J PROD INNOV MANAG 2014;31(6):1181–1198

DOI: 10.1111/jpim.12249

When Research Meets Development: Antecedents and Implications of Transfer Speed

Jingshu Du, Bart Leten, Wim Vanhaverbeke, and Henry Lopez-Vega

This paper focuses on the organization of new product development in large, R&D-intensive firms. In these firms, research and development activities are often separated. Research is conducted in dedicated research projects at specialized research labs. Once research results are achieved by research projects, they are transferred to business units for further development and commercialization. We investigate the speed whereby research projects transfer their first research results to business units (hereafter: transfer speed*). In particular, we analyze the antecedents and performance implications of transfer speed. Based on data of 503 research projects from a European R&D intensive manufacturing firm, our results suggest that a fast transfer speed (as measured by the time it takes for a research project to develop and transfer its first research result to business units) is associated with a better research performance (as measured by the total number of transfers the research project generates). Moreover, we find that different types of external R&D partners—science-based and market-based partners—play distinct roles in speeding up project first research transfers. While market-based partnerships (i.e., customers and suppliers) generally contribute to a faster transfer of first research results, science-based partnerships (i.e., universities and research institutions) only speed up first research transfers of technologically very complex projects. Our results also show that early patent filings by research projects accelerate first research transfers.*

Introduction

New product development (NPD) is at the heart of companies' survival and renewal in today's competitive industrial landscape. In many industries, new products account for more than 50% of firms' annual sales (Schilling and Hill, 1998) and NPD is perceived as a key management imperative (Cooper and Edgett, 2009). However, new product development is challenging and suffers from high failure rates (Castellion and Markham, 2013). The highest attrition rate occurs in the pre-development (research) phase (Cooper and Edgett, 2009) which features great risks and uncertainties. For instance, in the pharmaceutical industry, more than half of the research projects fail (Paul et al., 2010). Despite the high fall-off rate in the research phase, research activities strongly determine future product success (Markham, 2013) and greatly differentiate winners from losers on the market (de Brentani and Reid, 2012). Therefore, carefully managing the research phase is of paramount importance to improving the overall success of NPD activities.

In large R&D-intensive companies, research efforts are often separated from development activities (von Zedtwitz and Gassmann, 2002). By centralizing research in research labs, firms can benefit from economies of scale, reduce transaction costs associated with internal coordination, and generate more impactful research findings (Argyres and Silverman, 2004). Product development, on the other hand, is usually conducted by business units, creating new product offerings to satisfy specific market needs. Once a tangible research result is achieved in research labs, this result is transferred to business unit(s) that are interested in its further development and commercialization. As such, transfers symbolize successful research outcomes, and serve as the single most important input for business units in their development and commercialization activities (Chesbrough, 2006). Only transferred research results have the chance to be commercialized and launched in the marketplace, which makes the transfer of research results from research to development a crucial step for the overall success of new product development.

Despite its importance, the transfer of research results from research projects to business units remains a topic which has not yet received scholarly attention in the NPD literature. While there are many aspects that relate to research transfers, this paper focuses on the *speed* whereby research projects transfer their first research

Address correspondence to: Jingshu Du, Vlerick Business School, Vlamingenstraat 83, 3000, Leuven, Flemish Brabant, Belgium. E-mail: jingshu.du@vlerick.com. Tel: +32488586449.

results to business units (hereafter: *transfer speed*). In the existing literature, speed (or "cycle time") is pointed out as one of the most critical factors in the overall success of new product development (e.g., Cankurtaran, Langerak, and Griffin, 2013), but the speed of intra-firm transfers from research projects to development units has not yet been studied (Vanhaverbeke, Du, Leten, and Aalders, 2014).[1] Moreover, as increasingly more companies and the projects within open up and collaborate with external partners (Chesbrough, 2003; Du, Leten, and Vanhaverbeke, 2014), there is also a burning need in the open innovation literature to examine the speed implications of open innovation strategies on the NPD process. This paper investigates the antecedents and implications of *transfer speed*. More specifically, it examines the effect of having a fast (or slow) first transfer on the performance of research projects, as well as the impact of (early) patent filings and two types of open innovation partnerships—market-based and science-based R&D partnerships—on transfer speed, taking into account the moderating effect of the technological complexity of the research project.

[1] Transfer speed is different from the concept "fuzzy front end cycle time" (e.g., in Eling, Langerak, and Griffin, 2013), with the latter referring to the time it takes a project to complete the fuzzy front end activities such as opportunity identification, idea generation and screening, concept development, and project planning.

BIOGRAPHICAL SKETCHES

Dr. Jingshu Du is research fellow at Vlerick Business School and Hasselt University, both located in Belgium. She received her Ph.D in applied economics from Hasselt University. Her current research interests focus on open and collaborative innovation, business model innovation, and IP strategies in multinational firms.

Dr. Bart Leten is associate professor of innovation management at the Vlerick Business School (Belgium) and assistant professor of managerial economics, strategy and innovation at the KU Leuven (Belgium). He received a Ph.D. in applied economics from the KU Leuven. His research focuses on open innovation and intellectual property strategies of multinational firms.

Dr. Wim Vanhaverbeke is professor at the University of Hasselt. He is also visiting professor at ESADE Business School and the National university of Singapore. He has published in several international journals such as *Organization Science*, *Research Policy*, *California Management Review*, *Journal of Management Studies*, *Small Business Economics*, *Journal of Business Venturing*, and *Technovation*. He was co-editor with Henry Chesbrough and Joel West of the books *Open Innovation: Researching a New Paradigm* (OUP, 2006) and *New Frontiers in Open Innovation* (OUP, 2014). His current research is focusing on open innovation in SMEs, innovation ecosystems, and the implementation of open innovation practices. He was recognized by IAMOT as one of the top 50 authors of technology and innovation management for the period 2008–2012.

Dr. Henry Lopez-Vega is a post-doctoral researcher in the department of management and engineering (IEI–FEK) at Linköping University, Sweden. He has a MSc and a Ph.D. from ESADE Business School, Spain. His research contributes to the burgeoning discussions on the implementation of open innovation at MNCs and role of foreign subsidiaries in BRICS economies.

To investigate the antecedents and performance implications of transfer speed, we rely on a unique dataset of 503 research projects from a large European R&D–intensive manufacturing firm. This firm has an annual R&D budget above one billion euros during the entire observation period (2003–2010) and its activities span a variety of industries. Our findings show that research projects that generate fast first transfers are associated with a better research performance. Fast transfers enable research projects to collect early feedback from business units and help them to secure further research funding by sending a positive signal to the project sponsors and increase their confidence about the research project. Moreover, we find that while market-based partnerships speed up research transfers in general, science-based partnerships are only linked to the acceleration of research transfers of technologically (very) complex projects. Finally, research projects that apply for patents early on in the research process are more likely to generate fast first transfers to business units.

The remainder of this paper is structured as follows: the next section provides the theoretical background. The subsequent section presents the hypotheses, which is followed by a description of the data and research methods. The paper concludes with a discussion of the theoretical and empirical implications, as well as the limitations and avenues for further research.

Theoretical Background

A theory that underlies the mechanism of transfers and transfer speed from research projects to business units is the *intra-firm transaction theory* (Rotemberg, 1991). In intra-firm transactions, intermediate goods are produced and transferred between agents of the same firm (Kotabe, 1992). In the intra-firm transfer process, it is often difficult for the "buyer" agent to assess upfront the quality of the intermediate goods (potentially) transferred from the "supplier" unit, particularly when the goods are still in their early phase of development, which is characterized by great technological and market uncertainty. An important indicator for the "buyer" to signal the quality of the intermediate goods is *the time or speed by which the intermediate goods are delivered* (Rotemberg, 1991). Generally, delivery time can be influenced by two factors:

First, the supplier's choice of delivery. For instance, the supplier of intermediate goods may act cautiously and wait purposively until the goods are perfected before transferring them to the buyer agent. Second, the supplier is genuinely incompetent to deliver high-quality goods in time (Allen and Faulhaber, 1988; Rotemberg, 1991). When the delivery of intermediate goods takes a long time, it is hard for an interested buyer to ascertain which of the two aforementioned situations (e.g., prudence or incompetence) holds true (Rotemberg, 1991). Fearing the second possibility, the potential buyer may decide not to accept the intermediate good when it takes a long time for a supplier to deliver that good (Rotemberg, 1991). It follows that a competent supplier needs to show its competence early on to potential buyers in order to rule out a perception of being incompetent in the eyes of the potential buyer. In other words, if the supplier is sound and capable of delivering high-quality goods, the time frame in which he or she delivers these goods (*transfer speed*) can be of particular importance to the success of its transfers.

