typical forms are secrecy, lead time, complex design of new products or services, which make imitation more difficult, or an extremely rapid implementation of innovation projects to generate a lead time advantage.

Value capture strategies that also draw on sources of firm-specific appropriability such as secrecy may be more effective than patents alone (Thomä and Bizer, 2013). Hence, firms employ a combination of formal and informal measures of appropriation to prevent imitation and thus secure or develop competitive advantages which may occur in both strong and weak appropriability environments (Hertzfeld et al., 2006). This allows for flexibility to adjust to different internal or external strategic requirements (Anton and Yao, 2004), and hence determines the effectiveness of a firm's IP strategy (Leiponen and Byma, 2009; Reitzig and Puranam, 2009).

2.2. Determinants of appropriation strategies

Somaya (2012) provides an overview of theoretical drivers of companies' appropriation strategies. Previous empirical evidence indicates that the propensity of firms to use various mechanisms to capture value from their innovations varies with the institutional appropriability regime, industry, firm, and technological characteristics[1]. Prior studies further show significant differences in the effectiveness of each mechanism across firms (e.g., depending on R&D personnel, sales, size), industries (e.g., food vs. the pharmaceutical industry), characteristics of firms' knowledge bases (Leiponen and Byma, 2009; Peeters and van Pottelsberghe, 2006) and types of innovation (e.g., discrete vs. complex, product vs. process) (Cohen et al., 2000; Hall and Ziedonis, 2001; Levin et al., 1987). Moreover, informal appropriation means are more prevalent in institutional environments that provide weak patent protection, whereas formal value capture strategies are more prominent in environments with relatively strong patent protection (Cohen et al., 2002; Zhao, 2006).

Although some determinants of appropriation strategies have already been identified, scholars highlight the need for further drivers of value capture instruments (James et al., 2013) and argue that the strategic and competitive determinants of these mechanisms are still not fully explored (Hall et al., 2012; Rivette and Kline, 2000; Somaya, 2012). In that vein, we particularly focus on cooperation and coopetition as further determinants of appropriability. Our research question thus is: Do contextual factors such as firm-level innovation strategies influence a firm's choice of formal and informal appropriation mechanisms?

In the following, we address the question of how appropriation mechanisms may be embedded in firms' innovation strategies to deal with the collaboration-appropriation paradox. To do so, we build on the distinction of cooperation breadth (number of external innovation partners) and depth (intensity of cooperation with a specific partner). Considering these dimensions results in the matrix depicted in FIGURE 1 which we will explain later. In addition, we consider the major goal of firms to avoid knowledge spillover, mitigate risks and capture the innovation profits. Cooperation will also positively affect the performance of value capture strategies depending on the firm's respective environment, technology, size, market turbulence and the existence of institutions and social norms (e.g., intellectual property regimes (Teece, 1986) and a firm culture (Kale and Singh, 2009) that govern and support knowledge production and sharing). Of course, we are not trying to argue that any of the strategies is universally beneficial to all firms regarding

1 Please see James et al. (2013) for a recent overview of determinants of appropriation strategies.

value appropriation in any given competitive situation. Rather, rationality bounded managers will need to evaluate whether anticipated costs are smaller than potential benefits. We derive theoretical arguments for a dominant value capture strategy according to the degree of breadth and depth of a firm's cooperation strategy. Finally, this simple typology rests on the perspective of the focal firm. Rather than seeking to explain the specific rationale behind the decision of the firm, we give recommendations on how to manage and behave under the given circumstances of breadth and depth or when firms plan to enter any external innovation engagements. Our intention is not to diminish the importance of other plausible strategies under these circumstances but to provide a parsimonious and close-to-optimal selection of a plethora of strategies. Due to the limited attention of managers, it is very valuable for their consideration to be able to choose from a smaller amount of options.

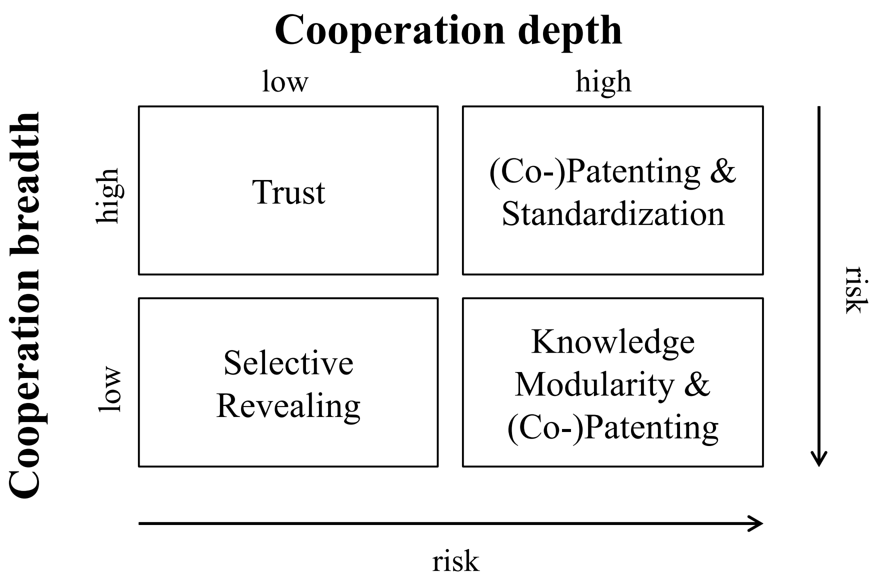


Figure 1. Appropriation strategies embedded in innovation strategies

We acknowledge that firms will usually engage in costly and time-intense collaboration negotiations resulting in formal contracts or in informal (non-legally binding) agreements which are based on mutual understanding but we do not visualize these here as we would like to shed light onto alternative strategies to deal with the paradox of cooperation. In the case of low depth and low breadth of cooperation, firms can simply rely on *trust* as a protection mechanism as trust can also help overcome transaction costs (Dyer and Singh, 1998; Poppo and Zenger, 2002) and appropriation concerns (legal copying of IP and illegal infringement of IPR) (Barney and Hansen, 1994), and it also facilitates the assessment of each other's likely behavior and the enforcement of property rights (Gulati and Singh, 1998) which is easier when cooperation is only taking place with one or two partners on a loose basis. In the case of broad external engagement on a low intensity level, *selective revealing*[2] may be a dominant strategy to deal with arising appropriation concerns. Firms voluntarily, strategically, and irrevocably disclose selected knowledge, so that this becomes available to the cooperation partner (Alexy et al., 2013). Selective revealing has been shown to act as a deterrence mechanism (Clarkson and Toh, 2010; Polidoro and Toh, 2011), particularly when controlling a wide range of external actors simultaneously is too costly to establish or coordinate (Baldwin and Henkel, 2011; Gulati and Singh, 1998). Thus, selective revealing may significantly reduce contracting costs as it neither requires formalized nor contractual collaboration in place (Spencer, 2003). Additionally, the fixed setup costs may be reduced with an increasing number of collaboration partners; however maintenance and control costs will simultaneously rise. Moreover, selective revealing does not necessarily cause harm for the focal firm; from a dynamic view, these outgoing spillovers may indirectly generate benefits to the revealing firm, especially when other firms along the way adjust and enhance this knowledge and it eventually returns to the revealing firm (Alexy et al., 2013).

Furthermore, when firms only collaborate intensively with a few partners, *co-patenting* or *standardization* may prove useful strategies. In general, patenting follows R&D collaboration efforts of firms (Ahuja, 2000; Brouwer and Kleinknecht, 1999; Sampson, 2005, 2007; Schilling and Phelps, 2007) and the co-ownership of patents (Belderbos et al., 2013; Hagedoorn, 2003) has shown to be another distinct strategy to capture benefits from external innovation collaboration. Firm cooperating intensely may also try to shape the technological trajectory and enter into standardization to reap the fruits of their labor (Blind and Mangelsdorf, 2013). Previous research proves that firms form alliances to develop and sponsor technical standards to extend an existing technological trajectory or create new trajectories. Intense and close interaction between the partners will lead to a convergence of the knowledge and thus to the evolution of a new and more favorable trajectory facilitating entry into standardization and hence eventually resulting in a new standard (Axelrod et al., 1995; Keil, 2002).

The picture however is less clear for the high-risk case of simultaneous broad and intense cooperation. Firms that use this form of external engagement face a severe attention and maintenance problem causing high costs. Therefore, an a priori defined mixed-method strategy based on the complementary use of both *formal protection* (*patenting*) and *informal* (*selective revealing* related to *knowledge modularity*) measures may be the most applicable, coherent coping strategy. This is in line with prior research arguing formal and informal mechanisms complement each other (Cohen et al., 2000).

A modular resource base may enable the firm to disclose knowledge partly or only on one layer of the industry architecture and simultaneously keep revenue streams originating from activities

2 We refer to 'selective revealing' as a specific form of secrecy regarding the firm's knowledge stock that is kept proprietary in relation to the part that is disclosed.

on other layers proprietary (West, 2003). Nonetheless, firms need to screen, take stock and decontextualize their knowledge base which can be a non-trivial endeavor (Baer et al., 2013) before applying this particular strategy. Formal appropriation mechanisms may complement this particular form of selective revealing as firms will already disclose some knowledge in patents prior to cooperation. Therefore, formal mechanisms and patents in particular may be more effective as entry ticket for collaboration negotiations (e.g., cross-licensing). Moreover, they can also be the result of a successful collaboration (e.g., co-ownership of IP). Due to economies of scale, transaction costs associated with filing, maintaining and enforcing formal property rights will be discounted across a wide range of partners which render formal instruments as more effective in appropriating profits from innovation. In sum, this typology shows that firms can strategically design their external relationships to secure access to resources while controlling the outflow of critical own knowledge and capabilities and thus, create a relatively predictable environment (Bresser and Harl, 1986; Gulati et al., 2000).

Cooperation

The rationale for cooperation in innovation is usually internally driven by the need to share R&D or production risks and costs, by the goal to pool resources, develop and expand markets together, address major technological challenges, and realize synergistic effects (Das and Teng, 2000; Tether, 2002), or externally by the requirement to comply with new regulations (Nakamura, 2003) or to develop common industry standards (Hertzfeld et al., 2006; Leiponen, 2008). Nonetheless, the open innovation literature emphasizes that the benefits of cooperation (focusing on the breadth and depth of cooperation) are subject to diminishing returns (Katila and Ahuja, 2002; Laursen and Salter, 2006). Cooperation can comprise and take all possible forms of partnerships[3] from joint decision-making for R&D investment to separate execution and no further or shared communication of results between partnership members (Hertzfeld et al., 2006).

In a first empirical study, Laursen and Salter (2013) provide evidence for a concave relation of appropriability and innovation collaboration but they do not differentiate between formal and informal appropriation mechanisms. As firms engage more intensely in innovation collaborations with external actors, they need to focus more on appropriability. Thus, from a transaction cost point of view, firms rely on and develop complex and costly contracts to safeguard own knowledge and knowledge resulting from the cooperation while maximizing the benefit of joint R&D. As these contracts are incomplete by nature, firms complementarily use informal measures to protect their tacit knowledge. However, in an intense collaboration, a firm's risk of transferring critical tacit knowledge is greater which renders informal measures ineffective. Moreover, increasing interaction between partners tends to blur the boundaries between them. In the case of intense cooperation, formal mechanisms may provide better protection ex-ante and ex-post cooperation

3 We particularly focus on cooperation with customers, suppliers, consultants, universities and research institutes.

than informal appropriation strategies. **Thus, we expect to observe a lower usage of informal appropriation mechanisms for firms cooperating in depth with partners.**

Cooperation with a greater number of different partners diminishes transaction costs associated with filing, maintaining and enforcing formal property rights. Due to economies of scale, formal instruments are more effective when firms simultaneously cooperate with a number of different partners. Nonetheless, informal measures (e.g., selective revealing) can serve as a deterrence mechanism (Clarkson and Toh, 2010; Polidoro and Toh, 2011) and at the same time may significantly reduce contracting costs (Spencer, 2003). We argue that firms incur lower costs from applying informal appropriation mechanisms than from using formal appropriation mechanisms (Cohen et al., 2000). Informal appropriation measures enable better value capturing from broad external innovation cooperation. **Thus, we expect to observe a lower usage of formal appropriation mechanisms for firms cooperating broadly.**

Coopetition

The term 'coopetition' (Brandenburger and Nalebuff, 1996) vividly captures an interaction of common and conflicting interests of firms as it combines the two diametrically different logics of cooperation and competition: A firm follows a coopetitive strategy if it carries out cooperative activities with other actors the focal firm itself classifies as competing, regardless of whether or not the competition is in the same product area or in the same industry (Bengtsson and Kock, 2000). As such, innovation cooperation with competitors can be seen as a special case of coopetition.[4] Competitors are valuable sources of complementary knowledge and resources, which can be accessed through cooperation (Grant and Baden-Fuller, 2004). Innovation management literature finds a positive effect of coopetition on new product development and innovation (Gnyawali and Park, 2011; Ritala and Hurmelinna-Laukkanen, 2009). Similar results can be found in the horizontal alliances literature (e.g., Belderbos et al., 2012; Garrette et al., 2009; Stuart, 2000). Amongst competition and general cooperation, coopetition has become another distinct strategic alternative as new and fast changing business environments require companies to become ambidextrous and pursue both competitive and cooperative strategies simultaneously (Jorde and Teece, 1989; Lado et al., 1997).

Different theories have been used to assess the value of coopetitive activities. Reasoning based on a transaction cost perspective renders coopetition beneficial with regards to decreasing the R&D

4 We limit our focus on innovation cooperation with competitors. Although coopetitive activities can occur at multiple levels, such as at the firm level, the industry level, the level of strategic business units, the department level, or between teams (Gnyawali and Park, 2011; Luo et al., 2006), we restrict our focus on coopetitive innovation activities at the firm-level. A firm's direct competitors are located along the horizontal dimension whereas suppliers and customers are located along the vertical dimension of the value net. Therefore, coopetition often is also referred to as horizontal collaboration (Brandenburger and Nalebuff, 1996).

inherent risk in environments of technological complexity and uncertainty. Firms joining forces are able to split R&D expenditures and the resulting risk of failure. Nonetheless, industrial organization literature has a long tradition to debate that efficiency gains from competitor collaboration may well be eaten up in subsequent market competition (Branstetter and Sakakibara, 2002). Negotiating contracts ex-ante further helps to control competitors more effectively (Chen and Chen, 2011; Quintana-García and Benavides-Velasco, 2004). Nonetheless, at the same time coopetition creates potential risks and tensions associated with collaboration because of the disclosure paradox[5] on the one hand and the involuntary leakage of tacit knowledge, imitation and unequal appropriation of rents from joint R&D to the collaborating, yet competing partners, on the other hand (Cassiman and Veugelers, 2002; Pisano, 2006; Teece, 1986). These relationships, in which firms can assume the role of partners, competitors, suppliers and customers for each other, create potential conflicts and tensions due to the risk of knowledge spillovers and appropriation of rents from joint R&D (Pisano, 2006; Teece, 1986). This tension between collaboration (i.e., revealing own knowledge to external actors) and protection of own knowhow and IP has recently been framed as the 'paradox of openness' (Bogers, 2011; Laursen and Salter, 2013).[6]

The risk and the dangers of copying, imitation or unplanned outward spillovers are much more pronounced in the context of innovation collaboration with competitors than in relation to engagements with any other actor in the firm's portfolio of external innovation collaborations (Laursen and Salter, 2013). This is because the product portfolio as well as the knowledge bases of both partners are very similar (Lane and Lubatkin, 1998), allowing competitors to recognize critical IP or knowledge exposed within the cooperation. Therefore, working with competitors is a particularly risky form of collaboration as it facilitates knowledge spillovers and imitation and thus, requires the firm to lay some extra focus on appropriability. Incentives for opportunistic behavior and free-ridership originating from the competitive dimension of this strategy theoretically undermine the benefits of the cooperative dimension (Quintana-García and Benavides-Velasco, 2004). Firms can apply indirect learning methods (e.g., reverse engineering of competitors' products or increasing own R&D speed while observing competitors' activities) (Slater and Narver, 1995) which is further facilitated through direct cooperation with competitors. In the coopetition formation stage, firms will thus actively engage in reducing the risk of partner opportunism. Negotiating contracts, adopting governance modes such as equity joint ventures or narrowing the scope of cooperation are different alternatives to mitigate the hazards of opportunism because (potentially diverging) incentives are more closely aligned (Oxley and Sampson, 2004). These collaborative hazards are considered to be greater in horizontal collaboration (with competitors) than in

5 Market mechanisms fail for tacit knowledge as its value is not known to a potential cooperation partner until after the knowledge is revealed. This paradoxically reduces the value of the knowledge because once it is revealed the necessity for the cooperation or paying for the knowledge is no longer existent as the cooperation partner already possesses it.

6 Based on Arrow's (1962) 'paradox of disclosure', Laursen and Salter (2013) have adapted this concept as openness (i.e., engaging with a broad set of external actors) may require firms as well as managers to pay more attention to protect their own knowledge form being copied.

vertical collaboration (e.g., with suppliers or customers) (Ahuja, 2000; Vanhaverbeke et al., 2009). Although firms have the option to employ a range of legal protection mechanisms to safeguard against imitation and unwanted spillovers, their value is highly dependent on their validity in legal suits and/or the firm's ability to impose a credible threat and launch a legal counter strike (Gans and Stern, 2003; Laursen and Salter, 2013; Sherry and Teece, 2004). Nonetheless, even if legal protection methods are enforceable, these formal mechanisms only provide partial protection (rivals may be able to invent around a patent) (Mansfield et al., 1981) which is why firms employ a complex bundle of formal and informal mechanisms to prevent imitation and knowledge spillover. Even informal mechanisms, such as secrecy, cannot guarantee a 100% protection against imitation as direct competitors can entice skilled employees from firms in the same market or reverse engineer their products.[7] Especially, in patent races and rapid technological progress, lead time or first mover advantages will not last long (Lieberman and Montgomery, 1988). Competitors may provide or have access to substantial complementary assets which may be more effective than the focal firm's own assets and capabilities and explains why the imitating competitor eventually reaps the 'lion's share' of the innovation's profits (Teece, 1986).

Adopting a transaction cost lens, the use of appropriation mechanisms under coopetition can also be explained. In a theoretically ideal state of symmetric spillovers and learning, there is no need for contracts and transaction costs are negligible. Partnering firms face a trade-off between a sufficiently open knowledge exchange and the unintended leakage of valuable know-how. Therefore, an appropriate governance mode can be a means to deal with the double-edged sword of coopetition (Oxley and Sampson, 2004).

Moreover, firms' expectation of non-symmetric spillovers within coopetitive activities call for the ex-ante negotiation of (formal) intellectual property mechanisms. Especially, in horizontal partnerships these can be highly complex (Hertzfeld et al., 2006). However, Cohen et al. (2000) argue that formal appropriation instruments are ineffective due to high transaction costs associated with filing for and enforcing formal property rights. **Thus, we expect that firms in coopetitive relationships will show a lower usage of formal appropriation mechanisms.**

In sum, prior literature well documents firm characteristics and industry variables as determinants for appropriation strategies. However, the relationship between firm-level innovation strategies and value capture (e.g., appropriation and imitation) has only been analyzed conceptually and qualitatively (Gnyawali and Park, 2011; Ritala and Hurmelinna-Laukkanen, 2009), but a larger-scale quantitative investigation of how a firm's cooperation and coopetition strategy explicitly influences its use of formal or informal appropriation mechanisms remains to be explored. We contribute to this stream of literature by quantitatively identifying and inferring further drivers of formal and informal appropriation strategies. We first propose that cooperation in depth leads

7 This is not only a problem in coopetitive relationships but may also arise in other forms of cooperation.

firms to use a lower level of informal appropriation measures to protect their tacit knowledge. Second, we expect to observe a lower usage of formal appropriation mechanisms for firms cooperating broadly. We further propose that firms engaged in coopetitive relationships to exhibit a lower level of usage of formal appropriation instruments.

3. Data

3.1. Sample

Our analysis is based on the Community Innovation Survey (CIS) Germany conducted by the Center for European Economic Research, Mannheim.[8] The CIS, jointly launched by Eurostat and the Innovation and Small and Medium-sized Enterprise Program in 1991, aims at improving the empirical basis of innovation theory and innovation policy on the European level. The CIS surveys generate cross-sectional data on firm-level innovation activities across the member states of the European Union by means of largely harmonized questionnaires. The CIS closely reflects the definitions of the Oslo Manual (OECD and Eurostat, 2005). Hence, it provides a good coverage of the indicators for innovation input, innovation output, innovation strategy, and the use and evaluation of IP appropriation strategies employed by firms. Initially, the CIS has been used to inform national and EU-level statistical analyses. In the past decade, the data have increasingly been used for scientific research on the micro-level in management (e.g., Belderbos et al., 2004; Cassiman and Veugelers, 2006; Laursen and Salter, 2006; Leiponen and Helfat, 2010) and in economics (e.g., Cassiman and Veugelers, 2002; Czarnitzki et al., 2007; Ebersberger and Herstad, 2012). We use the German edition of the fourth wave (CIS4) covering the years 2002–2004. The dataset contains 1,879 companies which actively employ appropriation strategies. These are the basis of the analysis below.

3.2. Measures

Dependent variables

Appropriation strategies:
The innovation survey inquires innovating companies about their usage of a set of measures to protect their IP: Patents, utility models, design patents, trademarks, copyright, secrecy, complexity of design, and lead time advantage. The survey also investigates the importance of the used appropriation measures on a three-level Likert scale (high – medium – low). We use a principal component analysis (varimax-rotated) to identify latent appropriation strategies in the responses (see TABLE 8 Panel A in Appendix C). We only extract the two factors with an eigenvalue larger than unity. The first factor bundles secrecy, complexity and lead time advantage. In accordance with the literature (Cohen et al., 2000; Levin et al., 1987), we interpret this as an **informal appropriation strategy**. The second factor bundles patents, utility models, design patents, trademarks, and copyright. We interpret this factor as a **formal appropriation strategy.**

8 Although the survey consists of consecutive waves of cross-sectional data it is misleadingly labeled as 'Mannheim Innovation Panel'. The weak panel properties of the consecutive waves do not allow for a construction of a panel from two or more cross sections.

