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Does open innovation speeds up R&D projects? Empirical evidence from a Multinational Enterprise

Henry Lopez Vega
Linköping University
Management and Engineering
henry.lopez.vega@liu.se

Jingshu Du
Vlerick Business School
Technology and Operations Management Area
jingshu.du@vlerick.com

Wim Vanhaverbeke
Hasselt University
Department of Business Studies
wim.vanhaverbeke@uhasselt.be

Abstract

Open innovation has become an alternative framework to study how firms benefit from opening their boundaries and enable inflows and outflows of knowledge. Yet there is insufficient understanding of the factors that explain and predict differences in innovation speed when collaborating with external scientific and market partners. This paper is to our knowledge the first study presenting an empirical analysis about innovation speed of open and closed innovation at the project level. Our analysis reveals that open innovation speeds up innovation projects and it is particularly relevant with market-based partners, rather than with science-based partners. Contradictory to our expectation, we find that projects that are with high technical capabilities are more efficient in their innovation process from their collaborations with partners, instead, R&D partnerships seem to slow down project innovations in firms? technologically advanced fields. When separating different types of partners, we find that projects that have a high level of technical strength speed up their innovation process when collaborating with science-based partners, while such technically-strong projects are prone to delay if collaborating with market-based partners. Finally, the findings suggest that there is an inverted U-shaped relationship between innovation speed (in product R&D phase) and project performance (measured by project financials). All these contributions have implications for R&D units, project managers and numerous academic

communities.

Keywords: Open innovation, innovation speed, innovation performance, market-based partners, science-based partners

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Does open innovation speeds up R&D projects?

Empirical evidence from a Multinational Enterprise

1. Introduction

Chesbrough (2006) explains that “open innovation is the purposive use of inflows and outflows of knowledge to accelerate internal innovation ... (and) assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology”. Until now, in the light of more research on the benefits of open innovation and external knowledge acquisition (Cassiman & Veugelers, 2006; Dahlander & Gann, 2010), a large project level study of open innovation speed is necessary to confirm when inflows of external knowledge speed up innovation projects (Praest Knudsen & Bøtker Mortensen, 2011). It would be naïve to accept open innovation consistently accelerates internal innovation due to the number of findings making reference to inhibitors such as knowledge integration and stickiness, coordination costs (Kessler & Chakrabarti, 1999; Leiponen & Helfat, 2010; Von Hippel, 1994). Similarly, numerous scholars have highlighted the strategic relevance of innovation speed (Eisenhardt & Martin, 2000; Kessler & Bierly, 2002) on internal product development (Chen, Damanpour, & Reilly, 2010; Eisenhardt & Tabrizi, 1995), market internationalization (Ramos, Acedo, & Gonzalez, 2011), R&D commercialization (Carbonell & Rodriguez-Escudero, 2009; Eisenhardt, 1989) and market share and revenues (Kessler & Chakrabarti, 1999; Lieberman & Montgomery, 1998). Gains in innovation speed, however, require firms to facilitate operations, engage in forward-looking debates and decentralize business units (Tushman & O'Reilly III, 1996).

Three features further challenge existing speed-related studies.

First, recent evidence shows that in several industries, there is a growing trend of separating products' upstream activities such as R&D, and their downstream activities such as manufacturing and production (Gassman and von Zedtwitz, 2002). However, in the existing literature, the majority of studies mainly explore the speed of firms' overall operational activities (Kessler and Chakrabarti, 1996; Griffin, 1997) and focus on the product development speed across all phases of the product operational process (e.g.: Griffin, 1993; Zirger and Maidique, 1990). Second, not only there is a need to better understand innovation speed, but perhaps more importantly, there is also a need to examine other 'untraditional' factors which may influence speed in product R&D phase. In their day-to-day operations,

projects do not only interact with departments within the firm, but also with partners outside the firm (Pisano, 1990; Cassiman et al., 2010). Third, regarding to the effect of innovation speed, so far, a variety of effects of speed on product performance have been found: a positive and stable linear effect (Droge et al.,2004; Goktan and Miles, 2000), a positive but diminishing effect, a curvilinear effect (Kessler and Bierly, 2002), or the mixture of both a linear and a curvilinear effect, depending on different scenarios (Chen et al., 2010). Particularly, the link between speed in *the R&D phase* of product development and project performance is still missing.

This study seeks to address the above-mentioned three research questions. To examine these questions, a large dataset with 558 R&D projects from a multi-divisional Global 100 manufacturing company is employed in this study. We test the effect of R&D collaborations on project innovation speed in its R&D phase. More specifically, we distinguish between two types of partners, namely, market-based partners and science-based partners, and compare their effect on project innovation speed. We further introduce *project technical strength* as a moderating variable on the contingency effect of the different types of partners. Finally, we investigate the effect of project innovation speed (in its R&D phase) and project performance. Our findings show that, being open to external partners generally pays off for accelerating project innovation speed, but the positive effect comes from collaborating with market-based partners, rather than from partnering with science-based partners. Moreover, we find that projects will accelerate their innovations more if have already possessed some levels of technical capabilities. Finally, the findings suggest that there is an inverted U-shaped relationship between innovation speed (in product R&D phase) and project performance (measured by project financials).

2. Background Literature

2.1 Innovation Speed

Innovation speed is understood as the “(a) initial development, including the conceptualization and definition of an innovation, and (b) ultimate commercialization, which is the introduction of a new product into the market place (Kessler & Chakrabarti, 1996)”. It has become a cornerstone for firms innovation strategy (Eisenhardt & Martin, 2000; Kessler & Bierly, 2002) as it benefits a) faster internal product development (Chen et al., 2010; Eisenhardt & Tabrizi, 1995); and b) market internationalization (Ramos et al., 2011). The

New Product Development (NPD) literature studied the specific strategic, project, process and team characteristics and environmental activities to speed up innovation processes and increase competitive advantage (Chen et al., 2010; Henard & Szymanski, 2001; Pattikawa, Verwaal, & Commandeur, 2006). Only limited research, however, investigated whether external partners could speed up the innovation process and creates larger market profit (Chen et al., 2010; Kessler & Chakrabarti, 1996; Stalk Jr, 1988; Vesey, 1992). For example, the NPD literature informs that early integration of suppliers increases quicker reaction to market opportunities, and development time, reduces manufacturing cost and improves quality and financial performance (Langerak & Hultink, 2005; Schiele, 2010).

