

INTEGRATED KNOWLEDGE EXPLOITATION: THE COMPLEMENTARITY OF PRODUCT DEVELOPMENT AND TECHNOLOGY LICENSING

ULRICH LICHTENTHALER^{1*} and HOLGER ERNST²

¹ University of Mannheim, Mannheim, Germany

² WHU – Otto Beisheim School of Management, Vallendar, Germany

In light of increasing licensing, we challenge the common assumption that product development and technology licensing are substitutes. We develop a resource-based framework, which distinguishes a firm's technological resource base and technology exploitation processes. We further combine survey, patent, and financial data of 228 medium-sized and large industrial companies to examine the interactions of firms' product development processes and technology licensing processes in order to explain heterogeneity in new product revenues, licensing performance, and firm performance. The results underscore that product development, which indicates innovative capacity, and technology licensing, which indicates desorptive capacity, are complements rather than substitutes in integrated knowledge exploitation in medium-sized and large firms. This complementarity is particularly pronounced in firms with an emphasis on cross-licensing and with a strong patent portfolio. Copyright © 2012 John Wiley & Sons, Ltd.

INTRODUCTION

In the past, most industrial firms focused on internally exploiting new technologies in their own products (Danneels, 2008). In recent years, firms have increasingly exploited their technologies externally (Gambardella, Giuri, and Luzzi, 2007). Internal technology exploitation refers to product development processes, which indicate innovative capacity. External technology exploitation relates to outward technology transfer, which indicates desorptive capacity and includes licensing technology either exclusively or in addition to its internal application (Lichtenthaler and Lichtenthaler, 2009). Several pioneering firms, for example, IBM, generate hundreds of millions of dollars in annual licensing revenues (Chesbrough, 2007).

In addition, licensing and cross-licensing may positively affect firms' product business (Arora, Fosfuri, and Gambardella, 2001).

The recent trend toward active licensing challenges the traditional view of licensing's role in technology exploitation, which is often based on transaction cost arguments at the level of single licensing transactions (Anand and Khanna, 2000; Arora *et al.*, 2001). Innovation and strategy research usually focused on licensing as an entry mode into product markets for which a firm has limited complementary assets (Arora and Ceccagnoli, 2006). International management research primarily regarded licensing as an alternative to foreign direct investment (Jiang, Aulakh, and Yigang, 2009). However, many of the pioneering firms in active licensing have complementary assets in multiple fields, and they are usually active in many international markets (Chesbrough, 2003). These firms establish licensing processes in addition to their internal innovation processes to simultaneously develop products and license technology (Davis and Harrison, 2001).

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*Correspondence to: Ulrich Lichtenthaler, Chair of Management and Organization, University of Mannheim, Schloss, D-68131 Mannheim, Germany. E-mail: lichtenthaler@uni-mannheim.de

These activities point to critical drivers of licensing beyond the traditional focus on market entry in firms with limited product development. A recent study supports this view by showing that important drivers of licensing do not require 'either-or' decisions (Lichtenthaler, 2008).

Prior licensing research has focused on firms' licensing revenues and number of licensing deals without directly examining licensing processes and their interactions with other activities. In particular, recent studies have concentrated on environmental licensing determinants, for example, the number of technology suppliers (Fosfuri, 2006). Our understanding of internal determinants is limited (Fosfuri and Giarratana, 2010), but prior conceptual research points to potential synergies of product development and licensing (Teece, 2006). Several arguments, therefore, motivate us to challenge the transaction-cost-based assumption of project-level studies, which suggests that product development and licensing are substitutes (Contractor, 1981). This paper focuses on the following critical question: are a firm's product development processes and technology licensing processes complements rather than substitutes in knowledge exploitation? Drawing on a resource-based perspective, we develop a conceptual framework and examine interactions of a firm's product development and licensing processes to explain interfirm heterogeneity in new product revenues, licensing performance, and firm performance. These interactions have been relatively neglected, and the need for further research is underscored by many firms' managerial difficulties in profiting from technology (Arora and Gambardella, 2010; Chesbrough, 2003).

This paper offers several contributions. First, it contributes to technology exploitation research by distinguishing product development and licensing as the internal and external processes of exploiting a firm's resource base. Specifically, we examine the complementarity of product development and licensing in leveraging technological competences to enhance new product revenues, licensing performance, and firm performance. This complementarity can hardly be explained by prior efficiency-based analyses of minimizing costs, for example, transaction costs. Second, we model the interactions of internal and external exploitation processes in the context of a firm's technological resource base, which may play an important role because it affects a firm's exploitation potential (Dierickx

and Cool, 1989). Third, we use data from a sample of industrial firms to study the performance effects of these interactions. We focus on sectors in which patents play a critical role, that is, automotive/machinery, chemicals/pharmaceuticals, and electronics/semiconductors (Cohen, Nelson, and Walsh, 2000). As such, this paper is among the first quantitative studies into the determinants of corporate licensing success, and shows that technology licensing is not an isolated activity. Moreover, the potential synergies of product development and licensing may deepen our understanding of interfirm heterogeneity in profiting from innovation (Teece, 2006).

CONCEPTUAL FRAMEWORK

Technological resource base

The distinction of technology exploration and exploitation is widely acknowledged (Gupta, Smith, and Shalley, 2006). In technology exploration, firms identify and generate new technological knowledge (March, 1991). Consistent with internal and external technology exploitation, technology exploration can be organized inside or outside the organization. Firms have to decide whether new technologies are generated internally or acquired from external sources (Cassiman and Veugelers, 2006). The new knowledge that was either developed internally or acquired from external sources is integrated in a firm's technological resource base, which constitutes the basis for subsequent technology exploitation. The technological resource base determines a firm's technology exploitation potential, that is, the volume of technological knowledge that may be exploited (Dierickx and Cool, 1989).

Specifically, the size and quality of the technological resource base affect a firm's exploitation potential (Arora *et al.*, 2001). The resource base of many industrial firms comprises technologies from different fields because the trend toward technology fusion often requires that many distinct technological components are built in a new product (Kogut and Zander, 1992). Most of these firms have substantial technological knowledge outside their core areas, and this knowledge constitutes an important basis for internal and external technology exploitation. The strength of the technological resource base only determines the exploitation potential, which has to

be achieved through product development and technology licensing processes (Danneels, 2007; Helfat, 1997).

Technology exploitation processes

Most industrial firms usually focused on internal technology exploitation (Danneels, 2002). These firms have established product development processes to match inventions with the context of their final markets (Helfat and Eisenhardt, 2004; Smith, Collins, and Clark, 2005). Related to this process-based understanding, prior research into internal technology exploitation processes has distinguished opportunity identification and subsequent product commercialization (Gruber, MacMillan, and Thompson, 2008). As new technologies often do not lead to obvious opportunities, the identification of exploitation opportunities depends on a firm's understanding of applications and markets (Danneels, 2007; Shane, 2001). A firm may lack the ability to exploit a large technological resource base, but it may also generate many innovations from a relatively limited resource base by identifying multiple applications. We refer to the *identification* of innovation opportunities and to the *commercialization* of new products as two critical stages of the product development process.

Besides exploiting technology in a firm's own products, the growing technology markets facilitate licensing. In contrast to product development, licensing includes the transfer of technological knowledge across a firm's boundaries (Silverman, 1999). '[L]icensing is an option not mutually exclusive with self production' (Arora *et al.*, 2001: 229). Because of the limited transparency of technology markets, licensing is more complex than the commercialization of most products (Silverman, 1999). To overcome the managerial challenges, firms need to establish specific processes for licensing and cross-licensing (Davis and Harrison, 2001). Consistent with product development, prior research has distinguished the identification of licensing opportunities and subsequent technology transfer (Lichtenthaler, 2008; Rivette and Kline, 2000). Opportunity identification is a major challenge, and it is particularly difficult in fields that are unrelated to a firm's own product business (Fosfuri, 2006; Kogut and Zander, 1992).

Many firms do not achieve their licensing potential because of limited market knowledge (Danneels, 2007; Davis and Harrison, 2001). Sufficient

market knowledge contributes to matching a firm's technologies and potential markets inside and outside its own industry. While many firms have difficulties with discovering opportunities, some others successfully identify licensees based on relevant market knowledge (Lichtenthaler, 2008). 'To extract value from licensing their technology to third parties, they need to understand customer needs to target applications, identify, assess, and select licensees' (Danneels, 2007: 531). After recognizing licensing opportunities, a firm transfers the knowledge to the licensee. We refer to the *identification* of licensing opportunities and to the subsequent *commercialization* by transferring knowledge as two critical stages of technology licensing.

