Project Level Approaches for Open Innovation

Project Characteristics and Open Innovation Configurations

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Abstract

This paper contributes to existing knowledge of open innovation approaches and practices through a novel analysis at the project-level. This enables increased specificity and robustness regarding search breadth and science based search. Furthermore the paper introduces the novel measures 'knowledge breadth' to capture the degree of heterogeneity of knowledge sources searched and "source depth" to capture the influence of inclusion of several similar knowledge sources. The influence of these aspects on the innovation potential of projects is moderated by technological maturity. The findings have implications for open innovation literature through increased robustness of extant knowledge in and contributions of novel insights and concepts. Furthermore, daily practitioners of open innovation will benefit from explicit understanding of beneficial configurations at the project level.

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1. Introduction

The concept open innovation (Chesbrough, 2003) has attracted increasing attention since presenting the view that assets and competences needed for the development and commercialization of innovations are more often than not dispersed across different firms and organizations, rather than being centralized in one. Following Chesbrough's introduction of this new paradigm (Chesbrough et at., 2006) researchers have increasingly sought to understand how the inclusion of external partners and knowledge helps firms become and remain innovative. Indeed the growing body of research in the area of open innovation is providing strong evidence that the innovative performance of firms is influenced by how firms access external innovative capabilities or knowledge. Among some of the factors influencing the innovative performance are the number of external collaborations, the depth of these and by the choice of different partner types for such collaborations (Köhler et at., 2012; Laursen and Salter, 2006; Sofka and Grimpe, 2010; von Hippel, 2005).

However, a prevailing issue with the majority of this research is the all but exclusive focus at the firm level. This has so far leaving the project-level underexplored (Salge et at., 2013), which has implications for the relevance and robustness of the insights into the phenomena. Indeed there are several benefits from increasing the attention towards the project-level in open innovation research. First, the project-level is where the primary execution of strategies takes place (Shenhar and Dvir, 2007) and where open innovation search efforts are carried out by firms (Haas, 2010). Consequently, the focus on the firm level limits the amount of knowledge about how open innovation is in fact executed by firms, which constitutes a significant research gap in the open innovation literature. This gap merits the attention of open innovation scholars in order to better understand the collaborative efforts employed to develop innovative technologies, products, processes or services, and the effects thereof (Bahemia and Squire, 2010). Second and closely related, modern firms, perhaps in particular the innovative firms, are characterized by dynamism. Strategies are contingently adapted to the circumstances and characteristics of specific contexts, such as the projects in which they are executed. Thirdly, the authors will argue, existing measurements and analyses at firm level have inherent difficulties in explicitly separating the use of different knowledge sources and the purposes of such use. Measurement at the aggregate firm level does not necessarily capture whether an individual knowledge source is in fact used as input for radical or incremental innovation, and what the effects of using that source has on the specifically related innovation output.

Following Chesbrough's introduction of the term 'open innovation' (Chesbrough, 2003) and its establishment as a line of research, a large body of literature has investigated the approach, its characteristics and its potential. This research has provided valuable insights about firms' open innovation strategies and the effects thereof on open innovation. Laursen and Salter shows that the breadth and depth of openness related to the amount of knowledge sources used and the intensity with which these are used, is an important factor in understanding the innovation performance of firms (Laursen and Salter, 2006). Another important insight has been how searching for knowledge in different directions will impact firms' ability to introduce different types of innovations. One example has been the importance of involving science-based knowledge in the pursuit of new-to-market products or competitors for the purpose of imitation of existing products (Köhler et at., 2012). This has complimented the seminal work of Eric von Hippel on the involvement of users in firms' innovation efforts and how this can positively impact innovation (Baldwin and von Hippel, 2010; von Hippel, 1988; von Hippel, 2005). This and related work has provided valuable insights into the open innovation strategies employed by firms and the effects there of. The majority of this work shares the characteristic of focusing on the firm level in terms of both strategies for and effects of open innovation. However, the point of execution for strategies is indeed the project level (Haas, 2010). This is also true for open innovation strategies, as firms' often execute these through collaborations with external partners either for limited periods of time, on particular tasks or challenges, on a particular part of their total activities or in a combination of these.

The paper assumes that few projects are identical in terms of their purpose or configuration. Based on this assumption and the above arguments for applying a project-level approach, the paper assumes that firms approach open innovation projects dynamically and adapt the amount of, type of and role of participants and knowledge to the specifics of a given project. Considering this, extant analyses at firm level can be seen as assuming static one-size-fits-all approaches in a dynamic, contingent context. The paper reflects the limitations of this current firm level approach and argues for the relevance of increased the use of project level analyses. This, the paper argues, will benefit an increase in details and improve the understanding of how different approaches benefit different innovations. Hypotheses are presented regarding the influence of extant open innovation research's findings on the influence of search breadth and science based sources, as well as a novel measure of knowledge breadth, i.e. the number of knowledge domains accessed, and the choice of including multiple actors from the same type of knowledge source on open innovation projects. Following extant approaches for evaluating team and project level aspects related to innovation the paper tests the influence of these aspects on the value and innovation potential of the individual projects is through evaluations from independent, third party experts (Franke et at., 2013; Poetz and Schreier, 2012; Salge et at., 2013).

The structure of the remaining sections is as follows: Section two reviews extant literature on open innovation, provides critical reflections on the importance of including project level analyses, and builds hypotheses. Section three presents the data, variables and analytical approach used to test the hypotheses. Section four then presents and discusses the results and provides conclusions, before section five rounds of with reflections on limitations and suggestions for future research.