So far, studies on innovation speed typically examine the overall process of product development, and investigate a wide array of factors that differentiate faster from slower innovation processes (e.g.: Griffin, 1997; Millson et al., 1992; Chen et al., 2010; Kessler and Chakrabarti, 1996; Menon et al., 2002; Filippini et al., 2004; Karagozoglu and Brown, 1993; Langerak and Hultink, 2008). In general, two major sets of factors have been proposed in the new product development literature as critical in influencing project innovation speed: 1) characteristics of the product team and its parent firm (in most cases are *within* the organization), and 2) Connections and transitions from one phase to the other in product development.

The first sets of factors are mainly concerned with the capability, strategy, and organization of the product development team and its parent firm. Critical factors such as team member and leader capability, shorter and longer tenure among team members (Kessler and Chakrabarti, 1999), team leadership style (McDonough and Barczak, 1991), team member motivation (Zirger and Hartley, 1994), incentives (Menon et al., 2002), upper management support (McDonough and Spital, 1984; Gupta and Wilemon, 1990), strategic orientation of the firm, clear time goals and delineation of product specifications (McDonough and Spital, 1984), emphasis on speed, strict planning and monitoring (Cooper et al., 2004), organizational culture (Menon et al., 2002), as well as organizational capability (staffing and structuring) (e.g.: Griffin, 1993 & 1997; Kessler and Chakrabarti, 1996 & 1999) have been investigated in a number of studies. Second, a number of techniques have been proposed to smoothen the transition from one phase to another, such as the adoption of R&D-marketing interfaces (Barczak et al., 2009; Griffin and Page, 1993), cross-functional teams (Song and Parry, 1996; Zirger and Hartley, 1994), etc. As in this paper we only research innovation speed in one

particular phase of product development, being the *R&D phase*, we will not detail the transitions between multiple phases at length.

Besides these two sets of factors, prior studies have pointed out that the speed at which a product is developed, is also affected by a number of moderating factors, such as project characteristics, product complexity (Zirger and Hartley, 1994), product innovativeness (Langerak and Hultink, 1996), and environmental (un)certainty (Kessler and Bierly, 2002; Cabonell and Rodriguez-Escudero, 2009). Consequently, besides the absolute time measure, a number of relative speed measures have been proposed in the NPD literature. For instance, speed relative to schedule, or “on-time performance” (McDonough and Barczak, 1991), speed relative to similar, previously completed projects in one’s organization (e.g.: Gupta and Wilemon, 1990; Millson et al., 1992; Zirger and Hartley, 1994), and speed relative to similar projects of competitors (e.g.: Stalk and Hout, 1990; Vesey, 1992). The basic idea is to compare innovation speed of projects with similar nature, instead of overly emphasize the absolute time each project takes to develop its products.

2.2 R&D partnerships and innovation speed

Open innovation research classifies external partners into scientific and market related partners. First, scientific partners range from universities, research centres, knowledge institutes (Cockburn & Henderson, 1998) to governmental research agencies (van Lente, Hekkert, Smits, & van Waveren, 2003). This type of partners provide firms with: a) access to scientific knowledge i.e. patents, research outputs, scientific cooperation (Narin, Hamilton, & Olivastro, 1997); b) opportunities to create patents and commercialize new technologies (Zucker, Darby, & Armstrong, 2002); c) support and validation from qualified scientific personnel i.e. consultancy (Cohen, Nelson, & Walsh, 2002); d) higher innovative performance and outputs (Pekermann & Walsh, 2007); e) benefit from scientific networks (Zucker et al., 2002); and f) reduce the cost of in-house R&D (Cassiman & Veugelers, 2006). Collaboration with scientific partners gives firms the advantage to better identify, understand and access external knowledge and advance internal technologies. Also, it is argued that consultancy services, offered by scientific partners, help firms to faster identify, solve technical problems as well as ensure the validity of the technology under development (Cockburn & Henderson, 1998).

Second, collaboration with market partners allows to access a) latest market knowledge; b) assistance in market preparation; and c) applicable knowledge that is predominantly available

at firm's customers, high-tech start-ups, SMEs or other value chain partners. Market partners are not only firms' primary external source of technology (Cohen et al., 2002) but also these help firms to quickly re-distribute resources along the value chain (Chesbrough 2003 p. 40) and represent a largely untapped source of creativity and offer considerable promise for the initiation of innovation. Recent evidence indicates that market partners might, by exposing a firm to consumer trends and sensitizing it to external developments, enhance firms' ability to utilize external knowledge in the pursuit of innovations (Alcacer & Chung, 2007). Besides the insights market partners provide, they also allow receiving other kinds of external knowledge as they have a clearer focus on which technology customers need.

2.3 Innovation speed and project performance

A faster innovation speed is generally considered as desirable for innovative firms, and it is regarded as beneficial for achieving better project performance (Kessler and Chakrabarti, 1996). A study from McKinsey & Company of hi-tech products found that new products that come to market six months late, but on-budget, earn 33% less profit than if they were on time, while new products which come to market on-time, but 50% over budget, earn only 4% less profit than if they were on budget (McKinsey & Co., 1983). A more recent study based on financial modeling shows that 12 months, 9 months, and 6 months reduction in time to market increases internal rate of return (IRR) by approximately 92%, 63%, and 39%, respectively, and these relationships are, for the most part, unaffected by changes in other variables including product life or product profitability (Douglass, 2011). With regard to market share, speed can help establish early segments and customer loyalty, gain first-mover advantage, as well as enjoy a wider range of strategic choices compared to slower innovators (Griffin, 1993; Kessler and Chakrabarti, 1996; Zirger and Hartley, 1994). However, recent studies have also cast doubts on a (overly) speedy innovation process (Swink et al., 2003), as there may be potential tradeoffs between respective pairs of NPD performance outcomes: speed-quality (Calantone and Di Benedetto, 2000; Harter et al., 2000); time-cost (Graves, 1989; Mansfield, 1988); and time-quality (Karlsson and Ahlstrom, 1999).

As such, it is questionable whether speed is "too much of a good thing" (Chen et al., 2008), and some previous studies reveal that speedy development is not universally welcome (Kessler and Chakrabarti, 1996). In line with the above-mentioned aspects, it is argued that speed is not universally appropriate in each industrial context. Firms must carefully determine the need for speed for different innovations within different task and regulatory environments

before blindly pursuing faster development (Kessler and Chakrabarti, 1996). Speed leads to success primarily in more predictable contexts, which suggests that a fast-paced innovation strategy is best when “you know where you’re going” (Kessler and Bierly, 2002).

