Chapter 2
Exploring the Knowledge Space Through Project-Based Sourcing

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Abstract Only recently has open innovation research emphasized the relevance of adopting a project-level contingency approach for explaining inbound sourcing choices. Our research aims to add to this issue by providing new insights on the knowledge-based determinants of sourcing decisions at the project level of analysis. We maintain that a new product development (NPD) project can be conceived as a strategic means not only to explore the knowledge space for the identification of high-value solutions, but also to search the sources that enable the firm to develop the specific knowledge features. We suggest that the knowledge space explored by an NPD project is grounded on the main elements of an industrial innovation system and that it is characterized by two key dimensions, namely knowledge novelty, the knowledge space of the performance features of a product that meet new customer needs, and knowledge breadth, the knowledge space of technological domains to draw on for solving product-related problems. Our research is implemented on a sample of NPD projects carried out by a group of leading Italian firms, operating in the machine tool industry. Findings show that in companies which define sourcing on a project-by-project basis, projects that explore at the frontier of either novel product features or heterogeneous technological domains, spur firms to rely on external sources and to choose R&D development agreements as the governance form to involve partners. Moreover, a high degree of knowledge novelty induces firms to search cognitive distant partners instead of similar ones. Proposing a project-based approach to strategi-

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cally organize inbound sourcing, the chapter provides evidence on the concept of a company sourcing strategy as a portfolio of decisions across projects.

2.1 Introduction

Open innovation research emphasizes the benefits and the drawbacks a firm may encounter in combining externally generated knowledge with that accumulated inside (Garriga et al. 2013; Knudsen and Mortensen 2011), but scant attention has been paid to the question of how firms make the decision to open up their innovation process (Hsieh and Tidd 2012). Specifically, this stream of the literature has not devoted enough attention to the drivers that explain the choice to rely on external sources and the related decisions concerning partner selection and the appropriate modes of governance of inter-organization knowledge production and acquisition. In this regard, the extant empirical evidence has considered the endowment of a company as the explanation for sourcing decisions, investigating how past accumulation of knowledge can be a premise that allows a firm to recognize and absorb external knowledge (Nooteboom et al. 2007; Tsai 2009; Zhang and Baden–Fuller 2010).

While the centrality of a project as a means of internal knowledge production is widely recognized by the literature on innovation and project management, this level of analysis is neglected in studies on how a firm engages external sources in the exploration and production of new knowledge, for new product development (NPD).

Only recently have studies emphasized the relevance of adopting a project-level contingency approach for explaining inbound open innovation (Bahemia and Squire 2010; Bonesso et al. 2011; Salge et al. 2013; Tranekjer and Søndergaard 2013). Our research aims to add to this issue by providing new insights into the knowledge-based determinants of inbound sourcing decisions at the project level of analysis. We maintain that the NPD project can be conceived as a strategic means not only to explore the knowledge space for the identification of high-value solutions to create new products (Macher 2006; Terwiesch and Xu 2008), but also to search the sources that enable the firm to develop the specific knowledge features required by an NPD project.

The remainder of this chapter is organized as follows. The next section introduces the project-based approach in studying inbound open innovation. Drawing on the sectoral innovation system framework, the subsequent section describes the attributes of the knowledge space that an NPD project can explore, namely knowledge novelty and knowledge breadth. Successively, we formulate the theoretical arguments underpinning the hypotheses on the impact of each knowledge attribute on the three main inbound sourcing choices, namely the decision: (1) to tap external rather than exclusively internal knowledge sources; (2) to co-develop the NPD project with external partners; (3) to rely on cognitive distant sources rather than on similar ones. Next, we describe the research setting, data sources, the variables included in the study, and the estimation methods. After presenting the most relevant results, in the final section, we discuss the findings and draw conclusions, proposing a project-based approach to strategically organize inbound sourcing.

2.2 Inbound Open Innovation at Project Level: A Knowledge-Based Perspective

Opening up the firm innovation process through inbound activities stimulates the generation of new knowledge by developing in-house core competencies and combining a diverse pool of complementary sources. This may lead to increased product portfolio diversity, better matching of the firm's offer and consumer needs, and consequently higher innovation performance (Laursen and Salter 2006; Parida et al. 2012; van de Vrande et al. 2009). The strategic organization of how firms get access to external new knowledge and integrate it internally represents a central topic in the recent debate on open innovation research (Gassmann et al. 2010). Sourcing decisions, related to the appropriate forms of governance, as well as partner selection have been analysed adopting primarily a transaction costs approach. This approach defines on the one hand advantages, in terms of R&D costs and risk sharing, and on the other hand, barriers, related to partner selection, and coordination, as well as risks of knowledge leakages and imitation (Becerra et al. 2008; Huang et al. 2009; Mol 2005; Mowery et al. 1998; Robertson and Gatignon 1998). While the debate on the impact of economic factors has advanced the understanding on external sourcing determinants to efficiently exploit partners and safeguard from opportunistic behaviours, it underestimates the role played by knowledge and its attributes in sourcing decisions. The main criticism is that this approach does not consider the strategic opportunity of knowledge creation through partnership (Zajac and Olsen 1993).

Through the knowledge-based perspective lens, a firm opening up its organizational boundaries searches for complementary external knowledge to create new products (Katila and Ahuja 2002) by strategically designing the external network of knowledge sources with which it could create new value (Zajac and Olsen 1993).

From this perspective, the innovation process can be represented as a knowledge search activated either at firm or at project level. The knowledge space, which a firm aims to explore by its search for novel knowledge and partners, is a sectoral or inter-sectoral competitive landscape (Danneels and Kleinschmidt 2001). Indeed, the sectoral innovation system sets the innovation opportunities and constraints (Malerba 2002, 2005) along the two main axes of market needs and technological solutions (Brunswicker and Hutschek 2010). Drawing on prior studies, we suggest that the main attributes of the knowledge space explored by a firm are related to these two coordinates (Bonesso et al. 2011; Nickerson and Zenger 2004; Terwiesch and Xu 2008) and consequently they affect how a firm strategically searches for new knowledge and organizes its network of external partners.

The open innovation literature has contributed to advancing the understanding of how a firm combines internal and external knowledge to create new value through innovation processes spanning organizational boundaries; however, less attention has been paid to the drivers that impact on the firm's decision to open up the innovation process. Moreover, research has remained silent on the knowledge attributes of new products that a firm aims to develop through sourcing activities and on how these attributes might impact on the decisions to cross organizational boundaries. Indeed, this stream of the literature mainly focuses on the innovation strategy of the firm (closed versus open approach), explaining the implementation process of business models and the consequent organizational solutions (Chesbrough 2006; Chiaroni et al. 2010; Mortara and Minshall 2011).

A few empirical studies have recently advanced the understanding of the knowledge attributes as inbound sourcing determinants (van de Vrande et al. 2009; Zhang and Baden–Fuller 2010). While these studies have provided new insights, they mainly focus on the characteristics of the knowledge base of the firm, rather than on the project level of analysis. As claimed by recent research “contingency studies on open innovation are hence needed especially at the project level” (Salge et al. 2013, p. 660), for three main reasons.

First, the NPD project represents the locus where knowledge exploration and production is primarily carried out (Lenfle 2008).

Second, we argue that a study of inbound open innovation at project level is sound due to the fact that the central inbound choices at the NPD project level concern whether, how and where to tap specialized external sources coherently with the knowledge attributes explored by the project. In the case of non-incremental NPD projects, a firm pursues new objectives by developing novel components and product architecture (Henderson and Clark 1990). Thus, it may be spurred to search for new knowledge not only beyond its organizational boundaries, but also by adopting sourcing decisions independently from those made in the past. This means it might define project-by-project the features of a product and the range of knowledge sources it wants to draw on (Bonesso et al. 2011; Knudsen and Mortensen 2011; Tranekjer and Søndergaard 2013).