In large, R&D-intensive firms, pre-development (research) and development activities are often conducted in different organizational units (von Zedtwitz and Gassmann, 2002). Research projects are typically conducted in research laboratories to benefit from economies of scale and scope, as well as reduced transaction costs (Argyres and Silverman, 2004; Belderbos, Leten, and Suzuki, 2013), while the subsequent development of these projects usually takes place in business units that have a better understanding of market needs and can build on their experience to launch new products.

Research projects produce research results—usually in the form of intermediate goods (e.g., prototypes, algorithms, models)—and transfer these intermediate goods to business units for further development and commercialization. In this transfer process, research projects operate as a cost center and function as the internal suppliers of the intermediate goods (research output) to business units. Business units, by contrast, act as a profit center and represent the internal buyers of the research results of research projects (Chesbrough, Vanhaverbeke, and West, 2006). Business units have limited budgets to spend, and the profits they make on the market depend on the business success of the research outputs they choose to transfer in from research projects. As a result, business units have to constantly screen the quality of research outputs of research projects and select the most promising ones (Chesbrough et al., 2006). The ability of business units to make the right transfer decisions—to evaluate and select the most promising research projects (and the intermediate goods they provide) in the early research phase when little information is known—is essential.

An important element in the intra-firm transfer process from research projects to business units is the speed of the first transfer. Fast first transfers have a signaling function and may increase the confidence of business units in the research project. In the existing NPD literature, product development speed or NPD cycle time refers to the overall cycle time and has been pointed to as one of the most critical factors in the success of new product development (e.g., Brown and Eisenhardt, 1995; Cankurtaran et al., 2013; Schilling and Hill, 1998). Numerous studies have elaborated on the importance of NPD speed, as it helps the firm to establish technology standards, jump ahead on the learning curve, respond rapidly to customer needs, and enjoy more alternatives than slower innovators (Cankurtaran et al., 2013; Chen, Damanpour, and Reilly, 2010; Langerak and Hultink, 2006). However, little is known about the speed of *intra-firm* research transfers by which research results are transferred from research projects to business units, and the link to the performance of research projects.

In the intra-firm research transfer process, research projects can adopt different strategies which may influence the transfer speed of their research results. One strategy is to open up and collaborate with external partners (Chesbrough, 2003; Grant and Baden-Fuller, 2004; Hagedoorn, 1993). The open innovation literature distinguishes between two important types of external R&D partnerships: science-based and market-based partnerships (Danneels, 2002; Du et al., 2014; Faems, Van Looy, and Debackere, 2005). Science-based partnerships feature collaborations with partners that have deep scientific knowledge, such as universities and research institutes. These partnerships provide research projects access to scientific knowledge (Cockburn and Henderson, 1998; Fabrizio, 2009). Market-based partnerships, on the other hand, consist of players with a close link to the market, such as suppliers and customers (Danneels, 2002; Faems et al., 2005). Relationships with market-based players provide research projects with the latest technologies that are available on the market and first-hand information about the market needs (von Hippel and Katz, 2002). Access to external knowledge may be particularly important for research projects that are conducted in "complex" technology fields where the new product consists of multiple components (Cohen, Nelson, and Walsh, 2000; Harhoff and Reitzig, 2004) and in-house knowledge on some components is likely to be missing. A second strategy research projects may take to attract interested business units is to file (early on) for patent protection of their research results. Research projects with early patent filings are attractive to business units since research findings are (partly) codified and, if granted, patents offer exclusive monopoly rights for the products that are introduced to the market (Arora and Ceccagnoli, 2006; Hall, Jaffe, and Trajtenberg, 2005).

Hypotheses

In this section, we develop hypotheses on the antecedents and performance implications of transfer speed. We first investigate the relationship between transfer speed and the performance of research projects (H1). Next, we examine three potentially influential factors of transfer speed: market-based partnerships (H2) and science-based partnerships (H3)—with the moderating effect of technological complexity (H4), as well as early patent applications (H5). Figure 1 provides a schematic overview of the research framework.

Transfer Speed and the Performance of Research Projects

The speed at which a research project transfers its first research result to business units (transfer speed) can be an important driver of the success of the research project, for the following three reasons:

First, a fast transfer speed may help to increase the confidence of the sponsor about the ongoing research it sponsors. Research is characterized by high risks and great uncertainties. As a result, many research projects fail to reach satisfying research outcomes. These "hanging" projects consume valuable resources. Therefore, the strategy "to detect and kill the failing projects early in the NPD process" (Cooper, 2008) is oftentimes put forward as a golden rule—which prompts for the efficient use of valuable resources and cost savings, by unplugging less promising projects early on and redirecting resources to the more promising ones. Financial sponsors of research projects (often business units) therefore have to constantly screen the progress of their project portfolio, and stop the further financing of under-performing research projects. Research projects that manage to quickly generate and transfer their first research results give a strong signal to their sponsors and increase their confidence in the research projects they are sponsoring, which, in turn, may help the research projects to secure further financing, instead of being filtered out early in the research process.

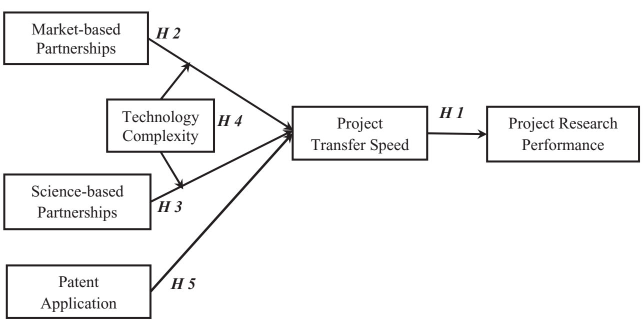

Figure 1. Conceptual Model

Second, fast first transfers enable research projects to collect early feedback from recipient business units. Early feedback may serve as valuable input for the ongoing research of the research projects and may help them to improve the quality of their work (von Hippel, 1986). Third, research projects that have fast first research transfers allow the recipient business units to seek a sharp product definition (Cooper and Edgett, 2012; Cooper, Edgett, and Kleinschmidt, 2004) and to learn beforehand about the value creation possibilities of the technologies under research (Chesbrough, 2003). Fast first transfers may therefore help to increase the attractiveness of the research results to potential recipient business units. In sum, we hypothesize that:

H1: Research projects with a fast transfer of first research results are linked to a better research performance.

Market-Based Partnerships and Transfer Speed

Market-based partnerships consist of players with a close link to the market, such as suppliers and customers (Danneels, 2002; Du et al., 2014; Faems et al., 2005). Market-based partners can help research projects to speed up the transfer of their first research results, because of the following reasons:

First, in research projects, defining and clarifying a specific research question as well as setting clear-cut research goals (Griffin, 1993) may take considerable time if the project team is working on its own without a clear view on what the market wants. When partnering with market-based partners, the project team gets equipped with up-to-date market information and timely adjustments of such information (Ulwick, 2002; Woodruff, 1997), which may enable the project team to detect and respond faster to market needs, and thus, speed up the development and transfer of their first research result to business units.

Second, market-based partners, and particularly lead customers, tend to be concerned with the timely execution of research projects, as this helps to better serve their own needs (von Hippel, 1986). Such market-pull factors (Chidamber and Kon, 1994) may give additional momentum to the research team to speed up the development and transfer of their first research result to business units. Research projects that are conducted in collaboration with market-based partners may also appear more appealing to potential recipient business units, as these projects are geared towards solving an (unmet) market need which is verified by the market-based partners.

Third, market-based partners provide market insights to the research project which enable early testing and fast failing in the research process. As a result, possibilities of rework and mistakes are reduced. A large portion of prolonged research activities in the NPD process stem from rework and mistakes (Kahn, Castellion, and Griffin, 2005). Market insights point out ways for improvement and adjustment before substantial rework is needed (Harrison and Waluszewski, 2008), and therefore may reduce the time needed to develop and transfer first research results. Taken together, we hypothesize:

H2: Market-based partnerships enable research projects to speed up the transfer of first research results.

Science-Based Partnerships and Transfer Speed

Next to market-based partners, research projects may also involve science-based partners (i.e., universities and research institutions) in their research process (Du et al., 2014; Rosenberg, 1990). Science-based partnerships may enable research projects to speed up their first research transfers, because of the following reasons:

First, science-based partners bring the research project specific resources and scientific knowledge, which may help to fill in the research gaps the project is facing. Research projects may experience delays in execution just because the key elements for the desired solution are missing in-house. As research becomes increasingly complex and multi-disciplinary (Brusoni, Prencipe, and Pavitt, 2001; Rycroft and Kash, 1999), it is likely that firms do not possess all the necessary capacities in-house (Narula and Hagedoorn, 1999). Slow innovators "reinvent the wheel," instead of actively building on knowledge that already exists (Chesbrough, 2003; Tao and Magnotta, 2006). On the contrary, science-based partnerships may help research projects to speed up research transfers by leveraging ready-to-use knowledge and technology from experienced scientific partners (Grant and Baden-Fuller, 2004).