Empirical studies on this topic have so far generated mixed results. While Goktan and Miles (2011) found a significant positive relationship between radical product innovation development and innovation speed, Chen et al. (2010), Langerak and Hultink (1996) both found a curvilinear effect of speed on product performance, contingent on environmental certainty and product innovativeness. In a general remark, it is suggested that “more contingencies should be explored” (Kessler and Chakrabarti, 1996). In particular, the effect of speed with external partnerships on project performance has not been well understood.

3. Hypotheses

3.1 Open Innovation and Project Innovation Speed

Innovation speed is one of the most important aspects of R&D project performance (Page, 1993 Griffin, 1997; Barczak et al., 2009)¹. We argue that speed can be accelerated when a project team collaborates with external partners. First, partnerships allow the project to partition tasks among partners and benefit from a “division of labour”. Research on the modularity of products (Brusoni and Prencipe, 2001) and architectural innovations (Henderson and Clark, 1990) suggest that innovations often can be disentangled into multiple components. Working in parallel on different components can reduce project development time. However, constrained by resource limitation of the firm (Griffin, 1997; PDMA, 2008; Baczark, 2009), it may be difficult for the project to obtain all the resources within the firm to work on all the components simultaneously. In contrast, when collaborating with partners, a project team can leverage the resources of its partners. This, in turn, may shorten project development time by pooling resources together and dividing project tasks among partners. Moreover, R&D partnerships also help to leverage partners’ expertise in particular technology fields. As products get increasingly complex and usually involve technologies from multiple disciplines (Rycroft and Kash, 1999; Brusoni and Prencipe, 2000), it is difficult for a firm to develop all the required expertise in-house. The “division of labour” concept suggests that

¹ There are also some contradictory arguments against fast NPD process, such as “first mover disadvantage” (Lieberman & Montgomery, 1988), “power of imitation” (Bolton, 1993), or “fast follower advantage”, despite these arguments, here we stick to the main stream that it is beneficial to develop a *good* product *faster*.

work can be done faster if it is split in different pieces, which are handled by specialists in each particular (technical) field, preferably in a parallel manner.

Furthermore, working together with external partners speeds up the innovation process by gaining and leveraging ready-to-use knowledge and technology. Slow innovators “reinvent the wheel” (Deschamps and Nayak, 1992) instead of actively building on knowledge that already exists (Tao and Magnotta, 2006; Chesbrough, 2003). Faster project teams know how to build on existing knowledge and concentrate their efforts only on the crucial and not yet developed parts of their product. This enables them to save considerable amount of time in project development.

Last but not the least, R&D collaboration with external partners also helps to reduce the possibilities of rework and potential mistakes that may occur along the project process. As it is pointed out, a large portion of delays in product development stems from mistakes and rework (PDMA, 2005). Since new product development is probing into the unknown, timely feedbacks are necessary because they point out ways for improvement and adjustment before substantial reworks take place. When the project is exclusively composed of team members internal to the firm, the project team may concentrate on its own way of working without being aware of the mistakes it has made, or the potential risks it may encounter. On the contrary, if external partners are involved in the process, the project is exposed to external scrutinize and different perceptions, therefore timely solutions as well as feedbacks can be (more easily) obtained, which, in turn, reduce chances of rework and shortens innovation time. Therefore, we hypothesize:

H 1: R&D Partnerships accelerate the innovation speed of R&D projects.

Despite the potential benefits that R&D partnerships in open innovation networks may bring in terms of project speed, it is well-known that collaboration with external partners is not an easy task. The complex nature of collaborations, such as goal diversity among partners (Lorange and Roos, 1992), different working habits (Bstieler and Hemmert, 2010), distinct organizational culture and thought worlds (Dougherty, 1992), as well as considerable coordination and communication complexities along the collaboration process (Gulati, 1999; Rothaermel and Deeds, 2006), may all offset the potential benefits of external partnerships on project speed, or even make the development time longer. These factors, however, are likely to differ according to the type of partners that are involved in the partnership. Science-based

partners are claimed to lie their strength in long-term explorative-oriented research which is not readily transferred into new, commercial applications (Mowery, 1998; Harryson et al., 2008). Moreover, bureaucratic hierarchy, schedule inflexibility, as well as different rewarding systems of science-based partners (Mowery, 1998) may all hinder the efficiency of R&D partnerships. Frictions may arise resulting from different organization cultures and perceptions (Bstieler and Hemmert, 2010). Compared to science-based collaborations, the goal between the project team and its market-based partners are more easily to get aligned because market-based partners represent market needs, and the objective of the project is to come up with innovative ideas to meet these needs. Moreover, searching for the right target market, monitoring customer behaviour, as well as catering to up-to-date market preferences, all take considerable time if the project team is working on its own without a clear view what customers exactly wants. When partnering with market-based partners, the project team is equipped with up-to-date market information and customer preferences, which enable it to better target the market needs, more quickly detecting and responding to market trends, while adjust its product strategy along each development phase. Therefore, we hypothesize:

H2: Partnerships with market-based partners accelerate the innovation speed of R&D projects rather than partnerships with science-based partners.

Further, we consider the effect of R&D partnerships on project innovation speed is not as given, but is contingent on the technical strength of the project. In order to gain efficiency in product development via R&D partnerships, the project team needs to have a certain level of technical strength in place to be knowledgeable about the underlying “knowledge architecture” of the innovation that it’s going to develop. Only then the project team is able to appropriately divide the project into different parts, partition work among its partners and “monitor” their progress if needed. The technical strength of the project team also enables its (smooth) integration of different parts of the innovation in a timely fashion, and it can be leveraged if some partners fail to perform as expected. In contrast, when the project team has a relatively weak technology base, it may not have a thorough understanding of the “knowledge architecture” of the innovation it’s going to develop, or without an overarching reference in mind, it is possible that the project team will be simply running between different parts of the innovation, each is handled by a different partner. The innovation speed altogether has to be dependent on the progress of its slowest partner, which may have other priorities in its agenda.

In such case, instead of speeding up the innovation process, the chance of delay can be rather big.