Independent variables

Cooperation:
In line with the literature in open innovation (Katila and Ahuja, 2002; Laursen and Salter, 2006), we capture two dimensions of firms' innovation collaboration activities: Cooperation breadth and cooperation depth. The **cooperation breadth** identifies the number of different collaboration partners (such as customers, suppliers, consultants, universities, research institutes), whereas the **cooperation depth** reports the share of partners with a high intensity of collaboration approximated by cooperation with this specific partner in more than one world region (Germany, Europe, US, other). Note that for these indicators, we only consider cooperation for innovation with partners other than competitors.

Coopetition:
We measure coopetition as the cooperation for innovation with competitors weighted by the value the firm assigns to information originating from competitors.

Controls

Competitive strategy:
To capture the competitive strategy of the firm, the survey asks the responding firms to rank the following factors according to their relevance for the firm's competitiveness in its main market: Price, quality, technological advantage, service and flexibility, variety of products, product design and marketing. With a principal component analysis (varimax-rotated), we extract the factors with an eigenvalue above unity (see TABLE 8 Panel D in Appendix C). Those can be interpreted as three latent competitive strategies following Porter's (1980) generic strategies: **differentiation through variety**, **differentiation through technological advantage** and product quality, and **cost leadership**.

Openness:
The openness of the innovation processes captures an important dimension of the firm‘s innovation culture. In accordance with Laursen and Salter (2006), we build indicators for the breadth of openness and for the depth of openness. The indicators are based on the firm‘s valuation (0 = *not used*, 1 = *low importance* … 3 = *high importance*) of different external sources of information such as customers, suppliers, consultants, universities, research institutes, conferences, journals and industrial associations. The breadth identifies the number of different sources used. The depth is the share of information sources that are of high value to the firm.

Firm characteristics are controlled for by the **size** measured by the logarithm of the number of employees, by the **R&D intensity** measured as the sales share spent on R&D, by the firm's involvement in international trade measured by the sales share generated by **exports** and by the firm's location in **Eastern Germany**. Usually the nature of the knowledge a firm's innovation activities build on affects the way and intensity of protection (e.g., Norman, 2002). To characterize the knowledge the firms rely on in their innovation activities, we build a dichotomous variable indicating whether the firm's innovation activities depend on an **analytical knowledge base** rather than a synthetic one (Asheim and Coenen, 2005; Laestadius, 2000). An additional dummy variable (CUM) indicates whether the innovation activities refer to a strong **cumulativeness of the knowledge bases** (Breschi et al., 2000), which might be closely related to product sequencing (Helfat and Raubitschek, 2000) and to related protection challenges. The basicness of research is captured by the firm's evaluation of universities, research institutes and journals as information sources. In a set of questions, the survey examines the **competitive environment** the firms in the sample operate in for which we also control. We use the six items scaled with a four-level Likert scale of agreement to construct latent dimensions of the competitive environment by means of a principal component analysis. We only extract factors with an eigenvalue above unity and yield two factors (see TABLE 3 Panel – B). In particular, we distinguish between environments where competition is driven by **product and technology dynamics** and environments where competition is driven by the **behavior of competitors and markets**. We also use a sector control capturing the overall sectoral affinity for employing formal or informal means of appropriation by the mean of the dependent variable broken down in NACE 3 digit sectors. We standardize all variables for the analysis and report the descriptive statistics in TABLE 1 and the correlations in TABLE 9 in the Appendix.

Table 1. Descriptive statistics of the variables in the analysis

	Min.	Mean	Std. Dev.	Max.
Appropriation strategy				
Formal appropriation strategy	-1.376	0.000	1.000	5.842
Informal appropriation strategy	-2.282	0.000	1.000	2.425
Cooperation & coopetition				
Cooperation breadth	-0.504	0.000	1.000	3.770
Cooperation depth	-0.247	0.000	1.000	9.619
Coopetition	-0.230	0.000	1.000	15.620
Open innovation culture				
Openness breadth	-2.177	0.000	1.000	1.100
Openness depth	-0.586	0.000	1.000	6.610
Competitive strategy				
Cost leadership	-5.505	0.000	1.000	2.473
Differentiation by techn. & quality	-5.199	0.000	1.000	2.001
Differentiation by variety	-2.833	0.000	1.000	3.152
Competitive environment driven by				
Behavior of competitors	-3.277	0.000	1.000	2.823
Technology dynamics	-2.101	0.000	1.000	2.684
Knowledge base				
Analytic knowledge base	-0.243	0.000	1.000	4.116
Basicness of research	-1.329	0.000	1.000	2.932
Cumulative knowledge base	-0.573	0.000	1.000	1.744
Firm characteristics				
Firm size	-2.281	0.000	1.000	4.345
R&D intensity	-0.319	0.000	1.000	8.193
Foreign ownership	-0.279	0.000	1.000	3.580
Export intensity	-0.846	0.000	1.000	1.810
Eastern German loc.	-0.674	0.000	1.000	1.483
Additional variables used in Appendix B				
Continuous R&D	-1.149	0.000	1.000	0.870
Economic barriers to innovation	-2.300	0.000	1.000	2.557
Internal barriers to innovation	-1.981	0.000	1.000	3.473
Competitors are larger	-1.313	0.000	1.000	0.762
Firm has monopoly	-0.153	0.000	1.000	6.552
Oligopolistic competition	-1.920	0.000	1.000	0.521

Note: All variables in the analysis are standardized.

4. Method

4.1. Bayesian model averaging and model uncertainty

During the identification of important determinants for the implementation of formal and informal appropriation strategies, we face the problem of model uncertainty. Model uncertainty arises, when the structure of the true model is essentially unknown (Chatfield, 1995, p. 421). That means that at the outset it is unclear which predictors should be included in the regression model. In this respect, model uncertainty amounts to variable selection uncertainty (George and Clyde, 2004; Hoeting et al., 1999).

One option to deal with model uncertainty is to simply ignore it, pick one model based on theoretical considerations, estimate the parameters, and draw conclusions based on this single model without further ado. This approach is unsatisfactory as it builds on a considerable degree of arbitrariness (Raftery, 1995). As a result, different sets of predictors and hence different models can lead to dramatically different conclusions (see e.g., the illustrating example in Appendix D). Furthermore, neglecting model uncertainty results in overconfident inference based on statistical estimates (Hoeting et al., 1999; Raftery, 1995).

Model averaging techniques address model uncertainty and recognize that, in addition to the parameters in the model, the structure of the model has to be estimated as well. The model averaging techniques do so without incurring the common problem of data mining, that is the search for and the selection of a single best model without presenting the process which leads to the selection (Brock et al., 2007; Chatfield, 1995). In sum, model averaging proposes a solution to model uncertainty by using several plausible models, by averaging over those models and by drawing inferences based on the weighted averages of those models. Basically, averaging techniques approach the issue of model uncertainty by using several models for inference rather than basing the inference on only a single model (Cohen-Cole et al., 2012).

Both non-Bayesian and Bayesian approaches exist for the model averaging. Non-Bayesian approaches are for instance documented in Hansen (2007) and in Hjort and Claeskens (2003). In this paper, we focus on an averaging approach in a Bayesian framework. The Bayesian Model Averaging (BMA) approach has recently attracted increasing attention in diverse areas of economic research such as macroeconomic growth models (e.g., Crespo Cuaresma et al., 2011; Durlauf, 2001; Magnus et al., 2010), forecasting (e.g., Liu and Maheu, 2009; Wright, 2009), or agricultural economics (e.g., Balcombe and Rapsomanikis, 2010; Tiffin and Balcombe, 2011). Micro-econometric applications of BMA in management research are still in their infancy with only a few applications in corporate finance (e.g., Avramov, 2002; Liu and Maheu, 2009; Pesaran et al., 2009) and other areas of management (e.g., Hansen et al., 2004).

Bayesian model averaging proceeds in three steps which we describe herein. Step 1 defines a set of models, the model space, which are the basis for the averaging process. Step 2 estimates the models in the model space. Step 3 then averages over the estimated models and provides the information for inference.

Step 1: Defining the model space and revealing prior knowledge

In the first step, the researcher defines the space of candidate models by selecting the functional form (e.g., a linear model) and by choosing a set of potential predictors that are deemed relevant based on theoretical considerations. The model space then comprises all models characterized by one of the 2^k combinations of the k predictors chosen in this first step.

For our analysis, we consider a simple linear model with k predictors $x_1, x_2, \ldots, x_k$ that influence the continuous dependent variable y linearly with the parameters $\alpha, \beta_1, \beta_2, \ldots, \beta_k$:

$$y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k + e_y$$

e_y is an error term; each observation i has an associated error e_i, where e_i is i.i.d. with zero mean and an unknown variance. In total, our analysis comprises a set of 19 predictor variable consisting of the 18 predictor variables summarized in TABLE 1 and a control for influences on the sectoral level which is the sector mean of the dependent variable. Overall, the model space consists of all combinations of the 19 variables and hence contains 524,288 (=2^{19}) models.

In the Bayesian approach to model averaging, the researcher has to characterize the model space in terms of his or her prior beliefs. In particular, beliefs have to be stated for the models and the model parameters. The prior beliefs represent information available to the researcher before conducting the actual data analysis. This prior information is required in Bayesian analysis. Combining the prior information with the information generated through the data analysis yields the so-called posterior.

Each of the variables in the model, the intercept α, the variance of the error and the regression coefficients $â_k$ have to be characterized by specifying a prior belief: For our application, we are a priori, completely uncertain about the intercept and the error variance; we believe that all values on the real line are equally likely.[9] Prior to the data analysis, not much is known about the distribution of the regression coefficients $â_k$. We capture this in a conservative belief that the parameter has a mean of zero. This means that prior to the data analysis, we assume that each

9 That is, we impose an improper, non-informative prior.

variable does not affect the appropriation strategies. So it will be left to the data to convince us otherwise.

Additionally, we have to specify the prior model probabilities. Those prior model probabilities indicate how likely we think it is that a given model is the true model. Before investigating the data, we believe that all the models in the model space are equally likely to be the true model. Essentially, this implies a probability of 50% that a given variable is part of the true model.

Step 2: Estimating the models

In the second step, the models in the model space are estimated. In our case, the model space is small enough so that we are able to estimate each of the models in the model space. Thus, for both the dependent variables, for formal and the informal appropriation strategies, we estimate 524,288 (=2^{19}) models.

Yet, with an increasing number of predictors the model space grows exponentially. Hence, with a greater number of predictors, the size of the model space becomes too large and the estimation of all models computationally impossible or too time consuming. Then, the analysis has to be restricted to a subset of models drawn from the model space. In this case, this second step includes the researcher's decision, which algorithm to employ for the identification of the models for estimation. In Appendix A, we briefly discuss two of these algorithms.

Step 3: Averaging the models and reporting the findings

In step 3, BMA constructs a weighted average distribution of the coefficient estimates of all models. Essentially, the weights capture the probability that this model is the true model (for a more formal exposition see (Hoeting et al., 1999; Montgomery and Nyhan, 2010; Raftery, 1995).

The weights are derived from posterior model probabilities based on Bayes' theorem (see e.g., (Hoeting et al., 1999). For each model, the weights in the BMA indicate to what extent the data support this model. The level of support is determined by the prior beliefs and by the performance of the model, that is, how good the model describes the data. Hence, the weights depend on the data and on the prior beliefs.

4.3. Interpreting the results of a BMA analysis

The results of the BMA analysis allow the researcher to address the research question from two different angles (e.g., Montgomery and Nyhan, 2010). These two angles tend to be confused when conventional analysis only focuses on p-values (Gill, 1999; Hoeting et al., 1999).

We now illustrate the interpretation of the BMA results using our research question about the determinants of formal and informal appropriation strategies.

The first angle, that the results of the BMA provide, refers to the likelihood of a predictor to be part of the true model (Cuaresma, 2010; Horvath, 2011; Shou and Smithson, 2013). Our particular interest here is the posterior inclusion probability (PIP) of this variable, which is the sum of the probabilities of those models that include this particular variable. Essentially, the PIP is the sum of the weights used for the averaging process (see e.g., equations (2) and (3) in Montgomery and Nyhan (2010)). Note, that this angle addresses the model uncertainty directly and responds with a probabilistic answer about the likelihood of each of the potential predictors to be part of the true model.

As a guideline for interpreting the PIP of a variable, the literature has agreed on the following conventions (Kass and Raftery, 1995; Raftery, 1995): A PIP between 0.50 and 0.75 is regarded as *weak evidence*, a PIP between 0.75 and 0.90 is interpreted as *positive evidence*. A PIP between 0.90 and 0.99 indicates *strong evidence* and a PIP larger than 0.99 is considered *decisive evidence* for the variable being part of the true model.

Table 2. PIP for the BMA of formal and informal appropriation strategies

	Appropriation Strategies	
	Formal	Informal
	Model I	Model II
	PIP	PIP
Cooperation & coopetition		
Cooperation breadth +	0.032	0.206
Cooperation depth +	0.029	**0.553**
Coopetition +	**0.905**	0.043
Open innovation culture		
Openness breadth +	0.030	**0.894**
Openness depth +	0.025	0.024
Competitive strategy		
Cost leadership +	0.024	**0.701**
Differentiation by techn. & quality +	0.030	0.064
Differentiation by variety +	0.047	0.107
Competitive environment driven by		
Behavior of competitors	0.029	**0.801**
Technology dynamics	0.026	**0.906**
Knowledge base		
Analytic knowledge base	0.025	0.082
Basicness of research	**0.976**	0.127
Cumulative knowledge base	0.023	0.021

Firm characteristics		
Firm size	**1.000**	0.278
R&D intensity+	0.082	0.043
Foreign ownership	0.025	0.122
Export intensity	0.125	0.275
Eastern German loc.	**0.753**	0.024
Sector control		
Sector mean of dep.var.	**1.000**	**1.000**
Number of observations	1,789	1,789
Number of models	524,288	524,288

Note: Posterior inclusion probability (PIP) indicating at least positive evidence is printed in bold face. + indicates predictors that have been controlled for potential endogeneity following the approach employed by Cassiman and Veugelers (2002). Details are documented in Appendix B. Our computational implementation of BMA is briefly sketched in Appendix A.

TABLE 2 reports the PIP for the BMA of formal and informal appropriation strategies. We find decisive evidence that the sectoral conditions (PIP=1.000) and that the firm size (PIP=1.000) are part of the true model determining formal appropriation strategies (TABLE 2 Model I). The posterior inclusion probability of the basicness of research (PIP=0.976) is strong evidence and the PIP of the Eastern German location (PIP=0.753) is positive evidence for inclusion in the true model. We find strong evidence that coopetitive strategies are part of the true model of determinants of formal appropriation strategies (PIP=0.905). We will address this finding later in this article, but we first investigate the determinants of informal appropriation strategies.

Analogous to our findings for formal appropriation strategies, we find decisive evidence for sectoral conditions (PIP=1.000) in the BMA for informal appropriation strategies (TABLE 2 Model II). Additionally, we find positive evidence for an innovation culture in the analysis captured by the breadth of openness (PIP=0.894), strong evidence for a competitive environment driven by technology dynamics to affect informal appropriation strategies (PIP=0.906), positive evidence for an environment that is driven by competitors‘ behavior (PIP=0.801) and weak evidence for the cost leadership strategy (PIP=0.701). The results of the BMA show weak evidence for cooperation depth (PIP=0.553).

However, it is rather interesting to observe that our BMA results show no evidence for cooperation breadth, open innovation culture, competitive strategy and the competitive environment to determine formal appropriation strategies and that the characteristics of the firm‘s knowledge base and firm demographic characteristics do not determine informal appropriation strategies.

The second angle provided by the results of BMA refers to the size of a predictor's effect once it is included in the model (see e.g., Montgomery and Nyhan, 2010). It can be analyzed by the posterior distribution of the coefficient estimate conditional on inclusion. This is the weighted average of the distribution of the coefficient estimates of all models where the variable is included. TABLE 3 and TABLE 4 summarize the distributions by their mean and their 95% highest posterior density interval (HPDI) as a credibility interval. The 95% HPDI is the interval that contains 95% of the distribution in such a way that inside the interval the coefficient values are more likely than outside the interval. The 95% HPDI can be interpreted that we are 95% sure that the coefficient lies within the boundaries of the interval (Koop, 2003).

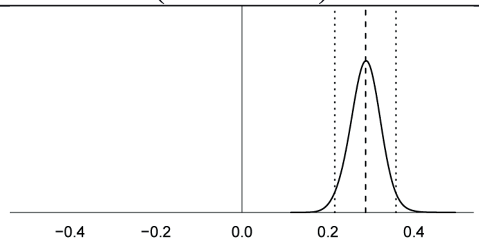
To support our interpretation of the posterior distributions of the estimates, we augment the summary statistics by plots of the distributions. Note, that most of the software packages briefly introduced in Appendix A supply plotting capabilities for the posterior distributions.

TABLE 3 reports the posterior coefficient densities for the predictors for which we have found at least positive evidence (PIP>0.75) in the analysis of formal appropriation strategy. Judging by the size of the HPDI, the coefficients for the firm size, the sectoral conditions captured by the sectoral mean of formal appropriation and the basicness of research have been estimated rather precisely. For the firm size, for the sectoral conditions and for the basicness of research, we find positive effects as in each of these three variables the lower boundary of the HPDI is strictly positive. We observe that the Eastern German location of the firm negatively affects the implementation of a formal appropriation strategy. The upper boundary of the HPDI is strictly negative.

When coopetition is included in the regression model, the coefficients are not estimated as precisely as they are for the other variables; the HDPI is markedly larger. However, the estimation clearly shows a negative coefficient for coopetition. The upper boundary of the HPDI is strictly negative; hence, the analysis supports the proposition about a negative effect of coopetition. Firms that implement a coopetitive strategy show a lower level of formal appropriation.

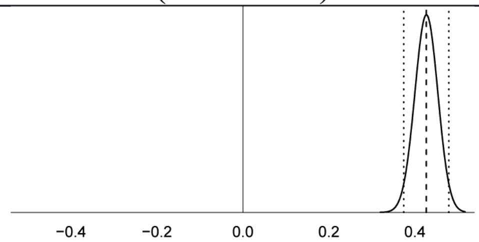
Table 3. Posterior coefficient densities (formal appropriation strategies)

Firm size
(PIP = 1.000)



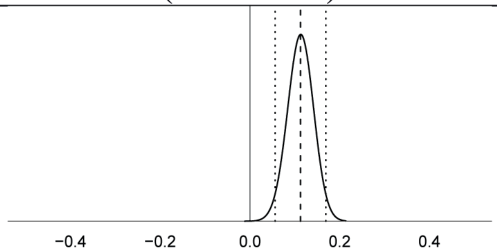
mean = 0.287; HPDI = [0.216, 0.358]

Sect mean of formal appropriation
(PIP = 1.000)



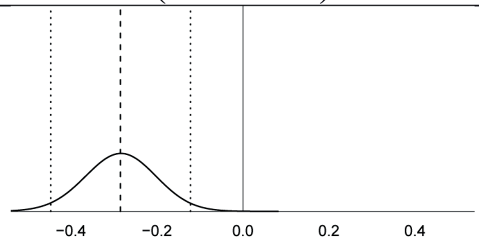
mean = 0.427; HPDI = [0.374, 0.479]

Basicness of research
(PIP = 0.976)



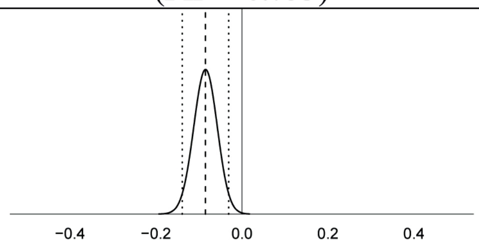
mean = 0.113; HPDI = [0.056, 0.169]

Coopetition
(PIP = 0.905)



mean = -0.285; HPDI = [-0.447, -0.122]

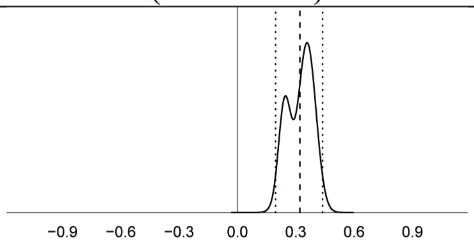
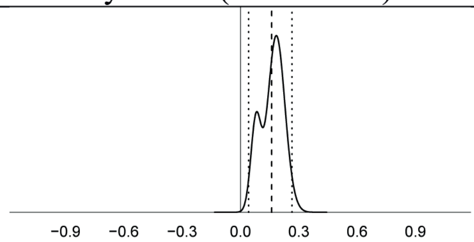
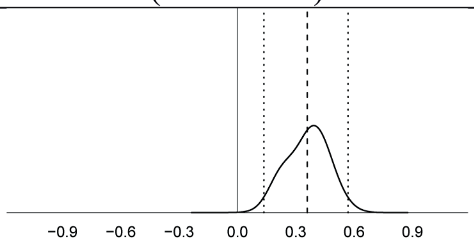
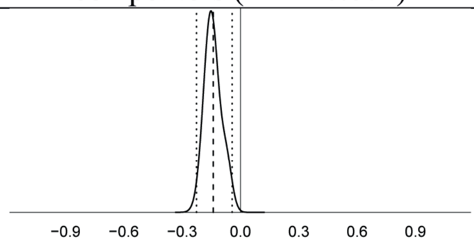
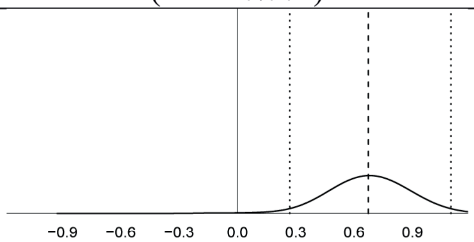
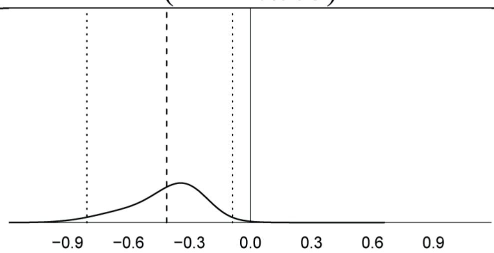
Eastern German loc.
(PIP = 0.753)



mean = 0.085; HPDI = [-0.139, -0.031]

Note: The distributions report the parameter estimates conditional on inclusion. The integral under the distribution curve adds up to the respective PIP reported in the cells above the distributions. The dashed vertical line indicates the mean of the distribution, the dotted vertical lines indicate the 95% HPDI of the distribution. As a reference the light vertical line indicates zero. Our computational implementation of BMA is briefly sketched in Appendix A

Table 4: Posterior coefficient densities (informal appropriation strategies)

Sector mean of informal appropriation. (PIP = 1.000)	Competitive environment: technological dynamics (PIP = 0.906)
	
mean = 0.321; HPDI = [0.196, 0.438]	mean = 0.161; HDI = [0.042, 0.265]
Openness breadth (PIP = 0.894)	Competitive environment: behavior of competitors (PIP = 0.801)
	
mean = 0.359; HPDI = [0.136, 0.569]	mean = -0.043; HDI = [-0.226, -0.043]
Strategy: cost leadership (PIP = 0.701)	Cooperation depth (PIP = 0.553)
	
mean = 0.673; HPDI = [0.269, 1.098]	mean = -0.413; HPDI = [-0.805, -0.089]

Note: The distributions report the parameter estimates conditional on inclusion. The integral under the distribution curve adds up to the respective PIP reported in the cells above the distributions. The dashed vertical line indicates the mean of the distribution, the dotted vertical lines indicate the 95% HPDI of the distribution. As a reference the light vertical line indicates zero. Our computational implementation of BMA is briefly sketched in Appendix A.