Concerning the third reason, we suggest that in line with studies on the project portfolio strategy of a firm (Knudsen and Mortensen 2011), the adoption of the project level of analysis to study inbound sourcing not only enhances the understanding of the sourcing decision of any single project, but also provides primary explorative evidence on the concept of a company sourcing strategy as a portfolio of decisions across projects.

Our study, bridging the literatures on open innovation, strategic project management and the knowledge-based view, aims to investigate the effects of the knowledge attributes a firm wants to develop project-by-project on inbound open innovation. In particular, we aim to advance the open innovation research, which is mainly focused on the firm level of analysis, adopting a project-based approach in studying the determinants of external sourcing. On the other hand, we want to add to the project management literature, considering the project not only a means to manage an NPD process efficiently and effectively but also as a vehicle to make sourcing portfolio decisions. Finally, we want to extend the knowledge-based studies by offering an conceptualization and operationalization of the knowledge attributes a project aims to generate.

2.3 Defining the Knowledge Space at Micro-Level: Knowledge Attributes Explored by NPD Projects

As claimed by Lenfle (2008, p. 471) "the result of the project is then no longer simply a product" but the opportunity to learn new knowledge that can significantly foster the capacity to be innovative (Söderlund et al. 2008). Firms generate new knowledge by selecting a problem to solve and starting an exploration process of valuable and innovative knowledge combinations (Macher 2006). When a firm wants to solve product-related problems it might engage in a search process by launching a new project. Therefore, the attributes of the knowledge space explored are not related to the stock of knowledge accumulated by the firm, but are those that characterize the new knowledge the firm aims to develop by the problem-solving process activated in each NPD project. These attributes can be conceived as the coordinates of the knowledge space (Terwiesch and Xu 2008) within which a project "engages in a process of search for high-value solutions" (Macher 2006, p. 827).

As suggested by prior studies, the knowledge space explored by an NPD project is grounded on the main elements of an industrial innovation system (Malerba 2002, 2005), which can be conceived as the landscape (Nickerson and Zenger 2004) within which firms aim to discover new knowledge combinations through the launch of NPD projects. We suggest that this landscape is structured around two key knowledge dimensions, namely knowledge novelty, the knowledge space of the performance features of a product that meet new customer needs, and knowledge breadth, the knowledge space of technological domains to draw on for problem solving (Bonesso et al. 2011; Danneels and Kleinschmidt 2001).

Knowledge novelty can be defined as a knowledge attribute which provides superior product functionalities for customers and thus improvements in performance features (Amara et al. 2008). Exploring knowledge novelty implies a process of product concept shift (Seidel 2007) or ideation (Dahl and Moreau 2002) that helps to depart from the existing industry offering. Indeed, knowledge novelty is a matter of degree (Freel and de Jong 2009), since if the project explores the space of customer problems and needs in order to develop a novel concept and new functionalities not available in the industry, this means that the project presents a high degree of knowledge novelty. On the other hand, a project presents a lower extent of novelty if new features are introduced into a firm's portfolio for the first time, but are already available on the market. In the latter case, knowledge novelty is not explored at its frontier. High-novelty projects develop original concepts and features by addressing problems not already solved by competitors and in so doing they satisfy emergent needs. For this reason they are usually positively associated with higher returns (Marsili and Salter 2005). Departing from the existing industrial solutions entails a stronger effort in the exploration of the solution space, in terms of time and resources devoted to scouting, understanding, evaluating and exploiting market opportunities for new functions which are not yet available in the existing products of the same industry.

Independently of the degree of novelty, new functionalities imply a problem-solving process: the expected features are carried out by elements whose operating principles are based on a scientific and technological domain (Brusoni and Prencipe 2006). Since a technological domain is “a group of technologies that solve primary problems” (George et al. 2008, p. 1449), the knowledge breadth of a project can be conceived in terms of the degree of diversity or heterogeneity among technological domains a project draws on to solve different primary problems (Wang and von Tunzelmann 2000). The dynamic transformation of several sectors towards technology fusion (e.g. mechatronics, biopharmaceuticals, optoelectronics) (Kodama 1992) implies a convergence and an integration of previously separated knowledge and technologies (Malerba 2005), which increases the heterogeneity of primary problems and the domains a firm may draw on through NPD projects. Empirical evidence confirms the blurring of boundaries between technological disciplines (Choi and Valikangas 2001) in high–tech as well as in low–medium-tech sectors (Bröring and Leker 2007; Freddi 2009; Wengel and Shapira 1994). This implies that sector-specific technological domains (for instance, chemistry in the pharmaceutical industry, mechanics in the equipment industry) are combining with diverse technological and scientific disciplines which have progressively been added to the search space that a firm can investigate through NPD projects (biology in the pharmaceutical industry, electronics and software in the equipment industry) (Gambardella and Torrisi 1998; Quintana–Garca and Benavides–Velasco 2008). Therefore, firms facing the challenge of technological fusion may need to master through an NPD project a wider range of disciplines than in the past. We claim that the integration of heterogeneous disciplines in an NPD project increases the extent to which the knowledge investigated by that project can be conceived as broad. On the other hand, knowledge breadth can be conceived as narrow, when the NPD project explores the consolidated industrial scientific and technological knowledge. Any different additional domain included in the search space of an NPD project expands the horizon for opportunities to scan for a new knowledge combination, but it also enhances the difficulties in understanding interdependencies among a wider range of interrelated problem settings.

In the next section, we present our theoretical arguments, suggesting that inbound sourcing decisions are contingent to the NPD features, and specifically to the degree of knowledge novelty and breadth explored by an NPD project.

2.4 Knowledge Attributes of an NPD Project and Inbound Sourcing

Defining the composition of the sourcing portfolio has become an important part of a firm’s overall strategy (van de Vrande 2013, p. 610). Although research demonstrates the benefit of having a diversity of sourcing portfolios depending on different circumstances, such as the degree of similarity between the firms and the external partners, the analysis of sourcing composition has not been considered in relation to the project portfolio characteristics.

Our research extends the literature on the contingent factors that influence the decision-making process of inbound sourcing, investigating the impact of the degree of knowledge novelty and breadth explored by the NPD projects on three main choices:

- whether to rely on external partners instead of relying exclusively on in-house sources;
- how to get access to the knowledge (modes of governance to implement);
- where to source the knowledge (distant versus similar sources).

2.4.1 Internal Versus External Sourcing

When a firm engages in an NPD project, exploring at the frontier of knowledge novelty (searching for radically new product concepts and functionalities to satisfy new needs) or knowledge breadth (searching for technological solutions in a heterogeneous technological and scientific space), it may be induced to open up its innovation process for valuable interactions with competent external sources.

The generation of original product features requires the adoption of a divergent way of thinking which implies the development of a wide range of non-conventional ideas (Colarelli O'Connor 1998). The exclusive reliance on internal sources may spur towards a convergent way of thinking; instead, interaction with external partners may not only enlarge the search space in terms of number of ideas providing room for inspiration (Freel and de Jong 2009), but also encourage divergent thinking through the departure from characteristics in the specific sector (high knowledge novelty). Studies have highlighted the relevance of the use of analogies, as a means of creative thinking for problem solving, to convey novelty in NPD projects (Dahl and Moreau, 2002; Gassmann and Zeschky 2008; Kalogerakis et al. 2010). The term "analogy" refers to the successful identification of similarities (superficial or structural) between a source and a target domain (Gentner 1983). Interaction with external sources might enhance problem-solving effectiveness and efficiency in terms of identification of far analogous solutions. Indeed, external partners may act as brokers, on the one hand making non-obvious connections between different categories of products which share some similarities, and on the other enabling the combination of functionalities not previously introduced into the projects of the firm-target's industrial context (Hagardon and Sutton 1997).