Second, collaborating with science-based partners may enable research projects to benefit from a "division of labor," i.e., the partitioning of research tasks among partners. Conducting research in parallel on different tasks may reduce the time to generate transferable research outcomes. Constrained by resource limitations (Barczak, Griffin, and Kahn, 2009; Griffin, 1997), it may be challenging for research projects to simultaneously work on all research tasks. By collaborating with science-based partners, the project team may leverage the resources and expertise of its partners by working in parallel with them, which may shorten the time needed in research. Consequently, science-based partners may help to accelerate the first transfer of research outcomes.

Third, science-based partners who possess profound scientific knowledge may quickly spot flaws in the research process and solve technical problems that research projects are facing, which may contribute to transfer speed acceleration. Moreover, science-based partners can provide research projects with access to advanced scientific equipment and research facilities (Du et al., 2014; Leten, Vanhaverbeke, Roijakkers, Clerix, and Van Helleputte, 2013), which may also accelerate the generation and transfer of research outcomes. Taken together, we hypothesize:

H3: Science-based partnerships enable research projects to speed up the transfer of first research results.

R&D Partnerships and Technological Complexity

Because of the distinctive nature of research projects, adopting a universal approach in all projects might not be effective (Clift and Vandenbosch, 1999; Kessler and Chakrabarti, 1999). One important dimension of differentiation is the technological complexity of research projects. Cohen et al. (2000) distinguish between "complex" and "discrete" technologies. The key difference between both types of technologies is whether the inventions are, respectively, comprised of multiple or relatively few patentable elements (Cohen et al., 2000).

Research projects in complex technology fields focus on inventions with multiple functionalities (Griffin, 1997), and for which the overall understanding of all the encompassing components is typically low (Carbonell and Rodriguez, 2006). Research projects in complex technology fields are expected to benefit more from R&D partnerships. In complex technology fields, because new products typically consist of a large number of components, it is likely that knowledge on some components is lacking in the firm. External R&D partnerships may provide research project teams in complex fields with knowledge on these specific component(s) that is unavailable internally. Further, external R&D partners may also equip research projects with a better overall understanding of the technological and market space in which they search for solutions for the problems they are addressing (Carbonell and Rodriguez, 2006; Griffin, 1997). As a result, research projects in complex technological fields may benefit more from external R&D partnerships in speeding up research transfers.

Moreover, in complex technology fields, multiple components interact with each other in determining the functionality of new products (Henderson and Clark, 1990). Any single mistake or misfit of one technology component may affect the functions of the overall product, resulting in unnecessary delays in product development. Collaborating with external partners helps the research project to access multi-disciplinary scientific and market knowledge, and to develop a "helicopter view" on different components and their interfaces in the knowledge architecture (Henderson and Clark, 1990). As a result, it may speed up the development of (first) transferable research outcomes. In sum, we hypothesize:

H4: Science-based and market-based partnerships have a larger effect on the speed of first transfers of technologically complex projects.

Patent Filings and Transfer Speed

Besides engaging in R&D partnerships, another important decision a research project makes is whether and when to file for patents to legally protect its research outcomes. Early patent filings may accelerate the speed of first research transfers, for the following reasons:

First, research projects that apply for patents on their technologies may—if the patents get granted—improve the possibilities of the recipient business unit to appropriate economic value from the transferred technologies, by offering them temporary monopoly rights on the use of the technologies (Arora and Ceccagnoli, 2006; Kultti, Takalo, and Toikka, 2007). Patent protection increases the economic value of innovations, which is referred to as the patent premium (Arora, Ceccagnoli, and Cohen, 2008; Hall et al., 2005). Research projects which have already filed for patent applications may be considered as more attractive to business units and the early filings of patents may therefore lead to faster first research transfers.

Second, research results are a combination of both tacit and codified knowledge (Kogut and Zander, 1993; Nonaka, 1994). To further develop and commercialize research results, the recipient business unit has to understand the transferred technologies. While codified knowledge can be easily transferred from one unit to another, tacit knowledge prevents efficient sharing between different units (Almeida, Song, and Grant, 2002; Grant and Baden-Fuller, 2004), especially when these units are of distinct nature and are featured with a large cognitive distance (Huber, 2012). This is particularly true for knowledge transfers from research projects to business units. When a research project files for patents, it engages in efforts to (at least partly) codify tacit research results by providing detailed descriptions of the functions and mechanisms of the underlying technologies in the patent application file. These detailed descriptions, in turn, may help the potential recipient business unit to better understand the transferred research results. Hence, early patent applications are expected to lead to faster first research transfers. This leads to the following hypothesis:

H5: Early patent filings enable research projects to speed up the transfer of first research results.

Methodology

Sample and Data Collection

Detailed information on research projects from one large European R&D-intensive manufacturing firm is used in this study. The sample firm invests heavily in R&D, with an annual R&D budget of more than one billion euros consecutively during all the sample years (2003–2010). There are several reasons as to why a single firm is chosen as the sample in this paper: First, in multiple firm studies, each of the firms may develop (slightly) different understanding of the research phase, transfer speed, and research performance. Given these differences, combining various data sources to form a unified multi-firm dataset is not only challenging but may also engender less accurate results. Second, as the primary focus is on intra-firm transfers of intermediate goods (research outputs), a single firm study enables us to better focus on the major variables of interest, filtering out possible confounding effects at the "macro level" (e.g., firm level), such as innovation policy and corporate culture. Third, a single firm study also allows us to dig deeper into the firm and get fine-grained data, making it possible to collect data on a large set of control variables at the project level.

Our dataset contains detailed information on 503 research projects that were initiated and executed in the different research labs of the company during the 2003–2010 period.[2] Instead of relying on subjective and retrospective evaluations of managers, this study relies on

[2] The same data structure has been adopted in prior research (Du et al., 2014).

objective information that is collected from the internal databases of the sample firm, containing information on project staffing, project management and research outcomes (i.e., research transfers). Our dataset includes both data on successful and failed research projects (i.e., projects that did not proceed on to the next stage of development). These research projects span many different technological fields, covering all eight main International Patent Classification (IPC)[3] technology fields (one-digit level) and 44 more detailed IPC technology fields (three-digit level). The five top-ranked technological fields in our sample of projects are: G06 (computing, calculating, and counting), A61 (medical science), H04 (electric communication), G01 (measuring and testing), and H01 (basic electrical elements).

The starting date and ending date (in case projects are ended before 2010) of each research project is recorded. A research project can end either because it achieved its research goal, or simply because the sponsor decides to terminate it. During the execution of a research project, research results can be achieved at any point in time. If perceived as valuable by business units, these research results are transferred to interested business units who are willing to commit resources (i.e., time, money, people) to further develop and commercialize them into new products and services. As a result, a research project may generate multiple research transfers during its lifetime. A research transfer implies that a research result is taken over by a business unit, and for which there is documented evidence of its intended use by this recipient. More specifically, a "transfer" has to fulfill the following criteria:

- A transfer involves a written transfer plan agreed between the research project and the business unit.
- A transfer coincides with a wrap-up of activity in the business unit that aims to utilize the knowledge being transferred from the research project.
- A transfer must conclude with an agreement from the receiving business unit that the transfer has taken place and that the transfer is complete.

While there are differences across transfers in the type of research outcomes that are transferred (prototypes, algorithms, models, etc.), the above-mentioned criteria ensure that transfers are comparable and can be used as an indicator of the performance of research projects. This was confirmed in interviews with managers of our sample company, as it uses the number of transfers as key performance indicators of research projects.

Research projects are initiated by either one of the *Business Units* of the firm, or by *Corporate Research*. Business Units earn their profits from product sales, and mainly sponsor research that is geared towards clear market needs. Corporate Research is the unit of the firm that manages the research labs. It has an annual R&D budget to sponsor research projects that are of strategic importance to the firm, and which are more general purpose in nature (e.g., platform technologies which do not cater to the specific needs of any business unit). About half of the research projects are sponsored by Business Units, and the rest are sponsored by Corporate Research.

There are various types of business units within the firm that act as recipients of research transfers. Most business units are organized around specific product groups. Besides the main business units that deal with the core business of the firm, the New Business Development (NBD) department explores the internal use of technologies that fall outside the scope of the firm's existing business fields. The Incubator department incubates early-stage technologies that have the potential to grow into a new business later on. The business departments—IP & Standards and Licensing—deal with external third parties and are responsible for licensing out or selling technologies that result from research projects for which there is no direct interest of the internal business units in commercializing them.

Business units that have received research transfers are often the sponsors of the transferring research projects, but other business units can also ask for transfer(s) of research results, if perceived as valuable to their business. We have illustrated the transfer process for one hypothetical research project in Figure 2. This research project was initiated by Business Unit 1 and has generated three research transfers. The first two transfers were requested by Business Unit 1 (the sponsor) while the third transfer was transferred to Business Unit 2. This project also filed for two patents, one preceding the first research transfer, and one between the first and the second research transfer.