Interdependencies of product development and technology licensing

Beyond generating royalties, firms license or cross-license technology to achieve important nonmonetary benefits, which help them improve their competitive position (Chesbrough, 2003). Securing these nonmonetary benefits is often more important than generating royalties (Lichtenthaler, 2008). With regard to the benefits from licensing, firms may enter new product markets because they may sell products that are complementary to the licensed technologies (Rivette and Kline, 2000). In these cases, licensing is primarily directed at strengthening a firm's product business. It is not a substitute for product sales, but it constitutes an enabler of new product market opportunities. These additional product sales may also derive from enhanced demand because the licensee provides a second source of supply (Davis and Harrison, 2001). Moreover, firms may license a technology to a weak rival to deter product market entry by stronger competitors. In other cases, a firm may license to strengthen its product business by finding external adopters of its technologies in order to establish an industry standard.

With regard to cross-licensing, firms may benefit from ensuring their freedom to operate (Grindley and Teece, 1997). These activities refer to a specific type of cross-licensing agreement, one in which patents are used as bargaining chips, usually without any transfer of technology. Here, the main driver of technology licensing is avoiding potential

patent infringement lawsuits, which would prevent a firm from further developing its technologies and commercializing its products. Moreover, cross-licensing may allow a firm to access external knowledge (Rivette and Kline, 2000), which is often critical for the development of new products (Cassiman and Veugelers, 2006). Cross-licensing may be primarily directed at acquiring external technology for product development. The data from our initial interviews reflect the importance of cross-licensing, and they underscore the interdependencies of product development and technology licensing. Table 1 presents some illustrative statements from the interviews.

Besides the positive 'revenue effect,' licensing may have a negative 'profit dissipation effect' grounded in a weaker competitive position in a firm's product markets, which may result from transferring competitively relevant technology (Fosfuri, 2006). Owing to these potential negative effects, many industrial firms are relatively reluctant to transfer technology because they fear selling corporate crown jewels (Rivette and Kline, 2000). Based on the potential benefits and risks of licensing, there may be positive or negative synergies between internal and external technology

exploitation. First, firms may internally and externally exploit different technologies. For instance, firms may develop a new product based on one particular technology, and they may license a different technology to enable other firms to develop complementary products. In these cases, a firm's new product business may be strengthened by internally applying one technology while licensing another one. This is a common strategic move of many electronics and software firms, such as Apple. Second, firms may simultaneously apply and license the same technology. An example is the recent cross-licensing deal of Microsoft and Panasonic, which was established in 2010 and binds each firm to transfer some of its technology to the other firm.

The positive and negative synergies may be particularly pronounced if a firm licenses to the same markets that it addresses with its own products. An example for the positive synergies of licensing and product development is licensing to other firms in order to establish an industry standard. Here, a classic example is Nintendo's success in establishing its technology standard in the video game market based on an active licensing strategy. At the same time, the negative synergies, which derive from building up competitors by transferring proprietary technology, may be

Table 1. Illustrative statements from the interviews

Topic	Illustrative statements from the interviews
Interdependencies of product development and licensing (Conceptual background)	<ul style="list-style-type: none"> - "Licensing is not always an either-or decision. . . it often goes along with product innovation" (R&D manager, chemical firm). - "Basically, we have no choice. . . we have to cross-license technology to keep our competitive position in the product markets" (Innovation manager, electronics firm).
Impact on new product revenues (Hypothesis 1)	<ul style="list-style-type: none"> - "Without cross-licensing many of our technologies, we could not successfully develop our products because our operating freedom would be strictly limited" (Head of R&D, semiconductors firm). - "The implementation of our licensing and cross-licensing agreements is critical for new product performance. . . and we often face problems that arise in transferring technology" (Head of R&D, electronics firm).
Impact on licensing revenues (Hypothesis 2)	<ul style="list-style-type: none"> - "Technology licensing is not a stand-alone activity. . . we strongly profit from related product development expertise" (Marketing manager, machinery firm). - "Without internally developing a product prototype, we would not have been able to license this technology" (Business development manager, automotive firm).
Impact on return on sales (Hypothesis 3)	<ul style="list-style-type: none"> - "Our licensing revenues cover more than the costs of the licensing activities. . . the indirect benefits on product innovation may be even larger, but they are difficult to calculate" (R&D manager, chemical firm). - "One of our competitors achieves higher profits by closely coordinating product development and licensing" (Innovation manager, electronics firm).

stronger in a firm's own markets than in unrelated markets. For instance, the Japanese chemical firm Nippon Shokubai initially licensed its propylene oxidation technology to other firms, but now it is much more reluctant to do so in light of a higher maturity of its own product market (Fosfuri, 2006).

Most prior research has examined the decision to either internally or externally exploit a specific technology based on transaction costs (Gambardella *et al.*, 2007). However, transaction cost analyses usually do not capture the interdependencies of product development and licensing, which require a firm-level perspective (Lichtenhaler, 2008). For example, a project-level analysis may identify high transaction costs, which suggest that licensing a particular technology does not pay off. In contrast, a firm-level view may show that the benefits from the interactions of licensing and product development compensate for the high transaction costs and that the decision to license is beneficial. The relation of product development and licensing goes beyond transaction costs and market entry due to limited complementary assets or limited foreign direct investment (Fosfuri, 2006). In particular, the recent increase in licensing may be driven by the growing importance of some other determinants, such as gaining access to external technology (Fosfuri, 2006; Motohashi, 2008). To achieve these benefits, firms need to simultaneously rely on their product development and licensing processes.

HYPOTHESES DEVELOPMENT

A firm's product development and licensing processes are not mutually exclusive, and they have different functions in capturing value from technology. As licensing processes require only limited resources relative to product development, high levels of product development and licensing may coexist. Beyond coexistence, these processes are expected to be complementary because their performance effects may depend on one another (Davis and Harrison, 2001). Complementarity logic can be traced back to the theory of supermodularity (Milgrom and Roberts, 1990; Topkis, 1998), which helps explain the superadditive value of resource configurations (Leiponen, 2005a; Milgrom, Qian, and Roberts, 1991; Tansriverdi and Venkatraman, 2005). A set of variables are considered complementary when more of any

one of them increases the returns to the others (Milgrom and Roberts, 1995; Topkis, 1978).

Following Cassiman and Veugelers (2006), suppose that there are two processes, X_1 and X_2 , which could refer to product development and licensing. Each process can be performed by the firm ($X_i = 1$) or not ($X_i = 0$) and $i \in (1, 2)$. The function $\Pi(X_1, X_2)$ is supermodular, and X_1 and X_2 are complements only if $\Pi(1, 1) - \Pi(0, 1) \geq \Pi(1, 0) - \Pi(0, 0)$. A supermodular function and complementary processes require that adding one process while the other process is already being performed has a higher incremental effect on performance (Π) than adding the process in isolation. Complementary variables tend to be positively correlated, and they positively interact in their performance effects (Bresnahan, Brynjolfsson, and Hitt, 2002; Mohnen and Röller, 2005). The marginal utility of strengthening one of the technology exploitation processes is relatively limited if a firm lacks a sufficient level of the other process. In contrast, a balanced development of the product development and technology licensing processes can be regarded as an indication that a firm recognizes complementarities and attempts to maximize its performance.

Tests for complementarity can draw on different approaches (Arora, 1996; Athey and Stern, 1998), which were applied in empirical studies (e.g., Cassiman and Veugelers, 2006; Leiponen, 2005b; Mohnen and Röller, 2005). Prior work has suggested two-way interactions to study complementarity in settings that are comparable to our analysis of exploitation processes (Snell and Dean, 1992; Whittington *et al.*, 1999; Wiklund and Shepherd, 2005). In the following, we discuss the interactions of product development and licensing in their effects on new product revenues, licensing performance, and firm performance. The trend toward active licensing seems to be particularly powerful in firms that have an emphasis on cross-licensing and a strong technological resource base (Chesbrough, 2003; Danneels, 2007). It may, therefore, be assumed that the complementarity of product development and licensing is stronger in firms with a superior technological resource base and an emphasis on cross-licensing (Figure 1).

New product revenues

A firm's new product revenues capture the success in internally exploiting technology. New technologies constitute an important basis for breakthrough

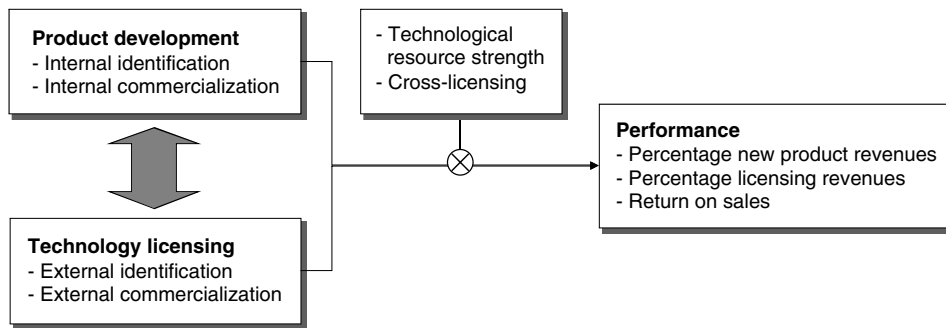


Figure 1. Conceptual framework

innovations. With insufficient product development, however, the value of a superior technology portfolio will be limited (March, 1991). A firm needs to establish product development processes, which are an essential driver of revenues from new products because they transform inventions to innovations in the product markets (Ernst, 2001). In addition to a firm's internal innovation processes, licensing and cross-licensing are a requirement rather than an option for many firms (Chesbrough, 2007), and these licensing processes may strengthen the positive effects of product development.