Moreover, external sourcing may transfer to producers the advanced experiences of innovative "lead users", who aim to solve their own ahead-of-market needs. In this regard, it has been demonstrated that in the process equipment or software sector, innovations transferred from users "tended to be those of stronger and more general interest to users, and thus of more value to producers as commercial products" (de Jong and von Hippel 2009, p. 1181). Therefore, this external technology source reduces the level of uncertainty of market acceptance of newness. Besides this advantage, sourcing user innovation in high-novelty projects enables reductions in engineering-related costs and risks due to the fact that the lead user has already carried out some preliminary prototyping tests (de Jong and von Hippel 2009). This is the case of Business-to-Business (B2B) producers whose lead users have the capabilities to anticipate and solve their own ahead-of-market needs (Robertson et al. 2003). Thus, we may expect that:

Hypothesis 1 The higher the knowledge novelty in an NPD project, the more likely the external sourcing.

When the degree of an NPD project's technological heterogeneity is high, the risks and costs of a search process in specific technological and scientific domains are better managed when they are partitioned among specialized partners. Time-to-market of NPD projects with high knowledge breadth may be decreased by external sourcing choices since knowledge suppliers match solutions and problems faster due to their experience curve. External sourcing also impacts positively on production costs because specialized suppliers in different disciplines may exploit economies of scale, since they can spread their investments over a larger base of development activities (Macher 2006). Moreover, the incentives to overcome barriers against external sources are even higher when the pace of change in non-core technology fields rises and firms need to keep up at the edge of all these fields (Mol 2005) without bearing the risk of the exploration process across different scientific frontiers. Thus, in the fast-changing technology landscape (Fleming and Sorenson 2003), it could be more convenient to adopt a flexible approach to sourcing by exploiting a partner's capacity to be at the frontier of a specific technological domain, avoiding at same time the high investments and sunk costs of in-house R&D.

Moreover, when an NPD project is characterized by diverse primary problems which can be solved through a search process in heterogeneous domains, a number of potential interdependencies arise among solutions offered by each single technological field. Problem-solvers face relevant constraints in structuring a problem which spans over multiple knowledge sets, due to the low understanding of the map of possible interdependencies (Macher 2006). Therefore, firms may prefer to focus their limited efforts and resources, on the one hand, on the search activity in the consolidated scientific and technological knowledge of the sector and, on the other hand, on the management of knowledge integration problems, while relying on specialized partners for solution-seeking within each additional domain. Thus:

Hypothesis 2 The higher the knowledge breadth in an NPD project, the more the external sourcing.

2.4.2 How to Source? Inbound Sourcing Through R&D Development Agreements

The exploration at the frontier of the knowledge space (high knowledge novelty or high knowledge breadth) may entail a significant cognitive endeavour that can jeopardize the recognition and the implementation of valuable solutions to innovation problems. Open innovation literature shows that non-equity-based collaborative relationships favour the process of exploration of market and technology opportunities and seem to offer flexibility, speed, and innovation (Dittrich and Duysters 2007; Laursen et al. 2010; van de Vrande 2013). Therefore, we maintain that firms exploring at the frontiers of the knowledge space through NPD projects may reduce these cognitive constraints and increase learning opportunities through R&D development agreements with external partners.

Recent studies show that novel ideas in terms of new product functionalities and performance features emerge from the original combination of pieces of knowledge across industries through far analogies (Brunswicker and Hutschek 2010). The identification of non-obvious analogies in the market offering of different industries brings higher customer benefits (high knowledge novelty) than those based on near analogies (Kalogerakis et al. 2010), but they "are more difficult to identify and require more cognitive effort" (Gassmann and Zeschky 2008, p. 98). As discussed by prior research, the successful identification of far analogies and their subsequent translation may require an interactive and mutual learning process between the seeker-source target and the solver-source domain (Enkell and Gassmann 2010). As suggested by Nooteboom et al. (2007, p. 1017) "When people with different knowledge and perspectives interact, they stimulate and help each other to stretch their knowledge for the purpose of bridging and connecting diverse knowledge". Therefore, the relationship between the firm and the external sources involved in the NPD cannot be treated purely as a transaction if the project aims to depart from the existing industry offering, but requires forms of co-development that makes it possible to better detect similarities (in terms of product features and functionalities) between unrelated domains and effectively transfer the contents to the target-firm's product features.

Moreover, firms exchanging knowledge with a partner in an early stage and at the frontier of the knowledge domain, might face high degree of ambiguity and it might be difficult to communicate and share sticky and contextual knowledge. Thus, they need to rely on appropriate coordination mechanisms and incentives to access the partner's skills and optimally internalize the exchanged technology (Trombini and Comacchio 2012). Hence:

Hypothesis 3 The higher the knowledge novelty in an NPD project, the more likely the R&D development agreement.

An important driver in implementing R&D development agreements is related to the complexity of the problem to be solved, which is higher when heterogeneous domains need to be explored (high knowledge breadth) and the understanding of the interdependencies among them is low (Macher 2006; Simon 1962). In order to reduce uncertainty and increase the understanding of the relationships between different technological domains, the engagement of external partners in the NPD project may be beneficial. R&D agreements imply frequent contacts that stimulate mutual understanding as well as the development of a common language and a communication code that can facilitate joint problem-solving and reduce the time and the cost related to the integration of different technological domains (Hsieh and Tidd 2012).

Moreover, firms may be willing to keep abreast by interacting with partners more expert in other technological fields. The learning process that can be activated by an R&D co-development might help to accumulate in-house basic knowledge in a diverse discipline, increasing a firm's familiarity with it, useful for future search processes. Therefore:

Hypothesis 4 The higher the knowledge breadth in an NPD project, the more the R&D development agreement.

2.4.3 Where to Source? Similar Versus Distant Partners

Not only can firms define project-by-project whether and how to involve external partners in the NPD process but also where to search for the potential solvers of product-related problems concerning both market needs and technological solutions.

Studies on partner identification and selection highlight the importance of similarities among partners in terms of shared goals and convergent interests as well as norms of behaviour that facilitate coordination, reduce risks of opportunism thanks to the development of close trust-based relationships and accelerate the learning process (Cummings and Holmberg 2012; Rothaermel and Boeker 2008).

Despite the positive effects of cognitive alignment or proximity among partners, open innovation literature positively evaluates a moderated distance among firms and provides empirical evidence on its inverted U-shaped effect on innovation performance (Nooteboom et al. 2007). Moreover, research on geographical clusters and social capital has pointed out the negative side of a high level of cognitive proximity such as lock-in effects and redundant relationships that prevent new knowledge creation (Boschma 2005; Burt 2005; McEvily and Zaheer 1999). Therefore, we maintain that when an NPD project explores at the frontier of the knowledge space, a firm may benefit from cognitive distant partners in terms of opportunities for discovering original product features and functionalities which depart from its sector. These learning advantages can counterbalance the costs of overcoming the barriers related to the access of physically and culturally distant sources (Al–Laham and Amburgey 2011). A first benefit that cognitive distance yields is related to the access to different customers' systems of meanings and interpretation that help to identify and better define ahead-of-market needs and identify solutions to translate into the firm's product offering. Second, diversity between the target problem and the source domain may favour the process of detecting non-obvious analogies (Kalogerakis et al. 2010), whereas if source and target share the same conceptual domain they will lead to incremental innovation (Gassmann and Zeschky 2008). Therefore:

Hypothesis 5 The higher the knowledge novelty in an NPD project, the more likely distant partners are involved.