Moreover, the problems of aligning different “thought worlds” (Leonard-Barton, 1992) and communicating between the project team and its external partners may be more pronounced if the technical capability of the project is not well in line with the type of partners it collaborates with. For instance, innovation process may be slower if projects that have a high level of technical capability (thus, more in the thought world of “science”) collaborate with market-based partners, or projects that have a low level of technical capability partner with science. Also, projects that have a relatively strong technical strength may have developed a higher level of absorptive capacity (Cohen and Levinthal, 1990) which enable them to better interact with their science-based partners and thus quicken the innovation process. While such technically-strong projects may be cautious when collaborating with their market-based partners because of a fear of unwanted knowledge leakage, which may, in turn, slow down the innovation process. In sum, we hypothesize:

H3: The effect of R&D partnerships on project innovation speed is contingent on the technical strength of the project team.

H4: Projects that are with a higher level of technical strength innovate faster when partnering with science-based partners, while slower when with market-based partners.

3.2 Project Innovation Speed and Project Performance

The ultimate goal of innovative companies is to generate a financial return. In this process, project speed may play an indispensable role to increase (or decrease) projects’ financials. There are a number of reasons to believe that a fast product innovation speed will benefit the firm financially. First, a major goal of product innovation is to detect and satisfy customer needs in a timely manner. Firms which are quick in responding to such needs may serve the market earlier than their competitors, establish product visibility, company brand and image, gain customer royalty, and benefit from “network effects”. Therefore, they may be able to enjoy first-mover advantages in the marketplace (Lieberman and Montgomery, 1988). Second, a fast product development may also help to reduce opportunity costs of product development. Because of the velocity of market needs and customer preferences (Eisenhardt and Martin, 2000), what the market wants today may no longer be the same tomorrow, particularly if

market trends switch or competitors come up with some new and better product offerings to address market needs. Therefore, firms which serve the market in a timely and efficient manner will be able to minimize their opportunity costs if the market trend changes during the innovation process of a new product. Last but not the least, a fast product innovation speed also helps quicken the pace of “metabolism” within the firm and release resources for better usage. The efficient usage of resources may reduce unnecessary product development costs, which may, in turn, increase potential revenues of the project.

However, an overly speedy product innovation process may be harmful to project financials. Prior studies point out that there are trade-offs in pairs of product performance dimensions (Swink et al., 2005). High speed in product development may imply that a project team skips (or combines) some intermediate development steps resulting in a product which has not a strong functionality or quality, and, therefore, is negatively influencing customer purchasing decisions (Cooper, 1979; Cooper and Kleinschmidt, 1987). Moreover, an overemphasis on speed may promote adoption of the standardized and formalized product development techniques (Harry and Schroder, 2000; Hackman and Wageman, 1995) such as adhering to documented systems and procedures, eliminating variations in processes and outputs, as well as standardization and generalizability across projects. As a result, it may rule out the possibilities of generating truly novel innovations, which in many cases have to experience several trials, errors, and drawbacks before they are ready, and require a much longer time to complete than those normal, routinized products. Therefore, combining the aforementioned arguments, we hypothesize:

H5: There is an inverted U-shaped curve relationship between project speed and the financial results of research projects.

4. Data and Sample

To test our hypotheses, we use a unique longitudinal dataset on the R&D projects that are conducted by a large multi-national multi-divisional European-based manufacturing company. This company has an annual R&D budget of more than 1.5 billion euros and is active in a variety of industries. This dataset contains detailed information on all research projects that have been initiated and executed in the company’s research labs during the year period 2003-2010. The company adopts a global R&D structure (von Zedtwitz and Gassmann, 2002) which is typical for large technology-based companies. Research is conducted in research

laboratories of the company; research projects can be initiated by either the Corporate central research lab or one of the corporate divisions. The research laboratories conduct research projects and transfer the finished projects to business units for further development and commercialization. This can be done either in the existing business lines of the firm, but the technology can also be licensed or transacted to a third party. The exact starting date and transfer date were carefully recorded for each project. Furthermore, each project is evaluated on a yearly basis from its start to termination (or to the current year if it is still running). From 2003 onwards, we have detailed information on R&D collaboration practices, management and performance of the research projects. After excluding the observations that have missing data, we have in total 558 project records. The most important indicator for the current study is collaboration with science-based as well as market-based external partners. The dataset also includes yearly information about the number of full time equivalent researchers (“FTE”), the business unit which is the recipient of the research project, as well as project management maturity (PMM) which represents management proficiency of the project.

4.1 Dependent Variables

Project Innovation Speed. Following the definition of speed as the rate at which a product is transformed from an idea to a *marketable* entity (Stalk and Hout, 1990; Kessler and Chakrabarti, 1996), we use the elapsed time from the start of the research project to its transfer as our measure of innovation speed. As mentioned before, along the R&D phase, a project may generate multiple transfers; therefore, one project can be linked to different innovation speeds. Consequently, we use two types of innovation speed in this study: the elapsed time from project start to its first transfer, and the multiple elapsed time to project’s different transfers (each transfer is considered as an event in the regression model. More details will follow in the methodology session). We will discuss the technique in more details in the methodology section.

Project Financial Performance. We use the financial revenue that is captured by the focal project team as project financial performance. Moreover, we take into account of revenues from both internal and external paths to market (e.g.: existing BGs, licensing, IP transaction, etc.). Of the 558 projects, in total there are 41 projects (8.1%) generated financial revenues.

4.2 R&D Collaboration Variables

We make a distinction between different types of research projects by categorizing them into three categories based on the type of external partners they collaborate with: science-based partnership projects, market-based partnership projects, and closed projects. Closed innovation projects are those that do not collaborate with any partner in the R&D project. We assume that once the collaboration takes place, the effect remains for the following years. Therefore, collaboration with science-based and / or market-based partners is captured by cumulative variables. More specifically, a collaboration variable gets a value of 1 if collaboration (with the particular type of partner) took place in at least one of the previous years.

Science-based Partnerships. Following prior studies, we define science-based partners as partners that are science-oriented such as universities and research institutions (Faems et al., 2005; Danneels, 2002; Deeds and Rothaermel, 2006). This is a 0/1 variable that takes a value “1” when during a research project the company collaborates with science-based partners in one of the previous years or in the current year.

Market-based Partnerships. Market-based partnerships denote the other type of external partnership which is more market-oriented. A market-based partnership implies that the project team collaborates with market-based partners such as customers, users, communities, or suppliers² during its lifetime. In line with the science-based collaboration variable, this is a dummy variable with value “1” if the project team collaborates with market-based partners in the current year or in any of the previous years, and “0” otherwise.