2. Open Innovation: Benefits of Project Level Analysis

The concept of 'search' has become central in the open innovation literature (Grant and Baden-Fuller, 2004; Koput, 1997; Köhler et at., 2012; Laursen and Salter, 2006) to explain where and to which degree firms search for and obtain external knowledge for innovation. This inbound part of open innovation (West and Bogers, 2013) is focused on identifying knowledge which the focal firm lacks, but may be access through the collaboration with one or more external partners. Extant literature has studied the influences on both mature and immature technologies from accessing knowledge from external sources such as universities, suppliers, customers and competitors (Grimpe and Sofka, 2009; Köhler et at., 2012; Laursen and Salter, 2006). Similarly, extant research has focused on how firms benefit from increasing breadth of openness towards external partners. Findings show that increased breadth, i.e. openness towards an increasing number of external partners, is beneficial to innovation and firm performance. However, this only applied to a certain extent, as increasing breadth beyond a certain point will eventually have negative impacts (Laursen and Salter, 2006). A shared feature of the extant research is the focus on firm level data and analyses. This, as will be argued below, presents some restrictions and limitations with regards to identifying whether one or the other source is used for radical or incremental innovation and to what effect. Similarly the influence of breadth on innovation output is not explicitly connected to one or the other innovation type. The following elaborates on these 'black box' limitations and argues how project level analysis can overcome these by complimenting existing firm level analyses.

2.1. Search Breadth

Despite the benefits of searching widely for and accessing distant external knowledge from a variety of sources (Jeppesen and Lakhani, 2010), there are limitations. As show by Laursen and Salter, an increasing breadth in terms of the number of external sources used by firms will eventually result in decreasing returns to their innovation performance (Laursen and Salter, 2006). The implications of this is that firms need to consider the upper boundaries of their absorptive capacity (Cohen and Levinthal, 1990), which is a significant restriction on the breadth of openness which will improve, rather than reduce, the firm's innovation output and performance. As argued by Laursen and Salter, innovation in mature technologies is likely to benefit most from high levels of breadth. This is due to an established dominant design (Suárez and Utterback, 1995; Utterback and Abernathy, 1975) and subsequent wide dispersion of knowledge related to the technology. As different sources can offer expertise on particular details related to incremental improvements on a mature technology, there are benefits from accessing a high number of these sources (Laursen and Salter, 2006). Conversely, in the less mature phase of technological life cycles the uncertainties regarding the technology is higher, previous knowledge of both the focal firm and their collaborations is likely to be obsolete and innovation are likely to be more radical (Afuah and Utterback, 1997; Anderson and Tushman, 1990; Utterback and Abernathy, 1975). Understanding and implementing uncertain and new, unknown knowledge will strain firms' absorptive capacities (Cohen and Levinthal, 1990), and exposure to too many radical ideas or too much new knowledge related to the immature technology is hence likely to negatively influence firms' innovations in the immature phase (Koput, 1997). Innovation in immature technologies is hence argued to benefit from lower search breadth than the mature technologies, since accessing fewer sources in depth will better facilitate the intake and utilization of complex and potentially distant knowledge needed for radical innovation at this fluent stage of technological maturity (Laursen and Salter, 2006).

Despite the significance of these insights, there are limits to the degree to which they explicitly measure the impact of a particular degree of breath and a related innovation output. This is due to an inherent inability of firm level data to distinguish between innovation activities related to mature or immature technologies, and explicitly connect search breadth to either and the influence thereof on innovation output, whether radical or incremental. The potential interference in the measurements and analyses is illustrated well by the fact that most firms are unlikely to exclusively pursue only radical or incremental innovations related to immature or mature technologies. In fact, an important motivation for engaging in open innovation is the opportunity to avoid lockins and missed innovation opportunities due to an exclusive focus on incremental improvements of mature technologies and products (Chesbrough, 2003; Chesbrough et at., 2006). Inherent in this motivation is the argument that firms pursue incremental improvements to existing offerings or processes, while also experimenting with more radical innovations in immature areas with future potential. Indeed most extant research categorizes radical and incremental innovation based on the fraction of a firm's sales from innovations which belong to one category or the other. The fact that firms rarely fit 100% within one or the other category confirms that occurrences of purely incremental or pure radical firms active only within mature or immature technological areas are rare (Grimpe and Sofka, 2009; Köhler et at., 2012; Laursen and Salter, 2006; Sofka and Grimpe, 2010). Rather, this confirms that firms' are ambidextrous in their approach to these two types of innovation. This presents an important challenge for the predominant aggregate firm level data used for measurements of search breadth. Such aggregation does not allow the analysis to distinguish between specific radical or incremental innovations, and which level of breadth is related to each. The consequence of limitation is that a significant degree of potential disturbance of the links found between breadth and innovation is accepted.