Specifically, both process stages of licensing may enhance the positive impact of product development. The identification of licensing opportunities is the first stage of licensing processes, and proficiency in this stage may improve a firm's understanding of distinct markets. This market knowledge allows a firm to identify opportunities for developing new products. A proficient identification of licensing opportunities may, therefore, strengthen the effect of product development processes on new product revenues. The second stage of licensing processes refers to transferring technology and is essential for a successful implementation of licensing agreements. For instance, it is critical in licensing to establish industry standards and in cross-licensing to gain access to external knowledge (Grindley and Teece, 1997; Leiponen, 2008). These arguments suggest that both stages of licensing, that is, identification and commercialization, strengthen the positive impact of product development.

Technology licensing is not an independent knowledge exploitation channel. Instead, it may interact with product development in influencing a firm's revenues from new products. The licensing processes are further critical to limit

potential negative effects by proficiently selecting licensees. In addition, licensing may help firms strengthen their interorganizational networks and achieve learning effects from the licensees' technology application, which may further enhance the positive effects of product development (Lichtenthaler, 2008). Licensing may be an important complement to product development in reaping the benefits from the technology portfolio through innovation (Danneels, 2007). Strong product development will have positive effects on a firm's new product revenues (Jansen, Van den Bosch, and Volberda, 2006). This positive effect is expected to be stronger if the level of licensing is high. These arguments point to positive synergies of product development and licensing. The benefits from developing either the product development or licensing processes will be limited, whereas their balanced development will have major positive effects on a firm's new product revenues. Hence, we expect a positive interaction and posit:

Hypothesis 1: The interaction of product development and technology licensing processes is positively related to a firm's revenues from new products.

Licensing performance

Licensing performance captures a firm's success in externally exploiting technology. A firm's technological resource base is necessary but not sufficient for successful licensing. Because of a limited understanding of potential applications, most firms do not achieve their initial licensing objectives (Danneels, 2007; Lichtenthaler, 2008). The mere act of marketing technological knowledge further involves the risk of disclosing its relevant characteristics to potential licensees (Arora *et al.*,

2001). Firms need to convince potential licensees of the value of their technologies up front. The subsequent technology transfer to the licensee poses further challenges. As cross-licensing usually involves partners from related industries, these challenges may not be as strong, but the identification and implementation of cross-licensing deals also entails major difficulties (Nagaoka and Kwon, 2006). Firms, therefore, need systematic licensing processes, whose positive effects may be enhanced by strong product development.

Both process stages of product development may strengthen the positive impact of licensing. First, the identification of product innovation opportunities may reinforce the effects of licensing processes by enhancing a firm's market knowledge, which helps overcome the most critical challenge in licensing, that is, the identification of licensees (Lichtenthaler, 2008). Moreover, firms need a sufficient understanding of the relevant product markets to support the licensee during the technology transfer (Arora *et al.*, 2001). A major means to develop this market knowledge is the identification of product opportunities in a variety of markets (Kogut and Zander, 1992). Firms may profit from sharing knowledge in the identification of product development and licensing opportunities because proficiency in opportunity identification is the basis for the first stage of both knowledge exploitation processes. Second, the commercialization stage of product development may further strengthen the positive effects of licensing. The successful application of a technology in a firm's own products is a strong indicator of the technology's value (Arora *et al.*, 2001). For instance, licensees often require the proof of concept, for instance, by means of a prototype (Jensen and Thursby, 2001). The proof of concept requires commercialization activity and strengthens the licensor's bargaining power (Sakakibara, 2010). These arguments suggest that both product development stages, that is, identification and commercialization, enhance the positive effects of licensing.

These interdependencies underscore the complementarity of product development and licensing. An isolated licensing process may be insufficient for successfully licensing or cross-licensing technology (Lichtenthaler, 2008). Instead, firms may benefit from aligning product development and licensing (Kotabe, Sahay, and Aulakh, 1996). Firms may consider licensing and cross-licensing early in the product development processes to

improve their licensing performance by identifying additional licensing opportunities. Some pioneering firms in active licensing, for example, Hewlett-Packard, IBM, and Texas Instruments, have strongly enhanced their licensing success by closely aligning their product development and licensing processes (Chesbrough, 2007; Grindley and Teece, 1997). This alignment illustrates the positive synergies that firms may achieve from integrated knowledge exploitation processes. The two processes are expected to have complementary effects on licensing performance, whereas a strong emphasis on one of the two will have limited effects. These arguments suggest a positive interaction, and we postulate:

Hypothesis 2: The interaction of product development and technology licensing processes is positively related to a firm's licensing performance.

Firm performance

The interaction of product development and licensing processes may be positively related to firm performance. Establishing high levels of the technology exploitation processes involves considerable costs (Ernst, 2001; Helfat *et al.*, 2007). A balanced development of the two processes helps a firm compensate for these additional costs because it offers two major benefits that go beyond the benefits from a single process. The first is the unique value of complementary processes (Tanriverdi and Venkatraman, 2005). The positive synergies from internally and externally exploiting a firm's resource base result in benefits that exceed the benefits from either product development or licensing. These positive effects result from interdependencies of product development with both licensing and cross-licensing. Proficient licensing processes may further strengthen the benefits from product development. In turn, product development may help firms profit from licensing and cross-licensing (Kotabe *et al.*, 1996).

The second benefit refers to competitors' challenges in detecting and imitating the complementarity of product development and licensing. The complementarity of these two processes is less evident than a single performance determinant (Song *et al.*, 2005). If two processes are complementary, the imitation of a single process may not pay

off. Competitors will have to imitate the combination of a firm's product development and licensing processes in order to achieve substantial benefits. These arguments further underscore the complementarity of product development and licensing in explaining firm performance. Because of interdependencies, an exclusive focus on one process may be insufficient. The two processes are expected to interact in their effects on firm performance, and we posit:

Hypothesis 3: The interaction of product development and technology licensing processes is positively related to a firm's overall performance.

METHODS

Sample and data collection

The empirical study examined medium-sized and large industrial firms with internal research and development (R&D). After a literature review and five preliminary unstructured interviews, we conducted semi-structured interviews with 45 R&D, innovation, marketing, and business development experts in 30 firms from the automotive/machinery, chemical/pharmaceutical, and semiconductors/electronics industries. We relied on the interviews to analyze whether the process stages of identification and commercialization reflect the critical tasks of product development and licensing. The interviews further helped us ensure that industry experts could distinguish these process stages. Finally, the interviews helped to understand measurement opportunities. Consistent with the assumed interaction of product development and licensing, many interviewees underscored the importance of the process stages and their interdependencies.

We therefore relied on our initial conceptual framework and conducted a survey of the 300 largest firms based on revenues in each of the following three German sectors: automotive/machinery, chemicals/pharmaceuticals, and semiconductors/electronics. Other data from a subset of the firms of this survey were used in an earlier article (Lichtenthaler, 2009). That article focused on different variables, and it has not complemented the survey data with additional patent and other data. Drawing on our interviews, we identified the head of R&D as the informant for the technology exploitation processes in the 900 firms. After

we contacted the potential informants by phone, they received an e-mail with a personal letter and an English questionnaire, which included an introductory text with definitions of critical concepts. Detailed pretests further showed that the language did not prevent a clear understanding. In addition, several informant competency measures indicated high levels of expertise.

After sending reminder e-mails and conducting follow-up phone calls, we achieved a response rate of 27.3 percent, that is, 246 persons. T-tests did not show any significant differences of responding/nonresponding and early/late responding firms for several variables. For 228 of the 246 firms, the patent data analyses, which are described below, yielded meaningful results. These 228 firms constitute the final sample. Despite our assurances of complete confidentiality, 18 firms did not disclose their licensing revenues. Moreover, we were not able to collect objective performance data for 40 companies. The sample is therefore reduced to 210 firms in the analyses of licensing revenues and to 188 firms in the analyses of firm performance. Additional examinations that only include the firms with complete data for all performance variables show no significant changes concerning hypotheses testing.