Methodology

We have conducted two different types of empirical analyses:

Transfer speed and project research performance. To investigate the relationship between the speed of

[3] IPC is a hierarchical technology classification that follows a tiered structure to classify inventions into technology fields. At the most detailed level (represented by an eight-digit code), IPC differentiates between 70,000 technologies. These technologies are aggregated into subclasses (four-digit code), classes (three-digit code), and sections (one-digit code).

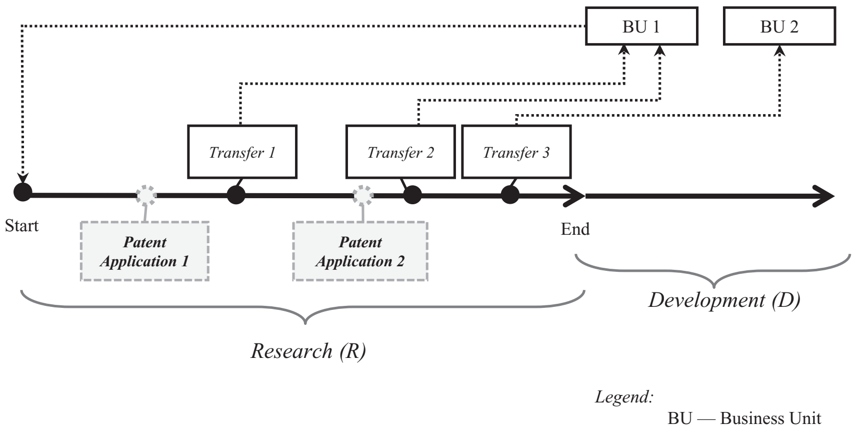

Figure 2. Transfer Flow and Research Flow of a Research Project

a first research transfer and project research performance, we used the Heckman two-step selection model. Since transfer speed can only be measured for research projects that generated at least one transfer, the performance analysis is limited to the subset of projects ($n = 170$) which have research transfer(s). The remaining un-transferred projects—which may also have the potential to generate a transfer but are however not observed in our sample—are left out. To control for selection effects due to the nonrandom nature of the subset of projects with transfers, the Heckman two-step selection model is employed in the study.

We first estimated the probability that research projects generated at least one research transfer—and for whom transfer speed could be calculated—using data on the full sample of 503 projects. We used the dummy variable "sponsor department" as selection variable. This variable takes the value 1 if a research project was sponsored by Corporate Research, and the value 0 when one of the firm's Business Units sponsored the research. We expect that, compared to research projects that are sponsored by Corporate Research, research projects that are sponsored by Business Units are more likely to generate a research transfer. This is because Business Unit sponsors focus on technologies that are directly related to their business needs; therefore, technologies that are sponsored by them are more likely to be transferred to them (i.e., the sponsor of the project) to fill in their needs. This is not the case for projects sponsored by Corporate Research, as they focus more on technologies that are general purpose in nature, and which are not directly linked to the needs of one specific business unit. However, despite the expected higher likelihood for Business Unit sponsored projects to generate one research transfer, there are no clear theoretical reasons to expect systematic differences in the overall performance (measured by the total number of transfers) of research projects that have different types of corporate sponsors.[4] As a result, the variable "Sponsor department" qualifies as a selection variable. In the second step, we estimated the relationship between transfer speed and research project performance for the subset of 170 research projects, controlling for the possible selection effects by including the inverse Mills ratio from the selection equation in the first step.

Data on project transfers is used to measure the performance of research projects. A transfer signals the commitment of the recipient business unit and its willingness to invest (time, money, people) in further developing and commercializing the research output. Hence, transfers can be considered as positive evaluation by business units of the value creation potential of the specific research output generated by the research project. In this way, project research transfers serve as a valuable indicator of project research performance. The larger the number of research transfers the research project delivers to business units, the better the (perceived) performance of the research project. To control for the skewed nature of this variable, we used the logarithmic transformation of the number of research transfers as our dependent variable.

Antecedents of transfer speed. To explore factors that may affect the (first) transfer speed of research projects, we used event history analysis, also known as survival analysis. Event history analysis has been frequently used in prior studies where "speed" or "time" was the focal variable of interest (e.g., Schoonhoven, Eisenhardt, and Lyman, 1990; Zander and Kogut, 1995). Event history analysis has several advantages in time-related studies:

[4] We have empirically tested this assumption. The dummy variable "sponsor department" is insignificant when included in the performance equation, using data of the subset of 170 research projects.

First, it takes into account both the occurrence and the timing of an event while estimating the effects of explanatory variable. Second, it takes care of right-hand censoring problems.

The dependent variable measures *how fast* a research project generates a first transfer (the hazard that a project reaches an event—a transfer). We opted for the Cox proportional hazard model (Cox, 1972) in this set of analyses, since this model requires no upfront assumption concerning the distribution of the hazard rate of project transfers. The Cox model allows the baseline hazard to be fitted from the data. The Cox model specifies the hazard that a project delivers a research transfer as the product of a baseline hazard h(t) and a project-specific hazard, with the latter modeled as an exponential function of the model parameters β_x and regressors x_{ij}:

$$h(t|x_{ij}) = h(t).\exp(x_{ij}.\,\beta_x)$$

To control for possible unobserved project-specific effects such as differences in project tasks, management styles, and team capabilities, we augmented the Cox model with a stochastic project-level component α_i (Blossfeld, Golsch, and Rohwer, 2007). This project-level component, or shared frailty term, enters the hazard function in a multiplicative manner and has a mean of 1 and a variance of θ. As we have detailed information about the start and transfer date of each transfer, we performed our analysis at the monthly level. We also specified the exit time of those projects that were ended before the end of our observation window.

Variables

Transfer speed. In the Heckman selection model, we measure transfer speed as the time from the start of a research project to its first transfer of research results. In line with our dependent variable in the Cox proportional hazard model this variable is detailed at the monthly level. By the end of our observation period in 2010, 170 of the 503 research projects generated research transfers. The remaining research projects were either still ongoing or ended without generating any research transfer. The average speed of first research transfers for the 170 transferring projects is 1.35 years.

Science-based and market-based partnerships. We have annual information on the involvement of external partners in research projects. More specifically, we know—for each project and year—whether it collaborated with science-based (i.e., universities and research institutions) and/or market-based partners (i.e., customers and suppliers). Science-based and market-based partnerships are both binary variables that take a value "1" if collaboration with the specific type of partners took place in the research project up to the observation year, and "0" otherwise. In our sample of 503 projects, 286 projects (56.9%) collaborated with both types of partners, 78 projects (15.5%) only with science-based partners, 68 projects (13.5%) only with market-based partners, and the remaining 71 projects (14.1%) had no external R&D partnerships.

Project patent application. Project patent application is a variable indicating the number of patent filings by research projects. The variable is measured annually and indicates the number of patents applied for by the research project at the European Patent Office (EPO) up to the observation year. We focus on EPO patent applications because our sample firm is headquartered in Europe and follows the EPO system for the majority of its patent applications.

Technological complexity. Technological complexity measures the average complexity of the technologies that are under development in a research project. Technologies are considered complex when they focus on inventions that comprise multiple functionalities (Griffin, 1997) and patentable elements (Cohen et al., 2000). Prior literature measured the complexity of technology fields by the average number of patent claims[5] in patents of that field (Cohen et al., 2000; Harhoff and Reitzig, 2004). To construct the complexity measure, we first calculated the average number of patent claims in each different IPC four-digit technology field, using data on the worldwide stock of EPO patent applications per field during the period 2000–2010.[6] Second, after having identified the technological complexity of each IPC field, we calculated the technological complexity of a particular research project as the average complexity of the different technologies encompassed by that research project. More details on the classification of research projects to their respective technology fields can be found in the section on control variables. Two different cut-off values to differentiate between less and more complex projects are used in this paper: the 50th and 75th percentile of the complexity values in our sample.

[5] Patent claims provide clear and concise definitions of what the patent legally protects (OECD, 2009).

[6] There are approximately 640 different IPC four-digit technology fields.

Control Variables

We added the following set of control variables to our analyses:

Project resources. Project resources have been pointed out as a critical factor determining project success or failure (Barczak et al., 2009; Carbonell and Rodriguez, 2006). We use the (log-transformed) number of full time equivalent researchers (FTE) working on a research project as proxy of the size and the resource endowments of the research project. This variable is recorded on a yearly basis and is calculated in a cumulative way by adding FTEs over the research project's lifetime up to the observation year.