While the author does not question the overall insights regarding breadth provided by extant research, it is argued to be reasonable to reflect on the limitations described above. This paper argues that project level analyses will be beneficial in overcoming these limitations and providing confirmation of the findings with increased robustness and accuracy. Whereas the firm level analyses do not capture aspects of ambidextrous innovation efforts, and rather only capture the aggregate number of sources and innovation output, the project level analyses present an opportunity to capture this nuance. This nuance may consist of firms using high breadth, i.e. many external collaborators, for innovation efforts in mature technologies, while simultaneously using low breadth, i.e. few collaborators, for their efforts in immature areas, or potentially the opposite. A firm may generate the majority of sales from few valuable incremental innovations related to existing mature products, while simultaneously working on multiple radical innovations of immature technologies. Such a firm would be defined as performing incremental innovation on mature technologies due to the majority of sales from incrementally improved existing products. However, the high number of external collaborators reported could potentially just as well be linked to the radical innovation efforts taking place related to immature technologies, as to the incremental efforts generating the highest fraction of the turnover. Extant research assumes a link between aggregated input in terms of breadth and aggregated output in terms of innovation type, which may not necessarily always be present. Making this link more explicit and subjecting it to specific testing will improve the level of detail in open innovation knowledge and the robustness of the existing findings.

As indicated above, the advantage of a project level approach to understanding the influence of search breadth is the possibility to distinguish between the levels of breadth specifically related to an innovation project within a mature or immature technology area. With measurement at the project level, the approach further benefits by an ability to explain the influence of breadth on mature and immature innovation respectively. As the author does not find apparent reasons to question the extant research's findings on the influence of search breadth on the different types of innovation, the paper expects these to apply to the project level. The hypotheses regarding search breadth at the project level are therefore based on the existing findings that search breadth's positive effect on innovation will take an inverted u-shape, meaning that increasing breadth will improve innovation, albeit only to a certain point, after which further increase will decrease innovation (Laursen and Salter, 2006). Therefore, the first hypothesis of this paper is:

H1: *The influence of search breadth takes an inverted u-shape to project's innovation potential*

Extant literature finds that increasing search breadth will have a higher positive influence on mature than immature innovation (Laursen and Salter, 2006). This is argued to be due to the need for more in-depth interaction with fewer sources to absorb the complex and distant knowledge needed to develop new products or technologies in an immature phase. In line with this, the author expects the author expects the influence of breadth on the potential of open innovation projects related to mature technologies to be more positive than for more immature technologies. Complimentary to the firm level it can be expected that an increasing breadth in a project will reduce the ability of participants to exchange and absorb the complex knowledge required for the development of innovations of a radical nature in the immature phase. Conversely it can be expected that higher breadth is likely to be more beneficial at the project level for incremental innovations on mature technologies. The argument applied at firm level is that knowledge is dispersed following the emergence of a dominant design (Utterback and Abernathy, 1975) and that many different sources thus possess detailed knowledge about specific aspects of the technology (Laursen and Salter, 2006). As such, the incremental innovations needed to improve the established, mature technology are likely to benefit from interaction with a higher number of external sources, meaning that increasing breadth will benefit the mature potential of open innovation projects focused on mature technologies more than will be the case for immature technology projects. Based on this expected reflection of the benefits of increasing breadth at firm level to the context of the project level, the second hypothesis of this paper expects the following to be true for search breadth and technological maturity:

H2: *The positive influence of search breadth on innovation potential is higher for projects focused on mature rather than for immature technologies*

2.2. Knowledge Sources

Similarly to the role of breadth, the influence of different knowledge sources on innovation performance has attracted significant attention in the existing open innovation research. Since the early coining of the term by Chesbrough, one of the main ideas has been that firms' innovation efforts benefit from the use of external sources with specific knowledge and competences, which would complement those of the focal firm (Chesbrough, 2003). This idea has formed the basis of explorations of how different knowledge sources influence innovation for mature or immature technologies. These extant analyses have focused on the importance of science based search directed primarily at universities, marked based search oriented towards customers and competitors, and supplier based search, and how use of these sources will benefit either incremental or radical innovation efforts in the mature or immature technology phases respectively (Köhler et at., 2012). However, similarly to the challenges described above regarding search breadth, the aspect of search direction suffers from some limitations when using firm level data and analysis to explore the influence of knowledge sources innovation outcomes.

As with search breadth, existing firm level analyses lack details about one particular knowledge source's direct application for one or the other type of innovation. As a result there is an inherent potential for some degree of disturbance related to the conclusions on how search direction's inclusion of certain sources influences the innovation output. This issue is also relatively straightforward when exemplified by the fact that most firms are engaged in multiple innovation efforts simultaneously. These may all potentially have different goals and characteristics, making the aggregate firm level measures of the different knowledge sources open to potential inference when used as predictor of innovation outcomes. On the input side the majority of knowledge sources may be science-based, while the minority of sources might be supplier based. On the output side, the firm may generate the majority of their turnover from one radical innovation for an immature technology, while continuously working on and introducing numerous incremental innovations for an established, mature technology. This example would, using firm level analyses, confirm prior conclusions that science based search is correlated to higher levels of success in terms of immature rather than mature technologies (Köhler et at., 2012). This is well supported by the argument that the high novelty level of the knowledge available from e.g. universities (Cohen et at., 2002) is indeed well suited for radical innovation in immature technologies. On the other hand, as the science based knowledge sources are somewhat distant from commercial targets, rather focusing on basic research and free sharing of the knowledge generated through publications (Link and Scott, 2005), these are argued and found to less beneficial to incrementally focused innovation in mature stages.