4.3 Control Variables

We use a range of control variables for the possible confounding effect.

Project Resources. We use the number of full time equivalent researchers (FTE) working on a R&D project as a proxy of project size and internal resource endowment. This information is available on a yearly basis. In line with the R&D collaboration variables, this variable is calculated as a cumulated variable over the past years. Moreover, this variable is highly correlated with project costs, and thus we use it as an alternative to the cost of the project.

² The “horizontal” type of partners, such as competitors are labelled as either market-based collaboration or technology-based collaboration according to the type of knowledge they provide in the innovation process. However, this type of collaboration is seldom adopted by research projects in our sample.

Project Technological Fields. We use a set of dummy variables to denote the technology fields in which R&D projects are executed. We have followed a two-step process to classify R&D projects into technological fields. First, for projects that have made patent applications, we use the technology class information on the patent applications. If a patent contains multiple technology classes (IPC4-digit level), a project is assigned to multiple fields. Second, the remaining projects are assigned manually to IPC technology classes by using information on the project content from the project titles and descriptions. To reduce the probability on misclassifications, we work at the level of IPC 4-digit classes. Technology classes with a low number of projects in our sample are grouped together in a rest category.

Project Technical Strength (Firm Patent Stock). This variable represents the technological strength of the company in the technology fields that are relevant for the R&D project. It measures to what extent the company has a strong technical expertise in the technological field(s) of the R&D project. These competences are expected to be (at least partly) accessible to the project team. This variable represents the previous 5-year patent stock of a project, which is measured based on the total number of the relevant 4-digit IPC code (5 years prior to the project year) of the patent applications the firm has made in EPO. The technological fields of a project are identified based on its 4-digit IPC code of the firm's patent stock. We have collected patent data for the sample firm at the consolidated level, including both the parent firm and their majority-owned subsidiaries. The consolidation was done on a yearly basis (2003-2010) to take into account changes in the firm group structure due to acquisitions, mergers, green-field investments, spin-offs and divestments. Based on the technological fields of each research project, we extracted the relevant patent stock in the same technological fields of the firm five years prior to project origination. We also calculated previous 3 years and 10 years patent stock as robustness checks.

Project Management. It is argued that successful projects are the ones that have implemented stage-gate processes in a more systematic way than the rest (Cooper, 1990; Kahn et al., 2006; Griffin, 1997). Following previous studies, in this paper we introduce the variable "project management maturity" (PMM) indicating to which extent the projects has followed a formalized management process. This indicator is evaluated on a yearly basis with a scale from 0 to 5.

of Projects Under Management. The more projects a project leader is actively managing, the less time and energy he may devote to each individual project, which may affect project

outcomes. Projects that receive more attention from their project manager may enjoy timely feedback, and receive more managerial support, and be ultimately more successful. In this study, we use number of projects that the project leader is managing concurrently during the project's life span as a proxy for (a possible lack of) managerial attention.

Corporate Research. In this study, research projects can be initiated from two types of sponsor units, i.e. corporate research, or the business groups which are in different business divisions. We control for the differences between project sponsors by adopting a dummy variable with value "1" representing a project initiated by corporate research, while "0" suggesting that a project is sponsored by business divisions.

Business Groups. Transfers are ordered by, and transferred to, business groups for further development. The preferences, capabilities, reputation, and experience of the business departments which order and commercialize the project results also affect the transfer and the final market success of the R&D project. To control for this, we add a set of 11 dummies that indicate which business departments have requested a transfer of project results.

Project Initiating Years. Finally, we control for the year in which the project started. The "project originating year" may signal the macroeconomic situations at a particular point in time, but it may also embody the effects of changes in corporate level strategy on the R&D projects. We use a range of dummy variables to control for effects related to specific external and internal conditions when R&D projects were initiated.

4.4 Methodology

Event History Analysis. We use event history analysis (also known as survival analysis) to investigate the innovation speed of R&D projects. Our research time window is 2003~2010, some projects may enter this time window earlier (left-hand truncation), some may end later (right-hand censoring), each at a different development pace. Event history analysis is known for its ability in dealing with left-hand truncation and right-hand censoring problems of time-related data (Blossfeld et al., 2007). Therefore, event history analysis techniques are chosen for our study. Further, because one project can generate several transfers to business units, we measure project innovation speed in two different ways: First, we look at how quickly a project is able to deliver its first transfer ("Time to first transfer"), regardless of whether it may deliver more transfers in a later stage. Thus, we measure innovation speed as the elapsed time from project start to its first transfer, once the first transfer is delivered, the project is

considered as has reached its goal and exit our dataset; Second, we take into account of all the transfer(s) a project generates (“Time to multiple transfers”), each transfer of the same project is regarded as an individual event, but altogether they are calculated as been spawn from the same project (more details see the description on “shared frailty” below). Thus, we also measure the elapsed time from project start to its multiple transfers. Compared to parametric models in survival analysis, the semi-parametric Cox model does not assume a specific shape of the survival curve. It thus allows for sufficient flexibility in the survival function, which has been mostly adopted by prior studies. Therefore, we adopt a Cox model as our main model in this analysis. Moreover, because each record of the same project shares a commonly unobservable random frailty, thus we add a shared frailty term (follows gamma distribution) to our analyses (Blossfeld et al., 2007). We also specify the exit time of those projects that have stopped before the end of our observation window, thus only the on-going projects and their transfers are calculated. In general, our 558 projects correspond to 1913 project-year observations, and 19531 project-month observations. Finally, for the development time of each project in our sample, we split it to monthly-recorded data. Because the same project may deliver several transfers in the same year, therefore using *year* as the basic observation unit may lose many valid “events” if they are all transferred in the same year (to model multiple events in survival analysis, each time point can only be corresponding to one event). To cope with this issue, we detail our observations at the month level instead of at the year level. In this way, project’s multiple transfers which took place in the same year are able to be preserved, and it also allows us to maximally preserve time-varying information along the project development process. We apply cox model with shared frailty among transfers that are generated from the same project. This then leads to 19531 project-month observations in our dataset.

Tobit Regressions. “Project financial impact” is a continuous variable truncated at 0. The Tobit model is chosen in preference to the more common least square regression because the dependent variable has a censored distribution (the lower threshold is 0 for the projects that do not generate any financial impact). Finally, because we operationalize on yearly data, we adopt the Tobit techniques on the yearly dataset.