Project technological fields. We use a set of dummy variables to denote the technological fields in which the research project is classified. Research projects that focus on different technological fields may face different challenges and generate distinct outcomes (Hall, Link, and Scott, 2003). We have followed a two-step approach to classify projects into their respective technology fields: First, for projects that have applied for patents, the technology class (IPC) information on their patent application files is used. If a patent contains multiple technology classes, a project is assigned to multiple technology fields. Second, the remaining projects that have not (yet) applied for a patent are manually assigned to technology fields by using information on the project's content from the project titles, abstracts, and descriptions. Technology fields with a low number of projects are grouped together into a rest category in the analyses.

Length of the research project. Project duration is another important factor that may affect the performance of research projects. For instance, projects that last longer may enjoy more time for research, and thus have a higher possibility to generate (more) transfers. In this paper, we use the number of months a research project lasts as the measure for project duration. This variable has been referred to as research cycle time in prior research (e.g., Eling et al., 2013).

Firm patent stock. This variable represents the technical strength of the firm in the technology field(s) to which a research project belongs. Technical competences of the firm in the field under research are expected to be (at least partly) accessible to the project team. We take the five-year prior patent stock of the sample firm to measure the technical strength of the firm in the relevant technology fields of the research project (Du et al., 2014). We have collected EPO patent data for the sample firm at the consolidated level, including patents that were assigned to the parent company or to its majority-owned subsidiaries. The consolidation was done on a yearly basis to take into account changes in the firm group structure. Patents of subsidiaries that are acquired and divested are, respectively, added and removed from the patent stock from the year of acquisition or divestment. Due to the long time-windows of patent granting decisions at the EPO,[7] we use patent application data to construct firm patent stock.

Project management formality. Following prior research (e.g., Cooper et al., 2004; Du et al., 2014), we control for the extent to which research projects have followed a formalized management process; that is, the research projects were planned, monitored, and controlled in a formal way by the project management team. The management process of each project is evaluated annually by the project manager. In line with prior work (Du et al., 2014), scores from 0 to 5 (a score of "0" means that the activity is not performed; a score of "5" indicates that great importance is given to the activity) are provided for each of the following three project management activities: (1) regular review of the project process, involving management, project owner, and project sponsors; (2) during project reviews, corrective actions are identified, documented, and tracked through to project completion; (3) progress reports are made available at the project level on a regular basis, including information on project termination and transferred results. The project management formality score is calculated as the average score on these three questions for projects that last longer than one year; the average score over time is used. A higher score implies that the project is managed in a more formal way by the project management team.

Number of projects under management. The more projects a project leader is actively managing, the less time he or she may devote to each individual project, which may negatively affect project performance (Geanakoplos and Milgrom, 1991). Projects that receive more attention from their manager may enjoy timely feedback and generate faster research transfers. We use the number of projects that a project leader is managing

[7] Patent granting decisions at the EPO take on average more than five years (Harhoff and Wagner, 2009).

Table 1. Variable Definitions, Measures, and Categories

Variable Name	Measure	Type
Performance of research projects	The number of transfers the research project generates	Count (log transformed)
Research transfer speed	The speed of the first transfer from research project to business unit	Continuous
Science-based partnerships	Collaboration with science-based partners	Binary
Market-based partnerships	Collaboration with market-based partners	Binary
Project patent application	Number of patent applications at EPO	Count
Technological complexity	Technological complexity of the technology field to which the research project belongs	Binary
Project resources	Full time equivalent (FTE) researchers work on a project	Count (log transformed)
Project technological fields	The technological fields the project is active in	Dummy
Length of the research project	The number of years a research project lasts	Count
Firm patent stock	Previous five-year patent stock of the firm in the technological field to which the project belong	Continuous (log transformed)
Project management formality	Average score of project management proficiency on (1) regular review of the project process, (2) corrective actions during project reviews, (3) progress reports	0–5 Likert scale
Number of projects under management	Number of projects a project leader is actively managing	Count (log transformed)
Sponsor department	The sponsor of the project: *Corporate Research* or one of the *Business Units*	Binary
Project initiating year	The year in which the research project is initiated	Dummy

concurrently in a certain year as proxy for the managerial attention of each individual project.

Sponsor department. In our data, research projects can be initiated by two types of sponsor units, i.e., *Corporate Research* (51% of sample projects), or any of the *Business Units* of the firm (49% of sample projects).[8] The variable sponsor department is a dummy variable, taking the variable 1 if a project is initiated by Corporate Research, and 0 otherwise. As explained in detail in the Methodology section, this variable also functions as the selection variable in the two-step Heckman estimations.

Project initiating year. Project initiating year refers to the year in which a research project started. This variable may signal the macroeconomic situations at a particular point in time, but it may also absorb the effects of changes in corporate level strategy. We include a range of dummy variables to control for project initiating years.

Table 1 gives a brief description of the variables we used in this study. Appendix A and Appendix B show the descriptive statistics and correlations for the dependent and explanatory variables in the event history analysis and in the Heckman two-step estimations, respectively.

[8] Models with separate dummies for the 10 business units give very similar results.

Empirical Results

Transfer Speed and the Performance of Research Projects

We first analyze the relationship between transfer speed and the performance of research projects.[9] Table 2 reports the results of the Heckman two-step regression model. Model 1 shows the selection result for the first step: whether a project generates a transfer or not. It includes the control variables and the selection variable (Sponsor Department). As expected, the coefficient of the selection variable is negative and significant, confirming that research sponsored by Corporate Research has a lower probability to generate research transfer(s). Projects that have more resources and that can build on a large firm-level patent stock have a higher probability to generate a research transfer. The results further show that research projects that are managed in a more formal way are more likely to generate a research transfer to business units.

Model 2 is the second step of the Heckman model where we regress the performance of research projects on transfer speed (as measured by the number of months a project takes to generate a first research transfer). We control for the possible selection bias by including the inverse Mills ratio in the equation. The inverse Mills ratio

[9] We used the “number of research transfers after the first delivery” as an alternative dependent variable. This specification gave qualitatively the same results.

Table 2. Heckman Two-Step Regressions on Transfer Speed and Performance of Research Projects

	Model	
Variables	Coefficient	Standard Error
Selection equation (Model 1)		
Sponsor department	−.460***	(.135)
Project management formality	.154*	(.085)
Firm patent stock	.0937*	(.0534)
Project resources	.721***	(.182)
# Projects under management	.123	(.1018)
Constant	2.653	(1.994)
Performance equation (Model 2)		
Transfer speed	−.0308***	(.0062)
Length of the project	.0211***	(.0038)
Project management formality	−.0382	(.117)
Firm patent stock	.0094	(.0649)
Project resources	−.1581	(.254)
# Projects under management	−.0176	(.1313)
Technology fields	*Included*	*Included*
Initiating year dummies	*Included*	*Included*
Constant	−4.375***	(.772)
Mills ratio	−.892**	(.435)
Number of observations	503	
Number of censored observations	333	
Number of uncensored observations	170	
Wald test: χ^2	88.79***	

Robust standard errors in parentheses: *** $p < .01$, ** $p < .05$, * $p < .1$.

is significant, showing that without controlling for this variable, our performance equation would suffer from a sample selection bias. We also control for the length of the research project. The coefficient of the transfer speed variable is negative and significant, confirming H1: Research projects with a fast first transfer (less months needed to generate a first transfer) to business units are associated with a better research performance.[10] Model 2 also shows that projects with a longer research cycle time perform, on average, better than their counterparts with a shorter research cycle time.

Antecedents of Transfer Speed

Table 3 reports the regression results of Cox shared frailty analyses for the impact of market-based partnerships, science-based partners, and (early) patent filings on the transfer speed of first research results. As the Cox model measures *the rate* at which a first transfer is delivered, a positive (negative) coefficient indicates that the variable accelerates (decelerates) transfer speed. Model 1 is the baseline model with only control variables. The results suggest that projects that have more resources and that are managed by project leaders who simultaneously manage multiple projects are linked to faster first research transfers. Further, we find that projects that are sponsored by Corporate Research take a longer time to transfer their first research results (have a slower transfer speed).

The market-based and science-based partnership variables are added to Model 2. A positive and significant effect is found for market-based partnerships on project transfer speed. This confirms H2: Market-based partnerships accelerate the transfer speed of first research results. The regression results show that market-based partnerships accelerate transfer speed by 69.55% (= exp [.528]-1). However, we do not find a significant effect for science-based partnerships on project transfer speed. As a result, we do not find empirical support for H3, that science-based partnerships (universally) speed up first research transfers.

Further, we add the patent application variable to our specifications in Model 3 and Model 4, respectively. The coefficient of this variable is positive and significant in both models. This confirms H4 that early patent filings in research projects speed up the transfer of first research results to business units. The coefficient shows that each additional patent application accelerates the transfer speed by 4.3% (= exp [.042]-1). The inclusion of the patent variable has no material effect on the R&D partnership variables.