While the author does not dispute existing findings that science based search is more beneficial to immature technologies than to mature, there are notable limitations to the measurements and analyses that have led extant research to such conclusions. As the innovation in- or output of the firm is measured at an aggregate level, there is limited opportunity to explicitly connect the science rather than supplier based input to the innovation efforts related immature technology output and vice versa. While concluding that the science- rather than supplier-based search is driving the success with innovation within the immature technology area is not necessarily incorrect, it does lack explicit identification and linkages. It is plausible that the above example would create some degree of misinterpretation. This may be due to firms generating the majority of their turnover from few radical innovations in immature technologies, which existing literature equates to such firms' science based search strategies being successful in positively influencing radical innovation. Nevertheless, with firm level analyses extant literature unable to reject the alternative explanation that the science sources are used as much or more for the purpose of the multiple incremental innovation efforts in mature areas, which are not necessarily generating the majority of the turnover. Based on aggregate firm level measures, such a scenario could drive conclusion that the science based search is influencing the innovation success within immature technologies, while in fact the science sources might be used just as much, more or exclusively for the mature technologies. While the link between science based search and radical innovations and immature technologies is not disputed by the author, the argument is that more explicit and precise identification will provide important confirmation and robustness for the findings. As such, the third hypothesis concerns the influence of science based knowledge sources on innovation:

H3: *The positive influence of science based search on innovation potential is higher for innovation projects within immature than mature technologies*

2.3. Source Breadth

Introduced by Laursen and Salter, the term search breadth reflects the number of different sources used (Laursen and Salter, 2006). However at the project level the author proposes the use of the modified term "source breadth", which allows a greater level of detail regarding the way in which knowledge from a certain source is used. While the original term search breadth compliments provides a measure of the number of sources accessed, the term introduced here provides a more detailed measure of the breadth of search within a single source. As such, source breadth measures the number of actors within a single source that are included in the innovation efforts. At the firm level the positive influence of increasing breadth on innovation is show to be greater for mature technologies than for immature (Laursen and Salter, 2006). As described earlier, this is due to the need for more intense interaction regarding immature technologies in order to develop and exchange the novel knowledge required for the often radical innovations resulting from efforts at this stage of maturity. Conversely, at the mature level, firms benefit from higher levels of breadth due to the dispersion of knowledge with several specialized sourced, possessing knowledge regarding detailed aspects of the technology, which can lead to incremental innovations.

The author expects the aspect of source breadth to follow a similar trend. For the immature technologies, the best strategy will be to include fewer actors within the specific source, i.e. low source breadth, in order to interact intensely and access the knowledge. This is due to the fact that knowledge is at this stage possessed by few actors since it is still novel, and the technology is still in flux without a dominant design which has allowed the wide dispersion of knowledge and capabilities. The mature technologies are however likely to benefit from an increase in source breadth. Knowledge is well developed at this point and several actors will have obtained specialist insights and capabilities, which can contribute to incremental innovations related to the mature technology. As such, the fourth hypothesis of the paper is:

H4: *The positive influence of increasing source breadth on innovation potential is higher for mature than for immature technologies*

2.4. Knowledge Breadth

Previous research has shown that firms that engage in distant rather than local search will be more radically innovative as distant search involves new combinations of knowledge and exploration of new knowledge domains (Katila and Ahuja, 2002; Rosenkopf and Nerkar, 2001; Rosenkopf and Almeida, 2003). While these findings focus on the distance between the focal firm and the source of innovation, they indicate that combining different knowledge domains will positively influence particularly radical innovation in immature technologies. While extant open innovation research has formed and tested hypotheses based on these insights, such efforts have faced limitations of firm level data (Grimpe and Sofka, 2009; Köhler et at., 2012; Laursen and Salter, 2006). Despite focusing on the importance and influence of the heterogeneity of sources used in open innovation efforts (Köhler et at., 2012), the extant research faces limitations caused by the use of firm level data and measures. The cause of this limitation is similar to those described earlier: There is an inherent inability to distinguish whether hetero- or homogeneity in the composition of sources is linked to mature or immature technologies and the innovation efforts and outcomes related thereto. Furthermore, these studies have not been able to distinguish in detail between the knowledge domains of different sources. This inability to differentiate between whether e.g. two suppliers contribute the same or different knowledge to the focal firm's innovation efforts may potentially lead to oversimplification. As such, extant research has not differentiated between whether five different firms can offer the same, two, three, four or even five different types of knowledge. In extant research one supplier is simply contributing the same as any other supplier, with no nuance of the potential heterogeneous differences in knowledge domains between these two independent sources. This paper argues that two different collaborators may offer significantly different knowledge despite the fact that they are both suppliers to the focal firm. The paper thus makes the proposition that distinguishing between whether the knowledge that is provided by two sources is homogeneous or heterogeneous is important to understanding both the nature and diversity of the knowledge which a firm accesses, and subsequently how this diversity may influence the innovation output.