The literature on regional innovation systems demonstrates how geographical areas present a specific degree of expertise in technological and scientific disciplines related to a specific sector (Malerba 2004). This localized learning process provides a firm with the opportunity to interact with partners specialized in different technological fields all related to the same industrial cluster, with a high alignment in terms of shared goals and cultural norms. When a firm engages in an NPD project that requires a problem-solving process in additional technological domains (high knowledge breadth), the cognitive proximity between the firm and the sources may be beneficial for tapping the specialized language and mindsets of a specific technological domain. We argue that the higher degree of diversity of the technological domains explored by the NPD project may prevent the firm from searching physically and culturally distant partners in order to avoid adding further complexity in its exploration process. Indeed, knowledge creation and production may require not only the use of codified solutions but also of inductive activities of testing, experimentation, simulation and practical work (Asheim and Coenen 2005). Especially in the case of fusion among previously separated technological domains, technical solutions are often the result of experience gained through learning by doing and interacting. The cognitive proximity between the firm and the source specialized in the additional knowledge domain may enable an interactive and trust-based learning that favours the understanding of the interdependencies among disciplines and the management of integration problems. Thus, we may expect that:

Hypothesis 6 The higher the knowledge breadth in an NPD project, the more likely similar partners are involved.

2.5 Methods

2.5.1 Research Setting

The setting of our research is the machine tool industry, which is a long-established sector in the most advanced economies and still plays a pivotal role in Europe (Freddi 2009; Wengel and Shapira 2004). Specifically, we carried out a survey on a sample of NPD projects undertaken from 2002 to 2006 by seven leading medium Italian firms operating worldwide.

The machine tool industry represents an ideal context in which to investigate the impact of knowledge attributes on inbound sourcing at project level for three reasons. First, studies on industrial innovation systems confirm that firms in this sector are progressively opening up their innovation processes through collaboration with a variety of external partners (Wengel and Shapira 2004). Second, research activities and learning processes in the machine tool firms are typically performed on a project basis (project duration usually ranges from six months to over 1 year), thus the knowledge attributes of a project are salient. Finally, the two knowledge attributes of the projects, novelty and breadth, modeled as explanatory factors of inbound sourcing are particularly relevant in this industry, in which both demand requirements and heterogeneity of technological domains are increasingly compelling.

Concerning knowledge novelty, in this highly competitive B2B environment the key players nowadays are those firms able to innovate at the front-end, meeting emergent market demand instead of merely adopting an efficiency-based approach.

Empirical studies support this argument, highlighting that in this industry the rate of introduction of new products is high in comparison with that in other long-established sectors (MacPherson and Kalafsky 2003). This could be motivated by the fact that machine tools are capital goods (e.g. lathes, punching machines, press brakes, machining centres) central to almost all durable products. The literature places machine tool firms within the "enabling sectors" (Robertson et al. 2003) or the "specialized suppliers" (Pavitt 1984), namely suppliers of pervasive technologies (Brusoni and Sgalari 2006) that have a large influence on the manufacturing performances of other industries. The innovation process aims to increase the value of these capital goods for the users, especially for highly innovative clients such as the automotive, aeronautical, aircraft, aerospace and electricity supply sectors. Moreover, a notable characteristic of these products is their high durability, which would imply that a customer takes many years to place a new order. To increase the rate of substitution, companies are spurred to introduce significant advancements in the market in terms of the functionality of their machines.

From the point of view of knowledge breadth, this sector, since the introduction of computer-controlled devices in the 1980s, has been facing a technological shift from a dominant paradigm to a reconfiguration of the technical knowledge embodied in the product (Chen 2009; Sandven et al. 2001). According to Kodama (1992), machine tools are a typical example of a mechatronic product,[1] which is characterized by progressive integration of the traditional technological field, mechanics, with two different technological disciplines, namely electronics and software engineering (Freddi 2009; Wengel and Shapira 2004).

2.5.2 Data Collection

We obtained the list of the machine tool firms operating in the North East of Italy from the Association of Italian manufacturers of machine tools, robots, automation and ancillary products (numerical control systems, tools, components and accessories) UCIMU. According to the UCIMU Annual Report, in 2004 the Italian machine tool industry comprised 415 firms and employed 28,120 people; 15 % of total firms were located in the North East (Ucimu 2006). Initial contacts were made by e-mail and afterwards each firm's representative was called in order to present the aims of the study. Fourteen firms agreed to participate in the research.

Once consent had been obtained, we interviewed by phone the person responsible for the innovation activity of the firm, namely the R&D manager or the Engineering manager, in order to identify and assess the type of projects that had been started since 2002. Seven firms indicated that they had introduced only minor incremental

[1] A mechatronic machine/component was defined as "a mechanical element controlled by an electronic application that is integrated into it. Control means that the machine/component has the ability to change performance according to a change in external conditions. It is the high level of integration between the different technologies (mechanics, electronics and informatics) that distinguishes a mechatronic device from a mechanical, electronic or informatic one" (Freddi 2009, p. 552).

changes to their products during the period under examination. Due to the fact that our research focuses on projects which aim to develop knowledge which departs to some extent from that already embodied in the previous machines, these firms were discarded.

A total of 86 NPD projects, developed from 2002 to 2006, were obtained from the remaining seven medium-sized firms.

The dataset was constructed through several visits on site and phone contacts, drawing on multiple data sources.

A structured questionnaire with closed-ended questions was administered in order to collect data on the characteristics of the company, its R&D/Engineering department, and its products. Data were gathered from different respondents (the owner or the top management and the functional managers) according to the information required.

Data at the project level of analysis were collected through in-depth semi-structured interviews administered face-to-face. On each research site, the R&D/Engineering manager provided us with a list of all the projects the company had carried out since 2002, and which fitted the aims of our study, namely projects that did not introduce merely incremental changes, such as restyling of current product lines (Smith and Tushman 2005). All the projects identified by the respondents, which regarded a machine as a whole or as a set of components, can be considered successful from the market performance point of view. This can be explained by the fact that in this industry firms decide to invest in projects beyond the first stages when there is a preliminary sale agreement signed by a client, in consideration of the high economic value of this type of industrial equipment and the related investment required in the detailed design stage. We did not include in our analysis cases of project failure since the high costs of these machines led the project team to devote considerable efforts towards the detection of potential failures during the preliminary stages. Therefore, possible technical problems that may affect market performance of a new product are identified and resolved before sourcing decisions are made. The last column of Table 2.1 reports the number of projects by company.

We interviewed at least two knowledgeable informants per firm, all senior technicians, namely the engineering or the R&D manager and project leaders. The respondents were asked to describe in detail the content of each NPD project started between 2002 and 2006. Some examples include new technological principles (laser and plasma in cutting processes), materials (ecological and energy-saving treatments of natural resources), architectures or components (morphology that increases general performance, more precise and productive bending systems which integrate sophisticated electronic control devices). Afterwards, we collected fine-grained data on the two knowledge attributes under analysis and on the sourcing choices made for each project. The respondents were asked to describe in detail the sources that each NPD project drew on. The presence of multiple respondents allowed us to discuss potential disagreements (Miller et al. 1997). To limit common method variance problems, we collected the data on the dependent and independent variables at different times (Podsakoff and Organ 1986). This also gave the respondents time to search their memory and consult the necessary technical documentation to answer the questions on the project dimensions under investigation.