In TABLE 4, we report the posterior coefficient distributions for the informal appropriation strategies. The distributions of the coefficients show considerably more spread than the distributions in TABLE 3. Note that the scale of the horizontal axis differs in both tables. Once they are included in the models, sectoral conditions, the competitive environment driven by technological dynamics, the breadth of openness and the cost leadership strategy clearly show positive effects. For these predictors, the HPDIs are strictly positive. Firms operating in an environment where technological dynamics drive the competition show a lower level of informal appropriation strategies. The results also suggest that when cooperation depth is included in the models, the coefficient estimate is negative. Hence, we find support for our proposition that cooperation, and in particular intensive cooperation, negatively affects the usage of informal appropriation mechanisms.

4.4. Bayesian model averaging and the relative importance of predictors

Although most of the applications of BMA are motivated by the assumption of model uncertainty, the terminology used in some of the discussions and the interpretation of BMA results clearly refer to the importance of predictors (e.g., „…human capital remains important in explaining growth differences…“ Cuaresma et al. 2012, p. 8; or [the] „…main reasons for using BMA in the first place is to assess which of the regressors are important for modeling growth…“ in Ley and Steel 2009, p. 664).

Hence, even if the application of BMA is not motivated by model uncertainty, its results might still be helpful in revealing how important predictors are. When the results of BMA are interpreted in this way, BMA contributes to a long debate about measuring the relative importance of predictors in multiple regressions (Nimon and Oswald, 2013) (e.g., Johnson and LeBreton, 2004; Nathans et al., 2012; Tonidandel and LeBreton, 2011). There, the notion of relative importance indicates how much a predictor, relative to other predictors in a model, contributes to the explanation of a dependent variable. We witness an increasing interest in measures of relative importance in the context of multiple regression analysis (Azen and Budescu, 2003; Baltes et al., 2004; Budescu and Azen, 2004; Johnson and LeBreton, 2004; LeBreton et al., 2013; Nimon and Oswald, 2013; Tonidandel and LeBreton, 2010; Tonidandel and LeBreton, 2011). Recently, relative importance has been measured, amongst others, by general dominance weights (Azen and Budescu, 2003; Budescu, 1993) replacing squared bivariate correlations, squared standardized regression coefficients, and their products, which assume orthogonal predictors (Johnson and LeBreton, 2004). General dominance weights capture the additional contribution of each variable in a regression across all subset regressions (Azen and Budescu, 2003; Budescu, 1993). The general dominance weight of a predictor is the average additional R^2 generated by adding this predictor to all possible subsets of the other predictor variables in the regression (e.g., LeBreton et al., 2013). For the formal and the informal appropriation strategy as dependent variables, TABLE 5 reports the general dominance weights and a corresponding ranking of the predictors. This is based on a regression model including all of the 19 predictor variables. Here, we have to emphasize that dominance analysis is contingent on the selected model (Budescu, 1993; Nathans et al., 2012), hence with this analysis we implicitly assume that the model including all 19 predictors is the true model.

Table 5. General dominance weights for formal and informal appropriation strategies

	Formal appropriation General dominance weight	Rank	Informal appropriation General dominance weight	Rank
Cooperation & coopetition				
Cooperation breadth +	0.0067	5	0.0083	2
Cooperation depth +	0.0080	4	0.0040	6
Coopetition +	0.0027	10	0.0004	17
Open innovation culture				
Openness breadth +	0.0026	11	0.0075	3
Openness depth +	0.0011	16	0.0007	16
Competitive strategy				
Cost leadership +	0.0034	9	0.0062	5
Differentiat. by techn. & quality +	0.0020	14	0.0016	13
Differentiation by variety +	0.0036	8	0.0019	10
Competitive environment driven by				
Behavior of competitors	0.0021	13	0.0020	9
Technology dynamics	0.0019	15	0.0063	4
Knowledge base				
Analytic knowledge base	0.0007	18	0.0017	12
Basicness of research	0.0055	6	0.0032	7
Cumulative knowledge base	0.0004	19	0.0003	19
Firm characteristics				
Firm size	0.0265	2	0.0023	8
R&D intensity +	0.0048	7	0.0011	15
Foreign ownership	0.0008	17	0.0012	14
Export intensity	0.0025	12	0.0019	11
Eastern German loc.	0.0085	3	0.0003	18
Sector control				
Sector mean of dep.var.	0.1013	1	0.0274	1

Note: The table reports general dominance weights capturing the average increase in R^2 for adding the respective variable to all subset models. The computation of the general dominance weights has been implemented in (R Core Team, 2012). The code can be obtained from the authors. + indicates predictors that have been controlled for potential endogeneity following the approach employed by Cassiman and Veugelers (2002). Details are documented in the Appendix.

In the context of BMA, the posterior inclusion probability (PIP) can serve as a measure for the relative importance of predictors (Shou and Smithson, 2013). To further compare the relative importance of the predictors based on BMA and on general dominance weights, TABLE 6 reports the predictors' ranks based on both approaches. Both approaches show a strong agreement in the relative importance of the predictors characterized by a strong correlation of the predictor ranking. This finding is largely in accordance with a recent simulation study by Shou and Smithson (2013), who also find general agreement between a dominance analysis and BMA in assessing the relative importance of predictors for some of their models.

Table 6. Comparing the relative importance based on BMA and general dominance weights

	Formal appropriation		Informal appropriation	
	BMA Rank	GDA Rank	BMA Rank	GDA Rank
Cooperation & coopetition				
Cooperation breadth +	9	5	9	2
Cooperation depth +	12	4	6	6
Coopetition +	4	10	15	17
Open innovation culture				
Openness breadth +	10	11	3	3
Openness depth +	15	16	17	16
Competitive strategy				
Cost leadership +	18	9	5	5
Differentiat. by techn. & quality +	10	14	14	13
Differentiation by variety +	8	8	12	10
Competitive environment driven by				
Behavior of competitors	12	13	4	9
Technology dynamics	14	15	2	4
Knowledge base				
Analytic knowledge base	15	18	13	12
Basicness of research	3	6	10	7
Cumulative knowledge base	19	19	19	19
Firm characteristics				
Firm size	1	2	7	8
R&D intensity +	7	7	15	15
Foreign ownership	15	17	11	14
Export intensity	6	12	8	11
Eastern German loc.	5	3	17	18

Sector control				
Sector mean of dep.var.	1	1	1	1
	Correlation 0.7594 p=0.0002		Correlation 0.8973 p=0.0000	

Note: GDA refers to general dominance weights. Posterior inclusion probability (PIP) indicating at least positive evidence is printed in bold face. PM is the posterior mean and PSD the posterior standard deviation. + indicates predictors that have been controlled for potential endogeneity following the approach employed by Cassiman and Veugelers (2002). Details are documented in the Appendix.

Although we find high correlation between the predictors' importance ranking based on BMA and on general dominance weights, we find slight disagreement in how both approaches judge the importance of cooperation and coopetition. Where BMA considers coopetition to be an important determinant of formal appropriation strategies (rank=4), general dominance weights indicate that cooperation breadth and cooperation depth are important predictors (rank=5, rank=4). For the informal appropriation strategy, both approaches agree on the importance of cooperation depth (rank=6). However, they strongly disagree on the importance of cooperation breadth, as general dominance weights suggest that cooperation breadth is the second most important of all 19 predictors in the model.

It is worth noting that both approaches maintain different assumptions about the respective model. The computation of general dominance weights assumes that the model including all 19 predictors is the correct, the true model (e.g., Budescu, 1993). BMA, however, is based on the basic idea that the structure of the true model is uncertain and that this uncertainty has to be treated in the same way as other forms of uncertainty (Cohen-Cole et al., 2012). In addition to this difference in underlying assumptions, the different estimation approaches might also contribute to the observed inconsistencies in the findings. BMA utilizes prior beliefs about the model and the parameters of the model whereas the estimation of general dominance weights does not. More in depth analysis is warranted to shed light onto the causes of the differences and similarities between dominance analysis and BMA. The recent analysis by Shou and Smithson (2013) is a first step into this direction.

5. Discussion and conclusion

This study examines the implementation of different formal and informal IP appropriation instruments available to firms in their quest to capture value from innovation. From a theoretical perspective, this paper sheds some light on the strategic and competitive determinants of appropriation strategies that have not been fully explored, as yet (Somaya, 2012). Moreover, prior literature shows ambiguous results regarding companies' prevalence for formal versus informal IP appropriation instruments. Thus, this article contributes to a relatively new stream of literature dealing with the complex interaction of external innovation collaboration and appropriation. We use BMA analysis to disentangle determinants of companies' use of specific appropriation strategies. Cooperation and coopetition in particular are connected to the joint development of new knowledge and innovations at the cost of revealing firm-internal critical IP to partners who may use that IP for imitation of products and services outside of the cooperation. Somaya (2012) emphasizes the importance for firms to align their appropriation strategy with their innovation cooperation in a comprehensive way. This can be achieved when firms selectively reveal some essential aspect of the exchanged knowledge while controlling access to strategically important aspects of the knowledge (Alexy et al., 2013; Laursen and Salter, 2013).

With respect to cooperation, the BMA analysis reveals weak evidence that cooperation depth is a determinant of informal appropriation strategies. When cooperation depth is considered a determinant and included in the models, then it clearly obtains a negative coefficient estimate. This finding emphasizes that deep and intense cooperation requires frequent, usually, face-to-face interaction of the cooperation partners which might render informal appropriation strategies ineffective or even a barrier to cooperation. We further do not find cooperation breadth to be a determinant for the usage of either formal or informal appropriation measures. Firms joining forces with different partners might rely on contracts or other forms of governance or exploitation to reap the fruits of their cooperation results. Obviously economies of scale (related to an increasing number of cooperation partners) do not play an important role in applying both types of appropriation instruments.

The analysis reveals strong evidence that coopetitive strategies can be considered a determinant of formal appropriation strategies. The coefficient estimate is strictly negative. This indicates that firms which pursue pre-competitive innovation activities in collaboration with competing partners employ less formal appropriation mechanisms. This is in line with Cohen et al. (2000), who observe a general ineffectiveness of formal appropriation instruments due too high transaction costs for filing and for enforcing those formal property rights. These are obviously even greater in partnerships with competitors. In contrast, coopetition has no influence on implementing informal appropriation strategies. The cooperation with immediate competitors neither requires additional informal appropriation efforts nor makes them redundant.

We employ BMA for our analysis of a firm-level implementation of formal and informal appropriation strategies. BMA is a valuable addition to the empirical researcher's tool kit in management or organization sciences. In sum, through conditioning inference on several models – potentially all models in the model space – rather than on one single model, BMA addresses issues of model uncertainty that have hitherto been neglected in management research. It also offers a novel perspective on the questions related to predictor importance that have been relevant for organization research for at least 60 years. There are several advantages of BMA.

First of all, BMA with its Bayesian approach offers a coherent and rather intuitive framework (Wintle et al., 2003), that through the public availability of software packages (see Appendix A) becomes more accessible for empirical research.

Second, BMA induces transparency as it encourages the researcher to lay open his or her prior knowledge about the model and the parameters. This advantage, however, may not be obvious as the selection of priors can turn out to be the most difficult aspect carrying out BMA (Clyde, 1999).

Third, BMA can jointly investigate a large number of potential predictors. This allows the researcher to investigate several theories in parallel and compare them. Additionally, the possibility to include a large number of predictors reduces the likelihood of an omitted variable bias (Horvath, 2011).

Forth, parameters of moderately correlated predictor variables that are estimated by model averaging techniques are less biased than those estimated by OLS (Freckleton, 2011). Therefore, collinearity seems to be less of a problem in BMA (Fernandez et al., 2001).

Fifth, the BMA computes the posterior inclusion probability, that is an estimate of the probability that a given predictor is contained in the true model (Cuaresma, 2010; Horvath, 2011; Shou and Smithson, 2013). This addresses the issue of model uncertainty. Additionally, the PIP can also be interpreted as a measure of predictor importance (Shou and Smithson, 2013). This leads to the sixth advantage. When analyzing the relative importance of predictors in models with a large number of predictors, the computational effort of a dominance analysis might become prohibitively high as regressions of all sub-models have to be estimated (Nathans et al., 2012). In this context, BMA might have a clear advantage as the computational effort can be limited by estimating only a subset of the model space avoiding full enumeration of the whole model space (see the brief discussion in Appendix A).

This article is based on cross-sectional data at the firm-level. This necessarily entails limitations. An analysis on the firm-level has to treat the firm as an aggregate of all its activities carried out, related to and motivated on a lower, e.g., project, level. Decisions about the use and implementation of appropriation mechanisms are typically found on this lower level. In our analysis on the firm-level, we miss those decisions and the interactions between them. For instance, we miss that firms tend to bundle different appropriation mechanisms across projects (Levin et al., 1987). Additionally, our analysis at the firm-level disregards the fact that innovation processes pass through different phases. These phases usually require different governance modes of cooperation (van de Vrande et al., 2006) and hence different IP appropriation instruments may be used at different stages of the innovation process. In line with Somaya and Graham (2006), we argue that value capture instruments are often complements rather than substitutes which we cannot disentangle within the limits of our data. Finally, our cross-section data implicitly treat both the implementation of appropriation strategies and the cooperative and coopetitive relationships as static. Yet, coopetitive relationships are unstable and highly dynamic (Park and Russo, 1996). This warrants an analysis exploiting the time dimension to elicit causes for changes in the appropriation strategies over time.

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Appendix

Appendix A: Bayesian model averaging and additional issues

In this Appendix, we briefly touch upon issues that we deem relevant for the empirical analyses employing BMA.

BMA and a large model space

Although our analysis bases on full enumeration of the model space, which results in an estimation of all 2^{19} = models, empirical applications of BMA can include an amount of predictors with a resulting model space where it is computationally too time consuming to estimate every model in the model space. Take for instance a problem with 53 potential predictors as in Cuaresma et al. (2012), where the model space has a size of almost 10^{16}. The whole model space cannot be fully enumerated, given the current computational performance. Hence, a search process is required to identify a subset of all models in the search space that is estimated.

The literature advances two search processes (Raftery et al., 1997). One search strategy is based on the notion of Occam's window introduced by Madigan and Raftery (1994). Please find a detailed description of Occam's window approach in (Hoeting et al., 1999, pp. 384–385). The second strategy bases on a Monte Carlo Markov Chain Model Composition (MC^3) (e.g., Hoeting et al., 1999). The MCMC samplers approximate the posterior model distribution, which is used to compute the averaging weights, by browsing its most important part and estimating the regression models therein. Descriptions of the algorithms and the most important parameters that have to be set can be found in the documentation of the statistical packages software used (see below).

BMA with second order and interaction terms

The set of predictors that is included in the analysis might also include interactions of variables. In the case of these interactions one can no longer assume that inclusion of the variables a priori is independent. In the case of interactions, say AB, between two so called parent variables A and B, we suggest to apply a strong heredity principle (Chipman, 1996). This requires that whenever the interaction variable AB is included in the regression all parent variables, here A and B, have to be included as well. If this principle is violated, the analysis of the interaction effects may under certain conditions produce misleading findings (see the discussion in and between (Crespo Cuaresma, 2011; Masanjala and Papageorgiou, 2008; Papageorgiou, 2011). This should also be considered when second order terms of variables are included in the model.

Software implementations of BMA

For the analysis, we use the statistical environment R (R Core Team, 2012) and in particular the package BMS (Feldkircher and Zeugner, 2012). The key command in the analysis is:

```
bms(D, iter=1200000, mprior="uniform", g="UIP", mcmc="enumerate", nmodel=2000)
```

where `D` is the data matrix, the first column of which contains the dependent variable; `mprior` specifies a uniform model prior; `g` defines the prior for the regression coefficients to be the unit information prior (cf. step 1, above); `mcmc` indicates that all models in the model space should be estimated (cf. step 2, above); `nmodel` specifies that the reported estimates are based on the 2,000 best models in the model space; `iter` specifies that not more than 1,200,000 models are estimated, which is sufficient for the 524,288 models in the model space.

Aside from BMS there are two other R-packages offering implementations of Bayesian model averaging: BMA (Raftery et al., 2012) and BAS (Clyde, 2012). Although each of the packages offers a unique approach and particular options, a comparison of the results on a benchmark data set with Ehrlich (1973) shows that all three packages generate largely identical results (Amini and Parmeter, 2012). In addition, the recently introduced STATA implementation of BMA in bma.ado (Luca and Magnus, 2011) offers a set of unique features by implementing the Bayesian model averaging and the weighted average least squares (WALS) (Magnus et al., 2010).

Appendix B: Treatment of endogeneity

In our attempt to deal with the endogeneity of cooperation, openness, competitive strategy and innovation effort, we combine Bayesian Model Averaging with Cassiman and Veugelers' (2002) approach of treating endogeneity (Cassiman and Veugelers, 2002). In a first step, we use BMA to regress all endogenous variables (cooperation, openness, competitive strategy and innovation effort) on the variables that we assume to be exogenous (such as firm characteristics, competitive environment). In the second step, we use the predictions of the endogenous variables as the predictors of the appropriation strategies in the BMA analysis. The BMA results reported in TABLE 2 are, hence, the results of this second step.

The results of the BMA in the first step are reported in TABLE 7 (Panel A-I). The base on the same prior beliefs about the parameters and the models that we applied in the second step above. With the limited number of predictors in the first step, we fully enumerate the model space, estimate all models and base the predictions on the 2,000 best models in the model space.

In addition to the variables employed in the second step, we include a dichotomous indicator for **continuous R&D efforts** and **factors hampering innovation activities** in the first stage BMA. Issues hampering the firm's innovation activities are bundled by a principal component analysis (see TABLE 8 Panel C in Appendix C) and, in line with the findings in Peeters and van Pottelsberghe (2006), give rise to two factors: **economic barriers** and **internal barriers**. For the first stage BMA analysis of coopetition, we also include information about the main competitors. Dichotomous indicators are employed for firms when the main competitors tend to be **larger**, for firms that report to have obtained a **monopoly** and for firms that report to compete under **oligopolistic competition**.

Table 7. First stage BMA analysis

Panel A: Dependent Variable: Innovation effort						
	Model 1			Model 2		
	PIP	PM	PSD	PIP	PM	PSD
Size	1.000	-0.098	0.017	1.000	-0.098	0.017
Export	0.018	0.000	0.002	0.018	0.000	0.002
Eastern Germany	0.270	0.010	0.019	0.269	0.010	0.019
Foreign ownership	0.029	0.000	0.004	0.029	0.000	0.004
Analytic knowledge base	0.291	0.011	0.019	0.291	0.011	0.019
Cumulative knowledge base	0.020	0.000	0.002	0.020	0.000	0.002
Continuous R&D	1.000	0.127	0.016	1.000	0.128	0.016
Internal barriers	0.327	-0.013	0.021	0.327	-0.013	0.021
Economic barriers	0.997	0.070	0.016	0.997	0.070	0.016
Behavior of competitors	0.043	-0.001	0.005	0.043	-0.001	0.005
Technology dynamics	0.098	0.003	0.010	0.100	0.003	0.010
Form. appr. (sect mean)	0.021	0.000	0.003			
Inform. appr. (sect mean)				0.084	-0.003	0.011
Dep. var. (sec mean)	1.000	0.485	0.016	1.000	0.487	0.017
Number of observations	1,789			1,789		
Number of models	8,192			8,192		
Prediction used as in	*Innovation effort* Table 2 Model I			*Innovation effort* Table 2 Model II		

Note: Results of the first step BMA analysis. PIP is the posterior inclusion probability, PM is the posterior mean and PSD is the posterior standard deviation.