To capture this potential diversity of knowledge, the author introduces the term 'knowledge breath', which similar to breadth in terms of the number of collaborators, reflects the homogeneity or heterogeneity of knowledge accesses in an open innovation effort. As such, knowledge breadth captures the degree to which open innovation efforts involve different knowledge domains. High knowledge breadth entails an open innovation effort which involves several different knowledge domains, while low knowledge breadth entails a more homogenous composition of knowledge. Innovation efforts may have high breadth in terms of the number of participants, but have low knowledge breadth in terms of the different knowledge domains. This would be the case when a collaboration involves several firms from the same industry. The knowledge offered by these firms is expected to be more homogeneous than if the firms had been from different industries. As extant research has found that distant search is related to radical innovations in immature technologies (Katila and Ahuja, 2002; Rosenkopf and Nerkar, 2001; Rosenkopf and Almeida, 2003) due to the access to new and different knowledge, the author expects that increasing the knowledge breath will similarly be beneficial to innovation in immature technology areas as new and profoundly different knowledge is combined to potentially result in radical innovations. On the contrary the author expects knowledge breadth to be less beneficial to incremental innovations in the mature technologies as this requires specialist, detailed knowledge about the technology in question (Laursen and Salter, 2006). Following this, the fifth hypothesis of this paper seeks to explore the influence of knowledge breadth on innovation:

H5: *The positive influence of increasing knowledge breadth on innovation potential is higher for immature than mature technologies*

3. Data and Analytical Approach

3.1. Data

The paper uses data on collaborative innovation projects, which have applied for co-funding from the European Commission under the 7th Framework Program. Data for the energy sector is used for the purpose of defining innovation projects within mature or immature technologies based on their respective technological areas. This provides a database of 1,729 project proposals submitted between 2007 and 2012. The data contains information on the 13,986 applicants involved in each project, which allows exploration of the specific configuration of each project. Furthermore the data contains the rating of the project provided by three to five independent experts, which is used to capture the effects of different configurations on the innovation potential of projects related to either mature or immature technologies. The data consists mainly of factual data regarding the technological areas of projects and the characteristics of the participants, with only the expert evaluators' score of projects a potential concern of validity. As described below, this measure consists of a thoroughly evaluated combination of at least three independent experts' individual scores, thereby increasing the validity and reliability. The author merges the project data with register data from the ORBIS database for each participant in order to develop control variables and checks of certain variables reported in the EU data. This unique dataset enables tests of extant findings on firm level open innovation regarding search breadth and the role of science based search. Furthermore it enables exploration of the potential impacts of knowledge breadth and source breadth on open innovation efforts.

3.2. Dependent Variable

The dependent variable in the analysis is the score given to each specific project by three to five anonymous, independent third party experts hired by the EU. Initially the experts create individual evaluation reports, before meeting to finalize the evaluation and provide the project score. The evaluation consensus is created at a physical meeting in Brussels with participation of all the experts, a European Commission staff member acting as chair to ensure that all voices are heard and all aspects covered, and finally another expert acting a rapporteur to summarize the agreements on, among other, the project score. This process ensures that bias and subjectivity of individual evaluators is minimized, thereby creating a high level of reliability and validity for this measure. All experts sign both a confidentiality agreement and a declaration of absence of conflict of interest, ensuring an unbiased peer review of the projects. Furthermore, the selection of the expert team is done to ensure a balance in backgrounds and the experts are required to evaluate all projects based on the same criteria each time, to ensure a cross project comparison. The dependent variable in the analysis is based on this evaluation, which is in turn based on three overall criteria that align well with previous research on the evaluation of proposed ideas or projects (Amabile et at., 2005; Kristensson et at., 2004; Moreau and Dahl, 2005; Poetz and Schreier, 2012): The first relates to technological excellence in terms of progressing beyond state-of-the-art and providing novelty compared to existing solutions within the particular technology area. The soundness of the project, the quality of the objectives and the methodology, as well as the work plan are also considered. The second criterion is related to the management structure and procedures of the project, the relevance of the participants, and the quality of the project consortia as a whole regarding complementarities and balance, as well as the appropriateness of the resource commitment in the project, which all reflects the feasibility of the proposed project. The third and final overall criterion concerns the potential impact from the project on European and international level and the plans for commercialization of the results. This criterion thus reflects the value of the idea in terms of creating benefits and solving challenges. As such, the project scores provide a measure which closely reflects both the aspects by which the majority of firms would consider a project to have high innovation potential, quality and value, and extant research’s well established measures of innovation quality and potential.

The use of a dependent variable consisting of experts’ evaluation of the quality or potential or an innovation or innovation project has been applied in previous related work. In their recent study of health care innovation projects, Salge et. al. apply a similar approach by using a dependent variable consisting of evaluations of innovation projects (Salge et at., 2013). These evaluations were performed by chief executives and reflected novelty, usefulness and likely commercial success and implementation of the proposed projects. In their work of analyzing the value of different problem solves’ contributions to new products, Franke et. al. use the evaluations of independent market experts to rate the novelty and usefulness of ideas generated (Franke et at., 2013). Similarly, Poetz and Schreier use the executives’ assessments of proposed solutions for the purpose of analyzing the value of user generated ideas compared to those provided by professionals (Poetz and Schreier, 2012). Indeed, the use of evaluations or ratings performed by supervisors, experts or other external evaluators to establish for instance the quality or potential of an idea, team or project is found by Anderson et. al. to be predominant in extant individual, team and project levels research (Anderson et at., 2014).