We used existing objective measures for the dependent variables and built on prior related work to capture the independent variables on scales from 'I strongly disagree' (1) to 'I strongly agree' (7). To ensure validity and reliability, we first conducted exploratory factor analyses to see whether the data support the variables' distinction. These analyses resulted in a four-factor solution (Table 2). The performance variables did not sufficiently load on any factor. After studying the loadings and the explained variance, we carried out reliability and confirmatory factor analyses. The results support all scales. The items have significant factor loadings, and the scales have an average variance extracted ranging between 0.75 and 0.93. The greatest common variance between the estimated factors is 0.57, and the larger values of the average variance extracted indicate discriminant validity (Fornell and Larcker, 1981). We then carried out further reliability and exploratory factor analyses, applying the Kaiser criterion. In sum, the data support our understanding that the process stages of product development and licensing are not only theoretically but also empirically distinguishable.

Table 2. Results of exploratory factor analysis

Items	Mean	S.D.	Internal identification	Internal commercialization	External identification	External commercialization
We are proficient in transforming technological knowledge into new products.	4.92	1.26	0.83	0.17	0.05	0.01
We regularly match new technologies with ideas for new products.	4.70	1.38	0.87	0.19	0.07	−0.02
We quickly recognize the usefulness of new technological knowledge for existing knowledge.	4.86	1.19	0.82	0.24	0.06	0.07
Our employees are capable of sharing their expertise to develop new products.	5.02	1.20	0.71	0.32	−0.07	0.13
We regularly apply technologies in new products.	4.76	1.36	0.38	0.60	0.07	0.08
We constantly consider how to better exploit technologies.	5.11	1.27	0.29	0.81	0.12	0.11
We easily implement technologies in new products.	4.56	1.30	0.39	0.65	0.10	0.11
It is well known who can best exploit new technologies inside our firm.	4.93	1.29	0.20	0.84	0.06	0.02
We regularly check our technology portfolio for external commercialization opportunities, e.g., out-licensing.	3.25	1.81	0.06	0.10	0.88	0.06
We frequently scan the environment for external technology commercialization opportunities, e.g., out-licensing.	3.16	1.81	0.06	0.11	0.88	0.25
We thoroughly observe opportunities to externally commercialize technology assets.	3.28	1.73	0.10	0.06	0.89	0.25
For valuable technologies, additional resources are employed to identify external commercialization opportunities.	2.99	1.72	0.09	0.15	0.81	0.09
We do not actively try to identify external technology commercialization opportunities (reverse coded).	3.63	1.98	−0.04	−0.02	0.63	−0.04
We often transfer technological knowledge in response to out-licensing opportunities.	2.73	1.55	−0.02	0.00	0.38	0.61
The transfer of technologies to the other firm is usually organized well.	3.47	1.57	0.06	0.08	0.26	0.90
The tasks of the different persons involved in outward technology transfer are coordinated well.	3.53	1.54	0.09	0.08	0.21	0.92
We provide sufficient support for an adequate transfer of technologies to the partner, e.g., licensee.	3.53	1.60	0.05	0.09	0.36	0.84

Descriptive statistics and results of common factor analysis with varimax rotation and Kaiser normalization.

Technology exploitation processes

To measure product development and licensing, we built on conceptual discussions and existing scales in related fields and considered the multidimensional nature of these processes. Following earlier product development and licensing research (Brown and Eisenhardt, 1995; Lichtenthaler, 2008), the scales measure the quality of executing the tasks in the process stages, that is, identification and commercialization. The measures capture to what degree a firm has set up high quality processes for the major tasks. The measures focus on a firm's competence level in the different process stages, and this focus ensured the inter-firm comparability of the results and facilitated the understanding of the items.

The four-item scale *internal identification* (Cronbach's $\alpha = 0.87$) captures a firm's proficiency in discovering internal exploitation opportunities. It refers to the combination of new and existing knowledge, and it addresses the matching of technologies with new product ideas. The items were taken from existing measures for internal technology exploitation (Jansen *et al.*, 2006; Lichtenthaler, 2009; Smith *et al.*, 2005). The four-item scale *internal commercialization* (Cronbach's $\alpha = 0.85$) addresses whether firms easily implement technologies and whether they constantly consider how to better exploit technologies. The scale further captures a firm's competence level in implementing product adaptations. The items were adopted from related scales (Jansen *et al.*, 2006; Lichtenthaler, 2009; Smith *et al.*, 2005).

The five-item scale *external identification* (Cronbach's $\alpha = 0.89$) captures a firm's proficiency in conducting the activities of identifying external exploitation opportunities, for example, scanning the environment for licensing opportunities. It further measures to what degree firms employ specific resources to identify these opportunities. This scale builds on existing items and conceptual discussions in the literature (Fosfuri, 2006; Gambardella *et al.*, 2007; Lichtenthaler, 2008). The four-item scale *external commercialization* (Cronbach's $\alpha = 0.90$) captures whether firms often transfer technologies and whether the transfer activities are well organized. In addition, it measures to what degree a firm supports the technology transfer to the recipient. The scale partly draws on existing items and

conceptual arguments in the literature (Arora *et al.*, 2001; Chesbrough, 2007; Lichtenthaler, 2008).

To test for product development and licensing as second-order factors, we compared alternative models. In the first model, the items form four correlated first-order factors. The second model has these four factors form two correlated second-order factors, which represent product development and licensing. The target coefficient (Tanriverdi and Venkatraman, 2005), the significant second-order factor loadings, and the positive correlations of the first-order factors (Table 3) provide strong support for the two exploitation processes as second-order factors. Additional models provide a worse fit. In particular, the correlation of the second-order factors significantly differs from zero, and this result is a first indication of complementarity. The correlations below the cut-off value of 0.90 underscore the distinctiveness of the two processes (Tanriverdi and Venkatraman, 2005). To further examine construct validity, we compared the scores of the four first-order factors with separate measures for the two exploitation processes (Rindskopf and Rose, 1988). The correlations between the first-order factors and the additional measures of the higher-order constructs are positive and significant at $p < 0.001$.

Performance

To limit common method bias, we used objective measures for the dependent variables. To capture new product revenues, we examined the *share of revenues from new products*. In the survey, we asked for the percentage of revenues from new products introduced during the previous three years relative to all revenues. The informants indicated this number in the following seven categories: zero-five percent, five-10 percent, 10–20 percent, 20–30 percent, 30–40 percent, 40–50 percent, and over 50 percent.

To measure licensing performance, we captured a firm's technology *licensing revenues* (Gambardella *et al.*, 2007; Lichtenthaler, 2008). As this number is highly confidential in most firms, it was measured in the following seven categories: EUR 0 million, EUR 0–1 million, EUR 1–3 million, EUR 3–10 million, EUR 10–30 million, EUR 30–100 million, and over EUR 100 million. Despite our assurances of confidentiality, 18 firms did not report their licensing revenues, and the sample is reduced to 210 firms in the analyses of