Panel B: Dependent Variable: Cooperation breadth						
	Model 1			Model 2		
	PIP	PM	PSD	PIP	PM	PSD
Size	1.000	0.213	0.018	1.000	0.218	0.018
Export	0.949	0.058	0.021	0.838	0.046	0.025
Eastern Germany	0.534	0.025	0.027	0.568	0.027	0.027
Foreign ownership	0.020	0.000	0.003	0.021	0.000	0.003
Analytic knowledge base	1.000	0.086	0.016	1.000	0.086	0.016
Cumulative know. base	0.575	-0.027	0.026	0.552	-0.026	0.026
Continuous R&D	1.000	0.183	0.018	1.000	0.165	0.018
Internal barriers	0.019	0.000	0.002	0.019	0.000	0.002
Economic barriers	1.000	0.130	0.017	1.000	0.128	0.017
Behavior of competitors	1.000	-0.087	0.016	1.000	-0.090	0.016
Technology dynamics	0.119	0.004	0.012	0.042	0.001	0.006
Form. appr. (sect mean)	0.022	0.000	0.003			
Inform. appr. (sect mean)				0.999	0.104	0.022
Dep. var. (sec mean)	1.000	0.232	0.018	1.000	0.172	0.022
Number of observations		1,789			1,789	
Number of models		8,192			8,192	
Prediction used as in		*Cooperation breadth* Table 2 Model I			*Cooperation breadth* Table 2 Model II	

Panel C: Dependent Variable: Cooperation depth						
	Model 1			Model 2		
	PIP	PM	PSD	PIP	PM	PSD
Size	1.000	0.241	0.018	1.000	0.246	0.018
Export	0.997	0.076	0.018	0.991	0.072	0.019
Eastern Germany	0.019	0.000	0.002	0.019	0.000	0.002
Foreign ownership	0.033	-0.001	0.005	0.034	-0.001	0.005
Analytic knowledge base	0.295	0.013	0.022	0.322	0.014	0.022
Cumulative know. base	0.217	-0.009	0.018	0.190	-0.007	0.017
Continuous R&D	0.901	0.058	0.026	0.575	0.033	0.032
Internal barriers	0.018	0.000	0.002	0.018	0.000	0.002
Economic barriers	1.000	0.095	0.018	1.000	0.095	0.018
Behavior of competitors	0.883	-0.053	0.025	0.906	-0.055	0.024
Technology dynamics	0.048	0.001	0.007	0.038	0.001	0.005
Form. appr. (sect mean)	0.018	0.000	0.003			
Inform. appr. (sect mean)				0.625	0.042	0.037
Dep. var. (sec mean)	1.000	0.210	0.019	1.000	0.194	0.024
Number of observations		1,789			1,789	
Number of models		8,192			8,192	
Prediction used in		Table 2 Model I			Table 2 Model II	

Note: Results of the first step BMA analysis. PIP is the posterior inclusion probability, PM is the posterior mean and PSD is the posterior standard deviation.

Panel D: Dependent Variable: Coopetition

	Model 1			Model 2		
	PIP	PM	PSD	PIP	PM	PSD
Size	1.000	0.185	0.019	1.000	0.185	0.018
Export	0.018	0.000	0.002	0.018	0.000	0.002
Eastern Germany	0.024	0.000	0.003	0.024	0.000	0.003
Foreign ownership	0.310	-0.014	0.023	0.313	-0.014	0.023
Analytic knowledge base	0.022	0.000	0.003	0.022	0.000	0.003
Cumulative know. base	0.837	-0.048	0.026	0.837	-0.048	0.026
Continuous R&D	0.404	0.020	0.027	0.383	0.018	0.026
Internal barriers	0.018	0.000	0.002	0.018	0.000	0.002
Economic barriers	0.997	0.079	0.018	0.997	0.079	0.018
Behavior of competitors	0.131	-0.005	0.014	0.133	-0.005	0.014
Technology dynamics	0.056	0.001	0.007	0.056	0.002	0.007
Form. appr. (sect mean)	0.094	-0.003	0.012			
Inform. appr. (sect mean)				0.026	0.000	0.004
Dep. var. (sec mean)	1.000	0.288	0.018	1.000	0.287	0.018
Competitors are larger	0.037	-0.001	0.005	0.037	-0.001	0.005
Firm has monopoly	0.025	0.000	0.004	0.025	0.000	0.004
Oligopolistic competition	0.019	0.000	0.003	0.019	0.000	0.003
Number of observations	1,789			1,789		
Number of models	65,536			65,536		
Prediction used in	Table 2 Model I			Table 2 Model II		

Note: Results of the first step BMA analysis. PIP is the posterior inclusion probability, PM is the posterior mean and PSD is the posterior standard deviation.

Panel E: Dependent Variable: Openness breadth

	Model 1			Model 2		
	PIP	PM	PSD	PIP	PM	PSD
Size	1.000	0.219	0.018	1.000	0.219	0.018
Export	0.021	0.000	0.003	0.021	0.000	0.003
Eastern Germany	1.000	0.086	0.017	1.000	0.086	0.017
Foreign ownership	0.035	-0.001	0.005	0.035	-0.001	0.005
Analytic knowledge base	0.023	0.000	0.003	0.023	0.000	0.003
Cumulative know. base	0.385	-0.017	0.023	0.384	-0.017	0.023
Continuous R&D	1.000	0.163	0.018	1.000	0.162	0.018
Internal barriers	1.000	0.182	0.017	1.000	0.182	0.017
Economic barriers	1.000	0.140	0.017	1.000	0.140	0.017
Behavior of competitors	0.021	0.000	0.003	0.021	0.000	0.003
Technology dynamics	1.000	0.082	0.017	1.000	0.082	0.017
Form. appr. (sect mean)	0.018	0.000	0.002			
Inform. appr. (sect mean)				0.075	0.003	0.012
Dep. var. (sec mean)	1.000	0.160	0.017	1.000	0.158	0.019
Number of observations	1,789			1,789		
Number of models	8,192			8,192		
Prediction used in	Table 2 Model I			Table 2 Model II		

Panel F: Dependent Variable: Openness depth

	Model 1			Model 2		
	PIP	PM	PSD	PIP	PM	PSD
Size	0.230	0.011	0.021	0.232	0.011	0.022
Export	0.027	0.000	0.004	0.027	0.000	0.004
Eastern Germany	0.117	0.004	0.013	0.117	0.004	0.013
Foreign ownership	0.022	0.000	0.003	0.022	0.000	0.003
Analytic knowledge base	1.000	0.138	0.018	1.000	0.138	0.018
Cumulative know. base	1.000	-0.191	0.018	1.000	-0.191	0.018
Continuous R&D	0.522	0.027	0.029	0.529	0.028	0.029
Internal barriers	0.913	0.058	0.025	0.912	0.058	0.025
Economic barriers	0.980	0.071	0.021	0.980	0.071	0.021
Behavior of competitors	0.026	0.000	0.004	0.026	0.000	0.004
Technology dynamics	0.775	0.045	0.029	0.774	0.045	0.029
Form. appr. (sect mean)	0.038	0.001	0.006			
Inform. appr. (sect mean)				0.021	0.000	0.003
Dep. var. (sec mean)	1.000	0.158	0.018	1.000	0.158	0.018
Number of observations		1,789			1,789	
Number of models		8,192			8,192	
Prediction used in		Table 2 Model I			Table 2 Model II	

Note: Results of the first step BMA analysis. PIP is the posterior inclusion probability, PM is the posterior mean and PSD is the posterior standard deviation.

Panel G: Dependent Variable: Strategy: Differentiation variety

	Model 1			Model 2		
	PIP	PM	PSD	PIP	PM	PSD
Size	0.924	-0.064	0.026	0.914	-0.062	0.026
Export	0.027	0.000	0.004	0.025	0.000	0.004
Eastern Germany	1.000	0.090	0.019	1.000	0.090	0.019
Foreign ownership	0.431	-0.022	0.028	0.399	-0.020	0.027
Analytic knowledge base	0.061	-0.002	0.008	0.061	-0.002	0.008
Cumulative know. base	0.023	0.000	0.003	0.023	0.000	0.003
Continuous R&D	0.355	-0.018	0.027	0.205	-0.009	0.019
Internal barriers	0.018	0.000	0.003	0.019	0.000	0.003
Economic barriers	0.021	0.000	0.003	0.021	0.000	0.003
Behavior of competitors	0.094	0.003	0.011	0.098	0.003	0.012
Technology dynamics	0.055	0.002	0.008	0.055	0.002	0.008
Form. appr. (sect mean)	0.372	0.019	0.027			
Inform. appr. (sect mean)				0.061	-0.002	0.009
Dep. var. (sec mean)	1.000	0.233	0.018	1.000	0.233	0.018
Number of observations		1,789			1,789	
Number of models		8,192			8,192	
Prediction used in		Table 2 Model I			Table 2 Model II	

Table 8. Principal component analyses

Panel A: Appropriation strategy		
Use and importance of	Factor 1	Factor 2
Patent application	0.350	0.622
Application of a utility model	0.215	0.723
Registering of a design patent	0.010	0.635
Registering of a trademark	0.245	0.616
Claiming copyrights	0.090	0.574
Secrecy	0.790	0.247
Complexity of the design	0.750	-0.028
Temporal advantage	0.836	0.182
Eigenvalue	3.029	1.210
Regression based scores are interpreted as	*Informal appropriation strategy*	*Formal appropriation strategy*

Panel B: Competitive environment		
Characteristics of the competitive environment	Factor 1	Factor 2
Behavior of competitors is hard to predict	0.147	0.699
Strong threat of market position by entry	0.102	0.674
Production technologies change fast	0.881	0.080
Goods and services become outdated fast	0.864	0.084
High degree of substitutability of own prod.	-0.183	0.481
Dynamics of demand is hard to predict	0.206	0.622
Eigenvalue	1.958	1.246
Regression based scores are interpreted as	*Competitive environment: Technology dynamics*	*Competitive environment: Behavior of competitors*

Panel C: Hampering factors		
Innovation projects are hampered by ...	Factor 1	Factor 2
Too high economic risk	0.677	0.316
Too high costs for innovation	0.714	0.319
Lack of internal financial resources	0.824	0.115
Lack of external financial resources	0.799	0.080
Organizational problems	0.187	0.657
Internal resistance against innovation projects	0.124	0.663
Lack of qualified personnel	0.180	0.665
Lack of technological information	0.217	0.720
Lack of market information	0.262	0.677
Lack of customer acceptance	0.356	0.507
Regulation, norms	0.444	0.378
Long approval procedures	0.480	0.278
Problems with identifying partners	0.474	0.400
Dominant position of incumbent firms	0.437	0.389
Eigenvalue	5.478	1.275
Regression based scores are interpreted as	*Economic barriers*	*Internal barriers*

Panel D: Strategy			
Competitive pos. of the firm bases on	Factor 1	Factor 2	Factor 3
Price	0.037	0.081	0.836
Quality	-0.030	0.866	0.059
Technological advantage	0.220	0.557	-0.509
Service	0.404	0.509	0.357
Variety in the product portfolio	0.814	0.088	0.134
Design and Marketing	0.830	0.000	-0.131
Eigenvalue	1.850	1.121	1.052
Regression based scores are interpreted as	*Strategy: Differentiation through variety*	*Strategy: Differentiation through technological advantage*	*Strategy: Cost leadership*

Table 9. Correlation table

		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Formal appropr. strategy													
2	Informal appropr. strategy	0.003												
3	Cooperation breadth	0.246	0.300											
4	Cooperation depth	0.231	0.196	0.593										
5	Coopetition	0.161	0.095	0.413	0.504									
6	Openness breadth	0.174	0.234	0.332	0.199	0.179								
7	Openness depth	0.097	0.085	0.214	0.162	0.156	0.332							
8	Cost leadership	-0.124	-0.216	-0.161	-0.132	-0.060	-0.120	-0.086						
9	Diff. by techn. & quality	-0.010	0.122	0.098	0.056	0.071	0.091	0.048	-0.038					
10	Diff. by variety	-0.001	-0.066	-0.116	-0.095	-0.057	-0.006	0.063	-0.018	-0.037				
11	Behavior of competitors	-0.037	-0.075	-0.129	-0.098	-0.058	-0.030	0.019	0.169	-0.067	0.066			
12	Technology dynamics	0.004	0.156	0.063	0.029	0.028	0.107	0.088	-0.226	0.120	0.006	-0.007		
13	Analytic knowledge base	0.003	0.009	0.119	0.064	0.034	0.012	0.161	-0.040	-0.002	-0.035	-0.010	0.001	
14	Basicness of research	0.178	0.240	0.457	0.288	0.220	0.769	0.566	-0.181	0.129	-0.007	-0.065	0.142	0.220
15	Cumulative knowl. base	0.019	0.023	-0.035	-0.029	-0.047	-0.050	-0.202	0.002	-0.037	-0.020	-0.034	-0.033	-0.026
16	Firm size	0.290	0.125	0.245	0.263	0.210	0.235	0.018	0.037	-0.024	-0.097	-0.097	-0.126	-0.025
17	R&D intensity	0.073	0.204	0.291	0.184	0.099	0.131	0.099	-0.211	0.119	-0.044	-0.051	0.157	0.092
18	Export	0.128	0.107	0.141	0.140	0.057	0.069	0.019	-0.082	0.060	-0.047	-0.041	0.040	0.015
19	Eastern German location	-0.117	-0.028	0.020	-0.040	-0.019	0.031	0.057	0.015	0.030	0.101	0.010	-0.017	0.063
20	Foreign ownership	0.091	0.032	0.064	0.052	0.017	0.034	-0.011	0.016	0.019	-0.076	-0.043	-0.021	0.006
21	Continuous R&D	0.219	0.364	0.330	0.186	0.142	0.287	0.085	-0.180	0.136	-0.092	-0.073	0.105	0.062
22	Economic barr. to innov.	0.008	0.132	0.138	0.081	0.069	0.172	0.105	-0.029	0.018	0.017	0.126	0.137	0.047
23	Internal barr. to innov.	0.060	0.099	0.053	0.045	0.040	0.239	0.082	0.006	0.002	-0.026	0.061	0.044	-0.035
24	Competitors are larger	-0.050	-0.016	-0.008	-0.037	-0.028	-0.032	0.013	0.003	0.015	-0.009	0.114	0.042	-0.012
25	Firm has monopoly	-0.033	-0.026	-0.005	-0.008	-0.026	-0.054	0.023	-0.073	-0.023	-0.012	-0.216	-0.010	0.032
26	Oligopolistic competition	0.038	0.113	0.078	0.047	0.034	0.055	-0.004	-0.056	0.025	-0.006	-0.050	-0.022	-0.022

		14	15	16	17	18	19	20	21	22	23	24	25
14	Basicness of research												
15	Cumulative knowl. base	-0.100											
16	Firm size	0.148	0.018										
17	R&D intensity	0.216	0.011	-0.156									
18	Export	0.090	0.021	0.146	0.033								
19	Eastern German location	0.097	-0.037	-0.220	0.112	-0.083							
20	Foreign ownership	0.019	0.025	0.187	-0.024	0.073	-0.086						
21	Continuous R&D	0.294	0.053	0.176	0.237	0.095	-0.017	0.079					
22	Economic barr. to innov.	0.193	-0.006	-0.176	0.180	-0.025	0.102	-0.081	0.096				
23	Internal barr. to innov.	0.150	-0.067	0.156	-0.052	0.016	-0.123	0.037	0.072	0.088			
24	Competitors are larger	-0.018	-0.006	-0.141	0.053	-0.002	0.018	-0.051	-0.002	0.060	-0.027		
25	Firm has monopoly	-0.004	0.013	-0.031	0.048	-0.014	-0.010	0.001	-0.047	-0.049	-0.045	-0.134	
26	Oligopolistic competition	0.020	0.016	0.077	0.031	0.080	-0.069	0.062	0.090	-0.029	0.041	-0.051	-0.293

As an illustration for model uncertainty take the two OLS models in TABLE 10 that explain the use of the formal appropriation strategy. Measured by their R^2, both models are comparable in their ability to explain the variation of the dependent variable and both models are of the same size measured by the number of predictors.

Table 10. Two illustrating OLS regressions of determinants of formal appropriation strategies

	Model 1		Model 2	
	Coeff.	Std. Er.	Coeff.	Std. Er.
Cooperation & coopetition				
Cooperation breadth	0.249	0.144	-0.408	0.150
Cooperation depth	-0.147	0.206	0.934	0.187
Coopetition	-0.249	0.091	-0.197	0.093
Firm level controls				
Size	0.279	0.036		
East German location	-0.081	0.027		
Foreign ownership	0.009	0.024		
Knowledge base				
Analytic knowledge base			-0.005	0.028
Basicness of research			0.087	0.030
Cumulative knowledge base			-0.009	0.026
(Intercept)	0.123	0.027	0.138	0.028
Sector control	YES		YES	
N	1,789		1,789	
F	68.00		55.49	
R^2	0.21		0.18	

Focusing on the cooperation variables based on Model 1, one would conclude that the breadth of innovation cooperation has a positive effect and the intensity (depth) of cooperation exerts a negative effect on the utilization of a formal appropriation strategy. Model 2, concludes exactly the contrary. The only difference between both models is that as controls Model 1 includes firm demographic characteristics and Model 2 includes characteristics of the knowledge base of the firm.

These two OLS regressions illustrate that more than one model exists which fulfills certain criteria of model fit (Chatfield, 1995), and that are based on sound theoretical grounds, but that lead to contradictory conclusions for the question at stake (see also Raftery 1995, pp. 120–124).

Navigating the IP Landscape – Exploring Firms' Usage of Defensive IP Strategies

Abstract

One commonly understood strategic use of intellectual property (IP) is to prevent the imitation of the firm's rent-yielding assets, which represents a *proprietary* IP strategy. By contrast, firms also often employ *defensive* IP strategies that are designed to respond to IP that can be potentially acquired and enforced against them by other firms and entities. However, research has remained largely focused on defensive patent portfolios or thickets, while a range of alternative defensive strategies – such as inventing around IP, terminating R&D projects to avoid infringement, licensing-in rights, opposing or revoking rights – remains underexplored. In this paper, we investigate the prevalence and predictors of companies' usage of a range of different defensive IP strategies. The empirical setting of this study is based on 2,995 innovative German manufacturing and service companies. We apply multiple correspondence analysis – a categorical data analysis technique – and find evidence for different combinations of defensive IP strategies among sector and size classes. Our results have implications for policy and the strategic management of IP.

Contents

1. Introduction

A dramatic growth in patenting since the early 1980s (also known as the patent surge) has raised the awareness of researchers who argue that firms increasingly use patents as a strategic weapon in technology competition (Blind et al., 2009; Neuhäusler, 2012).

Therefore, scholars have sought to understand the linkages between intellectual property (IP) as a strategic tool and its impact on firms' competitive advantage and performance (for a review see Pisano, 2006; Somaya, 2012). One commonly understood use of IP is to prevent the imitation of – or to 'isolate' – the firm's rent-yielding assets (Mahoney and Pandian, 1992; Rumelt, 1984), which represents a *proprietary* IP strategy. By contrast, firms also often employ *defensive* IP strategies that are designed to respond to IP that can be potentially acquired and enforced against them by other firms and entities. The ultimate goal of a defensive IP strategy is to retain freedom to operate (FTO) and commercialize (despite the IP held by others), and avoid being held up for exorbitant rents. Freedom to operate is a legal concept that comprises a relative assessment of IP landscapes 'whether the making, using, selling, or importing of a specified product, in a given jurisdiction, in a given geographic market, at a given time, is free from the potential infringement of third-party IP or tangible property rights' (Krattiger et al., 2007, p. 1317). Thus, an FTO analysis reveals potential hold-up situations that in turn influence firms' strategic decision making in relation to R&D investments and product commercialization.

Prior research on companies' reasons for obtaining patents has revealed a number of motives that are consistent with a defensive IP strategy, such as (defensive) blocking, building (defensive) thickets, avoiding litigation by others, and as bargaining chip in negotiation and exchange (e.g., Blind et al., 2009; Blind et al., 2006; Cohen et al., 2002; Cohen et al., 2000; Duguet and Kabla, 1998). Indeed, the idea that firms build patent portfolios or thickets to defend themselves against litigation by other patent owners is well understood (Hall and Ziedonis, 2001; Reitzig, 2004b; Ziedonis, 2004), and it is also recognized that these portfolios are often cross-licensed to avoid litigation (Galasso, in press; Galasso et al., 2011; Grindley and Teece, 1997). Recent trends in the smartphone industry have shown that strong patent portfolios can serve as a bargaining chip on the one hand but also as a means to obtain value from IP by generating licensing income (see TABLE 1).

Table 1. Estimated patent revenue for some phone makers, per year

Phone maker	**Estimated revenue per year in Euro**
Nokia	**500** million
Apple	**200** million
Samsung	Less than **100** million
Microsoft	**50** million
BlackBerry	**40** million
HTC	**10-30** million
Others	**90** million

Source: Sanford C. Bernstein estimates, The Wall Street Journal 16/12/2013

Furthermore, an increasing patent thicket problem makes it nearly impossible for these innovative firms to foresee potential infringements. Thus, non-transparent mobile patent lawsuits between various device and equipment manufacturers are the result (e.g., Apple vs. Samsung). While research has remained largely focused on these defensive patent portfolios or thickets, a range of alternative defensive strategies – such as inventing around IP, terminating R&D projects to avoid infringement, licensing-in rights, opposing or revoking rights, and so on – remains underexplored. Each of these strategies bears its own risks and advantages. Even, having no defensive strategy at hand or taking no action carries risk. For example, deferring or forgetting to obtain a license from a third-party could eventually lead to expensive licensing conditions, the decline of a license, or a patent infringement lawsuit (Krattiger et al., 2007). Additionally, we currently know very little about the prevalence of different defensive strategies and their distribution across different types of industries and firms. Thus, in this paper we investigate the prevalence and predictors of companies' usage of a range of different defensive IP strategies. Rather than focusing on a single defensive strategy – such as the building of deterrent IP portfolios – we take a broad exploratory approach to contribute to our neglected understanding of a wide range of defensive strategies.