5. Empirical Results

5.1 Descriptive Statistics

Table 1 gives an overview of the most important descriptive statistics. In general, the degree of openness of the firm is relatively high, with a mean of 0.8479, which corresponds to 482 projects (of the total 558 projects) in our sample. The degree of openness with respect to market-based partnerships is 0,669, while for science-based partnerships is a bit higher (0,706). The means of a firm's 5 year patent stock (log transformed) is 5,851, and each year there are on average 1,032 full time equivalent researchers working on the project. Project management proficiency is high, with an average score around 4 (out of 5) both for project monitoring. Corporate research initiates 45% of the project transfers. It takes a project on average 2 years to get transferred and there is 2,538 million euro per project year be delivered on average. However the deviation is rather high, as much as 36 million euros which shows the heterogeneous performance among the projects. The correlation among the independent variables is low. Moreover, based on the analysis results from variance inflation factor (Gujariti, 1995), the VIF scores are relatively low (mostly are around 1.5), therefore we do not have problems with multi-collinearity among the independent variables. The analysis results are shown in Table 2, Table 3, and Table 4. Table 2 presents the impact of R&D partnerships on projects' innovation speed, Table 3 shows the analysis result of project technical strength and its innovation speed with different types of partners. Finally, Table 4 shows the effect of project innovation speed on the financial revenues generated by R&D projects.

5.2 R&D Partnerships and Project Innovation Speed

Table 2 shows the relation between R&D partnerships and the speed of R&D projects. Closed innovation is the baseline model. Models 1-3 are Cox shared frailty analyses on the rate of time elapsed between the start of the project and its first transfer. Models 4-6 are Cox shared frailty analyses based on the rate of time elapsed between the start of the project and the different transfers (in case there is more than 1 transfer). All these models control for unobserved heterogeneity at the project level by adding a shared frailty term for each project. Endogeneity concerns are alleviated by shared frailty techniques and the set of time-varying control variables. Model 1 is the base model and only includes the control variables for project innovation speed to its first transfer. Positive and significant effects are found for project resources, project patent stock, as well as for project monitoring (Model 1). This

shows that projects that have more internal resources and large patent stocks generate a first transfer quicker than the other projects. Also, projects that are managed with regularly monitoring and review are generating transfers faster, while the opposite effect is found for projects initiated by corporate research department (Model 1). Model 2 introduces the open innovation variable. Collaborating with R&D partners has a positive effect; collaboration helps to accelerate project innovation speed (time to first transfer) by 68.9% ($=\exp(0.524)-1$) compared to projects where the company was not collaborating with partners. A similar effect is found for project's innovation speed to multiple transfers (Model 5), where implementing an open innovation strategy accelerates the project innovation speed (time to multiple transfers) even more with 74.5% ($=\exp(0.557)-1$). Both findings confirm hypothesis 1, i.e. that partnerships help to speed up project development process. Model 3 further differentiates between the two types of collaboration partners. A positive and significant coefficient is found for collaborating with market-based partners, which shows a speeding-up effect of the project by 54.0% ($=\exp(0.432)-1$). There is no effect for collaboration with science-based partners. A similar result is found in Model 6, where project innovation speed to multiple transfers is examined. This confirms hypothesis 2, which states that it is R&D collaboration with market-based partners, rather than collaboration with science-based partners, that helps to speed up the execution of R&D projects.

We then look at the possible contingency effect of project technical strength (measured by the previous 5-year patent stock of the mother firm in the project's technology field) on project innovation speed. Table 3 shows the result. As expected, projects that have a high level of technical strength speed up their innovation process when collaborating with science-based partners (Model 3, Model 4), while such technically-strong projects are prone to delay if collaborating with market-based partners (Model 2, Model 4). The finding also suggests that the positive effect of science-based partnerships on project innovation speed may be uncovered when the project team has already strong technical capability in place. While when such capability is missing or less developed, working with science-based partners may delay project innovation, instead of accelerating it.

Table 1. Descriptive Statistics and Correlations

	mean	s.d.	1	2	3	4	5	6	7	8	9	10	11
1. OpenInnovation	0,848	0,359	1,000										
2. Market-based Partners	0,669	0,471	0,575	1,000									
3. Science-based Partners	0,706	0,456	0,629	0,218	1,000								
4. (log)Project Patent Stock	5,851	2,028	-0,035	0,041	-0,001	1,000							
5. (log)Project Resources	1,032	0,603	-0,003	-0,022	0,052	0,010	1,000						
6. ProjectPlanning	3,989	0,878	0,082	0,160	0,027	0,063	0,027	1,000					
7. ProjectMonitoring&Review	4,041	0,747	0,079	0,181	0,012	0,030	0,030	0,645	1,000				
8. Corporate Reserach	0,449	0,498	-0,010	-0,160	0,053	-0,055	0,083	-0,194	-0,214	1,000			
9. Technical Performance	0,538	1,722	0,048	0,074	-0,004	0,107	0,136	0,073	0,103	-0,125	1,000		
10. Innovation Speed	1,978	1,571	0,220	0,247	0,233	0,030	0,673	0,098	0,083	-0,103	-0,069	1,000	
11. Financial Impact	2,538	36,001	0,029	0,037	0,022	0,023	0,019	0,004	0,018	-0,052	0,068	0,002	1,000

(Number of obs. = 1913 Project-Year)

Table 2 Cox Shared Frailty Regressions on Project Innovation Speed

	Cox Shared frailty Model on Time to First Transfer			Cox Shared frailty Model on Time to Multiple Transfers		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Open Innovation		0.524*** (0.166)			0.557*** (0.182)	
OI with Market-Partners			0.432*** (0.125)			0.458*** (0.144)
OI with Science-Partners			0.135 (0.146)			0.103 (0.143)
Project Resources	0.0502*** (0.019)	0.0548*** (0.0135)	0.0506*** (0.0135)	0.0521*** (0.0134)	0.0509*** (0.0134)	0.0470*** (0.0135)
Patent Stock	0.119* (0.0614)	0.117* (0.0617)	0.114* (0.0624)	0.128** (0.0628)	0.125** (0.0631)	0.123* (0.0636)
Project Monitoring	1.565*** (0.604)	0.550*** (0.133)	0.541*** (0.133)	3.099*** (0.590)	2.998*** (0.594)	2.875*** (0.596)
# of Projects under Mngt.	0.809*** (0.185)	0.733*** (0.184)	0.721*** (0.186)	0.607*** (0.105)	0.598*** (0.106)	0.593*** (0.105)
Corporate Research	-0.531*** (0.173)	-0.380*** (0.133)	-0.370*** (0.133)	-0.405*** (0.132)	-0.400*** (0.133)	-0.390*** (0.133)
Technology Fields	<i>Included</i>	<i>Included</i>	<i>Included</i>	<i>Included</i>	<i>Included</i>	<i>Included</i>
Business Groups	<i>Included</i>	<i>Included</i>	<i>Included</i>	<i>Included</i>	<i>Included</i>	<i>Included</i>
Initiating Years	<i>Included</i>	<i>Included</i>	<i>Included</i>	<i>Included</i>	<i>Included</i>	<i>Included</i>
Observations	17,804	17804	17804	19,531	19,531	19,531
Number of Projects	558	558	558	558	558	558
Log Likelihood	-3038	-3033	-3032	-3192	-3187	-3186
lrtest		11.40***	12.70***		9.80***	11.70***