In the context of project level open innovation and the effects of different configurations, the dependent variable used in this paper has the advantage of capturing the potential and quality of a specific project. Although not a standard performance measure it is well recognized in previous studies, and has several advantages in addition to a being a close proxy of what firms would consider high potential and quality: Firstly, it is isolated from exogenous factors as it is only related to the configurations of a given project at the given point in time. The variable is not influenced by factors such as a financial crisis, unobserved changes in markets and demands, policy changes, entry/exit of competitors etc. over time and unobserved influences on the firm. Such factors would be difficult to measure and control if using firm level measures. Secondly, the variable is directly linked to the project, enabling analysis of direct links between the aspects described above, the radicalness of the project and the innovation potential gained from the specific configuration. This would also be difficult to achieve with firm level measures, as numerous other factors apart from the specific project would be expected to influence the firm level. Thirdly, the data includes both approved and rejected projects. Studies of firm or project performance based on allocation of funding would disregard the large and important sample of firms or projects, which do not receive such funding. Inclusion of approved projects only would also have the consequence of not understanding whether the approved projects do in fact differ from those rejected, and if so, how. As such, while recognizing the limitations of the dependent variable employed, the author argues that is provides a unique opportunity to carry out a analysis, which provides detailed and specific insights that contributes significantly to the robustness of extant knowledge as well as novel knowledge about relevant aspects of the open innovation paradigm.

3.3. Explanatory Variables

To analyze the importance of the breadth of openness (Laursen and Salter, 2006) a count of the number of project participants is included as an independent variable called *breadth*. According to Laursen and Salter the breadth of openness impacts innovation outcome in an inverted u-shape, which is tested by including the squared term of the number of participants, *breadth2*. Science based search is found to influence innovation outcomes at the firm level (Köhler et at., 2012), which is explored at the project level using the variable *university*. This dummy variable takes the value 1 if a project involves science based actors. To measure the introduced concept of source breadth the author includes the variable *university_breadth*, which reflect the breadth in use of the science based sources. This is measured by a count of the number of participants from that particular source on each project. As such, a higher number reflects higher breadth and broader use of different actors from the science based source. The squared term is included to capture potential decreasing returns to increasing source breadth beyond a certain point.

To explore the importance of the concept knowledge breadth, the analysis includes the variable *knowledge_breadth*. This variable captures the NACE code of each participant and provides a count of the number of different codes on each project. Higher numbers of knowledge breadth thus reflects higher heterogeneity in the composition of sources and knowledge domains. This allows exploration of hypotheses that projects in immature technologies are positively influenced by increasing knowledge breadth, while projects in mature technologies will benefit less. Similarly to breadth in terms of the number of participants and source breadth, the author expects that the effects of increasing knowledge breadth will only remain positive until a certain point. After this, it is expected that further increases in knowledge breadth will have negative influences as absorptive capacity limits are reached and the complexity of combining too many and too diverse knowledge domains becomes more than what is possible. To capture this potential effect, the author includes the squared term *knowledge_breadth2*.

3.4. Maturity

The paper differentiates between mature and immature technologies based on data on the market penetration of the individual technologies in 2007 in terms of generation of electricity, heating or cooling from renewable sources (European Commission, 2010; Sanner et at., 2013), or when not available, the evaluation of these technologies by relevant sources. Market figures are available for the mature energy technologies "Wind", "Hydro" and "Bio", and for the immature "Geothermal" technology and the "Solar" technologies photovoltaic and concentrated solar power. The market shares of these technologies are reported in table 1 alongside the other technologies with categorization and number of projects in the data. For the technological area of "General renewable energy generation" the author defines this as mature given a 15,6% market share of renewable energy in the overall electricity generation market. As "Energy efficiency" technologies were already in 2005 at a maturity level to allow a 20% decrease of energy consumption through maturity level of these technologies, this is defined by the author as a mature technology (European Commission, 2005). Table 1 provides an overview of the technologies, the number of projects in each area and the number of participants on the projects in total. The market share of the technology in terms of total renewable energy generation capacity in the European Union is provided where available. When not, the below arguments have been applied to substitute market share data in creating the categorization of the technologies also available in the table.

Table 1: Technologies, Projects, Participants and Categorization

Project Technology:	**Projects:**	**Participants:**	**Market Share:**	**Categorization:**
Wind	92	918	19,8	Mature
Geothermal	12	145	1,1	Mature
Ocean	51	451	0	Immature
Hydro	16	129	59	Mature
Fuel Cells and Hydrogen	88	725	-	Immature
RES Heating and Cooling	111	984	11,8 [1]	Mature
Clean Coal	70	663	-	Immature
Future Tech and Novel Materials	265	1266	-	Immature
General RES Generation	67	499	15,6	Mature
Energy Efficiency	259	2724	20 [2]	Mature
Sustainable Automotive	8	57	3 [3]	Immature
Bio	419	3418	19,4	Mature
Solar	271	2007	0,9	Immature
Total	1729	13986		

[1] As share of total heating and cooling consumption in EU
[2] As potential of state of technologies per 2007
[3] As share of total energy consumed for transportation

The technology area defined in the data as “Future technologies and novel materials” is argued by the author to be inherently immature and defined as such in this paper. As for “Sustainable automotive” this technological area currently comprises three percent of the total automotive area in the European Union and is accordingly defined as immature (Eurostat, 2013). According to the European Association for Coal and Lignite’s 2012 report on the clean coal technology, this is still a very immature area with targets of the first operational plants being ready in 2020 (EURACOAL, 2012). Similarly the European Technology Platform for Hydrogen and Fuel Cells describe the 2015 goals of hydrogen and fuel cell technologies to be improvement and validation of technologies before any commercialization is feasible (HPF Europe, 2007). As such, the author defines both “Clean coal” and “Hydrogen and fuel cells” as immature technologies as of 2007. The “Ocean” technology area is defined as immature as this still in 2011 is to gain any commercial scope and production (Jeffrey and Sedgwick, 2011). Finally “Renewable heating and cool”, which comprises a total of 11,8 percent of the European Union’s heating and cooling capacity, is defined as mature.