Finally, technological complexity is included as the moderating variable of market-based and science-based partnerships in Model 5 and Model 6. In Model 5, we use the medium sample value of complexity (50th percentile) as cut-off value for technological complexity. In Model 6, we raise the bar of technological complexity to the 75th percentile to differentiate between technologically very complex projects and the rest. The complexity variable is negative and significant in both models, indicating that research projects that focus on complex technologies, in general, take more time to transfer first research results. The results further show that collaborations with market-based partners in general speed up the transfer process. Interestingly, while science-based partnerships do not universally speed up the transfer process of research projects, they have an acceleration effect on projects that deal with very complex technologies (as indicated by the positive interaction effect in Model 6). Thus, H5 is only partly supported: technological complexity only moderates the

[10] We also tested the possibility of a nonlinear relationship between transfer speed and project performance. However, no evidence of a curvilinear relationship was found.

Table 3. Cox Shared Frailty Regressions on the Antecedents of Project Transfer Speed

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Market-based partnership (MB)		.528***		.549***	.591**	.567**
		(.201)		(.205)	(.302)	(.232)
Science-based partnership (SB)		.0391		.0490	.078	−.139
		(.197)		(.201)	(.295)	(.225)
Project patent applications			.0423**	.0449**	.048**	.0470**
			(.0183)	(.0187)	(.019)	(.0192)
Complexity (50th percentile)					−.885*	
					(.464)	
MB* complexity (50th percentile)					.029	
					(.418)	
SB* complexity (50th percentile)					.007	
					(.415)	
Complexity (75th percentile)						−1.468**
						(.614)
MB* complexity (75th percentile)						−.0457
						(.518)
SB* complexity (75th percentile)						.983*
						(.549)
Project management formality	.185	.173	.194	.169	.156	.150
	(.114)	(.119)	(.120)	(.122)	(.127)	(.129)
Sponsoring department	−.742***	−.734***	−.782***	−.732***	−.789***	−.768***
	(.166)	(.180)	(.179)	(.184)	(.191)	(.189)
Firm patent stock	.110	.143*	.119	.138*	.159*	.130
	(.075)	(.0792)	(.0791)	(.0811)	(.086)	(.0845)
Project resources	.630***	.644***	.616***	.545**	.666***	.602***
	(.175)	(.210)	(.214)	(.223)	(.235)	(.232)
# Projects under management	.734***	.824***	.831***	.849***	.929***	.900***
	(.171)	(.190)	(.190)	(.196)	(.202)	(.202)
Project technological fields	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Project initiating year	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Observations	13,308	13,308	13,308	13,308	13,308	13,308
Number of groups	503	503	503	503	503	503
Number of events	170	170	170	170	170	170
Log likelihood	−911.7	−907.7	−909.0	−905.0	−901.06	−900.6

Standard errors in parentheses: *** $p < .01$, ** $p < .05$, * $p < .1$.

relationship between science-based partnerships and transfer speed.

Conclusion and Discussions

This paper focuses on the organization of R&D activities in large, R&D-intensive firms. In these firms, research is typically conducted in research projects within research labs. Product development, on the other hand, is executed by business units. Once research results are achieved, they are transferred from research projects to business units for further development and commercialization. We investigated the antecedents of transfer speed (the time a research project takes to deliver its first research result to a business unit) and the relationship between transfer speed and the performance of research projects (measured by the total number of transfers a project generates).

We found that fast first research transfers are linked to a better research performance. Fast first transfers give a strong positive signal to the project sponsors, increasing their confidence in the research project they sponsor and their willingness to further fund their ongoing research. Moreover, a fast first transfer enables research projects to collect early feedback from business units, which can be used to improve their ongoing research. R&D partnerships are found to be useful—under some conditions—to speed up research transfers. While market-based partnerships have a general positive effect on transfer speed, the speeding-up effect of science-based partners is limited to projects conducted in very complex technology fields. Furthermore, this study provides evidence that early patent filings by research projects accelerate the transfer of first research results to business units.

Somewhat surprisingly, we did not find a universal acceleration effect of science-based partnerships on the transfer of first research results. This finding deserves further considerations. In R&D partnerships, coordination may take substantial time when partners have diverse goals (Lorange, Roos, and Brønn, 1992), different working habits (Bstieler and Hemmert, 2010), and distinct organizational cultures and thought worlds (Dougherty, 1992). In such situations, coordination and communication complexities (Gulati, 1998; Rothaermel and Deeds, 2006) may offset the potential benefits of partnerships on transfer speed, or even extend the time to reach research transfers. These factors are likely to differ according to the type of R&D partners involved. For science-based partners, bureaucratic hierarchy, inflexibility, and different rewarding systems (Mowery, 1998) are expected to hinder their efficiency in research transfers. Frictions resulting from different organizational cultures and perceptions (Bstieler and Hemmert, 2010) may also arise. Furthermore, science-based partners are often involved in government-funded projects (e.g., European FP-7 projects) which have complex administration systems and reporting formalities (quarterly or yearly). As a result, the firm and its science-based partners involved in such projects are constrained in the transfer process, as the structure and process are predetermined by the government. These abovementioned factors may jointly offer an explanation as to why we did not find a general positive effect of science-based partnerships on transfer speed.

However, we find an accelerating effect of science-based partnerships for a specific set of research projects, namely those that focus on (very) complex technologies. Drawing from their expertise in scientific research, science-based partners are well positioned to develop a "helicopter view" on complex technologies that consist of multiple components in complex product architectures (Fleming and Sorenson, 2004; Rosenberg, 1990). This enables them to sort out the intricate relations between technology components and to speed up the development of transferable research outcomes. In general, the situated effect of science-based partnerships should be interpreted with caution. It might be that, although science-based partners do not (universally) accelerate research transfers, the research results of projects they are involved in are more innovative and/or of greater impact. In other words, the benefits of science-based partners might be materialized in a different way, i.e., via more impactful innovations or higher financial returns (e.g., Du et al., 2014).

In addition, we found that projects that share their project leader with multiple other projects generate faster research transfers. This seemingly unexpected result may be interpreted as follows: the variable "number of projects managed" may signal the attention each research project gets from its manager; but at the same time, it may also signal the scope of the research project, and the possible cross-fertilization across different projects the project leader is managing. On the contrary, the projects which are managed by one (dedicated) project manager, although getting the most managerial attention (as they are handled by project managers who have limited number of projects at hand), may take longer to transfer their first research results.

Theoretical Implications

This paper contributes to the NPD literature, in particular the research on NPD cycle time, in several ways. First, we introduce a new concept of speed—the speed of intra-firm research transfers from research projects to business units. Prior research on cycle time predominantly took a monolithic view on cycle time by studying the speed of the entire NPD process from ideation all the way down to product market launch (e.g., Cankurtaran et al., 2013; Chen et al., 2010). Consequently, "little is known about the specific effects of the cycle times of the different NPD stages on NPD performance," which "emphasizes the need to conduct performance effect studies of NPD cycle time at the stage level rather than at the monolithic process level" (Eling et al., 2013, p. 626). We focused in this paper on the research phase of NPD and more specifically, the speed whereby research projects generate and transfer a first set of research results to business units. As such, this paper contributes to the development of a better and more nuanced understanding of NPD cycle time. Second, this paper contributes to the recent debate in cycle time studies whether having a shorter cycle time is beneficial or disadvantageous to NPD performance (Swink, Talluri, and Pandejpong, 2006). We find that, at least for the speed of first research transfers, there is a positive relationship with performance. Third, this paper contributed to the NPD literature by introducing a new conceptual lens—the speed of research transfers—to make early assessments of NPD performance. In doing so, this paper also adds to the intra-firm transaction theory by emphasizing the importance of a fast delivery of intermediate goods in intra-firm transactions between research projects and business units.

Besides adding to the NPD literature, this paper also contributes to the open innovation literature by showing hard evidence of the effect of R&D partnerships on the transfer speed of research projects. Responding to the call of Chesbrough et al. (2006) that "neither the practice of nor research on open innovation are limited to the level of the firm" (p. 287), in this paper we analyzed open innovation at a more refined level, being the project level (Chesbrough, Vanhaverbeke, and West, 2014; Vanhaverbeke et al., 2014). Moreover, this paper added to the existing open innovation literature by investigating the "time" aspect—the effect on transfer speed—of different open innovation partnerships. Despite the burgeoning studies on the effects of open innovation on a wide range of performance dimensions, such as financials (Du et al., 2014), cost savings (Knudsen and Mortensen, 2011), number and share of innovative products (Faems et al., 2005; Laursen and Salter, 2006), whether R&D partnerships increase the time efficiency of the NPD process remained an open question in the open innovation literature. In this paper, we made a first contribution to this line of research by empirically studying the effect of different types of open innovation partnerships (market-based and science-based partnerships) on the speed of first research transfers. The findings help to develop a more holistic understanding about the effects of open innovation.