Table 3. Descriptive statistics and correlations

Variables	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Percentage new product revenues (1)	3.96	1.21																		
Percentage licensing revenues (2)	1.51	5.93	0.14 [†]																	
Return on sales (3)	7.12	4.84	0.21 ^{**}	0.01																
Firm size (4)	6.35	1.96	0.09	-0.20 ^{**}	0.22 ^{**}															
R & D intensity (5)	6.43	5.31	0.15 [†]	0.05	0.25 ^{**}	0.15 [†]														
Technology exploration (6)	4.69	1.31	0.40 ^{***}	-0.08	0.20 ^{**}	0.44 ^{***}	0.35 ^{***}													
Chemicals/pharmaceuticals (7)	0.33	0.47	-0.00	-0.06	0.06	-0.04	0.06	-0.06												
Electronics/semiconductors (8)	0.27	0.44	0.03	0.10	0.07	0.13	0.20 [*]	-0.01	-0.41 ^{***}											
Importance cross-licensing (9)	3.17	1.57	-0.02	0.08	0.06	-0.06	0.11	0.03	-0.07	0.16 [*]										
Technological diversification (10)	4.35	1.55	0.14 [†]	-0.03	0.03	0.35 ^{***}	-0.02	0.26 ^{**}	0.06	-0.11	0.02									
Product diversification (11)	4.70	1.58	0.12	0.09	0.10	0.21 ^{**}	0.08	0.11	0.01	0.03	0.04	0.55 ^{***}								
International diversification (12)	5.41	1.53	0.21 ^{**}	-0.00	0.20 [*]	0.42 ^{***}	0.12	0.31 ^{***}	-0.07	0.03	0.10	0.59 ^{***}	0.52 ^{***}							
Patent portfolio strength (13)	3.54	2.18	0.14 [*]	-0.01	0.27 ^{***}	0.56 ^{***}	0.20 [*]	0.25 ^{***}	-0.01	0.10	0.03	0.28 ^{***}	0.22 ^{**}	0.36 ^{***}						
Internal identification (14)	4.87	1.07	0.53 ^{***}	-0.01	0.12 [†]	0.15 [*]	0.08	0.52 ^{***}	0.08	-0.12	-0.13	0.13 [†]	0.00	0.18 [*]	0.04					
Internal commercialization (15)	4.84	1.08	0.53 ^{***}	0.02	0.20 ^{**}	0.25 ^{***}	0.18 [*]	0.58 ^{***}	0.06	0.01	-0.11	0.16 [*]	0.00	0.27 ^{***}	0.10	0.66 ^{***}				
External identification (16)	3.26	1.53	0.17 ^{**}	0.19	0.20 ^{**}	0.26 ^{***}	0.23 [*]	0.26 ^{***}	0.05	0.07	-0.06	0.06	0.11	0.11	0.20 ^{**}	0.13 [*]	0.22 ^{***}			
External commercialization (17)	3.32	1.36	0.06	0.15	0.11 [†]	0.34 ^{***}	0.16 [†]	0.31 ^{***}	0.03	0.01	-0.10	0.19 [*]	0.13 [†]	0.20 ^{**}	0.19 ^{**}	0.13 [*]	0.22 ^{***}	0.61 ^{***}		
Product development (18)	4.86	0.98	0.59 ^{***}	0.01	0.18 ^{**}	0.22 ^{**}	0.14	0.61 ^{***}	0.08	-0.06	-0.13	0.16 [*]	0.00	0.25 ^{**}	0.08	0.89 ^{***}	0.90 ^{***}	0.19 ^{**}	0.88 ^{***}	
Technology licensing (19)	3.29	1.30	0.13 [*]	0.16	0.18 ^{**}	0.33 ^{***}	0.22 [*]	0.32 ^{***}	0.04	0.05	-0.09	0.13 [†]	0.14 [†]	0.17 [*]	0.22 ^{**}	0.14 [*]	0.25 ^{***}	0.90 ^{***}	0.88 ^{***}	0.22 ^{**}

Pearson correlations; [†] $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

this variable. To consider the role of firm size in licensing, we calculated the dependent variable as the percentage of licensing revenues relative to a firm's overall annual revenues. To calculate these percentages, we used the means of the categories for the first six categories. The seventh category (over EUR 100 million) was set to EUR 250 million. Sensitivity analyses with other values led to consistent findings. We further cross-validated this measure with the percentage of licensing revenues relative to a firm's R&D expenditures. These additional analyses led to consistent results, which can be explained by the strong and positive correlation of firm size and R&D expenditures.

To capture firm performance for the year of the survey and for the subsequent year, we collected *return on sales* (ROS) data from financial databases and annual reports. These procedures yielded data for 197 firms in the year of the survey and for 188 firms in the subsequent year, that is, with a one-year lag. To give stability to this variable, we used the mean of ROS in these two years. Additional analyses with data from one of the years led to consistent results that can be explained by the strong and positive correlation of the measures from the two years. Moreover, we conducted further analyses with ROS data with a two-year lag that was available from databases and annual reports for 159 firms. These additional analyses also provided consistent findings with regard to hypotheses testing.

To cross-validate the three objective performance measures, we assessed subjective performance with survey data from a second informant from marketing, business development, or innovation management in 169 of the 228 firms. To cross-validate new product revenues, we used the following three-item scale (Lichtenthaler, 2009): (1) 'The overall performance of our new product development program has met our objectives,' (2) 'From an overall profitability standpoint, our new product development program has been successful,' and (3) 'Compared with our major competitors, our overall new product development program is far more successful.' To cross-validate licensing performance, we used the following three-item scale (Lichtenthaler, 2008): (1) In relation to our direct competitors, we are successful in external technology commercialization activities, (2) Our licensing revenues are considerably higher than the licensing revenues of our direct

competitors' and (3) We externally commercialize technology more successfully for strategic objectives than our direct competitors.

To cross-validate firm performance, we relied on a scale for perceptual performance, which was developed by Reinartz, Krafft, and Hoyer (2004: 304). It comprises four items: 'Relative to your competitors, how does your firm perform concerning the following statements?' 1) 'Achieving overall performance.' 2) 'Attaining market share.' 3) 'Attaining growth.' 4) 'Current profitability.' The items for these performance measures were answered by the second informant, and they were also included in the first informant's questionnaire. The values of interrater agreement indicate strong agreement (LeBreton and Senter, 2008). Below, we report the findings for the analyses with the objective dependent variables. Additional analyses with the subjective measures led to consistent results, which provide support for the same hypotheses.

Controls

We controlled for *firm size* with the logarithm of the firms' annual revenues in millions of Euros. In addition, we included a firm's *R&D intensity*. We further controlled for *technology exploration*, which may affect the exploitation potential. Based on prior work (Jansen *et al.*, 2006: 1672; Smith *et al.*, 2005), the survey included a three-item construct (Cronbach's $\alpha = 0.84$): (1) We often invent new technologies, (2) We develop technologies that are completely new, and (3) We accept demands that go beyond existing technologies. In response to our cross-industry approach, we also controlled for a firm's *industry*, which may affect innovation activities (Leiponen and Helfat, 2010). We examined firms from three sectors: automotive/machinery, chemicals/pharmaceuticals, and semiconductors/electronics. For the later two sectors, we included a dummy (1 = pertaining to this industry; 0 = not pertaining to this industry).

We further controlled for the role of *cross-licensing* (Grindley and Teece, 1997) by including the informants' answer to the following statement: the share of cross-licenses in all out-licensing agreements is high. We also included three diversification variables. A high degree of *technological diversification* may drive firms to license noncore technology (Gambardella *et al.*, 2007). Technological diversification (Cronbach's $\alpha = 0.89$)

was measured on a three-item scale: (1) Our technology portfolio comprises technologies in many different technological areas, (2) The important technologies of our business units are very different, and (3) We apply technological knowledge from completely different fields of technology. *Product diversification* determines a firm's complementary assets, which facilitate product development (Teece, 2006). It was measured on a three-item scale (Cronbach's $\alpha = 0.82$): (1) Our product portfolio comprises a large number of different products, (2) The diversity of our product portfolio is high, and (3) We are active in various industrial areas. *International diversification* by means of foreign direct investments may limit licensing to enter foreign markets (Contractor, 1981). It was measured with a three-item scale (Cronbach's $\alpha = 0.88$): (1) We have affiliates in a large number of countries, (2) The international business is very important to our firm, and (3) A large part of our company's sales are generated abroad.

We further controlled for a firm's technological resource base by measuring *patent portfolio strength*. We gained meaningful patent data from the European Patent Office's Worldwide Database for 228 out of 246 firms. We multiplied a firm's number of active patent families by their average relative citations and calculated the logarithm of this figure. The relative citations refer to a patent's number of forward citations in relation to the average forward citations of all patents in the database from the same year (Hall, Jaffe, and Trajtenberg, 2005). Finally, we conducted cross-validation analyses, in which we additionally controlled for a firm's past performance. We included the firms' ROS one year, three years, or five years before the survey. The additional analyses did not significantly change the findings. We did not integrate past performance in the models reported below because ROS in the year before the survey has a very strong and positive correlation with the dependent variable for firm performance, whereas including ROS three or five years before the survey leads to a considerable drop in the number of observations.

RESULTS

The descriptive statistics in Table 3 show relatively strong product development processes in

many firms (mean value of 4.86). The average level of technology licensing is considerably lower (mean value of 3.29). This finding illustrates that active technology licensing is a major managerial challenge. The significant correlations between the product development and technology licensing processes are consistent with complementarity theory (Milgrom and Roberts, 1995).

To examine complementarity, we used interaction analyses, which are further described in the Appendix. The percentage of revenues from new products is the dependent variable in Models 1–9 (Table 4). Model 1 includes only the controls, and Model 2 shows a highly significant and positive effect of product development, whereas technology licensing has a marginally significant effect ($p < 0.1$) on the percentage of revenues from new products. In Model 3, the interaction of product development and licensing has a positive and marginally significant effect at $p < 0.1$. This finding provides some support for Hypothesis 1. Models 10–18 provide the results for the percentage of revenues from licensing (Table 5). We find a significant and positive effect of licensing in Model 11 and a significant and positive interaction effect in Model 12. This result provides support for Hypothesis 2. Licensing performance is primarily determined by a firm's licensing processes and their interaction with product development. The analysis of ROS in Models 19–29 provides similar results (Table 6). We find a significant interaction of product development and licensing in Model 21, and this finding supports Hypothesis 3.

To understand the form of the interactions, simple slope analyses were performed. These analyses show that product development is positively related to firm performance at all levels of licensing, which positively affects the strength of the relationship between product development and firm performance. If licensing increases, the positive effect of product development becomes stronger. Equivalent effects can be observed for the other dependent variables. Technology licensing further strengthens the positive relationship between product development and revenues from new products. Product development further strengthens the positive relationship between technology licensing processes and licensing performance.