The empirical setting of this study is based on 2,995 innovative German manufacturing and service companies. The data we use come from the 2008 German MIP (Mannheim Innovation Panel; ZEW) which represents the German Community Innovation Survey (CIS). We detect and interpret underlying structural relationships among the different defensive strategies in an exploratory fashion with the help of multiple correspondence analysis – a categorical data analysis technique. Categorical data are common results of survey research. However, the analysis of such data is often hindered by the requirements and limitations of many familiar research tools (e.g., factor analysis). Correspondence Analysis (CA) is a versatile and easily implemented analytical method to detect and interpret relationships among variables and thus, understand complex management phenomena.

The empirics reveal interesting differences for manufacturing and non-manufacturing sectors as well as for subclasses within the manufacturing sectors, which can be explained by differences in the underlying IP regime in each sector. In general, we find that the two most common defensive strategies used by manufacturing firms are inventing around others' IP and in-licensing whereas the two least common ones are the cancellation of R&D projects due to missing access to property rights and cross-licensing. Evidently, the portfolio of defensive IP strategies used varies by size such that smaller firms mainly rely on one or two strategies whereas bigger firms employ a larger defensive IP strategy arsenal. We also find evidence for different combinations of defensive IP strategies among sector and size classes.

2. Literature review

2.1. Proprietary IP strategies

Protection instruments provide important incentives to perform R&D and innovation activities (Somaya et al., 2011) because they create monopoly profits which are assumed to cover innovation-related costs and risks. In general, protection strategies can be divided into two groups of measures (e.g., Blind et al., 2006; Cohen et al., 2002; Cohen et al., 2000): *Formal appropriation instruments* which grant inventors and innovators an exclusive right to prevent others from the utilization of the protected subject matter (e.g., patents, trademarks, utility patents or copyright) and *informal appropriation instruments* which encompass various measures to avoid spillovers of own innovation efforts and thus to safeguard the appropriation of one's own innovation returns (e.g., secrecy, complex design of new products or services, lead time advantage).

In sum, all these instruments are examples of *proprietary* IP strategies describing measures a company actively undertakes to secure rents from R&D and innovation.

Scholars have sought to understand why some firms profit from their innovations whilst others do not. In 1986, David Teece developed his 'Profiting from Innovation (PFI)' framework which predicts that the profits generated by successful technological innovation tend to go to the owners of either the underlying invention (depending on the underlying *appropriability regime*[1]) or to the owners of complementary technologies and/or assets (including other components of the value chain) (Teece, 1986). Thus, appropriability refers to the degree to which a firm captures the profits generated when it introduces innovations (Ceccagnoli, 2009; Teece, 1986). Patents and other appropriation instruments serve as isolating mechanisms that protect the firm's key technologies and resources from imitation (Lippman and Rumelt, 2003; Rumelt, 1984).

In sum, research reveals that firms prevent imitation by building on a full portfolio of protection mechanisms available to them and thus secure or develop a competitive advantage (Somaya, 2012). In some industries (e.g., ICT and semiconductors) patenting is not solely used as an exclusion right anymore but rather for strategic purposes. Filing for formal IP thus serves two purposes which go hand in hand: (1) proprietary protection and exclusion of others from using the invention and (2) defensive protection of freedom to operate and commercialize in case of infringing IP held by others.

1 Hereby, the *appropriability regime* refers to the protection instruments that span both legal mechanisms (e.g., patents, copyrights, and non-disclosure agreements) and 'natural' barriers to imitation (e.g., degree of difficulty in reverse engineering, and lead time advantage).

2.2. Defensive IP strategies

Patent offices have witnessed an increase in patenting beginning in the 1980s (also known as the patent surge) which can only partly be explained by an increase in patent races. A *proprietary* patent strategy seeks to prevent imitation of valuable rent-generating assets and thus, creates or protects a competitive advantage position. Generally, most inventions represent minor advances on the current state-of-the-art, which implies that obtaining patent protection requires firms to demonstrate and describe the originality and superiority of their invention (Reitzig and Puranam, 2009). Granted protection rights for these small improvements mainly serve strategic purposes afterwards.

By using IP strategically, firms on the one hand seek to protect themselves from being blocked by competitors and on the other hand seek to force or negotiate access to rivals' technologies on better conditions (Cohen et al., 2000; Hall and Ziedonis, 2001).

Additionally, firms may use patents and other formal IP to exhibit strategic commitment to a technological or research trajectory in order to drive competitors into exiting R&D competition, patent races or terminating their R&D efforts (Agrawal and Garlappi, 2007; Baker and Mezzetti, 2005; Gill, 2008; Somaya, 2012) or to prevent patenting by others (Guellec et al., 2011). In this vein, firms increasingly use the patent system to create their own freedom of design and operation. Firms actively file for patents or acquire already granted patents to be able to in-license competitors, new entrants and others. Moreover, this strategy provides the firm with a bargaining chip for cross-licensing deals in case it (un)intentionally infringes on other companies' patents (Pisano, 2006; Pisano and Teece, 2007).

Additionally, due to increased technology competition, accelerated product life cycles and shortened time-to-market, firms may need to have a viable strategy for defending against patents owned (and potentially enforced) by others to guarantee that they are not put at a competitive disadvantage or at risk of being held up for rents (Somaya, 2012). Furthermore, a typical innovation process exposes firms to uncertainty regarding which patents will be needed or who will own them and thus requires an effective defensive strategy.

In turn, the owners of such patents can bargain for significant rents (e.g., by generating licensing incomes, trading IP in cross-licensing agreements or negotiating access to new technologies) and thus, hold up the alleged infringer with the threat of an injunction (Hall and Ziedonis, 2001; Neuhäusler, 2012; Somaya, 2012).

The goal of this so-called *defensive* strategy is to retain the freedom of the firm to operate and commercialize its technologies without interference of other firms' patents.

In this paper, we focus on a range of alternative defensive strategies – such as inventing around IP, terminating R&D projects to avoid infringement, licensing-in rights, opposing or revoking rights, and so on – which remains underexplored. The main question of when and how to pursue any of the options is discussed hereunder.

Abandonment

At the beginning of an innovation project, possible infringements cannot be easily predicted, as firms cannot foresee the R&D and product development plans of competitors. Therefore, patent races may occur. Before making large investments in risky innovation projects, a firm needs to be sure that IP developed by other firms' product development efforts will not hamper the commercialization of its own technology.

To tackle this issue, firms may try to identify all infringements as they arise and negotiate separate licenses for each. However, this approach is complex and leads to an explosion of transaction costs and at the same time induces large risks for the potential licensee. Thus, a project could be abandoned early on releasing resources for safer and more promising innovation investments. The best time to abandon a project thus is before starting any research and development when regular planning meetings with experts already conceivably show that the project is associated with great risks and costs to obtain access to all IP rights needed (Krattiger, 2007).

Cancellation

Sometimes, an innovation project is cancelled after a firm has started it. There are two possible reasons for this behavior. Firstly, the firm may have realized that it will not obtain all IP necessary to commercialize the technology or it is too expensive. Thus, by cancellation the firm tries to avoid infringement and litigation. Secondly, companies often use IP information strategically and lay a false trail of which technological trajectory they are pursuing. After having misguided their competitors, companies may cancel ongoing R&D projects (Reitzig, 2004a). Occasionally, firms redirect their R&D and innovation activities into technological areas where litigation is less likely and thus, current projects are cancelled due to missing access to IP or resources (Lerner, 1995).

Invent around

Inventing around a patented product requires a research team to seek new, unknown alternatives to develop the product in question and concurrently seek patent protection. It often takes substantial time to invent around patents (Mansfield, 1985) which is why the main disadvantage is that costs are high. Thus, this option would slow down product development but could lead to significant advantages in terms of innovations, new intellectual property as a bargaining chip for cross-licensing, and perhaps improved products. Inventing around is more likely to happen the longer the patent life of the product (Gallini, 1992). Thus, the costs and benefits of developing an entirely new product should be weighed against the costs and benefits of licensing. In reality, both strategies are pursued in parallel.

Nonetheless, following an invent around strategy will only work if at least one alternative exists that would work at least equally well as the technology in question and an analysis of potential infringements is conducted in the early stages of the R&D process. This is necessary to avoid fruitless years of work where a license unexpectedly seems quite attractive, if not necessary, in order to gain freedom to operate (Krattiger, 2007).

Wait and see

Another option is to commercialize the technology in question despite access to all relevant property rights and wait if the IP holder notices this and requests a license. This is a rather risky strategy as it is not clear a priori whether it will still be possible to negotiate a licensing deal. In addition, this strategy involves the intentional and conscious abandonment of access to relevant IP and can cause litigation suits. On the other hand, a cross-license might be offered in exchange if the technology in question or other IP of the alleged infringer are of value to the IP holder.

Cross-licensing

Cross-licensing happens when two IP holders exchange intellectual property to ensure that they enjoy the freedom to manufacture without infringement: 'Firm A' licenses a set of patents to 'Firm B' and in exchange B licenses a set of patents to A. In many high-technology and complex products (e.g., electronics and semiconductors) one innovation builds on another and a single firm cannot develop the entire product internally. Thus, unavoidably overlapping developments and mutually blocking patents are the rule and firms will try to develop, search and hold a portfolio of quality patents that their competitors also use (Hall and Ziedonis, 2001) to place the company in a stronger cross-licensing position regarding certain competitors. Otherwise, they must increasingly pay royalties. It is however important not to necessarily compete with the portfolio of a potential cross-licensing partner but to bundle R&D in those areas in which it has the most expertise to develop patents that cover large areas of the partner's product markets. This will yield maximum bargaining power in negotiations (Grindley and Teece, 1997). Bargaining positions via licensing will be constrained if a patentee is not dependent on access to the focal firm's patents. In recent years, many companies have faced severe and heavy injunctions and out-of-court settlements caused by specialized patent-holding firms or so-called patent 'trolls' (also 'sharks' or non-practicing entities (NPEs)) that are invulnerable against mutually held patents (Fischer and Henkel, 2012; Reitzig et al., 2010; Reitzig et al., 2007).

In-licensing

As IP portfolios are proactively developed and defended, industry participants find it increasingly necessary to license in technology to ensure freedom to operate avoiding the risk of being held up by other firms with similar technology. This option hardly causes any costs associated with patenting but can be quite risky in case no license is acquired as time and resources invested in R&D up to this point are irrevocably lost. Therefore, acquiring a license from the owners/assignees for each IP right that the product is likely to infringe solves all problems related to freedom to operate but at the same time can be very costly and effortful (Krattiger, 2007).

In particular, firms with strong patent portfolios are able to capture significant value from their patent estates by generating royalty income (Grindley and Teece, 1997). In some cases, in-licensing has become a source of funds for R&D or the sole business model which generates all profits.[2] Nokia possesses 30,000 patents, which it can now leverage to generate licensing income. Before the sale of its handset business to Microsoft, Nokia hardly took advantage of its strong portfolio as the firm's main objective was to protect the IP in its own devices.

Revocation

A patent is not necessarily valid once it is granted as alleged infringers may counter by challenging the scope, validity, and enforceability of patent rights issued in the first stage by the patent office (Kesan and Ball, 2006).[3]

Essentially, in U.S. law patents can be challenged on grounds of novelty, utility, and non-obviousness. A successful challenge on the basis of any of these three criteria will invalidate a patent claim, and sometimes the entire patent. Patent enforcement implies an uncertain outcome and considerable direct [4] and indirect costs mainly attributable to the time and effort in terms of manpower involved (e.g., key managers, lawyers, engineers, and scientists of a firm). Moreover, a patent-invalidity trial comprises significant ex-ante research and investigation that is similar to a freedom to operate analysis. Lerner (1995) suggests that litigation generally leads to a 2–3.1 percent average decline in the market value of the firms involved. Another possible drawback is that the assignee/inventor of the patent at stake may return to court and countersue with additional claims.

2 Being a pure 'licensing company' not directly involved in the product market and increasingly disconnected from the manufacture and design of the product itself can be a risky strategy. Such a strategy on the one hand can generate less revenue than developing and commercializing products and on the other hand lead to a decline in innovation activities.

3 Due to an increasing volume of patent applications, patent offices have large backlogs which in turn puts pressure on examiners and leads to misjudgments of relevant prior art and obviousness. Moreover, there is uncertainty about patentability in many new technology areas.

4 Direct legal costs alone can run in the range of $1.0–3.0 million (in 1997 U.S. dollars) for each side through trial (Somaya, 2012).

Lanjouw and Schankerman (2004) find evidence that reputation building plays a significant role in the case of patent litigation.[5] In addition, litigation suits can help build strategic positions (Teece et al., 1997) that can confer advantages in future rounds of competition (Somaya, 2003, 2004). Moreover, to secure a bargaining position, patentees are more likely to go to court to protect patents particularly if they form the base of a cumulative chain or technological trajectory. Hence, a firm's ability to appropriate value from their subsequent, incremental inventions, either through direct manufacturing or licensing, depends on their control over the initial invention (Lanjouw and Schankerman, 2001).

Out-of-court settlement

Sometimes out-of-court settlement is used to avoid any legal disputes or litigation over protection rights. Different authors find evidence that approximately 80-95% of all patent cases settle. Thus, the legal system encourages firms to settle their disputes out of court implying that the courts may be fulfilling their role of protecting patent rights at relatively low cost. However, the small number of final verdicts shows that very few patents are being examined to determine the scope, validity, and infringement of patent rights (Kesan and Ball, 2006). Settlements of IP conflicts can comprise different arrangements such as unrestricted or restricted licenses, cross-licensing arrangements, pools, agreements not to license third parties or to license only jointly, market division or field-of-use agreements (Krattiger, 2007). Further, out-of-court settlement agreements raise antitrust concerns as they are quite typically horizontal, particularly in patent cases, between either actual or potential competitors in the market.[6] Moreover, companies can exert out-of-court settlement as well as revocation to raise market entry barriers and thus impose a threat to potential new market entrants.

2.3. Determinants of defensive IP strategies

Although a lot of research has focused on the determinants of formal measures (for a recent review see James et al., 2013) and a new stream of literature is increasingly dealing with the determinants for the choice of either strategic or formal protection measures (e.g., Cohen et al., 2002; Cohen et al., 2000), the drivers for defensive strategies have only been investigated recently (Müller et al., 2013). The reasons why firms use different defensive IP strategies may vary across industries and technologies.

Most prior research focuses on the determinants of patent litigation (Bessen and Meurer, 2005; Cremers, 2004; Lanjouw and Schankerman, 2001; Ziedonis, 2003).

5 Hence, litigation risk is much higher for patents that are owned by individuals and firms with small patent portfolios.

6 As a result, IP settlement agreements raise significant antitrust issues. Indeed, some of those agreements would be illegal per se if created in the absence of a genuine IP dispute (Hovenkamp et al., 2002).

In addition to the litigation emphasis, several determinants such as firm size, sector affiliation and research intensity or the existence of a patent department potentially explain the wide range of defensive strategies. Large firms tend to possess more resources, market power, financial capacity and experience in patenting to defend themselves against infringements than smaller firms (Neuhäusler, 2012). Nonetheless, the size of the infringing company (small vs. large firm) in relation to the size of the infringed company (small vs. large) can also have an impact on the usage of all defensive strategies. Additionally, large or research-intensive companies usually generate more patents with substantial economic benefits ('valuable patents') (Allison et al., 2004; Harhoff et al., 2003) and thus induce a greater threat potential due to the mere presence of a large patent portfolio which in turn unlocks potential for cross-licensing negotiations or trade with other firms (Cohen et al., 2000; Hall and Ziedonis, 2001). Nonetheless, they also incur greater costs, since, relatively seen, they are more likely to challenge IP rights and negotiate licensing deals which requires more financial resources. Another driving factor identified in prior literature is technological opportunity, which is high when the cost of developing an invention is low e.g., in emerging sectors with a low concentration of firms (Cohen and Klepper, 1992). Technological opportunity describes another determinant for the usage of defensive strategies assuming that the more technological opportunities exist, the greater a firm's likelihood to exert these strategies.

The sector that a company operates in and the underlying appropriation regime (i.e., patent competition) similarly influence the decision to use defensive strategies as does research intensity.

Neuhäusler (2012) argues that in complex product industries, i.e., the electrical engineering and automotive industry, the number of patents per market-exploitable innovation is considerably larger than in discrete product industries, like the chemical sector. Particularly, companies in complex industries use patents more often strategically (e.g., to force rivals into negotiations), than companies in discrete industries which use patents to block rivals (Cohen et al., 2000). Thus, firms operating in these sectors should be more prone to using defensive strategies as they have to defend more IP.

Institutional and environmental factors such as rules, norms, routines, business processes, policies and the behavior of other firms may also impact firms' usage of defensive strategies. Moreover, the degree of internationalization of a company can also influence its usage of defensive IP strategies assuming that more international companies operate in more markets and thus face more potential competition. Furthermore, increased market competition is associated with more strategic patenting which in turn relates to defensive strategies as the threat of being sued rises (Neuhäusler, 2012).

The mere existence of a patent department is an indicator that a firm has developed routine in information and FTO searches and enforcing patents as well as that it is able to identify own infringements and thus, the likelihood of exercising any form of defensive strategy rises

(Somaya et al., 2007). In sum, a cost-benefit analysis of exercising each defensive option determines the usage of the same.

2.4. Research question and contribution

Although a considerable body of literature investigates firms' usage of formal and informal appropriation mechanisms, Somaya (2012) argues on a general account that strategic and competitive determinants of protection strategies are still not fully explored. Scholars have found a positive relationship between both *proprietary* (Hall et al., 2005; Reitzig, 2004b) and *defensive* (Reitzig, 2004b) patent strategies on firm market value (Somaya, 2012); however, the drivers of companies' use of defensive IP strategies remain to be studied. In addition to Arora and Ceccagnoli (2006) and Arora (1997), who emphasize the need to better understand the interplay between different formal and strategic IP instruments available, we analyze firms' use of defensive IP strategies in their pursuit to appropriate rents from innovation. This paper tries to shed some more light onto the question which firm characteristics exert an influence on the decision for or against a specific defensive strategy. Additionally, we currently know very little about the prevalence of different defensive strategies and their implementation across different types of industries and firms. Research has remained largely focused on defensive patent portfolios or thickets, while a range of alternative defensive strategies – such as inventing around IP, terminating R&D projects to avoid infringement, licensing-in rights, opposing or revoking rights, and so on – remains underexplored. Thus, in this paper we investigate the prevalence and predictors of companies' usage of a range of different defensive IP strategies by taking a broad exploratory approach to contribute to our neglected understanding of these strategies. In sum, we complement the extant discussion on formal versus strategic appropriation instruments by analyzing determinants of firms' usage of defensive IP strategies as well as different combinations of them among sector and size classes.

3. Empirical analyses

3.1. Sample

We use data from the Mannheim Innovation Panel (MIP), ZEW, Mannheim, which is the German version of the Eurostat Community Innovation Survey (CIS). It includes additional alternating questions. The MIP is sent out every year to a random sample (stratified by size, region, and sector) of German companies. It addresses topics such as IP, innovation performance, cooperation, etc. To address mortality, new companies (observations) are added every other year. Among scholars (e.g., Belderbos et al., 2004; Cassiman and Veugelers, 2002; Leiponen and Helfat, 2011; Miotti and Sachwald, 2003; Tether, 2002), the interest in CIS data has risen for two reasons. Firstly, the data provide indicators for innovation performance, and secondly, CIS data are used as a supplement to traditionally used patent data (Kaiser, 2002; Leiponen and Helfat, 2011), thus downsides of patent data can be tackled. We analyze data from the MIP 2008, containing information about defensive strategies and protection measures used by the companies in the sample. Furthermore, we match patent and trademark stock data on a 1:1 basis using an ID variable unique to each company throughout the MIP. The final data set contains 2,995 innovative companies and is cross-sectional. In particular, the sample comprises 1,758 companies active in manufacturing and 1,247 in service sectors. For firms to be included in the analysis they had to have selected one of the prescribed answers ('yes' or 'no') for all eight defensive strategies outlined above; 2,995 (83.9%) of the 3,517 firms in the full sample did this and were retained for further analysis. This high percentage suggests that most of the surveyed firms were content that the prescribed answers reflected their defensive strategy orientations and activities.

3.2. Measures

Variables

As major variables of interest, we employ eight different types of defensive strategies. The operationalization is derived from the question 'In the years from 2005-2007, did your company encounter any incidents concerning the access to IPR?' and results in the eight strategies 'Abandonment', 'Cancellation', 'Invent around', 'Wait and see', 'In-licensing', 'Cross-licensing', 'Revocation' and 'Out-of-court settlement'. Hence, the variable for each strategy is binary, 1 coding that a company has exercised a particular strategy, and 0 coding that it has not employed a strategy. In our estimations, we also include variables, which potentially influence the likelihood of exercising defensive IP strategies. For firm size, we examine the number of employees in a company, which reflects a categorical variable on a scale from 0 to 4. Firm size codes 0 for a company with less than ten employees and, hence, codes a small company. A value of 4 represents a firm with more than 300 employees.

By size, firms were divided into five classes: with sampling divided across these five bands, 12.3% had less than 10 employees, 23.5% 11-30 employees, 23.9% 31-100 employees, 18.9% 100-300 employees, and 21.2% over 300 employees[7].