Managerial Implications

Several managerial implications can be drawn from this study. This paper shows that, when little information is available in the early research phase for project sponsors to assess the potential of research projects, a good strategy for research projects is to have an early first research transfer. Instead of being prudent in continuing to refine initial research results, the research project may actually be better off if presenting initial research results to business units early on in the research process. A fast first transfer can improve the confidence of the project sponsor on the capabilities of the research project, which, in turn, gives the research project a better position to negotiate additional research funding to sustain its further research.

Next, regarding the strategic choices of a research project to speed up its transfer of research outcomes, our findings suggest that collaboration with external R&D partners is no panacea under all circumstances when it comes to speeding up research transfers. Instead, the effect of R&D partnerships on the transfer speed of research projects depends on the type of partners involved in the collaboration process and the technological complexity of the research project. Market-based partnerships in general contribute to fast first research transfers, while science-based partnerships are found to be only beneficial in accelerating first research transfers of technologically very complex projects. As a result, R&D managers in large, R&D-intensive firms need to choose the type of partners based on the objectives and the characteristics of the research project. Other factors hold equal, for projects in less complex technology fields, if there is time pressure to quickly transfer research results, teaming up with market-based partners may be a better strategy, compared to collaborating with science-based partners. While for technologically very complex projects, both types of external partnerships are helpful to speed up first research transfers.

Last but not least, our research results suggest that, in terms of transfer speed, it is beneficial for a research project to file patents early on in the research process, as early patent filings are instrumental in speeding up first research transfers. Early patent applications help to codify research results, and facilitate knowledge flows between the research team and the potential business recipients. Moreover, early patent applications also provide an option to legally protect technologies under research, improving the attractiveness to business units.

Limitations and Future Research

Although we handled our research with great care, this study has several limitations. First, beyond the factors that we included in our conceptual model, there may be other factors that determine the speed of first research transfers. We encourage scholars to further enrich our conceptual framework by studying additional determinants of transfer speed, such as the potential role of internal partnerships between research projects and business units. Research projects that have strong internal links to (multiple) business units may be better positioned to find recipients for their research results and therefore to speed up research transfers.

Second, our dataset does not allow us to gain insights on the identity of external partners of research projects. This limitation prevents us from performing a more fine-grained analysis on the role of R&D partnerships in speeding up transfers and from including measures on the quality of partner involvement. We believe that splitting R&D partnerships into more finely grained categories will help to further improve our understanding on the role of R&D partnerships. Further, we encourage future studies to explore the interplay of market-based and science-based partnerships with respect to transfer speed. Of special interest is the question whether both types of

R&D partnerships act as complements or substitutes to each other. Finally, it may be interesting to check to what extent our results hold across different firms and industries than our sample firm.

References

Allen, F., and G. Faulhaber. 1988. Optimism invites deception. *The Quarterly Journal of Economics* 103 (2): 397–407.

Almeida, P., J. Song, and R. Grant. 2002. Are firms superior to alliances and markets? An empirical test of cross-border knowledge building. *Organization Science* 13 (2): 147–61.

Argyres, N. S., and B. S. Silverman. 2004. R&D, organization structure, and the development of corporate technological knowledge. *Strategic Management Journal* 25 (8–9): 929–58.

Arora, A., and M. Ceccagnoli. 2006. Patent protection, complementary assets, and firms' incentives for technology licensing. *Management Science* 52 (2): 293–308.

Arora, A., M. Ceccagnoli, and W. M. Cohen. 2008. R&D and the patent premium. *International Journal of Industrial Organization* 26 (5): 1153–79.

Barczak, G., A. Griffin, and K. B. Kahn. 2009. Perspective: Trends and drivers of success in NPD practices: Results of the 2003 PDMA best practices study. *Journal of Product Innovation Management* 26 (1): 3–23.

Belderbos, R., B. Leten, and S. Suzuki. 2013. How global is R&D? Firm-level determinants of home-country bias in R&D. *Journal of International Business Studies* 44 (8): 765–86.

Blossfeld, H. P., K. Golsch, and G. Rohwer. 2007. *Event history analysis with Stata*. Mahwah, NJ: Taylor & Francis.

Brown, S., and K. Eisenhardt. 1995. Product development: Past research, present findings, and future directions. *Academy of Management Review* 20 (2): 343–78.

Brusoni, S., A. Prencipe, and K. Pavitt. 2001. Knowledge specialization, organizational coupling, and the boundaries of the firm: Why do firms know more than they make? *Administrative Science Quarterly* 46 (4): 597–621.

Bstieler, L., and M. Hemmert. 2010. Increasing learning and time efficiency in interorganizational new product development teams. *Journal of Product Innovation Management* 27 (4): 485–99.

Cankurtaran, P., F. Langerak, and A. Griffin. 2013. Consequences of new product development speed: A meta-analysis. *Journal of Product Innovation Management* 30 (3): 465–86.

Carbonell, P., and A. I. Rodriguez. 2006. Designing teams for speedy product development: The moderating effect of technological complexity. *Journal of Business Research* 59 (2): 225–32.

Castellion, G., and S. K. Markham. 2013. Perspective: New product failure rates: Influence of argumentum ad populum and felf-interest. *Journal of Product Innovation Management* 30 (5): 976–79.

Chen, J. Y., F. Damanpour, and R. R. Reilly. 2010. Understanding antecedents of new product development speed: A meta-analysis. *Journal of Operations Management* 28 (1): 17–33.

Chesbrough, H. 2003. *Open innovation: The new imperative for creating and profiting from technology*. Boston, MA: Harvard Business School Press.

Chesbrough, H. 2006. *Open business models: How to thrive in the new innovation landscape*. Boston, MA: Harvard Business School Press.

Chesbrough, H., W. Vanhaverbeke, and J. West, eds. 2006. *Open innovation: Researching a new paradigm*. Oxford: Oxford University Press.

Chesbrough, H., W. Vanhaverbeke, and J. West, eds. 2014. *New frontiers in open innovation*. Oxford: Oxford University Press.

Chidamber, S. R., and H. B. Kon. 1994. A research retrospective of innovation inception and success: The technology-push, demand-pull question. *International Journal of Technology Management* 9 (1): 94–112.

Clift, T. B., and M. B. Vandenbosch. 1999. Project complexity and efforts to reduce product development cycle time. *Journal of Business Research* 45 (2): 187–98.

Cockburn, I. M., and R. M. Henderson. 1998. Absorptive capacity, coauthoring behavior, and the organization of research in drug discovery. *The Journal of Industrial Economics* 46 (2): 157–82.

Cohen, W. M., R. R. Nelson, and J. P. Walsh. 2000. *Protecting their intellectual assets: Appropriability conditions and why US manufacturing firms patent (or not)*. Cambridge, MA: National Bureau of Economic Research.

Cooper, R. G. 2008. Perspective: The Stage-Gate® idea-to-launch process—Update, what's new, and NexGen systems. *Journal of Product Innovation Management* 25 (3): 213–32.

Cooper, R. G., and S. J. Edgett. 2009. *Generating breakthrough new product ideas: Feeding the innovation funnel*. Product Development Institute.

Cooper, R. G., and S. J. Edgett. 2012. Best practices in the idea-to-launch process and its governance. *Research Technology Management* 55 (2): 43–54.

Cooper, R. G., S. J. Edgett, and E. J. Kleinschmidt. 2004. Benchmarking best NPD practices. *Research Technology Management* 47 (3): 31–43.

Cox, D. 1972. Regression models and life tables. *Journal of the Royal Statistical Society, Series B (Methodological)* 34 (2): 187–220.

Danneels, E. 2002. The dynamics of product innovation and firm competences. *Strategic Management Journal* 23 (12): 1095–121.

de Brentani, U., and S. E. Reid. 2012. The fuzzy front-end of discontinuous innovation: Insights for research and management. *Journal of Product Innovation Management* 29 (1): 70–87.

Dougherty, D. 1992. Interpretative barriers to successful product innovation in large firms. *Organization Science* 3 (2): 179–202.

Du, J., B. Leten, and W. Vanhaverbeke. 2014. Managing open innovation projects with science-based and market-based partners. *Research Policy* 43 (5): 828–40.

Eling, K., F. Langerak, and A. Griffin. 2013. A stage-wise approach to exploring performance effects of cycle time reduction. *Journal of Product Innovation Management* 30 (4): 626–41.

Fabrizio, K. R. 2009. Absorptive capacity and the search for innovation. *Research Policy* 38 (2): 255–67.

Faems, D., B. Van Looy, and K. Debackere. 2005. Interorganizational collaboration and innovation: Toward a portfolio approach. *Journal of Product Innovation Management* 22 (3): 238–50.

Fleming, L., and O. Sorenson. 2004. Science as a map in technological search. *Strategic Management Journal* 25 (8–9): 909–28.

Geanakoplos, J., and P. Milgrom. 1991. A theory of hierarchies based on limited managerial attention. *Journal of the Japanese and International Economies* 5 (3): 205–25.