3.5. Control Variables

A number of control variables are obtained through merging the project data with register data from the ORBIS database from Bureau van Dijk. *Size* is included as control for the effects that the number of employees may have on the innovativeness of firms, given that larger firms may have more specialized R&D personnel or smaller firms may be more agile and innovative. Similarly, *turnover* controls for whether the size of each participant’s turnover will have an influence on the project, as financial strength may increase innovation resources and capabilities, and thus the potential of the project rather than the configuration of the participants. The variable *nuts* captures the geographical origin of each participant to control for potential national or regional influences. Finally, the variable *call_id* captures the particular call which each project applies within, with information on the year of application and particular foci of individual calls such as on promoting collaboration with BRIC countries or other.

3.6. Statistical Model

The author employs an ordinary least squares regression to analyze the continuous dependent variable capturing the score given to each project by the expert evaluators and applies robust standard errors to account for potential heteroskedasticity caused by any potentially omitted variables. To check for potential multicollinearity in the model the variance inflation factor is checked for both the incremental, radical and full sample. In all cases the VIF remains below 3.73 for all variables and the mean VIF below 2.11. Appendix 1 reports the full tables from the VIF tests. Table 2 provides the distribution of the experts’ scores by project types. While the non-normality of the distribution requires that the interpretation of the coefficients remains attentive to this, the findings are not devalidated by this issue.

Table 2: Project Types and Score Distributions

Project Type		Rating Intervals 0-25	25-50	50-75	75-100	Total
Mature	Count:	3,803	772	2,202	2,040	8,817
	Percentage:	43.13	8.76	24.97	23.14	100.00
Immature	Count:	1,473	681	1,651	1,364	5,169
	Percentage:	28.50	13.17	31.94	26.39	100.00
Total	Count:	5,276	1,453	3,853	3,404	13,986
	Percentage:	37.72	10.39	27.55	24.34	100.00

4. Results and Discussion

4.1. Descriptive Statistics

Through the use of project level data from applications for EU funding for collaboration innovation projects the paper explores configurations of open innovation projects and their influence on innovation potential. In table 1 above the list of technologies is provided with the designation of these into the mature or immature categories according to the definitions provide in the previous section and a count of the projects in the dataset. Table 3 provides descriptive statistics for the full sample, while tables 5 and 6 in the appendix provide similar statistics for the separate mature and immature samples.

Table 3: Descriptive Statistics Full Sample

Variable	Obs	Mean	Std. Dev.	Min	Max
expert rating	13986	45.54425	32.49149	0	100
breadth	13986	11.32161	5.531678	1	34
university_part	13986	.8732304	.3327266	0	1
uni_breadth	13986	3.047905	2.494927	0	16
knowledge_depth	13986	5.107393	2.057325	1	14
turn_over	13986	.451809	.49769	0	1
size	13986	.4016159	.4902425	0	1
call_id	13986	17.72287	9.070864	1	39
nuts	13986	550.1291	311.2091	1	1108

4.2. Results

The results of the regression analysis provided in table 4 show partial support for hypothesis 1. The output confirms extant literature's finding of an inverted u-shape relationship between breadth and innovation performance (Laursen and Salter, 2006), or in this context the innovation potential of open innovation projects, albeit only for mature technologies. These technologies benefit from increasing breadth as firms' access the specialist knowledge dispersed among several actors following the establishment of a dominant design and increasing specialization. This does however eventually lead to a negative influence as too many sources may be added and the upper boundaries of the participants absorptive capacity is reached. Interestingly we find a negative influence on the immature technologies, which is not previously show in open innovation research at the firm level. Although hypothesis 2 expected the positive influence of breadth to be greater for mature technologies, the significant negative effects are not only a very strong indicator of this, but a novel extension. Extant research has shown that mature technologies benefit more than immature technologies when search breadth is increased (Laursen and Salter, 2006), although a directly negative effect has not been shown on the immature areas. This does however find support from the argument that the immature technologies need few sources with more dedicated and deep interaction in order to absorb and make use of the distant new knowledge provided (Katila and Ahuja, 2002; Rosenkopf and Almeida, 2003). It is therefore reasonable to expect that an increasing breadth for the immature technologies would in fact have a negative impact on innovation, something which is confirmed by the results of this paper.

We find support for hypothesis 3 in the results showing that science based search has a positive and significant influence on immature technologies, while having no significance on mature technologies. This confirms extant literatures firm level finding that science based search is positively correlated with innovation performance in immature technologies (Köhler et at., 2012) by findings similar results at the project level. Furthermore, the results also show more explicitly than previous research that the influence on mature technologies is lesser than for immature through the lack of significance. The concept of source breadth was introduced and hypothesis 4 expected this to be more positively associated with innovation potential for projects related to mature than immature technologies. Support is found for this from the significant and positive results of *uni_breadth* on both mature and immature technologies, while the coefficient is higher for the mature. The interpretation of this result relates to hypothesis 3 as well. We see that the mature technologies do not benefit from the original inclusion of a science based source. Only once multiple sources are included, reflected by *uni_breadth* is the effect significant. Extant literature argues that mature technologies benefit more from inclusion of a wider range of input for innovation than the immature technologies since the knowledge is dispersed with several sources (Laursen and Salter, 2006). The author argues that the results here indicate that more universities and research organizations have relevant knowledge for the mature technologies and that these different science based sources are each increasingly specialized within their particular area, thus creating greater benefits from the inclusion of more of these on projects related to mature technologies. On the other hand, for the immature technologies it is likely that fewer science based sources are specialized within the emerging technology yet, and that the need for intense collaboration in exchanging and developing knowledge is what creates the lower benefit from increased source depth for the immature technologies. In fact, the results of hypothesis 3 show that one science based source is valuable to immature technologies, while having no significance for the mature technologies, providing further support for this interpretation of the confirmation of hypothesis 4.