Remark: Cox Proportional Hazard Models with shared frailty.

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

Table 3 R&D Partnerships, Project Technical Strength, and Innovation Speed

VARIABLES	Model 1	Model 2	Model 3	Model 4
Open Innovation	1.981*** (0.757)			
OI with Market-Partners		0.971** (0.463)		1.140** (0.467)
OI with Science-Partners			-0.962** (0.400)	-1.076*** (0.410)
Patent Stock	0.315*** (0.116)	0.184** (0.0813)	0.0305 (0.0691)	0.110 (0.0844)
OI_PatentStock	-0.215** (0.108)			
Market.Par _PatentStock		-0.0787 (0.0688)		-0.111* (0.0597)
Science.Par._PatentStock			0.183*** (0.0612)	0.192*** (0.0625)
Project Resources	0.0503*** (0.0134)	0.0483*** (0.0133)	0.0479*** (0.0133)	0.0450*** (0.0132)
Project Monitoring	3.037*** (0.595)	2.869*** (0.594)	2.900*** (0.584)	2.696*** (0.587)
# of Projects under Mngt.	0.597*** (0.105)	0.594*** (0.105)	0.612*** (0.105)	0.600*** (0.105)
Corporate Research	-0.374*** (0.131)	-0.369*** (0.130)	-0.405*** (0.130)	-0.384*** (0.130)
Technology Fields	<i>Included</i>	<i>Included</i>	<i>Included</i>	<i>Included</i>
Business Groups	<i>Included</i>	<i>Included</i>	<i>Included</i>	<i>Included</i>
Initiating Years	<i>Included</i>	<i>Included</i>	<i>Included</i>	<i>Included</i>
Observations	19,531	19,531	19,531	19,531
Number of groups	558	558	558	558
Log Likelihood	-3185	-3186	-3187	-3181

Standard errors in parentheses:
 *** p<0.01, ** p<0.05, * p<0.1

Table 4. Tobit Regressions on Project Innovation Speed and Project Financial Performance

VARIABLES	Model 1 Selection	Model 2 Performance	Model 3
MultiSpeed			34.17*** (9.571)
MultiSpeed2			-15.85*** (1.015)
Project Resources	0.508*** (0.111)	3.562 (9.75)	-116.6*** (9.643)
Patent Stock	0.0343 (0.0503)	11.98*** (3.61)	18.77*** (3.504)
Project Monitoring	0.284*** (0.0904)	-43.99*** (5.77)	-133.6*** (5.737)
Corporate Research	1.749*** (0.423)	-37.14** (18.77)	-725.7*** (18.99)
# Projects Under Management	0.0261 (0.103)	-96.60*** (8.36)	-124.4*** (8.372)
Project Patent Applications	0.146 (0.154)	120.22*** (21.14)	36.45* (20.86)
Project Transfers		122.95*** (11.11)	99.57*** (10.95)
Sponsoring Units	<i>Included</i>	<i>Included</i>	<i>Included</i>
Business Department	<i>Included</i>	<i>Included</i>	<i>Included</i>
Technology Fields	<i>Included</i>	<i>Included</i>	<i>Included</i>
Initiating Years inmills	<i>Included</i>	<i>Included</i> -330.37*** (31.08)	<i>Included</i> -986.1*** (32.39)
Sigma		277.1*** (8.293)	264.8*** (8.429)
Constant	-5.746*** (0.763)	-63.54*** (24.51)	2,587*** (24.41)
Total Observations	536	487	487
Uncensored Observations		41	41
Log Likelihood	-276.7	-332.3	-325.8
Pseudo. R-squared	0.238	0.142	0.159

Robust standard errors in parentheses:

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

Contradictory to our expectation, projects that are with high technical capabilities do not seem to be more efficient in their innovation process from their collaborations with partners (do not distinguish between the type of partners, Model 1), instead, R&D partnerships seem to slow down project innovations in its technologically advanced fields. Possible explanation may be if the project is already technically advanced, it can perform the task quicker with internals within the firm, instead of reaching out for external support. After all, partner-searching, communication, coordination among partners all take considerable time, and thus may slow down the innovation process. Moreover, attention paid on knowledge protection against their partners in the technically more advanced projects can be counter-productive to innovation speed as well.

5.3 Project Innovation Speed and Project Financial Impact

Finally we look at the impact of R&D partnerships on the financial revenues of R&D projects. Table 4 shows the result on this dimension. Note that because the dependent variable in Table 4 (project financial performance) represents the final performance of projects and thus is different from the dependent variable in Table 2 and Table 3 (project innovation speed in the R&D phase which measures only the R&D phase), here we add a set of additional control variables for the possible confounding effect on project financials: “Project Patent Applications” is a dummy variable measuring whether the project applied for patent or not (partly signals project’s technical superiority); “Sponsoring Units” is also a set of dummy variables denoting the sponsoring unit of the project (in total there are 11 broad sponsoring units); “Business Department” measures which business group receives the transferred project. Finally, because only those successfully transferred projects are able to reach the final market and therefore generate financial revenues, “Project Transfers” is added as a dummy variable measuring whether the project has generated any transfers. In Table 4, Model 1 is probit regression on projects’ probability of being transferred, Model 2 and Model 3 are Tobit regressions operationalized on cross-sectional data with corrections for sample selection. Because only those projects that are successfully transferred are able to have an innovation speed, and to generate financials in the marketplace, we need to correct for the sample selection problem allowing for those un-transferred projects (at the same time also do not have an “innovation speed”) to be included into the analysis. In doing so, in the first stage, the transfer equation is estimated. In a probit model, we regress whether the project is transferred on the following independent variables: project management, number of projects under management, project patent applications, project resources, firm patent stock, corporate