Finally, we drew on secondary data: (1) each firm's archive of product catalogues from the period under analysis which embodied the technical content developed by the projects; (2) articles from specialized magazines which reported the description of the firms' products; (3) the web site information of the leading international trade fairs where the companies presented their machines, and (4) discussion with external experts on the project description provided by the respondents. The use of multiple sources of information allowed a process of data triangulation (Sonali and Corley 2006), thus reducing potential bias deriving from an individual's memory failure and protection mechanisms and ensuring the internal validity of the measures regarding project novelty and breadth.

2.5.3 Variables

2.5.3.1 Dependent Variables

Internal versus external sourcing Drawing on the classifications traditionally proposed in the literature, we identified two categories of sourcing choices that may be implemented in each project: internal and external (Cassiman and Veugelers 2006; Veugelers and Cassiman 1999). Internal sourcing includes the firm's own R&D and technological transfer and assistance from parent or associate companies. External sourcing encompasses a wide range of modes: arm's length arrangements, which refer to unilateral knowledge flows (licensing agreements and purchasing from supply chain actors), intermediate mechanisms between market and hierarchy, namely R&D cooperation with other firms, and the acquisition of other companies prompted by the requirements of an ongoing project (Narula and Hagedoorn 1999; van de Vrande et al. 2009; Zhao et al. 2005). We constructed a binary variable that takes the value 1 when the project involved external sources. Whereas when the project was developed relying exclusively on internal sources, such as the firm's own R&D department and transfer from parent firms, the variable takes the value 0.

R&D development agreements Sourcing can be achieved through the use of different modes of governance with diverse implications in terms of opportunities for inter-firm learning (Narula and Hagedoorn 1999; van de Vrande 2013). Our respondents were asked to describe the forms of governance each NPD project used for its development. In our sample we distinguished between projects that do not use modes of governance that enable the activation of an inter-firm learning process (market transaction and in-house development) and projects that involved the partners in forms of agreements characterized by a high level of inter-firm interaction. We constructed a binary variable that takes the value 1 when the project involved for its development an R&D cooperation based on contractual agreements with external sources (suppliers, clients, universities, consultants, etc.), otherwise the variable takes the value 0.

Partner distance We measured the difference among firms in terms of cultural and physical distance between the firm and the sources involved in the NPD project (Boschma 2005; Teixeira et al. 2008) as a proxy for cognitive distance. The respondents were asked to indicate the geographical localization of the sources involved in the development of each NPD project, identifying in each project the nationality of the sources. The partner distance has been measured on a 3-point scale, where 0 means that the project does not draw on sources beyond the firm's boundaries, thus there is no cognitive distance; 1 means that the project involves only sources geographically located in the same country (Italy), and 2 means that the projects engage sources located in foreign countries.

2.5.3.2 Independent Variables

Knowledge novelty The extent of novelty is assessed according to the existing market offerings. For each NPD project we asked respondents to evaluate whether the knowledge generated was new to the industry or only to the firm (thus already present in the world market offerings). From the interviews, it turned out that the novelty of the project was not unexpected by the firm, but there was an ex-ante intent to innovate at a certain level. Indeed, the firms had on the shelf innovative machine concepts in search of industrial applications, but due to the high costs of the machines they decided to further develop the concept only once a client was ready to invest in it. Drawing on innovation literature (Amara et al. 2008; OECD 2005), we measured the degree of project novelty with a dichotomous variable that takes the value 1 when the project introduced knowledge new to the industry and the value 0 when the project introduced knowledge new to the firm. Examples of projects which convey performance features not available in the world market offerings are direct drive heads, without help of gears and belts, which perform rotations both in working and in positioning in a very short time and with unique accuracy. Other examples are systems in press brakes that allow the bending of a sheet at the desired angle in a controlled way with the necessary accuracy without having to go through trial-and-error phases which inevitably lead to waste of material, or a proportional frame deflection compensation system that allows any bend to be made at a constant angle, regardless of the length of the workpiece. These projects are characterized by a high degree of novelty compared to the knowledge embodied in the extant products of the industry. On the other hand, projects which introduce knowledge that is new to the firm but already in the market are, for instance, a plasma cutting system that allows the elimination of the cutting fumes with half the power compared to traditional systems, or "direct drive" rotary tables which grant maximum accuracy and very short rotation times.

Knowledge breadth Prior research measured breadth at the firm level in terms of the expansion of a firm's technology base into a wide range of technological fields (Quintana–Garca and Benavides–Velasco 2008; Zhang et al. 2007; Zhang and Baden–Fuller 2010). At the project level the operationalization of breadth implies the definition of the body of technical knowledge (technological domains), investigated in a specific project, which contributes to solve primary problems through the identification of the operating principles that makes it possible to match functions to components. According to the conceptualization of breadth as the degree of heterogeneity among technological domains, we maintain that the simple count of the technological fields investigated at the project level makes it difficult to assess the complexity that any additional domains bring into a project that already relies on the consolidated body of knowledge of an industry. The breadth measure should take into account the composition of domains which define the technological solution landscape for a specific project. Indeed, a technical problem can be solved by drawing on consolidated disciplines at the base of the sector or can require reliance on additional diverse domains in which the number and the characteristics of the possible alternatives are less defined and more uncertain. Moreover, each additional domain increases the degree of knowledge heterogeneity. Therefore, the breadth in the first case should assume a lower value than in the second case.

In order to operationalize the degree of breadth at the project level, we first drew on the technical characteristics of the machine tool product. A detailed analysis of the sector, based on the review of the specialized literature and discussion with experts, supported the findings of previous studies (Freddi 2009; Mazzoleni 1999; Wengel and Shapira 2004). It turned out that the traditional discipline in the machine tools industry, namely mechanics, is progressively blending with two different bodies of technical knowledge, electronics and software engineering, generating the so-called mechatronic product (Kodama 1992). However, as other research has shown, the core competencies of the machine producer industry still "lie firmly within the mechanical field" (Lissoni 2001, p. 1495).

Each of the three domains solves distinct primary problems. Mechanics offers solutions to problems concerning the acceleration and deformation of objects under known forces or stresses. Operating principles drawn from mechanics allow the transmission of power and movement through racks and ball screws, and the traversing movements by sliding blocks and circulating ball guides. Electronics addresses problems related to the use of the controlled motion of electrons through different media; sub-domains are, for example, control engineering, microelectronics, signal processing. The numerically controlled technology in machine tools is based on the principles of electronics and devices such as drivers, transistors, encoders which allow the movement controls and the automation of processes. Software engineering deals with problems concerning the development of instructions and interfaces for programming and controlling the hardware components. For instance, in machine tools the software automatically creates the programming CAM for the machine for optimizing the working sequence, choosing the right tools and calculating the developments. Thus, this solution from the software domain generates new interdependencies both with mechanical and electronic components.

During the interviews the respondents were asked to indicate which of the three technological domains they investigated to solve technical problems in each project. We calculated the Manhattan distance, comparing the domain composition of each project with that of a "standard" project, which relies exclusively on theconsolidated knowledge domain of the sector (namely mechanics). Accordingly, the degree of breadth has been evaluated on a 3-point scale, where 0 means that there is no distance between a project under scrutiny and a "standard" one, both relying on the single traditional field of the sector (no heterogeneity); 1 means that the domain composition of the project under scrutiny encompasses one technological domain (electronics or software engineering) additional to the single domain of the "standard" project; 2 means that the project encompasses two additional fields (electronics and software engineering). These latter projects are defined exploratory due to their high degree of breadth, since the problem-solving activity implies a search for technical solutions in heterogeneous domains.