To examine whether the first or second process stage of product development and licensing drive the interaction effects, we conducted additional exploratory regression analyses, in which

Table 4. Results of OLS analyses (percentage new product revenues)

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Dependent variable	Percentage new product revenues	Percentage new product revenues	Percentage new product revenues	Percentage new product revenues	Percentage new product revenues	Percentage new product revenues	Percentage new product revenues	Percentage new product revenues	Percentage new product revenues
Firm size	-0.13* (0.07)	-0.11* (0.06)	-0.11* (0.06)	-0.11 (0.10)	-0.01 (0.11)	-0.21** (0.08)	-0.01 (0.10)	-0.10† (0.06)	-0.10† (0.06)
R & D intensity	-0.01 (0.02)	0.01 (0.02)	0.02 (0.02)	0.01 (0.03)	0.03 (0.03)	0.01 (0.03)	0.04 (0.04)	0.00 (0.02)	0.00 (0.02)
Technology exploration	0.41*** (0.10)	0.06 (0.10)	0.05 (0.10)	0.03 (0.14)	0.03 (0.15)	-0.04 (0.16)	0.09 (0.14)	0.07 (0.10)	0.08 (0.10)
Chemicals/pharmaceuticals	0.14 (0.25)	-0.08 (0.22)	-0.06 (0.23)	0.01 (0.29)	0.01 (0.33)	-0.26 (0.32)	-0.00 (0.34)	-0.07 (0.22)	-0.06 (0.22)
Electronics/semiconductors	0.21 (0.27)	0.16 (0.24)	0.17 (0.24)	0.19 (0.32)	0.06 (0.37)	0.08 (0.29)	-0.02 (0.39)	0.14 (0.24)	0.15 (0.24)
Importance cross-licensing	-0.00 (0.07)	-0.02 (0.07)	-0.02 (0.07)	-0.03 (0.09)	-0.01 (0.12)	-0.00 (0.14)	0.09 (0.20)	-0.00 (0.07)	-0.00 (0.07)
Technological diversification	-0.01 (0.09)	0.00 (0.08)	0.01 (0.08)	0.10 (0.11)	-0.17† (0.13)	-0.03 (0.10)	-0.08 (0.13)	0.01 (0.08)	0.02 (0.08)
Product diversification	0.03 (0.08)	0.09 (0.07)	0.09 (0.07)	0.02 (0.10)	0.14 (0.11)	0.10 (0.10)	0.12 (0.12)	0.08 (0.07)	0.08 (0.07)
International diversification	0.09 (0.09)	0.00 (0.08)	0.00 (0.08)	0.01 (0.12)	0.02 (0.12)	0.03 (0.10)	0.03 (0.12)	0.01 (0.08)	0.01 (0.08)
Patent portfolio strength	0.14* (0.06)	0.08† (0.05)	0.08 (0.05)	0.13 (0.12)	0.09 (0.09)	0.09† (0.07)	0.06 (0.08)	0.08† (0.05)	0.08† (0.05)
Product development		0.63*** (0.12)	0.58*** (0.11)	0.64*** (0.14)	0.59** (0.19)	0.66*** (0.17)	0.52** (0.19)	0.57*** (0.12)	0.56*** (0.12)
Technology licensing		0.12† (0.11)	-0.04 (0.11)	0.08 (0.15)	0.05 (0.18)	0.05 (0.16)	0.05 (0.17)		
Prod. dev. X Tech. lic.			0.19† (0.10)	0.26* (0.17)	-0.08 (0.16)	0.28* (0.26)	0.18† (0.14)		
External identification								0.15 (0.12)	0.14 (0.12)
External commercialization								-0.17 (0.12)	-0.17 (0.12)
Prod. dev. X Ext. ident.									
Prod. dev. X Ext. comm.								0.28* (0.11)	0.03 (0.14)
R ²	0.19	0.38	0.40	0.45	0.34	0.46	0.38	0.40	0.39
R ² adjusted	0.12	0.41	0.33	0.33	0.15	0.36	0.20	0.32	0.31
F	2.69**	5.80***	5.33***	3.76***	1.78†	4.43***	2.13*	5.16***	5.07***
Number of observations	228	228	228	114	114	101	100	228	228
Median split patent portf.	All	All	All	High	Low	All	All	All	All
str.									
Median split cross-licensing	All	All	All	All	All	High	Low	All	All

† p < 0.1; * p < 0.05; ** p < 0.01; *** p < 0.001; † variables mean centered; unstandardized coefficients with standard errors in parentheses.

Table 5. Results of OLS analyses (percentage licensing revenues)

Variables	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18
Dependent variable	Percentage licensing revenues	Percentage licensing revenues	Percentage licensing revenues	Percentage licensing revenues	Percentage licensing revenues	Percentage licensing revenues	Percentage licensing revenues	Percentage licensing revenues	Percentage licensing revenues
Firm size	−0.96*** (0.26)	−0.99*** (0.27)	−0.99*** (0.27)	−0.28* (0.13)	−1.02* (0.56)	−1.26** (0.48)	−0.72** (0.24)	−1.01*** (0.27)	−1.00*** (0.27)
R & D intensity	0.06† (0.05)	0.06 (0.05)	0.06 (0.05)	0.01 (0.04)	0.08 (0.08)	−0.11 (0.15)	0.05† (0.04)	0.06† (0.05)	0.06† (0.05)
Technology exploration	0.29 (0.33)	0.07 (0.40)	0.07 (0.41)	−0.02 (0.18)	0.12 (0.75)	0.15 (0.92)	0.17 (0.33)	0.06 (0.41)	0.05 (0.41)
Chemicals/ pharmaceuticals	0.35 (0.91)	0.11 (0.92)	0.09 (0.93)	0.05 (0.38)	0.24 (1.75)	−0.92 (1.91)	0.78 (0.80)	0.01 (0.94)	0.13 (0.93)
Electronics/ semiconductors	1.78* (0.98)	1.78* (0.98)	1.78* (0.98)	0.72* (0.36)	1.42 (1.31)	1.95† (1.78)	0.10 (0.89)	1.66* (0.99)	1.71* (0.99)
Importance	0.48* (0.25)	0.29 (0.28)	0.26 (0.27)	0.11 (0.10)	0.63 (0.59)	0.91 (0.95)	0.76† (0.49)	0.28 (0.28)	0.28 (0.28)
cross-licensing	−0.38 (0.34)	−0.34 (0.34)	−0.35 (0.34)	0.17 (0.14)	−0.84 (0.70)	−1.45* (0.62)	0.12 (0.34)	−0.35 (0.34)	−0.34 (0.34)
Technological diversification	0.58* (0.31)	0.60* (0.31)	0.58* (0.31)	0.01 (0.13)	0.93 (0.59)	0.95* (0.54)	0.63* (0.30)	0.62* (0.32)	0.62* (0.32)
Product diversification	0.14 (0.34)	0.11 (0.35)	0.10 (0.35)	0.10 (0.15)	0.13 (0.61)	0.70 (0.67)	−0.50† (0.30)	0.08 (0.35)	0.09 (0.35)
Patent portfolio strength	0.10 (0.21)	0.11 (0.21)	0.11 (0.22)	0.09 (0.15)	0.36 (0.50)	0.10 (0.43)	0.20 (0.19)	0.12 (0.22)	0.09 (0.22)
Product development	0.26 (0.50)	0.26 (0.50)	0.19 (0.48)	0.00 (0.17)	0.38 (1.03)	0.85 (0.92)	−0.15 (0.48)	0.72† (0.47)	0.60† (0.47)
Technology licensing	0.69* (0.36)	0.69* (0.36)	0.62* (0.46)	0.29† (0.19)	0.69† (0.96)	1.52† (0.98)	0.36 (0.42)	0.19 (0.53)	0.19 (0.53)
Prod. dev. X Tech. lic.			0.41* (0.28)	0.41* (0.28)	0.02 (0.84)	0.93* (0.57)	0.49† (0.25)	0.48 (0.57)	0.54 (0.57)
Internal identification			0.37* (0.31)					0.30* (0.39)	0.29† (0.37)
commercialization									
Tech. lic. X Int. ident.									
Tech. lic. X Int. comm.									
R ²	0.17	0.21	0.23	0.32	0.26	0.32	0.36	0.21	0.22
R ² adjusted	0.10	0.13	0.15	0.14	0.06	0.15	0.20	0.12	0.12
F	2.56**	2.78**	3.29***	2.79**	1.29	1.89*	2.17*	2.51**	2.54**
Number of observations	210	210	210	105	105	93	92	210	210
Median split patent portf.	All	All	All	High	Low	All	All	All	All
str.									
Median split	All	All	All	All	All	High	Low	All	All
cross-licensing									

† p < 0.1; * p < 0.05; ** p < 0.01; *** p < 0.001; * variables mean centered; unstandardized coefficients with standard errors in parentheses.