Moreover, we investigate sectorial differences based on the OECD sector classification[8]. Additionally, we differentiate between manufacturing and service firms but also include various sector subclasses to gain a fine-grained picture of the distribution of defensive IP strategies among them. We also account for firms' usage of different formal appropriation mechanisms (patents, utility patents, design patents, trademarks, and copyright) which we derived from the survey question 'Which of the following formal IPR mechanisms have been used in your company from 2005-2007?'. Both sector and appropriation variables are binary and their coding resembles that of the defensive strategy variables. Furthermore, patent and trademarks stock (Patent Stock (ln); Trademark Stock (ln)) variables are added. For an overview of all employed variables, please refer to TABLE 2.

7 The analysis contains seven missing values for firm size.

8 The information on sectors is provided by NACE codes and is translated into the OCED classification based on Eurostat (2009).

Table 2. Summary statistics (*N*=2,995)

Variable	Mean	Std. Dev.	Min.	Max.
Defensive strategies				
Abandonment	0.038	0.192	0	1
Cancellation	0.028	0.164	0	1
Invent around	0.171	0.376	0	1
Wait and see	0.102	0.303	0	1
In-licensing	0.188	0.391	0	1
Cross-licensing	0.033	0.18	0	1
Revocation	0.121	0.326	0	1
Out-of-court settlement	0.129	0.335	0	1
Formal protection mechanisms				
Patents	0.373	0.484	0	1
Utility Patents	0.297	0.457	0	1
Design Patents	0.11	0.313	0	1
Trademarks	0.396	0.489	0	1
Copyrights	0.201	0.401	0	1
OECD sectors				
High-tech	0.046	0.21	0	1
Medium high-tech	0.183	0.386	0	1
Medium low-tech	0.194	0.396	0	1
Low-tech	0.124	0.33	0	1
Knowledge-intensive services	0.354	0.478	0	1
Less-knowledge-intensive services	0.013	0.112	0	1
NACE sectors				
Manufacturing	0.584	0.493	0	1
Chemicals and pharmaceuticals	0.055	0.228	0	1
Plastics and rubber	0.037	0.188	0	1
Manufacturing of non-metallic mineral products	0.025	0.157	0	1
Manufacturing of food, beverages and tobacco	0.033	0.18	0	1
Metal processing	0.081	0.273	0	1
Electrical engineering	0.109	0.311	0	1
Mechanical engineering	0.127	0.333	0	1
Manufacturing of textiles, clothes and leather	0.03	0.17	0	1
Manufacturing of wood, paper and furniture	0.045	0.208	0	1
Printing and reproduction of recorded media	0.019	0.138	0	1
Other manufacturing	0.102	0.302	0	1
Services	0.416	0.493	0	1
Information and communication	0.077	0.268	0	1
Professional scientific and technical activities	0.112	0.315	0	1
Financial and insurance activities	0.047	0.213	0	1
Other services	0.145	0.352	0	1
Size				
Employees	2.133	1.323	0	4

Descriptives

The descriptive statistics in FIGURES 1-5 reveal interesting differences for manufacturing and non-manufacturing sectors as well as for subclasses within the manufacturing sectors, which can be explained by differences in the underlying IP regime in each sector.

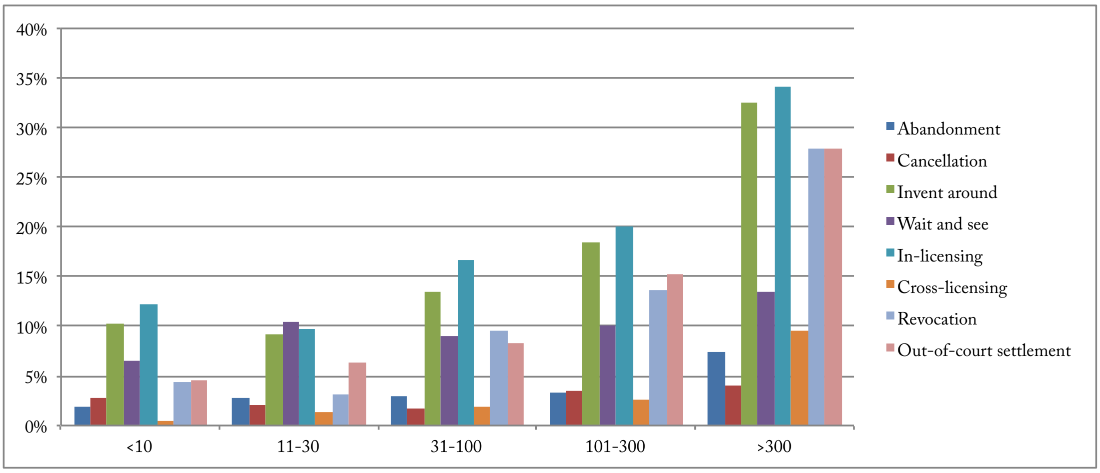

Figure 1. Incidences of defensive strategies over firm size

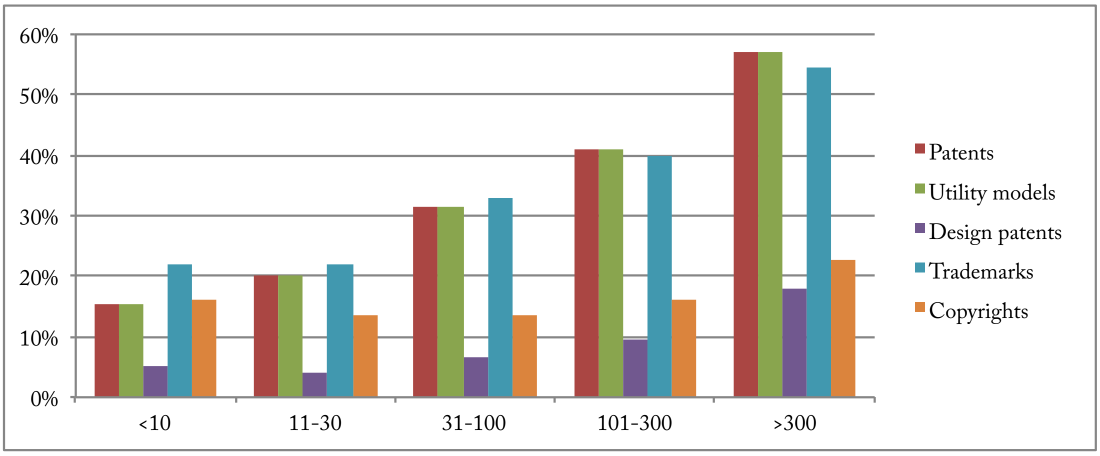

Figure 2. Incidences of formal protection mechanisms over firm size

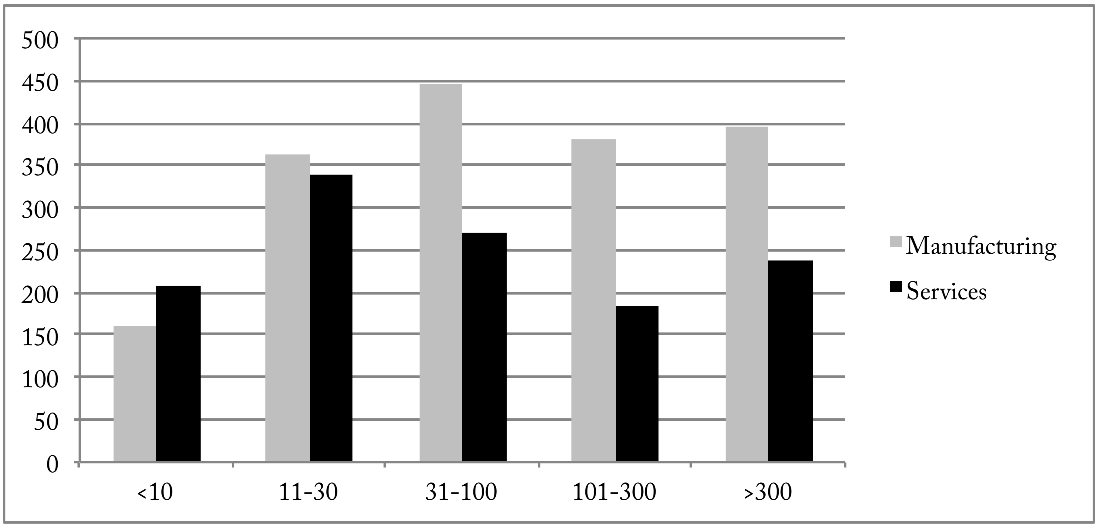

Figure 3. Number of observations by firm size and industry affiliation

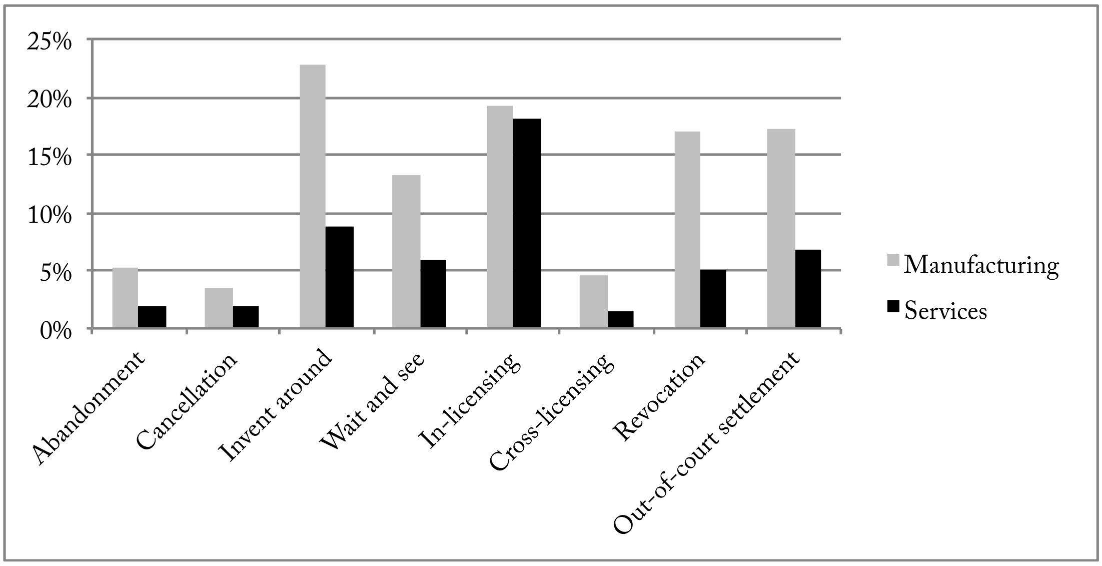

Figure 4. Incidences of defensive strategies over industry affiliation

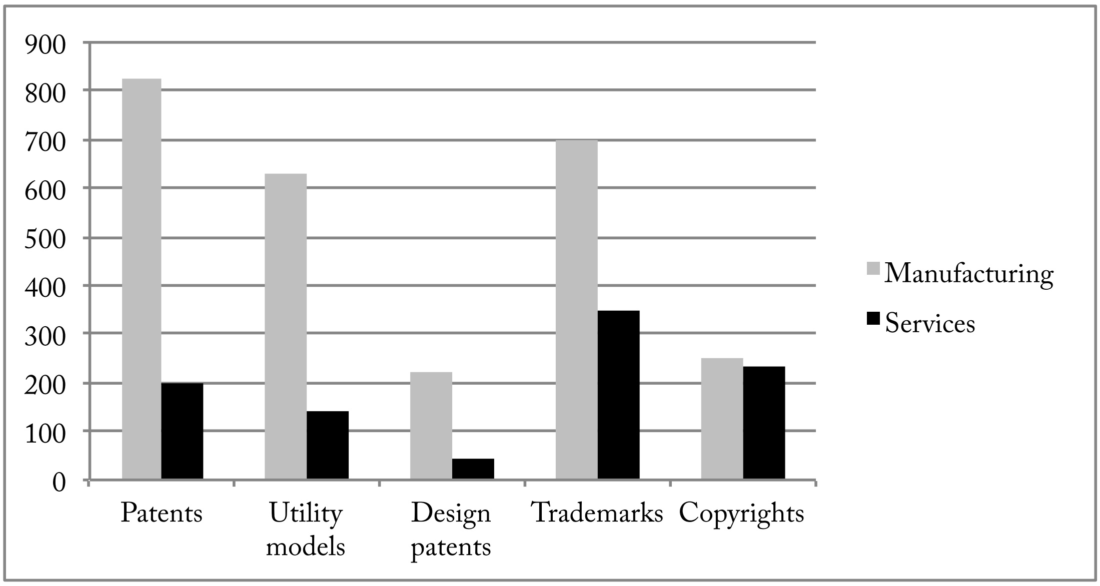

Figure 5. Number of observations by formal protection instruments and industry

We find that the two most common defensive strategies used by manufacturing firms are inventing around others' IP (22.9%) and in-licensing (19.3%) whereas the two least common ones are the cancellation of R&D projects (3.4%) due to missing access to property rights and cross-licensing (4.6%). Moreover, for companies in non-manufacturing sectors the most pursued strategy is in-licensing (18.1%) followed by inventing around the IP held by other entities (8.9%); the least employed strategies are cross-licensing (1.5%), abandonment (1.9%) and cancellation (1.9%) of innovation projects (see FIGURE 4). TABLE 3 shows a more fine-grained picture and reveals that particularly the chemical and pharmaceutical, the mechanical engineering and non-metallic goods manufacturing sectors are prone to applying revocations and out-of-court settlements as defensive mechanisms. In-licensing is most often used in chemical and pharmaceutical and electrical engineering industries whereas inventing around is dominant among firms operating in electrical or mechanical engineering and the manufacturing of non-metallic goods. With regards to services, in-licensing is the most frequent strategy in information and communication as well as finance and insurance sectors.

Table 3. Incidences of defensive strategies across manufacturing sectors

Sectors	Abandon-ment	Cancel-lation	Invent around	Wait and see	In-licensing	Cross-licensing	Revo-cation	Out-of-court settlement
Chemicals and pharmaceuticals	10%	7%	27%	15%	32%	4%	21%	24%
Plastics and rubber	6%	4%	19%	15%	10%	7%	22%	17%
Manufacturing of non-metallic mineral products	11%	9%	33%	14%	21%	4%	30%	24%
Manufacturing of food, beverages and tobacco	3%	2%	12%	8%	15%	2%	16%	13%
Metal processing	4%	3%	17%	13%	14%	3%	12%	14%
Electrical engineering	6%	4%	30%	16%	24%	6%	17%	19%
Mechanical engineering	4%	2%	30%	15%	20%	7%	23%	21%
Manufacturing of textiles, clothes and leather	3%	0%	16%	9%	17%	2%	17%	13%
Manufacturing of wood, paper and furniture	3%	3%	8%	6%	17%	1%	4%	10%
Printing and reproduction of recorded media	2%	2%	7%	7%	5%	2%	3%	3%
Other manufacturing	4%	3%	22%	13%	19%	1%	12%	13%
Information and communication	3%	3%	13%	9%	29%	3%	7%	10%
Professional scientific and technical activities	3%	3%	15%	8%	15%	1%	6%	5%
Financial and insurance activities	0%	1%	6%	2%	27%	1%	1%	8%
Other services	1%	1%	4%	4%	13%	1%	5%	6%

FIGURE 1 shows that the portfolio of defensive IP strategies used varies by size such that smaller firms mainly rely on one or two strategies whereas bigger firms simultaneously employ a larger defensive IP strategy arsenal. TABLES 4-6 display that there are different combinations of defensive IP strategies among sector classes. In manufacturing, inventing around is most frequently accompanied by in-licensing, revocations and out-of-court settlements. In service sectors, inventing around others' IP is frequently pursued simultaneously with in-licensing and in-licensing in turn appears parallelly with out-of-court settlement, but at a much lower level than in manufacturing industries.

In manufacturing, the majority of companies has 31-100 employees; in services the majority of firms falls into the category of 11-30 employees (FIGURE 3). We also see that larger companies possess a greater number of formal IP rights than smaller companies (FIGURE 2). Patents and trademarks are the dominating formal protection measures in manufacturing sectors whereas firms operating in service sectors seem to rely on trademarks and copyrights (FIGURE 5).

While the descriptive statistics already shed some light on the incidences of defensive strategies across sectors and firm sizes, only multivariate analyses can reveal relationships between the variables. The results of these analyses are reported herein.

Table 4. Frequencies of strategies appearing together – full sample (*N*=2,995)

	Abandon-ment	Cancel-lation	Invent around	Wait and see	In-licensing	Cross-licensing	Revo-cation	Out-of-court settlement
Abandonment	**115**							
Cancellation	49	**83**						
Invent around	82	63	**511**					
Wait and see	38	27	146	**305**				
In-licensing	56	37	209	98	**563**			
Cross-licensing	20	11	72	32	69	**100**		
Revocation	55	37	214	95	166	71	**362**	
Out-of-court settlement	54	36	209	106	188	73	216	**385**

Table 5. Frequencies of strategies appearing together – manufacturing (*N*=1,748)

	Abandon-ment	Cancel-lation	Invent around	Wait and see	In-licensing	Cross-licensing	Revo-cation	Out-of-court settlement
Abandonment	**91**							
Cancellation	37	**59**						
Invent around	65	47	**400**					
Wait and see	27	15	118	**232**				
In-licensing	42	28	162	76	**337**			
Cross-licensing	17	9	63	28	53	**81**		
Revocation	49	28	187	81	137	62	**299**	
Out-of-court settlement	46	29	177	88	145	61	184	**301**

Table 6. Frequencies of strategies appearing together – services (N=1,247)

	Abandonment	Cancellation	Invent around	Wait and see	In-licensing	Cross-licensing	Revocation	Out-of-court settlement
Abandonment	**24**							
Cancellation	12	**24**						
Invent around	17	16	**111**					
Wait and see	11	12	28	**73**				
In-licensing	14	9	47	22	**226**			
Cross-licensing	3	2	9	4	16	**19**		
Revocation	6	9	27	14	29	9	**63**	
Out-of-court settlement	8	7	32	18	43	12	32	**84**

Bivariate analysis

In this section, we present a number of bivariate tables in order to assess the relationship of firm size, sector affiliation, usage of IP with the incidence of using each type of defensive strategy. We explicitly do not presume causal relationships.

FIGURE 1 suggests that the firm size correlates with the usage of defensive strategies, that is larger firms use more types of defensive IP strategies simultaneously than smaller firms. Furthermore, the probability of the implementation of the strategies 'Invent around', 'In-licensing', 'Revocation' and 'Out-of-court settlement' is higher for firms with more than 300 employees. In general, the association of all defensive strategies with the firm size is statistically significant. Only for the strategy 'Cancellation' the contingency tests (both χ^2 test and Fisher's exact test) do not suggest a statistically significant relationship (see TABLE 8 in the appendix). This might be due to the fact that 'Cancellation' is a very infrequently exercised strategy across all firms. Next, the usage of protection mechanisms (patents, utility models, design patents, trademarks, copyrights) is significantly correlated with firm size. Thus, the probability of having any type of protection mechanism increases the larger the firm (see TABLE 9 in the appendix). The panels in FIGURE 4 show differences between manufacturing and service sectors regarding the usage of defensive strategies. The contingency analysis reveals that the differences between manufacturing and services in using different defensive strategies are statistically significant except for the strategy 'In-licensing' which seems to have an equivalent importance within both sectors. These results highlight the necessity and increased usage of defensive mechanisms in manufacturing sectors (see TABLE 10 in the appendix). These results seem to be reflected in firms' usage of formal protection mechanisms. Firms operating in manufacturing sectors have a greater usage of protection mechanisms as compared to firms in service sectors. However, for the protection mechanism 'copyright' the contingency tests (both χ^2 test and Fisher's exact test) do not find a statistically significant relationship (see TABLE 11 in the appendix) suggesting that this protection measure is equally important for firms in manufacturing and services.

3.3. Statistical method

We were interested in whether underlying patterns exist in which defensive strategies are pursued together by firms, and we therefore used multiple correspondence analysis, an exploratory statistical technique equivalent to principal components analysis for categorical data, to examine the data. Correspondence analysis (CA) has received considerable attention in the statistical and psychometric literature under a variety of names, including dual scaling, method of reciprocal averages, optimal scaling, canonical analysis of contingency tables, categorical discriminant analysis, homogeneity analysis, quantification of qualitative data, and simultaneous linear regression. Complete histories are given by Leeuw (1973), Greenacre (1984), and Nishisato (1980). Though very few applications of CA have been reported in the management literature, it has been frequently analyzed in marketing research (e.g., Carroll and Green, 1988; Hoffman and Franke, 1986; Hoffman and Leeuw, 1992) and interest in management research is increasing.

Usually, multidimensional scaling and unfolding, discriminant analysis and principal component analysis have been used to analyze and represent interrelationships between the rows and/or columns of a data matrix. However, these methods have little applicability to the categorical data that arise in many survey research applications because of the limitations and constraints imposed on the data collection process.

The joint graphical display obtained from a correspondence analysis can help in detecting structural relationships among the variable categories, which permits a rapid interpretation and understanding of the data. Finally, CA has flexible data requirements. The only strict requirement for conducting CA is a rectangular data matrix with non-negative entries (Hoffman and Franke, 1986).

Moreover, multiple correspondence analysis (MCA) extends simple CA as it incorporates more than two variables simultaneously. Basically, it is a simple CA executed on an indicator matrix containing some measure of correspondence between cases (in our case firms) as rows and categories of variables (in our case defensive strategies) as columns. Similar to the identification of components in principal components analysis, or factors in factor analysis, (multiple) correspondence analysis identifies and extracts a number of dimensions which capture the deviations from the expected values (which would be zero if the variables were statistically independent). The idea of this method is to estimate and maximize the distances between the row or column points in the tables. Hence, the first few dimensions will capture the greatest part of the overall deviation from statistical independence between the variables whereas the following dimensions will do so less.