2.5.3.3 Control Variables

In accordance with the extant literature on technological innovation we introduced a number of control variables that might influence the propensity of the firm to rely on external sourcing.

We used *firm age* as a proxy for the firm's legacy. As previous studies show, more established firms are more likely to engage in autonomous innovation instead of relying on external actors (Zhao et al. 2005). This might be due to the fact that older firms may have accumulated experience and knowledge over the years, and have built their own in-house capability to become more autonomous in innovation than younger firms. Furthermore, older firms develop established procedures and routines that create resistance to the integration of external sources (Freel 2003; Li and Tang 2010). Given these findings we predict that firm age will have a negative effect on external technology sourcing. Firm age was measured as the number of years since the firm was founded to the year the projects started.

Then we included *firm size* as a proxy for market power. As suggested by empirical research, larger firms have the capacity to attract and to deal with external partners and they are more likely to be engaged in a wider range of activities that may require external sources (Belderbos et al. 2004; Fritsch and Lukas 2001; Tether 2002). Firm size was measured by the logarithm of the average number of the firm's employees over the 2 years before the projects started. Moreover, we measured the ratio of the average number of the firm's R&D employees to the total number of employees over the 2 years before the projects started as a proxy of R&D intensity. Veugelers (1997) found that R&D spending does not have an impact on cooperation in R&D unless firms have their own R&D department and personnel. In previous empirical studies, R&D intensity is used as an indicator of the firm's ability to recognize, value and exploit technological opportunities from outside (Cohen and Levinthal 1990; Fritsch and Lukas 2001). Finally, since our sample is composed of multiple projects from a small number of firms we included dummy variables in the model in order to control for the non-independence of the observation due to firm differences.

Table 2.1 Number of NPD projects by firms

Firms	Internal sourcing	External sourcing	Total number of projects per firm
1	4	5	9
2	8	4	12
3	10	6	16
4	4	7	11
5	4	8	12
6	18	1	19
7	0	7	7
Total number of projects per sourcing decision	**48**	**38**	**86**

2.6 Findings

2.6.1 Open Innovation and Sourcing Project-by-Project

A first preliminary analysis is necessary to understand if in our sample firms adopt a sourcing strategy project-by-project or whether they implement a common strategy across the project portfolio. Indeed, our research hypotheses on the impact of knowledge attributes of an NPD project on sourcing decisions are tested in the first type of firm.

A qualitative analysis carried out on the sample showed that in two firms the decision to draw on internal or external sources in NPD projects is predetermined by a common orientation, namely the protection of knowledge from technological leakage and hold-up risk. From the data we gathered through the field interviews it turned out that one firm prefers to rely on its own R&D resources and on the parent firm, whereas the other develops all the projects through long-term partnerships, which allows a high control over the knowledge generated. The approach adopted by the two companies can be ascribed to the closed innovation paradigm (Chesbrough 2003), which leads to a common sourcing strategy across their NPD projects. On the other hand, in the remaining five firms the interviewees maintained that they assess the two sourcing choices (internal versus external) project-by-project. The qualitative data has been supported by the findings of the independence test described below.

Table 2.1 summarizes the conjoint distribution of the above-mentioned variables: internal versus external sourcing, in the columns, and firms in the rows.

To validate the qualitative analysis on the sample of seven firms we carried out a Chi-square test of independence between the variables firms and internal versus external sourcing decision.

The *p*-value of the χ^2 test is approximately zero (χ^2 statistic $= 26$, df $= 6$, *p*-value $= 0.0002$), so we reject the null hypothesis of independence between firms and internal versus external sourcing decision. To verify that the projects of a single

Table 2.2 Statistics and p-value for the leave–1–out χ^2 test for independence

Firm	χ^2 statistics	p–value
1	25.647	0.0001
2	25.152	0.0001
3	25.479	0.0001
4	24.470	0.0002
5	23.672	0.0003
6	10.985	**0.0517**
7	16.932	0.0046

Table 2.3 Statistics and p-value for the leave-2-out χ^2 test for independence

Firm	2	3	4	5	6	7
1	24.897	25.224	23.987	23.132	10.982	16.134
	(0.0001)	(0.0000)	(0.0001)	(0.0001)	(0.0268)	(0.0028)
2		24.433	23.856	23.129	8.399	16.575
		(0.0001)	(0.0001)	(0.0001)	(**0.0780**)	(0.0023)
3			24.178	23.446	8.625	16.841
			(0.0001)	(0.0001)	(**0.0712**)	(0.0021)
4				21.644	10.546	14.347
				(0.0002)	(0.0322)	(0.0063)
5					10.129	13.187
					(0.0383)	(0.0104)
6						4.596
						(**0.3313**)

firm affect the results of the independence test, we repeated the χ^2 test removing the project of k firms (Bruce and Martin 1989). Therefore, when $k = 1$ we performed seven tests in each of which we dropped the projects of a firm. In the analysis, the testing procedure was conducted for $k = 1$ and $k = 2$. This leave-k-out procedure allows us to exclude the projects of two firms and to consider only the subset of projects of the firms that present potentially analogue behaviour with regard to internal versus external sourcing decisions.

The results of the test leave-1-out are summarized in Table 2.2. They show us that the firm 6 has conditioned the test of independence, indeed the p-value of the independence test when we exclude the data relative to firm 6 is 0.0514. Thus, we accept the null hypothesis of independence.

Table 2.3 summarizes the results of the testing procedure when $k = 2$ and shows us that removing firms 6 and 7 jointly produces a higher p-value (0.3313) than the leave-1-out test. Therefore, we removed the projects of these two firms, which implement a common sourcing strategy across all their NPD projects, and thus we restricted the sample to the projects of those firms which make their sourcing choice project-by-project. This implies that the sample size decreases to 60 NPD projects.

Table 2.4 Cross tabulation of novelty with breadth

	Novelty		
Breadth	0	1	Total
0	11	5	16
1	9	5	14
2	14	16	30
Total	**34**	**26**	**60**

The size of our sample is not small if we compare it to prior studies which adopted the project level of analysis addressing the sourcing decisions in the context of the innovation process. For instance, Cassiman et al. (2010) based their analysis on a sample of 52 R&D projects developed by one company, Kessler et al. (2000) relied upon a survey of 75 NPD projects carried out by ten firms, and Salge et al. (2013) carried out their study on 62 NPD projects developed by one firm.

2.6.2 Hypotheses Testing

The analysis of the composition of the final sample shows that half of the projects drew on external sources, primarily suppliers (24 projects) and, to a lesser extent, universities (5 projects), clients (4 projects), and consultants (4 projects). Concerning the governance modes adopted, 17 out of 60 projects were implemented through R&D development agreements. As far as the geographical distribution of the external sources is concerned, it turned out that 44.4 % of the sources are located beyond national boundaries.

Concerning the knowledge attributes (Table 2.4), according to our definition of *Novelty* the sample is characterized by 43 % of projects new to the industry and by 57 % new only to the firm. The extent of the *Breadth* is equal to 0 in 27 % of the sample, to 1 in 23 % and to 2 in half of the projects.

Table 2.5 displays the descriptive statistics and the correlations of all of the variables included in the model. The χ^2 test carried out between Novelty and Breadth variables shows that the two knowledge attributes are independent (p-value = 0.286). This means that projects with high novelty may require operating principles not necessarily from heterogeneous technological domains, whereas projects with high breadth may convey performance features which may also not be radically new for the industrial demand.