Grant, R. M., and C. Baden-Fuller. 2004. A knowledge accessing theory of strategic alliances. *Journal of Management Studies* 41 (1): 61–84.

Griffin, A. 1993. Metrics for measuring product development cycle time. *Journal of Product Innovation Management* 10 (2): 112–25.

Griffin, A. 1997. The effect of project and process characteristics on product development cycle time. *Journal of Marketing Research* 34 (1): 24–35.

Gulati, R. 1998. Alliances and networks. *Strategic Management Journal* 19 (4): 293–317.

Hagedoorn, J. 1993. Understanding the rationale of strategic technology partnering: Inter-organizational modes of cooperation and sectoral differences. *Strategic Management Journal* 14 (5): 371–85.

Hall, B. H., A. Jaffe, and M. Trajtenberg. 2005. Market value and patent citations. *The Rand Journal of Economics* 36 (1): 16–38.

Hall, B. H., A. N. Link, and J. T. Scott. 2003. Universities as research partners. *The Review of Economics and Statistics* 85 (2): 485–91.

Harhoff, D., and M. Reitzig. 2004. Determinants of opposition against EPO patent grants—The case of biotechnology and pharmaceuticals. *International Journal of Industrial Organization* 22 (4): 443–80.

Harhoff, D., and S. Wagner. 2009. The duration of patent examination at the European patent office. *Management Science* 55 (12): 1969–84.

Harrison, D., and A. Waluszewski. 2008. The development of a user network as a way to re-launch an unwanted product. *Research Policy* 37 (1): 115–30.

Henderson, R., and K. Clark. 1990. Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. *Administrative Science Quarterly* 35 (1): 9–30.

Huber, F. 2012. On the role and interrelationship of spatial, social and cognitive proximity: Personal knowledge relationships of R&D workers in the Cambridge information technology cluster. *Regional Studies* 46 (9): 1169–82.

Kahn, K. B., G. Castellion, and A. Griffin. 2005. *The PDMA handbook of new product development*. Hoboken, NJ: John Wiley & Sons, Inc.

Kessler, E. H., and A. K. Chakrabarti. 1999. Speeding up the pace of new product development. *Journal of Product Innovation Management* 16 (3): 231–47.

Knudsen, M., and T. Mortensen. 2011. Some immediate—but negative—effects of openness on product development performance. *Technovation* 31 (1): 54–64.

Kogut, B., and U. Zander. 1993. Knowledge of the firm and the evolutionary theory of the multinational corporation. *Journal of International Business Studies* 24 (4): 625–45.

Kotabe, M. 1992. *Global sourcing strategy: R&D, manufacturing, and marketing interfaces*. Westport, CT: Quorum Books.

Kultti, K., T. Takalo, and J. Toikka. 2007. Secrecy versus patenting. *The Rand Journal of Economics* 38 (1): 22–42.

Langerak, F., and E. J. Hultink. 2006. The impact of product innovativeness on the link between development speed and new product profitability. *Journal of Product Innovation Management* 23 (3): 203–14.

Laursen, K., and A. Salter. 2006. Open for innovation: The role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal* 27 (2): 131–50.

Leten, B., W. Vanhaverbeke, N. Roijakkers, A. Clerix, and J. Van Helleputte. 2013. IP models to orchestrate innovation ecosystems: IMEC, a public research institute in nano-electronics. *California Management Review* 55 (4): 51–64.

Lorange, P., J. Roos, and P. S. Brønn. 1992. Building successful strategic alliances. *Long Range Planning* 25 (6): 10–17.

Markham, S. K. 2013. The impact of front-end innovation activities on product performance. *Journal of Product Innovation Management* 30 (S1): 77–92.

Mowery, D. C. 1998. The changing structure of the US national innovation system: Implications for international conflict on cooperation and R&D. *Research Policy* 27: 639–54.

Narula, R., and J. Hagedoorn. 1999. Innovating through strategic alliances: Moving towards international partnerships and contractual agreements. *Technovation* 19 (5): 283–94.

Nonaka, I. 1994. A dynamic theory of organizational knowledge creation. *Organization Science* 5 (1): 14–37.

OECD. 2009. *OECD patent statistics manual*. Paris: OECD Publishing.

Paul, S. M., D. S. Mytelka, C. T. Dunwiddie, C. C. Persinger, B. H. Munos, S. R. Lindborg, and A. L. Schacht. 2010. How to improve R&D productivity: The pharmaceutical industry's grand challenge. *Nature Reviews Drug Discovery* 9 (3): 203–14.

Rosenberg, N. 1990. Why do firms do basic research (with their own money)? *Research Policy* 19 (2): 165–74.

Rotemberg, J. J. 1991. A theory of inefficient intrafirm transactions. *The American Economic Review* 81 (1): 191–209.

Rothaermel, F. T., and D. L. Deeds. 2006. Alliance type, alliance experience and alliance management capability in high-technology ventures. *Journal of Business Venturing* 21 (4): 429–60.

Rycroft, R. W., and D. E. Kash. 1999. *The complexity challenge: Technological innovation for the 21st century*. New York: Pinter.

Schilling, M. A., and C. W. L. Hill. 1998. Managing the new product development process: Strategic imperatives. *Academy of Management Executive* 12 (3): 67–81.

Schoonhoven, C. B., K. Eisenhardt, and K. Lyman. 1990. Speeding products to market: Waiting time to first product introduction in new firms. *Administrative Science Quarterly* 35 (1): 177–207.

Swink, M., S. Talluri, and T. Pandejpong. 2006. Faster, better, cheaper: A study of NPD project efficiency and performance tradeoffs. *Journal of Operations Management* 24 (5): 542–62.

Tao, J., and V. Magnotta. 2006. How air products and chemicals "identifies and accelerates. *Research Technology Management* 49 (5): 12–8.

Ulwick, A. W. 2002. Turn customer input into innovation. *Harvard Business Review* 80 (1): 91–97.

Vanhaverbeke, W., J. Du, B. Leten, and F. Aalders. 2014. Exploring open innovation at the level of R&D projects. In *New frontiers in open innovation*, ed. H. Chesbrough, W. Vanhaverbeke, and J. West, 115–31. Oxford: Oxford University Press.

von Hippel, E. 1986. Lead users: A source of novel product concepts. *Management Science* 32 (7): 791–805.

von Hippel, E., and R. Katz. 2002. Shifting innovation to users via toolkits. *Management Science* 48 (7): 821–33.

von Zedtwitz, M., and O. Gassmann. 2002. Market versus technology drive in R&D internationalization: Four different patterns of managing research and development. *Research Policy* 31 (4): 569–88.

Woodruff, R. B. 1997. Customer value: The next source for competitive advantage. *Journal of the Academy of Marketing Science* 25 (2): 139–53.

Zander, U., and B. Kogut. 1995. Knowledge and the speed of the transfer and imitation of organizational capabilities: An empirical test. *Organization Science* 6 (1): 76–92.

Appendix A. Descriptive Statistics and Correlations (Cox Regressions: Monthly Records)

	Mean	S.D.	1	2	3	4	5	6	7	8	9
1. Market-based partners	0.608	0.488	1.000								
2. Science-based partners	0.693	0.461	0.245	1.000							
3. Technological complexity (75 percentile)	0.219	0.414	–0.036	0.068	1.000						
4. Sponsor department	0.582	0.493	–0.155	0.053	0.016	1.000					
5. Number of patent applications	0.890	4.738	0.040	0.058	0.007	–0.042	1.000				
6. Firm patent stock	5.771	2.120	0.026	–0.075	–0.145	–0.010	0.008	1.000			
7. Project resources	1.892	0.595	0.243	0.282	0.034	0.020	0.230	0.017	1.000		
8. Project management formality	3.956	0.824	0.146	–0.016	0.001	–0.200	0.028	–0.013	0.068	1.000	
9. # Projects under management	3.298	0.804	0.050	0.142	0.013	–0.036	0.013	–0.207	0.223	–0.053	1.000

(n = 13,308).

Appendix B. Descriptive Statistics and Correlations (Heckman Two-Step: Transferred Projects)

	Mean	S.D.	1	2	3	4	5	6	7
1. Total # of transfers	3.594	4.074	1.000						
2. # Months to transfer	16.19	10.52	–0.215	1.000					
3. Length of the project	44.95	20.01	0.297	0.311	1.000				
4. Project management formality	4.087	0.740	0.156	0.168	0.127	1.000			
5. Firm patent stock	6.260	1.934	0.162	–0.098	0.082	0.075	1.000		
6. Project resources	1.451	0.392	0.154	–0.030	–0.087	0.125	0.078	1.000	
7. # Projects under management	3.307	0.742	–0.235	0.210	–0.370	0.066	–0.167	0.130	1.000

(n = 170).