Table 6. Results of OLS analyses (return on sales)

Variables	Model 19	Model 20	Model 21	Model 22	Model 23	Model 24	Model 25	Model 26	Model 27	Model 28	Model 29
Dependent variable	Return on sales	Return on sales	Return on sales	Return on sales	Return on sales	Return on sales	Return on sales	Return on sales	Return on sales	Return on sales	Return on sales
Firm size	0.11 (0.29)	0.08 (0.29)	0.08 (0.29)	0.75 (0.74)	-0.39 (0.34)	-0.37 (0.44)	0.68† (0.43)	0.12 (0.29)	0.12 (0.29)	0.08 (0.29)	0.07 (0.29)
R & D intensity	0.01 (0.05)	0.01 (0.05)	0.01 (0.05)	-0.32† (0.21)	-0.07 (0.05)	0.09 (0.14)	0.02 (0.06)	0.00 (0.05)	0.01 (0.05)	0.00 (0.05)	0.00 (0.05)
Technology exploration	0.51† (0.36)	0.25 (0.44)	0.25 (0.44)	-0.37 (0.99)	0.19 (0.46)	-0.28 (0.86)	0.39 (0.58)	0.28 (0.44)	0.28 (0.44)	0.23 (0.44)	0.25 (0.44)
Chemicals/ pharmaceuticals	1.24 (0.98)	0.98 (0.99)	1.01 (1.01)	2.39 (2.12)	0.31 (1.07)	1.73 (1.77)	0.49 (1.40)	0.96 (1.02)	1.03 (1.02)	0.84 (1.02)	0.87 (1.01)
Electronics/ semiconductors	0.83 (1.06)	0.82 (1.06)	0.83 (1.07)	2.33 (2.02)	-0.33 (1.20)	0.65 (1.66)	0.14 (1.56)	0.73 (1.07)	0.76 (1.07)	0.68 (1.08)	0.67 (1.08)
Importance	-0.01 (0.28)	-0.19 (0.31)	-0.17 (0.31)	-0.22 (0.53)	-0.11 (0.36)	0.91 (0.89)	-1.01 (0.85)	-0.11 (0.31)	-0.11 (0.31)	-0.21 (0.31)	-0.22 (0.31)
cross-licensing											
Technological diversification	-0.61† (0.37)	-0.58† (0.37)	-0.57† (0.37)	-0.48 (0.77)	-0.16 (0.43)	-0.51 (0.58)	-0.95† (0.58)	-0.55† (0.37)	-0.55† (0.37)	-0.59† (0.37)	-0.58† (0.37)
Product diversification											
International diversification	0.16 (0.34)	0.19 (0.34)	0.19 (0.34)	0.30 (0.70)	-0.21 (0.36)	-0.14 (0.50)	0.79† (0.52)	0.16 (0.34)	0.16 (0.34)	0.21 (0.34)	0.21 (0.34)
Patent portfolio strength	0.53† (0.37)	0.48 (0.38)	0.48 (0.38)	1.60* (0.85)	0.18 (0.38)	0.97† (0.62)	-0.07 (0.52)	0.48 (0.38)	0.49 (0.38)	0.45 (0.38)	0.44 (0.38)
Technology development											
Technology licensing	0.40* (0.23)	0.41* (0.23)	0.40* (0.24)	0.12 (0.83)	0.23 (0.31)	0.37 (0.39)	0.44† (0.32)	0.40* (0.24)	0.39† (0.24)	0.42* (0.24)	0.43* (0.24)
Prod. dev. X Tech. lic.	0.37 (0.54)	0.38 (0.54)	0.38 (0.54)	1.28† (0.95)	-0.22 (0.63)	0.93 (0.95)	0.16 (0.84)	0.37 (0.54)	0.38 (0.55)	0.68† (0.51)	0.70† (0.51)
Prod. dev. X Ext. ident.	0.63† (0.49)	0.60 (0.53)	0.60 (0.53)	0.22 (1.08)	0.42 (0.59)	0.62 (0.91)	0.53 (0.74)				
Internal identification			0.41* (0.24)	0.43* (0.31)	0.18 (0.51)	0.34† (0.38)	0.29† (0.43)				
Internal commercialization											
External identification								0.76† (0.55)	0.70 (0.56)		
External commercialization								-0.26 (0.57)	-0.29 (0.57)		
Prod. dev. X Ext. ident.								0.47* (0.36)	0.17 (0.45)		
Prod. dev. X Ext. comm.										0.45* (0.38)	0.32† (0.41)
Tech. lic. X Int. ident.											
Tech. lic. X Int. comm.											
R ²	0.15	0.16	0.18	0.38	0.11	0.21	0.23	0.20	0.18	0.21	0.19
R ² adjusted	0.08	0.09	0.11	0.23	0.01	0.09	0.08	0.13	0.10	0.14	0.11
F	1.91*	2.02*	2.17*	2.45*	1.02	2.07*	2.12*	2.21*	1.91*	2.29*	1.98*
Number of observations	188	188	188	94	94	85	83	188	188	188	188
Median split patent portf.	All	All	All	High	Low	All	All	All	All	All	All
str.											
Median split	All	All	All	All	All	High	Low	All	All	All	All
cross-licensing											

† p < 0.1; * p < 0.05; ** p < 0.01; *** p < 0.001; † variables mean centered; unstandardized coefficients with standard errors in parentheses.

we split up the processes into their two stages, that is, identification and commercialization. For new product revenues as the dependent variable, the data show a significant and positive interaction of the identification of licensing opportunities with product development in Model 8. The commercialization stage does not significantly interact with product development in Model 9. For licensing revenues as the dependent variable, the data show a positive and significant interaction of the identification stage and a positive and marginally significant interaction of the commercialization stage of product development with technology licensing in Models 17 and 18. Both stages of the product development process strengthen the effects of licensing processes on licensing performance. Finally, the data show positive and significant or marginally significant interactions of both stages of product development and of the identification stage of licensing in the effects on firm performance in Models 26, 28, and 29. The interaction of product development and the commercialization stage of licensing in Model 27 is not significant. In sum, these analyses show that both stages of product development strengthen a firm's benefits from licensing, but only the identification stage of licensing enhances a firm's benefits from product development.

To further examine the role of a firm's technological resource base, we split the sample at the median of patent portfolio strength. Model 4 shows the interaction of product development and licensing in the effect on new product revenues for firms with relatively strong patent portfolios. Model 5 shows this interaction for firms with relatively weak patent portfolios. Equivalent analyses are presented in Models 13 and 14 for licensing performance and in Models 22 and 23 for firm performance. In the analyses of all three dependent variables, the data show stronger and more significant interactions of product development and licensing in firms with strong patent portfolios. The benefits from integrating product development and licensing are considerably higher in firms with strong technological resource bases.

To examine the differences between licensing and cross-licensing, we split the sample at the median of the control that captures the importance of cross-licensing. Model 6 shows the interaction of product development and licensing in the effect on new product revenues for firms with a relative emphasis on cross-licensing. Model 7 displays

this interaction for firms with a relatively limited importance of cross-licensing. Equivalent analyses are presented in Models 15 and 16 for licensing performance and in Models 24 and 25 for firm performance. Consistent with our conceptual arguments, the interaction effects are stronger and more significant in firms with a relative emphasis on cross-licensing. The complementarity of product development and licensing is not limited to firms that focus on cross-licensing. However, it is particularly pronounced in firms that put relative emphasis on cross-licensing.

DISCUSSION

The empirical study has implications for research into licensing, innovation, and technological competence leveraging. With regard to licensing, we have examined in detail a firm's licensing processes. As such, this paper is among the first quantitative studies into the internal determinants of corporate licensing performance, and it helps explain the heterogeneity between some firms that actively license technology and many others. In particular, the results have shown that many firms have difficulties in identifying licensing opportunities. The willingness to license is only necessary but not sufficient to achieve licensing opportunities (Gambardella *et al.*, 2007). In addition, firms need to establish licensing processes in order to overcome the managerial challenges that derive from market inefficiencies.

Moreover, licensing positively affects subsequent firm performance. This positive performance effect was posited in managerial work (Chesbrough, 2007), but quantitative empirical evidence was lacking. In light of the relatively limited licensing activity in many firms, the data do not point to negative 'profit dissipation effect[s]' (Fosfuri, 2006: 1141) that could result from transferring competitively relevant knowledge. While a dedicated licensing function is a first step toward establishing licensing processes, our results have underscored that firms need integrated technology exploitation processes, which align licensing with the product business (Kotabe *et al.*, 1996). In industrial firms, licensing is not a stand-alone activity, and its interactions with product development are a major driver of licensing performance.