Qualitative cases from our sample support this finding. Exploratory projects from a customer perspective (high novelty) can introduce functions new to the industry by drawing exclusively on mechanical domains. An example can be a project which aims to produce a machine that does not need expensive, bulky and uncomfortable foundation pits, normally necessary in similar machines in the industry to have an acceptable distance between table and spindle nose. The solution to the technical problems, raised by the function required, namely a lowered trim morphology, has

Table 2.5 Descriptive statistics and correlation matrix

	1	2	3	4	5	6	7	8	Variance inflation factor
1. Internal versus external sourcing	1.00								
2. R&D development agreements	**0.63**	1.00							
3. Partner distance	**0.95**	**0.58**	1.00						
4. Novelty	**0.47**	**0.42**	**0.47**	1.00					1.086
5. Breadth	**0.26**	**0.30**	**0.25**	0.19	1.00				1.113
6. Firm age	0.02	– 0.11	0.02	– 0,03	0.00	1.00			1.374
7. Firm size	0.20	– 0.05	0.17	0.18	0.11	**0.36**	1.00		2.176
8. Firm R&D intensity	0.02	0.04	0.00	– 0,12	– 0.25	– 0,08	**– 0.31**	1.00	1.746

Correlation coefficients in bold are significant at 5 % level

been identified investigating exclusively the mechanics domain. On the other hand, exploratory projects from a technical perspective (high breadth) can introduce features new only to the firm as in the case of a project which introduced into a machine direct drive rotary tables, already used by other firms in the industry, in order to achieve higher accuracy and shorter switching times. This project implies a combination of knowledge from the mechanical, the electronics and software engineering fields. Mechanical principles are used for the design of the continuous rotary tables which allow the positioning and the clamping of the pallets on tapers, assuring stability and rigidity during machining operations. The electronics domain is investigated for the implementation of motion and measuring systems (motor, encoder, circuitry and indicator to display actual position and to monitor speed) which guarantee the total absence of backlash and the high resolution direct read-out of the position. Knowledge from the software engineering field means it is possible to program the machine while it is operating.

In order to examine multicollinearity, we calculated the variance inflation factor (VIF). VIFs are all below the rule-of-thumb cut-off of 5, thus issues of multicollinearity do not seem to prompt concern.

To verify the research hypotheses we fitted logit models to the data. This model allows us to use categorical variables. The independent variables are *Novelty*, a dichotomous variable, and *Breadth* whose values range across the following set: 0, 1, 2. The three dependent variables measure the sourcing choices at project level, and specifically:

- internal versus external sourcing, a dichotomous variable, where 1 indicates that the NPD project was carried out drawing on external sources and 0 indicates the absence of external technology sourcing.
- R&D development agreement, a dichotomous variable, where 1 indicates that the project involved R&D agreements for its development and 0 indicates the absence of joint development agreements with external sources.

Table 2.6 Results of the fitting model: internal versus external sourcing in NPD project

Variables	Model 1			Model 2		
	Coefficient	s.e.	p–value	Coefficient	s.e.	p–value
Constant	– 1.562	0.564	**0.006**	16.360	39.713	0.680
Novelty	1.991	0.610	**0.001**	2.052	0.714	**0.004**
Breadth	0.583	0.330	**0.077**	0.799	0.371	**0.031**
Firm age				0.020	0.203	0.921
Firm size				– 3.562	6.780	0.599
Firm R&D intensity				10.005	41.635	0.810
Dummy for firm 2				– 3.425	4.395	0.436
Dummy for firm 3				– 5.546	7.750	0.474
Dummy for firm 4				– 1.628	4.472	0.716
Dummy for firm 5				– 2.086	4.474	0.641
Chi-square	16.586		**0.000**	20.983		**0.013**
Number of cases	60			60		
Correctly predicted (accuracy rate)	73.3%			78.3%		

- Partner distance, measured on a 3-point scale, where 0 means that the project draws on similar cognitive sources within the firm's boundaries, 1 means that the project involves sources geographically located in the same country, and 2 means that the project engages sources from different countries, and therefore with a higher cognitive distance.

The model for testing H1, H2, H3 and H4 is the following:

$$f(y) = \frac{e^y}{1 + e^y} \tag{2.1}$$

where $f(y)$ may be interpreted as the probability that y is 1 for the external technology sourcing and R&D development agreement. Moreover, y is a linear combination of explanatory variables, that is:

$$y = \beta_0 + \beta_1 \text{Novelty} + \beta_2 \text{Breadth} \tag{2.2}$$

The model has been modified for testing H5 and H6 in order to take into account the dependent variable "partner distance" which is ordinal.

The results of the estimation procedure obtained by gretl software are shown in Tables 2.6, 2.7 and 2.8.

In Tables 2.6 and 2.7 the parameters of the models, that measure the contribution of the independent variables, are all significant and positive. Thus, the result supports H1, H2, H3 and H4, which predict the positive effect of the single knowledge attribute on external sourcing and on R&D development agreements. The two

Table 2.7 Results of the fitting model: R&D development agreement

Variables	Model 3			Model 4		
	Coefficient	s.e.	*p*–value	Coefficient	**s.e.**	*p*–value
Constant	– 3.144	0.833	**0.000**	3.548	54.556	0.948
Novelty	1.899	0.687	**0.005**	2.463	1.153	**0.032**
Breadth	0.859	0.404	**0.033**	1.164	0.444	**0.008**
Firm age				0.101	0.234	0.667
Firm size				– 2.510	9.668	0.796
Firm R&D intensity				12.900	49.789	0.796
Dummy for firm 2				0.922	6.420	0.886
Dummy for firm 3				– 1.197	10.536	0.886
Dummy for firm 4				– 0.476	4.802	0.921
Dummy for firm 5				1.073	4.874	0.826
Chi-square	15.056		**0.000**	20.043		**0.018**
Number of cases	60			60		
Correctly predicted (accuracy rate)	78.3 %			88.3 %		

Table 2.8 Results of the fitting model: partner distance in NPD project

Variables	Model 5			Model 6		
	Coefficient	s.e.	*p*–value	Coefficient	s.e.	*p*–value
Novelty	1.598	0.548	**0.004**	1.604	0.690	0.020
Breadth	0.391	0.330	0.236	0.623	0.369	**0.092**
Firm age				– 0.209	0.196	0.286
Firm size				– 2.676	8.179	0.744
Firm R&D intensity				9.245	37.175	0.804
Dummy for firm 2				– 3.711	5.277	0.482
Dummy for firm 3				– 5.764	8.808	0.513
Dummy for firm 4				– 0.065	3.548	0.985
Dummy for firm 5				– 4.882	4.913	0.320
Chi-square	15.477		**0.000**	20.885		**0.013**
Number of cases	60			60		
Correctly predicted (accuracy rate)	60.0 %			63.3 %		

estimated models seem to be able to correctly predict the sourcing choices: respectively 75 and 88.3 % of the fitted values match the observed values. The *p*-value of the likelihood ratio test is 0.012 and 0.017, thus the models can adequately explain the relationship between variables. Concerning H5 and H6 on the relationship between NPD project's knowledge attributes and the choice to rely on distant partners, the results show that novelty is significant (p-value = 0.02), therefore H5 is supported. As far as knowledge breadth is concerned, the p-value of the estimated coefficient is about 0.09, thus H6 is not supported. Knowledge breadth seems not to impact on decisions to rely on similar versus distant partners. From the results it turned out that firms aiming to add additional technological domains through an NPD project search for this knowledge outside the organizational boundaries and implement R&D development agreements, as confirmed by hypotheses H2 and H4, but the locus of this search can be both national and international, depending on where the specialized knowledge resides. Considering that the machine tool sector has a pivotal role both in the Italian manufacturing system but also in other countries (Germany, USA, Japan), the pool of specialized knowledge for the firms operating in this industry may be both national and international. The estimated model predicts correctly 63.3 % the observed values. The p-value of the likelihood ratio test is 0.013.