In general, (multiple) correspondence analysis is used for exploratory, inductive research rather than hypothesis testing and deductive research (Le Roux and Rouanet, 2009; Tether and Tajar, 2008). This exploratory approach generates scatter-plots with the scores of the column variables plotted in the dimensions obtained from MCA. MCA disentangles variables with a high degree of coherence, which have similar scores in the analyzed dimensions and hence lie close together. For interpretation, it is also important to note that points and groups that are further away from the origin of the plots, are also associated stronger. Usually, MCA produces as many scatter-plots as there are binary combinations of the dimensions. Nonetheless, scholars mainly analyze and interpret the first two or three dimensions because these capture the greatest deviance from statistical independence in the data (Le Roux and Rouanet, 2009; Tether and Tajar, 2008).

3.4. Results

The multiple correspondence analysis for the full sample reveals 8 dimensions, each of which accounts for between 34.6% and 5.9% of the total variation in the data (see TABLE 7). For our interpretation, we will focus on the first two dimensions, which individually account for the largest amount of variation in the data, and together account for roughly 50% of the variance.

Table 7. Revealed dimensions from multiple correspondence analysis (*N*=2,995)

	Principal inertia	Percent	Cumulative percent
Dimension 1	0.346	34,6%	34,58%
Dimension 2	0.154	15,4%	49,95%
Dimension 3	0.114	11,4%	61,35%
Dimension 4	0.098	9,8%	71,20%
Dimension 5	0.09	9,0%	80,20%
Dimension 6	0.075	7,5%	87,70%
Dimension 7	0.064	6,4%	94,10%
Dimension 8	0.059	5,9%	100,00%

FIGURE 6 shows the plot of the defensive strategy variables for the full sample included in the multiple correspondence analysis according to their scores in dimensions 1 and 2.

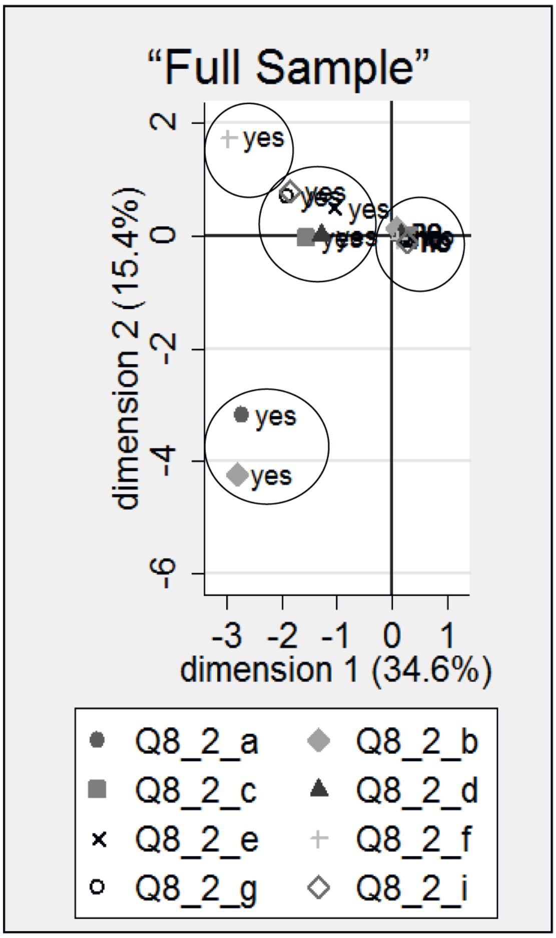

Figure 6. Identifying associations of defensive strategies in the full sample

As explained earlier, where variables are closely grouped together, particularly if this is at some distance from the origin, this shows variables with high levels of association. A clear cluster of variables appears in the bottom left corner of FIGURE 6. This includes positive answers to the question whether a firm has abandoned (Q8_2_a=1) or cancelled (Q8_2_b=1) an innovation project due to missing access to property rights. A second cluster of variables is found slightly to the left along the horizontal axis. This group of variables consists of all other strategies (Invent around, Wait and see, In-licensing, Revocation and Out-of-court settlement) except for cross-licensing (Q8_2_f=1) which appears to be a single point in the upper left corner of the plot suggesting that it either is a strategy that is less frequently employed or radically different from all other defensive strategies. The plot also shows another cluster of variables, located close to the center of the plot. This is comprised of the corresponding negative variables ('no' answers) for all defensive strategies and hence identifies the variables of the strategies that firms do not employ. We conducted the same analysis by comparing both manufacturing and service sectors. FIGURE 7 reveals some interesting differences. For manufacturing, we identify four clusters of variables similar to the ones revealed in the full sample suggesting that the manufacturing sector seems to be a better representation of the full sample than the service sector.

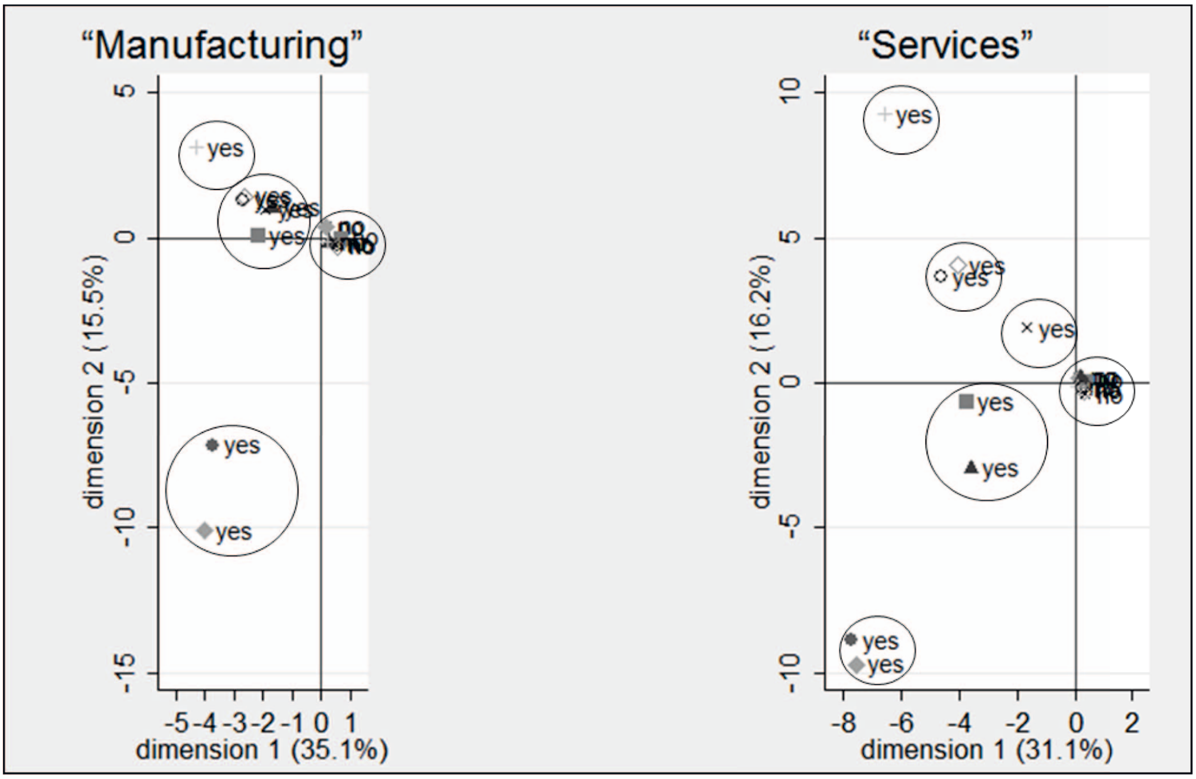

Figure 7. Identifying associations of defensive strategies – manufacturing and service sectors

As the descriptives have already shown, most larger companies and firms operating in the manufacturing sectors also have a greater arsenal of defensive strategies they employ which may explain the stronger association of the variables for this sector affiliation. Another reason might be due to the fact that the service sector is very diverse and comprises small sector subclasses. For the service sector, the picture is less clear. The variables 'Abandonment' and 'Cancellation' group together in the lower left corner. Another cluster consists of 'Invent around' (Q8_2_c=1) and 'Wait and see' (Q8_2_d=1) and a third group comprises the strategies 'Revocation' (Q8_2_g=1) and 'Out-of-court settlement' (Q8_2_i=1). In the service sector, 'In-licensing' (Q8_2_e=1) and 'Cross-Licensing' (Q8_2_f=1) reflect separate strategies. For a more precise overview, FIGURE 8 shows different associations of defensive strategies based on two selected sectors (Chemicals and Pharmaceuticals as well as Information and Communication sectors).

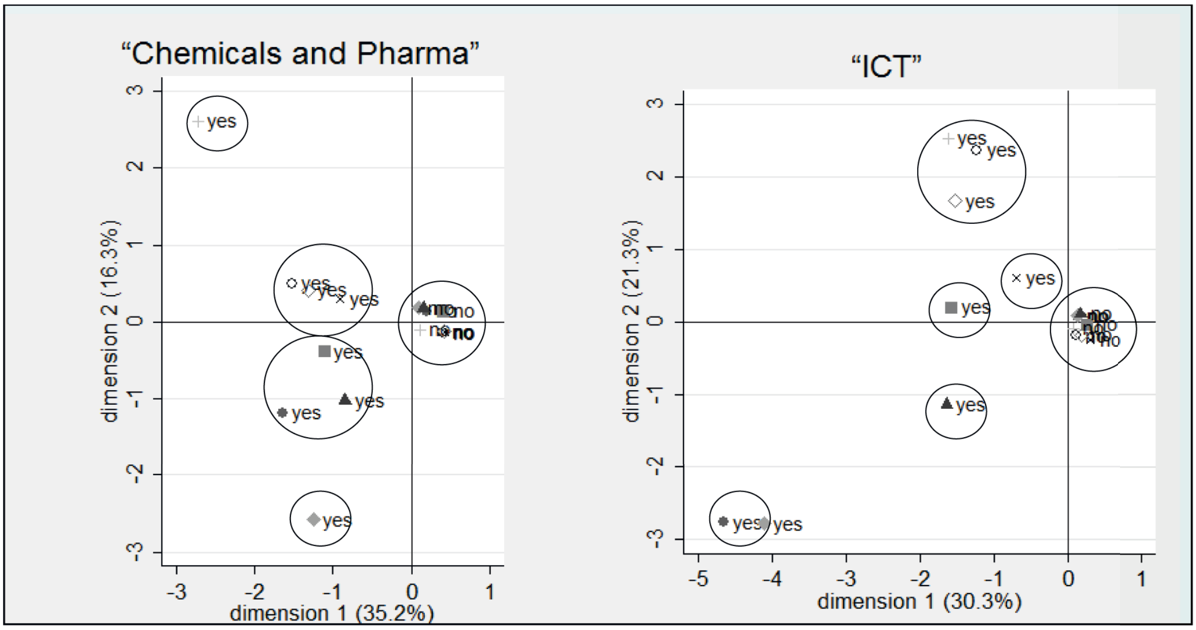

Figure 8. Identifying associations of defensive strategies – chemical and pharmaceutical and information and communication sectors

For Chemicals and Pharmaceuticals, we find five different clusters of defensive strategies. Cluster one comprises the strategy ‘Cancellation’ in the bottom of the plot, cluster two the strategies ‘Abandonment’, ‘Invent around’ and ‘Wait and see’, cluster three ‘In-licensing’, ‘Revocation’ and ‘Out-of-court settlement’. In the top left corner of the plot, we find ‘Cross-licensing’ reflecting another cluster with a single strategy. In contrast, the graphical representation for the Information and Communication sector shows a different pattern of six defensive strategy combinations. Cluster one represents the strategies ‘Abandonment’ and ‘Cancellation’, in another cluster at the top of the plot the strategies ‘Cross-licensing’, ‘Revocation’ and ‘Out-of-court settlement’ appear together. However, the strategies ‘In-licensing’, ‘Invent around’ and ‘Wait and see’ seem to reflect separate strategies in this sector. All these differences among the sectors may be due to the underlying IP regime in each sector.

In sum, the results suggest that there is evidence for different combinations of defensive IP strategies among sector classes. A drawback of the method relates to the ratio distortion of the maps; the scales on the vertical axes are usually different from that on the horizontal axes (Tether and Tajar, 2008).

4. Discussion and implications

Adding to the work of Arora and Ceccagnoli (2006) and Arora (1997), this study examines the interplay between different defensive IP instruments available to firms in their quest to appropriate rents from innovation. From a theoretical perspective, this paper sheds some light on the prevalence of different defensive strategies and their distribution across different types of industries and firms. With a broad exploratory approach, we are able to identify different combinations of defensive IP strategies among sector and size classes.

Moreover, prior research suggests that management of the different options of defensive IP strategies remains unclear. In this paper, we contribute to resolve this issue by linking firm determinants to defensive IP instruments. By doing so, we hope that managers gain a better understanding of the general relevance and hence the impact of exercising these different strategies. For example, the patent and the legal landscape co-evolve as the specifications of products are modified and improved, and as patent applications are filed, issued, expired, or invalidated.

Furthermore, very early in the innovation process freedom to operate has to be considered an integral component of firms' endeavors. The greater the R&D investments, the more difficult the bargaining position. Therefore, a sound strategy for obtaining FTO for an innovation comprises all defensive strategies and a cost-benefit analysis of each in relation to the institutional context, the product type, and market dynamics. Nonetheless, a detailed and early investigation on every potential product can be complex, expensive and thus just not feasible (Krattiger et al., 2007). In reality, the different defensive strategies are executed simultaneously and dynamically adapted to changing circumstances. Inventing around for example may be a more viable strategy during the R&D stages, whereas litigation or abandonment of a project may become the only strategy if nothing else works. Integrating and effectively managing FTO as part of a firm's strategy requires cooperation and a shared understanding among many different actors such as R&D staff, strategic decision makers, IP managers, and employees in business development or finance. In sum, the focus is not only on having an FTO strategy – but using it (Krattiger et al., 2007). Moreover, firms and their managers should be aware of the prevalent defensive strategies employed in the sectors they are operating in. Especially smaller firms – that usually apply less of these strategies – can benefit from this analysis here.

In this paper, we use MCA to disentangle associations of companies' use of specific defensive strategies. Correspondence analysis has a long research tradition as a technique for exploratory data analysis with a few exceptions; management scholars have not reported many applications of its use. Moreover, CA has received little attention in the management literature (Carroll and Green, 1988). Researchers often need to detect and interpret underlying relationships among variables. The purpose of our article is to increase awareness of the business research community for a multivariate descriptive statistical method that represents graphically the rows and columns of a categorical data matrix.

MCA does have limitations. It is a multivariate descriptive statistical method and hence is not suitable for testing hypotheses. Finally, it must be recognized that in many ways MCA is a subjective technique. Often it is possible to obtain many different representations of a data set, resulting in different analysis categories and solutions. Nonetheless, MCA offers great flexibility which can initiate more insight into the underlying relationships of the variables studied due to the different portrayal options. Hence, flexibility comes at the cost of subjectivity of the analysis (Hoffman and Franke, 1986).

A crucial feature of our data is that the unit of observation is at company level – not at product level. This might be important when analyzing defensive IP strategies as these often refer to specific products or components of technologies rather than entire product portfolios. Nonetheless, we assume a certain extent of homogeneity in the product portfolio of the firms in the sample.

Our analysis provides two main insights. First, innovating companies must early on assess the benefits and drawbacks of the different organizational IP strategies, and then decide for the most effective defensive strategy for the given context. Second, a valid defensive strategy at hand and as an essential part of the firm's business strategy is important and should not just be treated as an 'afterthought' (Somaya et al., 2011). The technological and research trajectories of a company have to be well aligned with its usage of defensive strategies. Hence, IP becomes a strategic weapon in the corporate arsenal (Reitzig, 2004a). This paper further shows that firms may not only file patents for proprietary reasons but rather to be strategically well positioned in case of counter-lawsuits and in terms of competition. Thus, companies more often use patents as a strategic weapon in the competitive arena. Recent figures provided by the United States Patent and Trademark Office (USPTO) seem to support this assumption: The number of patent applications has roughly quadrupled between 1983 and 2010. By contrast, neither innovation nor R&D expenditures have exhibited any particular upwards trend, not to speak of factor productivity. While patent litigation has increased, few patents are actively used (Boldrin and Levine, 2012). The same is true for the European Patent Office (EPO) which has seen a patent application upsurge since the 1990s (Blind et al., 2006). Discouraged by a growing fear of lawsuits, firms are increasingly afraid to invest in expensive research projects. Especially small companies, which only own few patents, increasingly invest more carefully as they cannot a priori assess whose patents they infringe upon (Schwiebacher, 2012).

In sum, companies having had experience with infringement situations might have developed their arsenal of defensive strategies based on these prior experiences and hence, a successful invent around experience may induce the use of this strategy again.

For policy-makers, this study delivers some interesting aspects of defensive strategies with regard to frequency and increasing importance across all sectors but particularly in the manufacturing industries. Companies seem to feel the urge to exercise these types of strategies due to a non-transparent patent system. Oftentimes firms face severe difficulties in gathering all necessary information on already existing patents. Particularly, in some industries (e.g., information and communication technologies or semiconductors), it is difficult to develop innovations or new products without infringing on other companies' rights. This leaves room for improvement of the patent system which needs to become more coherent and accessible. Additionally, the above mentioned weaknesses raise another voice for a more efficient patent system especially against the background of the new European patent announced to be introduced in 2014.

5. Conclusion and further research

The ultimate goal of a defensive IP strategy is to retain freedom to operate and commercialize and avoid being held up for exorbitant rents by other entities. Defensive strategies have increasingly raised awareness as they seem to become companies' strategic weapon in an ever faster moving, complex business environment with growing competition and shorter product life cycles. We detect and interpret underlying structural relationships among the different defensive strategies in an exploratory fashion with the help of multiple correspondence analysis – a categorical data analysis technique. The empirics reveal interesting differences for manufacturing and non-manufacturing sectors as well as for subclasses within the manufacturing sectors, which can be explained by differences in the underlying IP regime in each sector. Evidently, the portfolio of defensive IP strategies used varies with size such that smaller firms mainly rely on one or two strategies whereas bigger firms employ a larger defensive IP strategy arsenal. We also find evidence for different combinations of defensive IP strategies among sector and size classes. Due to the limitations of the statistical method we employ, we are not able to detect any causal relationships. However, in a further paper we focus particularly on the drivers and determinants of companies' use of defensive IP strategies. From a theoretical perspective, this paper emphasizes the importance for managers to understand the importance of defensive IP strategies as crucial for value appropriation from innovation. According to Reitzig (2004a), firms should govern and exploit their IP assets more effectively and integrate their defensive IP strategy into a cohesive corporate strategy (Somaya et al., 2011). The results of this study have implications for policy. Companies' use of defensive strategies reveals weaknesses and inefficiencies which call for a reform of the patent system.