Regarding innovation research, our findings have shown strong interactions of product development

and licensing processes. Separate analyses of product development or licensing could, therefore, be misleading. By modeling the complementarity of the two technology exploitation processes, we discovered synergies, and their positive correlations suggest that many firms attempt to achieve these synergies. The positive effects of one process are stronger at high levels of the other process, and this complementarity is particularly high in firms that strongly rely on cross-licensing. As the benefits from imitating a single process are limited, their complementarity is a major reason why integrated technology exploitation processes may be an important source of superior performance (Song *et al.*, 2005).

Specifically, the data have emphasized that the identification of licensing opportunities strengthens the positive effects of product development, whereas the commercialization stage does not significantly interact with product development. Innovation processes are increasingly interorganizational, and firms may benefit from integrating the identification of product development and licensing opportunities because proficiency in opportunity identification is core to succeeding in the first stage of both product development and licensing. For instance, a firm may profit from cumulatively developing market knowledge if this knowledge is shared in product development and licensing. These interactions may deepen our understanding of interfirm heterogeneity in profiting from innovation. The critical role of the technological resource base, which is developed in exploration processes, further shows that firms need to balance exploration and exploitation (Gupta *et al.*, 2006). The interplay of the resource base and the exploitation processes suggests that a balanced development of the resource base and the exploitation processes positively affects new product revenues, licensing performance, and firm performance.

With regard to technological competence leveraging, this study has deepened our understanding of the intellectual property route to technology leveraging by means of licensing (Danneels, 2007). The positive interaction of product development and licensing has further provided empirical evidence that '[r]egardless of the route to commercialization, via internal product development or intellectual property, firms need a second-order marketing competence' (Danneels, 2007: 531). The identification of new applications and markets for

a firm's technologies is an essential stage of licensing processes because it matches technologies and markets. The simultaneous internal and external exploitation of technology can hardly be explained by efficiency-based analyses of minimizing costs, for example, transaction costs, in individual licensing transactions, which usually suggest either-or decisions (Arora *et al.*, 2001). In dynamic environments, firms often exploit the same technology internally and externally to achieve a sufficient return on their R&D expenditures (Chesbrough, 2003). Besides minimizing costs, for example, transaction costs, firms seek to maximize value by establishing product development and technology licensing processes.

Moreover, the data have shown that the benefits from establishing product development and licensing processes depend on the potential associated with these processes (Danneels, 2007). Without a strong technological resource base, the benefits from establishing exploitation processes are limited. These interdependencies underscore that competence leveraging processes are context-dependent and do not automatically lead to superior performance (Gupta *et al.*, 2006). Instead, these processes need to be thoroughly aligned with a firm's technology exploitation potential, which may help explain different innovation strategies within and across industries (Gans and Stern, 2003). These findings underscore the importance of strategic fit in matching the development and utilization of competence leveraging processes with the internal and external context (Helfat *et al.*, 2007).

In addition, the study has important managerial implications. Product development and licensing have complementary effects. A stronger emphasis on one process may not have a positive effect without a sufficient level of the other process. A balanced development of the exploitation processes in the context of a firm's technological resource base positively affects new product revenues, licensing performance, and firm performance. For a firm's competitors, it is challenging to imitate the two complementary processes. In particular, firms need to develop a licensing process—which was often neglected even though it constitutes a fundamental driver of licensing success because it indicates absorptive capacity (Lichtenthaler and Lichtenthaler, 2010). In particular, systematic licensing processes help firms overcome the challenges of identifying licensing opportunities (Davis and Harrison, 2001).

Moreover, most firms' traditional focus on product development may be insufficient. Beyond generating royalties, licensing has nonmonetary benefits, which may be a prerequisite for new product success. Firms may increase their performance by establishing licensing processes. The complementarity of product development and licensing points to benefits from integrated technology exploitation, which aligns product development and licensing (Kotabe *et al.*, 1996). In addition, performance depends on a firm's technological resource base. A high innovation and licensing potential may be unrealistic if firms lack a strong technology portfolio. Instead, firms need to balance technology exploitation with technology exploration, which contributes to developing the technological resource base.

In addition, a few limitations of this study are worth noting. First, our findings reflect the current situation in Germany, and it would be useful to conduct a similar study in the United States because some U.S. firms are leading in active licensing. Second, the sample refers to a relatively small number of medium-sized and large industrial firms in sectors in which patents play an important role. The results may not be directly transferred to small firms, which are often forced to license technology because of limited complementary assets. Thus, the complementarity of product development and technology licensing may be limited in small firms. The findings may further not be applicable to other industries, in which the role of patents is less important (Griliches, 1990). Third, further studies may specifically consider the costs of establishing technology exploitation processes beyond examining financial firm performance.

A final limitation refers to the cross-sectional nature of our data apart from lagged ROS data. Based on these data, it is impossible to claim causal relationships, and we can only control for observed heterogeneity. To the extent that there are omitted variables, which are correlated with others, a bias in the estimates may occur although complementarity might still be consistently estimated (Athey and Stern, 1998; Mohnen and Röller, 2005). Firms may have unobserved processes or other characteristics, such as an underlying innovation strategy, that are positively correlated with product development, licensing, and the interaction term. In this case, the underlying variable rather than product development and licensing positively affects performance, and this would undermine our

arguments. The results may be driven by unobserved heterogeneity, but the insignificant interaction of product development and the commercialization stage of licensing in Model 9 suggests that unobserved heterogeneity does not necessarily determine all results. Moreover, the lagged dependent variable and the additional analyses with a firm's ROS in the previous years as a further control support our arguments (Greene, 2007). Lagged performance as a dependent variable and past performance as a control may absorb some of the unobserved heterogeneity that could influence product development, licensing, and their interaction.

CONCLUSION

The data have provided support for our conceptual framework, which distinguishes product development and licensing as internal and external technology exploitation processes. Product development processes indicate innovative capacity, and they positively affect a firm's revenues from new products. Technology licensing processes indicate absorptive capacity, and they are positively related to a firm's licensing revenues. In particular, the findings have emphasized the complementarity of the two processes, which positively interact in their effects on new product revenues, licensing performance, and firm performance. While the identification of licensing opportunities strengthens the positive effects of product development, the technology transfer to licensees does not significantly interact with product development. The complementarity of product development and licensing is particularly strong in firms in which cross-licensing plays an important role, but it is not limited to these firms. Moreover, a firm's technological resource base plays a key role because it affects a firm's exploitation potential. These results deepen our understanding of interfirm heterogeneity in profiting from innovation, and they are important in light of an increasing interest in successful technology exploitation.

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APPENDIX

We relied on ordinary least squares (OLS) regressions to examine the hypotheses. The ordinal nature of the variable capturing revenues from new products calls for the use of ordered logit analyses. Because of the challenges of interpreting interaction terms in logit analyses (Ai and Norton, 2003, 2008; Hoetker, 2007), however, we present the results of OLS models. The findings are consistent with the ordered logit analyses. We further cross-validated the results by splitting the variable new product revenues at the median into a high and low category and then analyzing the interaction effects in logit analyses (Hoetker, 2007). To check for potential multicollinearity, we calculated the variance inflation factors. The highest value of 2.71 for electronics/semiconductors in Model 18 is acceptable.

To examine complementarity, we built on prior work (Bresnahan *et al.*, 2002; Snell and Dean, 1992; Wiklund and Shepherd, 2005) and examined two-way interactions. We aggregated the scales by calculating the means of the higher-order constructs (Hoegl and Gemuenden, 2001). Cross-validation analyses with the factor values led to consistent findings. Further cross-validation analyses, in which we directly calculated the values of the second-order factors as the mean of

the first-order items did not significantly change the results. Additional cross-validation analyses, in which we eliminated the items with the lowest factor loadings from the technology exploitation processes, led to consistent findings. To reduce multicollinearity, we used mean centering (Cohen *et al.*, 2002). The regression coefficient and the partial F of the change in R^2 were analyzed to test for interaction. To examine the form of the interaction, we analyzed simple slopes at one standard deviation below and above one variable's mean (Cohen *et al.*, 2002). These procedures showed positive interactions for all significant regression coefficients.

To examine the role of a firm's technological resource base, we followed prior research (Cassiman and Veugelers, 2006) and split the sample at the median of patent portfolio strength. To cross-validate these split-sample analyses, we additionally calculated three-way interactions of product development, technology licensing, and patent portfolio strength. The results of these additional analyses are consistent with the split-sample analyses. The same split-sample procedure was used to examine the role of cross-licensing. The number of observations is slightly lower in these analyses because we had to exclude the observations with the median value based on the ordinal nature of the cross-licensing variable.