Nevertheless, we have to highlight that the number of observations used to estimate the models is small, though sufficient for the models without control variables. This suggests some caution in interpreting the findings.

As regards the control variables, the regression coefficients for the firm age, size and R&D intensity are not significant. The findings also remain robust when introducing the dummies in order to control for firms' differences.

We also investigated the possible effect of the interaction between *Novelty* and *Breadth* on external technology sourcing by estimating a complete model, but we did not find any significant interaction between the two independent variables (the p-value of the parameter of the interaction factor was 0.65).

2.7 Discussion and Conclusion

The chapter has addressed the issue of sourcing determinants proposing a project-level contingency approach. We focused on antecedents at the same level of analysis of the phenomenon under investigation, studying the attributes of the knowledge an NPD project aims to generate. We defined these attributes, accordingly with the literature conceiving the generation of new knowledge by a project as a discovery process within the sectoral knowledge landscape. The first attribute is *knowledge novelty*, defined in relation to the knowledge space of original product concepts and functionalities for market needs, and the second is *knowledge breadth*, defined according to the heterogeneity of technological fields that provides solutions to product problems. In our research we investigated the impact of these two NPD projects' attributes on three key sourcing choices.

Concerning the first decision (external versus internal sourcing), the empirical findings show that when a project engages in exploration at the frontier of knowledge novelty and knowledge breadth external partners are sources from which it might benefit from the point of view of learning advancements, uncertainty reduction and efficiency gains. As far as learning advantages are concerned, external sources, on the one hand, encourage divergent thinking for the generation of new state-of-the-art product concepts and functionalities (high novelty), and on the other hand increase the possibility to accumulate knowledge on heterogeneous technological fields (high breadth). Moreover, external sources might reduce the level of uncertainties related, on the one hand, to market acceptance of new concepts or functionalities when the project aims to meet ahead-of-market needs (high novelty), and on the other hand to the understanding of the possible interdependencies among heterogeneous problem settings (high breadth). Finally, efficiency benefits derive from the preliminary prototyping tests that external sources carry out in implementing new functionalities (high novelty), from the partitioning of project development risks and costs among external specialized partners and finally from compression of time to market due to partner expertise (high breadth).

As far as the second decision (how to source), is concerned results show that the exploration at the frontier of the knowledge space induces firms to involve external partners in NPD projects by means of R&D development agreements. This form of governance of the relationship allows the firm to pursue higher learning benefits in terms of successful identification of far analogies and effective transfer of the similarities detected (high novelty). Moreover, co-development agreements represent a learning vehicle also in terms of better understanding of different technological domain integration and in-house accumulation of specialized knowledge (knowledge breadth).

Concerning the third decision (where to source), from the findings it emerged that knowledge novelty spurs firms to rely on cognitive distant partners. The difficulty to overcome the physical and the cultural barriers seem to be counterbalanced by the benefits a firm can pursue by searching far from its local environment in terms of access to different customer mindsets and discoveries of non-obvious analogies. Especially in the B2B industries, as in the case of machine tools firms, specialized in complex industrial product adapted to the customer's needs with a strong component of complementary services, the search of original products' features and functionalities benefits from the interaction with nonlocal partners that allow the identification of cross-cultural differences that can be included in the firm offering. The exploration of additional technological domains through an NPD project (high knowledge breadth) turned out not to impact on the decision to involve similar rather than distant partners. The decision-making process about this specific sourcing choice can be influenced by further factors such as the relationships that the firm has built in prior NPD projects with partners in specialized domains. If in the past the firm worked with expert sources operating in the electronics or software engineering fields and over time they developed a shared system of meanings and norms, the firm may continue to rely on these sources independently of their geographical location. To this regard, explanatory factors at the project level should be complemented with antecedents at the firm level, such as prior experience with the same partner (Gulati et al. 2009). Moreover, the presence of regional clusters specialized in the same industry in different countries increases the opportunities for the companies to draw on a pool of expert partners within and across national boundaries.

Our research extends and contributes to the literature in three main ways.

First, the paper adds to the inbound open innovation literature by addressing the issue of a firm's sourcing strategy as a portfolio of decisions across NPD projects, complementing studies at the firm level of analysis. Some recent research that focuses at the firm level of analysis has made the implicit assumption that sourcing decisions are made project-by-project (Carson et al. 2006; Huang et al. 2009; Knudsen and Mortensen, 2011), but only a few studies have provided direct evidence of this (Bonesso et al. 2011; Cassiman et al. 2010; Kessler et al. 2000). Building upon this line of enquiry, we were able first to provide empirical evidence of a sample of firms which make their sourcing choices project-by-project, and second to theorize explanatory antecedents at the same level of analysis of sourcing decisions.

Second, we add to the project management literature, drawing attention to the issue of inbound choices related to the NPD project. This research has primarily provided tools and practices that enable firms to increase the effectiveness and efficiency of the internal NPD process neglecting the role played by projects as a means for exploring external sources in open innovation decisions.

Finally, we contributed to the knowledge-based view literature. The focus on the knowledge base determinants at the firm level investigated by previous research has overshadowed the analysis of the knowledge generated at project level (Nickerson and Zenger, 2004). Our research provides a theoretical contribution to overcome this gap by offering a conceptualization and operationalization of the two constructs of novelty and breadth that are coherent with the level of analysis investigated.

Our findings could find generalizability in a number of project-based industries (Hobday 2000), considering the relevance of "the ongoing projectification' of several sectors" (Söderlund et al. 2008, p. 517). Furthermore, we maintain that insights from the sector investigated in our research could be extended to similar industrial systems characterized by technological convergence.

Among the managerial implications that can be drawn from our results, we highlight that sourcing decisions made across a project portfolio calls for the need for a flexible network of collaborations (Faems et al. 2005; van de Vrande 2013) that can be quickly reconfigured in exploratory projects to meet any new market needs and to handle heterogeneous technological domains.

Moreover, our study has provided a point of departure for the debate of sourcing strategy as a portfolio of decisions made across projects. Our research shows that the advantages brought about by external sourcing are contingent to the knowledge a project aims to develop. Therefore, managers could select external sources through a careful analysis of the project portfolio.

Some limitations in this study have to be acknowledged. First, we favoured the richness of the data set on projects built upon a small sample of firms. Replication of the findings in a larger sample would be welcome. Second, we based our analysis on retrospective data. We tried to overcome major bias by the way in which we conducted our interviews (Miller et al. 1997), as reported in the method section; however, the known limits of this data collection method suggest some caution. Moreover, we operationalized partner cognitive distance using the geographical distance as a proxy. This measure does not consider other dimensions of partners' differences in terms of systems of interpretation and meanings, besides the cultural and the physical space factors. Finally, we did not include in our analysis the firms' prior partnering experience, which can complement project-level antecedents in explaining inbound choices.

We suggest that future research takes more explicitly into account the project level of analysis and its attributes in investigating sourcing choices. This research provides the opportunity for some new thoughts about the way knowledge novelty and breadth, as the coordinates of the search space in which a project searches for solutions, can be conceived as well as operationalized. Moreover, given the scarcity of previous theoretical and empirical work on this issue, future research could adopt a multilevel approach and delve into the integration between the knowledge base of the firm and the knowledge attributes of the project as antecedents of boundary spanning choices. Further studies could take into consideration the different firms' sourcing strategies approach adopted (project-by-project or common strategy across the project portfolio) in studying the antecedents that drive sourcing decisions.

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