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Table 8. Contingency tables: firm size and usage of defensive strategies

	Abandonment				
Firm size	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
<10 (*n* = 368)	98.1	[97%, 99%]	1.9	[1%, 3%]	100
11-30 (*n* = 704)	97.2	[96%, 98%]	2.8	[2%, 4%]	100
31-100 (*n* = 715)	97.1	[96%, 98%]	2.9	[2%, 4%]	100
101-300 (*n* = 566)	96.6	[95%, 98%]	3.4	[2%, 5%]	100
>300 (*n* = 635)	92.6	[91%, 94%]	7.4	[6%, 9%]	100
Total (*n* = 2988)	96.2	[96%, 97%]	3.8	[3%, 4%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(4) = 29.5738$
Pearson: design-based F(4, 11948) = 14.4647

	Cancellation				
Firm size	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
<10 (*n* = 368)	97.3	[96%, 98%]	2.7	[2%, 4%]	100
11-30 (*n* = 704)	97.9	[97%, 98.5%]	2.1	[1.5%, 3%]	100
31-100 (*n* = 715)	98.3	[97.5%, 99%]	1.7	[1%, 2.5%]	100
101-300 (*n* = 566)	96.5	[95%, 97%]	3.5	[3%, 4%]	100
>300 (*n* = 635)	96.1	[95%, 97%]	3.9	[3%, 5%]	100
Total (*n* = 2988)	97.3	[97%, 98%]	2.7	[2%, 3%]	100

Pr = 0.068
Pearson: uncorrected $\chi^2(4) = 8.7438$
Pearson: design-based F(4, 11948) = 4.2766

	Invent around				
Firm size	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
<10 (*n* = 368)	89.7	[87%, 92%]	10.3	[8%, 13%]	100
11-30 (*n* = 704)	90.8	[89%, 92%]	9.2	[8%, 11%]	100
31-100 (*n* = 715)	86.6	[85%, 88%]	13.4	[12%, 15%]	100
101-300 (*n* = 566)	81.6	[79%, 84%]	18.4	[16%, 21%]	100
>300 (*n* = 635)	67.4	[65%, 70%]	32.6	[30%, 35%]	100
Total (*n* = 2988)	82.9	[82%, 84%]	17.1	[16%, 18%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(4) = 157.9294$
Pearson: design-based F(4, 11948) = 77.2442

	Wait and see				
Firm size	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
<10 (*n* = 368)	93.5	[91%, 95%]	6.5	[5%, 9%]	100
11-30 (*n* = 704)	89.6	[88%, 91%]	10.4	[9%, 12%]	100
31-100 (*n* = 715)	90.9	[89%, 92%]	9.1	[8%, 11%]	100
101-300 (*n* = 566)	89.9	[88%, 92%]	10.1	[8%, 12%]	100
>300 (*n* = 635)	86.5	[84%, 88%]	13.1	[12%, 16%]	100
Total (*n* = 2988)	89.8	[89%, 90.5%]	10.2	[9.5%, 11%]	100

Pr = 0.007
Pearson: uncorrected $\chi^2(4) = 14.1679$
Pearson: design-based F(4, 11948) = 6.9296

	In-licensing				
Firm size	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
<10 (*n* = 368)	87.8	[85%, 90%]	12.2	[10%, 15%]	100
11-30 (*n* = 704)	90.2	[88.5%, 92%]	9.8	[8%, 11.5%]	100
31-100 (*n* = 715)	83.4	[81%, 85%]	16.6	[15%, 19%]	100
101-300 (*n* = 566)	80	[78%, 82%]	20	[18%, 22%]	100
>300 (*n* = 635)	65.8	[63%, 68%]	34.2	[32%, 37%]	100
Total (*n* = 2988)	81.2	[80%, 82%]	18.8	[18%, 20%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(4) = 148.4874$
Pearson: design-based F(4, 11948) = 72.6261

	Cross-licensing				
Firm size	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
<10 (*n* = 368)	99.5	[98.5%, 100%]	0.5	[0%, 1.5%]	100
11-30 (*n* = 704)	98.7	[98%, 99%]	1.3	[1%, 2%]	100
31-100 (*n* = 715)	98.2	[97%, 99%]	1.8	[1%, 3%]	100
101-300 (*n* = 566)	97.3	[96%, 98%]	2.7	[2%, 4%]	100
>300 (*n* = 635)	90.4	[89%, 92%]	9.6	[8%, 11%]	100
Total (*n* = 2988)	96.7	[96%, 97%]	3.3	[3%, 4%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(4) = 101.1817$
Pearson: design-based F(4, 11948) = 49.4886

	Revocation				
Firm size	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
<10 (*n* = 368)	95.7	[94%, 97%]	4.3	[3%, 6%]	100
11-30 (*n* = 704)	96.9	[96%, 98%]	3.1	[2%, 4%]	100
31-100 (*n* = 715)	90.5	[89%, 92%]	9.5	[8%, 11%]	100
101-300 (*n* = 566)	86.4	[84%, 88%]	13.6	[12%, 16%]	100
>300 (*n* = 635)	72.1	[70%, 74.5%]	27.9	[25.5%, 30%]	100
Total (*n* = 2988)	88	[87%, 89%]	12	[11%, 13%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(4) = 229.2156$
Pearson: design-based F(4, 11948) = 112.1107

	Out-of-court settlement				
Firm size	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
<10 (*n* = 368)	95.4	[94%, 97%]	4.6	[3%, 6%]	100
11-30 (*n* = 704)	93.6	[92%, 95%]	6.4	[5%, 8%]	100
31-100 (*n* = 715)	91.7	[90%, 93%]	8.3	[7%, 10%]	100
101-300 (*n* = 566)	84.8	[83%, 87%]	15.2	[13%, 17%]	100
>300 (*n* = 635)	72.1	[70%, 74.5%]	27.9	[25.5%, 30%]	100
Total (*n* = 2988)	87.1	[86%, 88%]	12.9	[12%, 14%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(4) = 192.7266$
Pearson: design-based F(4, 11948) = 94.2637

Table 9. Contingency tables: firm size and usage of protection measures

	Protection measures: patents				
Firm size	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
<10 (*n* = 368)	82.6	[79%, 85%]	17.4	[15%, 21%]	100
11-30 (*n* = 704)	77.4	[75%, 80%]	22.6	[20%, 25%]	100
31-100 (*n* = 715)	65.5	[63%, 68%]	34.5	[32%, 37%]	100
101-300 (*n* = 566)	54.8	[51.5%, 58%]	45.2	[42%, 48.5%]	100
>300 (*n* = 635)	40.2	[37%, 43%]	59.8	[57%, 63%]	100
Total (*n* = 2988)	62.7	[61%, 64%]	37.3	[36%, 39%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(4) = 261.6275$
Pearson: design-based F(4, 10932) = 118.3323

	Protection measures: utility models				
Firm size	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
<10 (*n* = 368)	83.2	[80%, 86%]	16.8	[14%, 20%]	100
11-30 (*n* = 704)	81.6	[79%, 84%]	18.4	[16%, 21%]	100
31-100 (*n* = 715)	73.2	[70.5%, 76%]	26.8	[24%, 29.5%]	100
101-300 (*n* = 566)	63.3	[60%, 66.5%]	36.7	[33.5%, 40%]	100
>300 (*n* = 635)	53	[50%, 56%]	47	[44%, 50%]	100
Total (*n* = 2988)	70.2	[69%, 72%]	29.8	[28%, 31%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(4) = 155.9126$
Pearson: design-based F(4, 10348) = 67.5935

	Protection measures: design patents				
Firm size	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
<10 (*n* = 368)	93.7	[91%, 95.5%]	6.3	[4.5%, 8%]	100
11-30 (*n* = 704)	95.1	[93.5%, 96%]	4.9	[4%, 6.5%]	100
31-100 (*n* = 715)	91.8	[90%, 93%]	8.2	[7%, 10%]	100
101-300 (*n* = 566)	87.4	[85%, 90%]	12.6	[10%, 15%]	100
>300 (*n* = 635)	77.3	[74%, 80%]	22.7	[20%, 26%]	100
Total (*n* = 2988)	89	[88%, 90%]	11	[10%, 12%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(4) = 104.8958$
Pearson: design-based F(4, 9564) = 43.0773

Firm size	Protection measures: trademarks No Row (%)	 95% CI	 Yes Row (%)	 95% CI	 Total Row (%)
<10 (n = 368)	74.9	[71%, 78%]	25.1	[22%, 29%]	100
11-30 (n = 704)	75	[72%, 77.5%]	25	[22.5%, 28%]	100
31-100 (n = 715)	62.9	[60%, 66%]	37.1	[34%, 40%]	100
101-300 (n = 566)	54	[51%, 57%]	46	[43%, 49%]	100
>300 (n = 635)	39.2	[36%, 42%]	60.8	[58%, 64%]	100
Total (n = 2988)	60.4	[59%, 62%]	39.6	[38%, 41%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(4)$ = 200.4845
Pearson: design-based F(4, 10532) = 88.0678

Firm size	Protection measures: copyrights No Row (%)	 95% CI	 Yes Row (%)	 95% CI	 Total Row (%)
<10 (n = 368)	81	[77%, 84%]	19	[16%, 23%]	100
11-30 (n = 704)	83.4	[81%, 86%]	16.6	[14%, 19%]	100
31-100 (n = 715)	83.5	[81%, 86%]	16.5	[14%, 19%]	100
101-300 (n = 566)	79.2	[76%, 82%]	20.8	[18%, 24%]	100
>300 (n = 635)	72	[69%, 75%]	28	[25%, 31%]	100
Total (n = 2988)	79.9	[79%, 81%]	20.1	[19%, 21%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(4)$ = 30.1014
Pearson: design-based F(4, 9708) = 12.4826

Table 10. Contingency tables: sector affiliation and usage of defensive strategies

	Abandonment				
Manufacturing	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
No (*n* = 1247)	98.1	[97.5%, 98,5%]	1.9	[1.5%, 2.5%]	100
Yes (*n* = 1748)	94.8	[94%, 95.5%]	5.2	[4.5%, 6%]	100
Total (*n* = 2995)	96.2	[96%, 97%]	3.8	[3%, 4%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(1) = 21.2234$
Pearson: design-based F(1, 2994) = 41.6152

	Cancellation				
Manufacturing	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
No (*n* = 1247)	98.1	[97.5%, 98.5%]	1.9	[1.5%, 2.5%]	100
Yes (*n* = 1748)	96.6	[96%, 97%]	3.4	[3%, 4%]	100
Total (*n* = 2995)	97.2	[97%, 98%]	2.8	[2%, 3%]	100

Pr = 0.0009
Pearson: uncorrected $\chi^2(1) = 5.6842$
Pearson: design-based F(1, 2994) = 11.1457

	Invent around				
Manufacturing	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
No (*n* = 1247)	91.1	[90%, 92%]	8.9	[8%, 10%]	100
Yes (*n* = 1748)	77.1	[76%, 78.5%]	22.9	[21.5%, 24%]	100
Total (*n* = 2995)	82.9	[82%, 84%]	17.1	[16%, 18%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(1) = 100.5464$
Pearson: design-based F(1, 2994) = 197.1536

	Wait and see				
Manufacturing	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
No (*n* = 1247)	94.1	[93%, 95%]	5.9	[5%, 7%]	100
Yes (*n* = 1748)	86.7	[85.5%, 88%]	13.3	[12%, 14.5%]	100
Total (*n* = 2995)	89.8	[89%, 91%]	10.2	[9%, 11%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(1) = 43.7882$
Pearson: design-based F(1, 2994) = 85.8608

	In-licensing				
Manufacturing	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
No (*n* = 1247)	81.9	[80%, 83%]	18.1	[17%, 20%]	100
Yes (*n* = 1748)	80.7	[79%, 82%]	19.3	[18%, 21%]	100
Total (*n* = 2995)	81.2	[80%, 82%]	18.8	[18%, 20%]	100

Pr = 0.2639
Pearson: uncorrected $\chi^2(1) = 0.6368$
Pearson: design-based F(1, 2994) = 1.2487

	Cross-licensing				
Manufacturing	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
No (*n* = 1247)	98.5	[98%, 99%]	1.5	[1%, 2%]	100
Yes (*n* = 1748)	95.4	[95%, 96%]	4.6	[4%, 5%]	100
Total (*n* = 2995)	96.7	[96%, 97%]	3.3	[3%, 4%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(1) = 21.8140$
Pearson: design-based F(1, 2994) = 42.7734

	Revocation				
Manufacturing	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
No (*n* = 1247)	94.9	[94%, 96%]	5.1	[4%, 6%]	100
Yes (*n* = 1748)	82.9	[82%, 84%]	17.1	[16%, 18%]	100
Total (*n* = 2995)	87.9	[87%, 89%]	12.1	[11%, 13%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(1) = 99.5051$
Pearson: design-based F(1, 2994) = 195.1119

	Out-of-court settlement				
Manufacturing	No		Yes		Total
	Row (%)	95% CI	Row (%)	95% CI	Row (%)
No (*n* = 1247)	93.3	[92%, 94%]	6.7	[6%, 8%]	100
Yes (*n* = 1748)	82.8	[81.5%, 84%]	17.2	[16%, 18.5%]	100
Total (*n* = 2995)	87.1	[86%, 88%]	12.9	[12%, 14%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(1) = 71.4031$
Pearson: design-based F(1, 2994) = 140.0088

Table 11. Contingency tables: sector affiliation and usage of protection measures

Manufacturing	**Protection measures: patents** No Row (%)	95% CI	Yes Row (%)	95% CI	Total Row (%)
No (n = 1120)	82.3	[81%, 84%]	17.7	[16%, 19%]	100
Yes (n = 1619)	49.1	[47%, 51%]	50.9	[49%, 53%]	100
Total (n = 2739)	62.7	[61%, 64%)	37.3	[36%, 39%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(1)$ = 312.2897
Pearson: design-based F(1, 2738) = 565.8242

Manufacturing	**Protection measures: utility models** No Row (%)	95% CI	Yes Row (%)	95% CI	Total Row (%)
No (n = 1081)	87	[85.5%, 88.5%]	13	[11.5%, 14.5%]	100
Yes (n = 1512)	58.3	[56%, 60%]	41.7	[40%, 44%]	100
Total (n = 2593)	70.3	[69%, 72%]	29.7	[28%, 31%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(1)$ = 249.9276
Pearson: design-based F(1, 2592) = 434.0257

Manufacturing	**Protection measures: design patents** No Row (%)	95% CI	Yes Row (%)	95% CI	Total Row (%)
No (n = 1045)	95.8	[95%, 97%]	4.2	[3%, 5%]	100
Yes (n = 1352)	83.7	[82%, 85%]	16.3	[15%, 18%]	100
Total (n = 2397)	89	[88%, 90%]	11	[10%, 12%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(1)$ = 87.4945
Pearson: design-based F(1, 2396) = 143.9182

Manufacturing	Protection measures: trademarks No Row (%)	95% CI	Yes Row (%)	95% CI	Total Row (%)
No (n = 1138)	69.6	[67.5%, 72%]	30.4	[28%, 32.5%]	100
Yes (n = 1502)	53.4	[51.5%, 55%]	46.6	[45%, 48.5%]	100
Total (n = 2640)	60.4	[59%, 62%]	39.6	[38%, 41%]	100

Pr = 0.000
Pearson: uncorrected $\chi^2(1)$ = 71.0302
Pearson: design-based F(1, 2639) = 125.0230

Manufacturing	Protection measures: copyrights No Row (%)	95% CI	Yes Row (%)	95% CI	Total Row (%)
No (n = 1086)	78.3	[76%, 80%]	21.7	[20%, 24%]	100
Yes (n = 1348)	81.3	[80%, 83%]	18.7	[17%, 20%]	100
Total (n = 2434)	80	[79%, 81%]	20	[19%, 21%]	100

Pr = 0.063
Pearson: uncorrected $\chi^2(1)$ = 3.4602
Pearson: design-based F(1, 2433) = 5.7489

Conclusion

Summary

This thesis contributes to our neglected understanding of the tension between open innovation and appropriation as well as of the learning mechanisms within organizations by taking an interdisciplinary approach. Thus, this dissertation informs different debates in the literature on innovation management, IP management, strategy and organizational learning. The first paper shows that firms learn from own and other firms' product-related failure experience and adapt their innovation strategy accordingly. Paper number two provides empirical evidence that firms with experience regarding the legal copying of their IP are less willing to engage in research collaboration, while in contrast, firms with experience regarding the illegal infringement of their IPR are more likely to cooperate on R&D. This result highlights that companies are able to reflect on their failure experience and adapt their behavior accordingly and that IPR infringement might also associate with positive effects for companies. Subsequently, I find that firms' open innovation activities associate with imitation revealing a further driving factor of imitation of IP. Article number four taps into the gap of how firm-level strategies determine a firm's choice of appropriation mechanisms. With the help of Bayesian Model Averaging, I am able to disentangle different determinants for both formal and informal appropriation strategies. Furthermore, my research findings indicate that firm size and sector affiliation exert an influence on the decision for or against a specific defensive strategy. Thus, firms build their IP arsenal by employing and exercising different defensive strategies simultaneously to avoid hold-up situations and retain their freedom to operate and commercialize.

Main results

Learning from own and others' product-related failure is highly important

This doctoral thesis contributes to the understanding of product failure as a further trigger of innovativeness and strategic change. Prior research has shown that there are significant barriers that prevent the efficient learning from failure experience. These may also be existent in the case of product recalls. Adopting the typology developed in this thesis, I reveal that product failure associates with different reactions in the short and long-run depending on whether the focal firm or other firms have made the initial failure experience. In sum, in the case of a product defects firms need to have a viable product recall strategy at hand which can reduce costs and minimize a recall's severe consequences for the firm substantially. This can also be valuable when fast reactions need to be executed. However, as I only provide first conceptual findings, these need further empirical validation.

Companies learn differently from experience regarding the legal copying of their IP and the illegal infringement of their IPR

My research has shown that legal copying and illegal infringement both are important topics with impact on companies since the evaluation and the resulting reactions differ for both incidences. Controlling for different factors, we see opposite responses indicating that the firms derive different lessons learnt from their experiences. My findings suggest that companies can even use illegal IPR infringement to their advantage by purposefully leaving space for imitation. Firms can then leverage on another entity's infringement of their IPR by initiating negotiations over collaboration with the entity or by claiming royalties. In most cases, this position potentially leads to a cross-licensing deal in which the initially infringed company has an advantaged position as it can threaten the infringer with litigation. Moreover, a shortsighted reaction to withdraw from or reduce R&D cooperation after having experienced legal copying can harm a company in the long run regarding its innovativeness and competitiveness. As a result, firms can actively evaluate the benefits and risks associated with each reaction according to the characteristics of their products, the industry they are operating in, and according to their current business and innovation strategy. Moreover, managers should neither be overly nor routinely focused on protecting IP since a firm might miss out on valuable opportunities of knowledge exchange and new product development otherwise. However, on a case-by-case basis, firms can derive individual solutions depending on the type of affected product and the extent of the damage.

Unraveling the tension of openness and appropriation

This dissertation contributes to the emerging debate on the tension between an open paradigm and a restrictive setting relying on IP. I have shown that openness associates with innovators' concerns regarding the capturing of all profits as imitation may occur. Moreover, I find that appropriation concerns, particularly in cases of unprotected IP, may influence a firm's openness decisions. Moreover, firms can choose from a whole set of formal and informal appropriation mechanisms according to their innovation cooperation strategy. Some partner types, such as the high risk collaboration with competitors may require a different bundle of appropriation mechanisms than cooperating with a university. Thus, these rising tensions associated with the paradox of openness require firms' to align their open innovation activities with their IP strategy. Furthermore, one possible strategy to cope with these concerns has recently been termed 'selective revealing'. Accordingly, firms ideally select and offer less critical resources and capabilities that are still valuable for the partner and keep more valuable knowledge for themselves. Consequently, a firm's awareness of its core competencies and capabilities and which of these are critical for its performance and competitive advantage is the prerequisite for appropriate protection decisions.

IP increasingly serves strategic purposes as reflected in firms' usage of defensive strategies

In my dissertation, I have shown that IPR are important strategic weapons in an ever more competitive and turbulent environment. As a result, firms need to be aware of potential hold-up situations and have a valid defensive strategy at hand. A firm should focus its R&D activities on high quality patents that cover significant product markets and that are needed by other firms. Moreover, firms should concentrate on their core competencies and try to avoid duplication of others' research efforts as in complex industries infringement is almost inevitable. The resulting legally and technically strong patents have great bargaining and cross-licensing value.

Another strategy often executed refers to the purchase of a patent portfolio that enables firms to establish cross-licensing relationships. This phenomenon has recently been seen with the acquisition of Motorola Mobility by Google. In summary, the dynamics in the marketplace today suggest that companies should proactively develop IP portfolios by simultaneously keeping an eye on the market for technology.

Policy implications

By providing a regulatory environment, policy can enhance the spread of knowledge and learning about other firms' failure across companies within the same sector. Thus, new, improved regulations to prevent the occurrence of the same or similar failures can be facilitated.

Particularly, companies' increased strategic use of defensive strategies and IPR reveals weaknesses and inefficiencies which call for a reform of the patent system. The results of this thesis support the call for a more efficient patent system since filing and enforcing patents is associated with uncertainties and high transaction costs.

I further show that informal mechanisms seem to complement formal appropriation mechanisms as firms increasingly develop their own complex IP strategy to deal with the inefficiency and disclosure problems related to patents. In some industries (e.g., information and communication technologies or semiconductors), it is difficult to develop innovations or new products without infringing on other companies' rights. An economically viable enforcement of patents could create more accessibility, transparency and legal certainty which can improve the current system.

My research has shown that IPR infringement does not necessarily lead to negative consequences for the affected companies. My thesis suggests that firms can even use the infringement of IPR to strengthen their bargaining position in cross-licensing or cooperation agreements. Therefore, policy makers may need to reconsider their biased position towards IPR infringement and be more open for potential positive effects.

Further research

Regarding the theoretical predictions on learning from product-related failure, further empirical works on organizational learning are needed to test and verify the typology and framework presented in this dissertation. A qualitative approach using the techniques shadowing, interviews or long-term observation of a firm over a period of time might be necessary to gain a full picture to what led to the experience and how the firm copes with the experience.

Further interesting areas of quantitative testing refer to the learning from product recalls for example in the automotive industry. Here, it might be interesting to examine an affected firm's patenting behavior before and after the incident. I would assume that firms having learned from their failure experience might invest in R&D to improve the component at stake which in turn manifests in new or better products and technologies. Moreover, I would like to gain more knowledge about firms' learning processes in an innovation context by collecting new and unique data. These learning processes do not necessarily have to be limited to a single industry but across different industries to generate more reliable results. In general, it is worthwhile to investigate potential reactions to product-related failure, e.g., shifts in patenting behavior, changes in innovation strategy of companies (e.g., shortening of the product life cycle), etc.

While my doctoral thesis is able to shed some light onto further driving factors for R&D cooperation and imitation, it has clear limitations. These limitations provide valuable opportunities and promising directions for future research. In the next years, I will focus my research on the questions that my dissertation currently cannot answer. It is worthwhile to understand why companies are more likely to engage in external collaboration after they have experienced the infringement of their IPR – qualitative interview data could establish clarity on that matter. Another big challenge in the context of this research is the access to reliable data that ensure exogeneity. I have addressed the endogeneity problem where applicable in this thesis. Particularly, the endogeneity of infringement incidences can only be tackled only using panel data with exogenous policy shocks because access to infringement lawsuit data is hard obtain.

More broadly, it would be interesting to investigate the role of IP and IPR in an open innovation context which has proven a relevant topic for firms across many different industries, disciplines or stages of the value chain. Especially, multi-invention contexts (e.g., ICT and semiconductor industries) are known for their complex IP structures. When a large set of technologies is required to commercialize products or the patented technology is an integral part of many different products, the exposure to others' patents could hinder firms from using even their own inventions if patents on other inventions required for commercialization include claims against them. In turn, the owners of such patents can bargain for significant rents (e.g., by generating licensing incomes, trading IP in cross-licensing agreements or negotiating access to new technologies) and thus, hold up the alleged infringer with the threat of an injunction. Therefore, I believe it is worth to dig deeper into the area of digital innovation which has tremendously expanded in the past few years especially with new technologies in the smartphone and tablet markets and the increasing trend of developing apps. Here, another emerging area of research refers to the strategic management of different IP in collaborative digital innovation. How do firms navigate through the IP landscape when they jointly develop new applications? Which infrastructure do they need to successfully work together and share the results (e.g., profits, IP) of their work? These and other relevant problems will be challenges I would like to focus my future work on.