research, sponsoring units, technology fields, and initiating years. From the resulting estimation, we construct the Heckman correction term (?) to be included in the financial regression. From the first step equation (Model 1), it is clear that a higher level of project monitoring, more project resources, and corporate research projects have higher possibility to be transferred to business departments. In the cross-sectional model, we calculated the relation between project innovation speed and project financial performance (Model 3 and Model 4). Model 2 is the baseline model with only control variables. More project transfers, more project patent applications, greater project patent stock, are important factors that lead to better financial returns at the project level, however, it seems that regular project monitoring, number of projects under management, corporate research have a negative effect to monetary returns (Model 2). The negative effect of corporate research on project financial impact, may capture the fact that most long-term research projects are conducted in corporate labs, with the result that there is a high attrition rate and only few projects make it. Also, corporate research is not always intending to develop new product launches, the corporate research projects may be ordered to test whether a particular technology road works or not; to explore new technical areas without specific applications in mind; as well as to piggyback on technologies others developed to explore that area and build defensive IP walls. During the long time to get the product developed and launched also implies that alternative technologies may pop up in the meantime, competitors are earlier on the market which makes the initial market opportunity unattractive. Model 3 confirms the hypothesis that there is an inverted U-shaped curve relation between project speed and their financial performance (Model 3). Therefore, Hypothesis 5 is supported, that project innovations should neither be too fast nor too slow to realize the highest financial outcome.

6. Discussion and Conclusion

To our knowledge, this paper is among the first empirical studies that systematically examine the effect of open innovation networks on the speed of R&D projects at the project level of analysis. We compare “open” projects - those projects in which R&D teams collaborate with external partners - with “closed” projects - those projects in which R&D teams do not collaborate with external partners. Within those “open” projects, we compare between projects with market-based partnerships and projects with science-based partnerships. We examine their respective effect on project innovation speed taking into account of contingencies of project technical strength, and we further examine the effect of project

innovation speed on project financial success. This manuscript shows open innovation can be beneficial to speed R&D projects of large Multinationals. We test the effect of open innovation based on a reliable, longitudinal dataset, therefore we are able to rely on accurate data about the formal and informal partnerships of each R&D project, as well as the exact starting and ending date of each R&D project in our sample. Thus, instead of relying the subjective, retrospective evaluation of project managers, which is usually inevitably error-prone, this study gives objective information based on the real timing of each R&D project. Moreover, we make a distinction between science-based partners and market-based partners. This study suggests that product development speed may depend on different types of partners that are involved in R&D projects.

Our results show that, for project efficiency, being open generally pays off: collaboration with external partners is instrumental in accelerating project innovation speed. However, despite the general benefits, open innovation should not be considered as a panacea for improving innovation efficiency under all circumstances. Collaborations with partners deserve careful consideration and implementation in practice. This study explores such contingency effects from the type of partners that are involved in R&D projects: while R&D partnerships with market-based partners help to accelerate the speed of R&D projects, collaborations with science-based partners do not have the same effect.

When considering the effect of project technical strength on R&D partnerships and innovation speed, Surprisingly, we find that projects that are with high technical capabilities do not seem to be more efficient in their innovation process from their collaborations with partners, instead, R&D partnerships seem to slow down project innovations in its technologically advanced fields. When separating different types of partners, we find that projects that have a high level of technical strength speed up their innovation process when collaborating with science-based partners, while such technically-strong projects are prone to delay if collaborating with market-based partners. The finding also suggests that the positive effect of science-based partnerships on project innovation speed may be uncovered when the project team has already strong technical capability in place. While when such capability is missing or less developed, working with science-based partners may delay project innovation, instead of accelerating it.

As external partners have different effects on project innovation speed, managers should consider and compare the benefits and costs before establishing relations with external

partners. In terms of innovation speed and project financial return, our results also suggest that there is an inverted U-shaped curved relation between project innovation speed and its financial performance. Therefore, neither too speedy nor too slow an innovation process in the project R&D phase is beneficial for product development. Hence, project managers should control a healthy rhythm of project development, and not overly emphasize a faster project innovation speed.

Our study contributes to the literature in different ways. Open innovation as a burgeoning field of research, has attracted considerable scholarly attention in recent years. The majority of studies explored the effectiveness of open innovation, namely, number of patent applications e.g.: Sampson, 2007 and financial revenues generated in the marketplace (e.g.: Faems et al., 2005; Belderbos et al., 2010). Despite the increasing number of studies focusing on the “effectiveness” of open innovation, our understanding on its “efficiency” side, namely, the impact of open innovation on speed of product development has been lagged behind. Although it is argued that open innovation helps to speed up project development (Chesbrough, 2003), so far there was any hard evidence systematically showing that collaborations with external parties indeed shorten (or lengthen) project development time. This manuscript contributes the effect of external collaboration and innovation speed (Kessler et al., 2000; Zander & Kogut, 1995) and to the coordination and appropriation literature (Gulati & Singh, 1998). This study is the first study exploring external collaboration with scientific and market partners at the project research level within a multinational technological firm. Until now, most research on innovation speed was based on survey data (Praest Knudsen & Bøtker Mortensen, 2011) that has numerous limitations to reveal detailed innovation insights. Together, these contributions provide an excellent opportunity to connect and extend the research on open innovation and innovation speed.

Finally, this study has its limitations but also offers a number of opportunities for research. First, we focus only on the speed of the transfers while it may be interesting to determine whether open innovation projects generate more transfers to business units (and licensing arrangements with other firms) than closed innovation projects. Second, it is necessary to determine whether projects collaborating with external partners could generate larger market sales and improve firm’s financial performance compared to projects that do not involve any type of external collaborations. It is also interesting to determine differences among technological base of industries i.e. consumer products, pharmaceuticals, electronics that

reflect differences in the time to transfer technologies. Further, future research could reveal whether endogenous factors could decrease the speed of innovation i.e. market dynamism and uncertainty, market potential (Carbonell & Rodriguez, 2006; Guimaraes, Cook, & Natarajan, 2002). Until now, these results reflect antagonistic effects and inconclusive findings on the benefits for the speed of combinatory sources of external knowledge. All this will give us a better understanding of the benefits of open innovation for firms and allow for the integration of research on new product development, dynamic capabilities and external search.

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