Table 4: Robust OLS Regression Explaining Expert Scores

Project Type	**Incremental**		**Radical**	
Variables	Coef.	S.E.	Coef.	S.E.
breadth	1.872***	0.273	-1.699***	0.455
breadth2	-0.0318***	0.00774	0.0351**	0.0170
university_part	-0.716	-1.359	3.612**	-1.751
uni_breadth	4.621***	0.512	2.998***	0.701
uni_breadth2	-0.261***	0.0474	-0.234***	0.0732
knowledge_breadth	-3.183***	0.719	13.04***	-1.133
knowledge_breadth2	0.176***	0.0547	-1.397***	0.111
turn_over	-3.716***	-1.359	-3.629**	-1.583
size	-0.237	-1.335	-0.406	-1.628
call_id	0.629***	0.0347	0.272***	0.0432
nuts	-0.00329***	0.00109	-0.00194	0.00130
Constant	21.00***	-2.309	23.41***	-2.555
Observations	8,672		5,314	
R-squared	0.120		0.079	

Robust standard errors provided
*** p<0.01, ** p<0.05, * p<0.1

Finally, support is found for hypotheses 5a and 5b on the influence of the concept knowledge breadth. The variable *knowledge_breadth* is significant for both mature and immature technology projects, and has a positive influence on the immature projects, while negative on mature technologies. This confirms the hypotheses that mature technologies innovation benefits mostly from a local search (Rosenkopf and Nerkar, 2001; Rosenkopf and Almeida, 2003), which is limited in its knowledge breadth and focused on accessing the expert knowledge of sources with experience within the knowledge domain of the particular technology. On the other hand the immature technologies benefit from knowledge breadth, albeit to a certain point. As reflected by the negative influence of the squared term, knowledge breadth will eventually create too much complexity and knowledge diversity, resulting in an overload that reduces the quality of the open innovation efforts. Before this happens however, the projects related to immature technologies will benefit from knowledge breadth, which includes multiple different knowledge domains. This is argued to be due to the need for different and new knowledge in order to pursue radically new innovations.

5. Conclusion, Limitations and Future Research

A significant contribution is made by providing a novel project-level insight to the open innovation research stream. All but every empirical study of open innovation has focused on the firm level. This has resulted in a somewhat simplified view of open innovation, how firms use it and what effects it has. As such, this paper provides novel and important insight by exploring how firms reconfigure their open innovation strategies to accommodate either open innovation projects with a focus on either mature or immature technologies, and how such differences in configurations influence the outcome of projects depending the stage of technologies. The paper also more deeply understands the value of science based sources at the specific project level, rather than a generic firm level. In addition to this confirmatory contribution to the open innovation literature focus on the firm level, the paper makes several novel contributions based on elaborations of the firm level knowledge and the introduction of new concepts show to be significant to open innovation projects.

It is show that immature technologies do not only benefit less than mature technologies from increases in breadth, but are in fact negatively influenced. This provides stronger than before evidence that firms are better served with few intense interactions when pursuing innovations in immature technologies. Additionally, the paper introduces the concept of source breadth to reflect the extent to which multiple actors from a certain source are used. In the context of this paper the focus is on how the increase of science based sources will influence innovation, and results show that increasing the source breadth to access the knowledge of multiple actors within a certain source has positive influences on both mature and immature technologies. The influence is show to be stronger for mature technologies, which is argued to complement existing insights that knowledge in mature technologies is dispersed among several actors and therefore access to several of these is beneficial (Laursen and Salter, 2006). The novelty lies in showing this to be true particularly within individual sources rather than among a range of overlapping sources, and in providing evidence that for the mature technologies, the mere inclusion of one science based actor serves no purpose, while multiple actors will be able to provide the broad ranging knowledge valuable for incremental improvements.

Furthermore, the paper contributes with the novel concept of knowledge breadth. The author finds that increasing knowledge breadth to involve more knowledge domains is valuable for radical innovation, albeit with an upper boundary, most likely caused by limitations to the absorptive capacity of firms (Cohen and Levinthal, 1990). For mature technologies an increase in knowledge breadth is found to have a negative impact, which is likely to be caused by the need to have a narrow, in-depth knowledge about the technology in question in order to make the required incremental improvements. On the other hand, immature technologies benefit greatly from differentiated knowledge domains in order to develop more novel innovations, which is complimentary to the argument of distant search as a driver of radical innovation (Katila and Ahuja, 2002; Rosenkopf and Almeida, 2003). Combined with the insight on source breadth the insight would seem to be that mature technologies are best advised to focus on narrow breadth of knowledge although collecting this from multiple actors with each their expertise. Conversely, the immature technologies benefit from accessing a broad scope of heterogeneous knowledge, although from fewer sources within each area, since there is a need for intense interaction with these for the development and exchange of complex knowledge. Indeed, this would seem obvious implications not just for open innovation researchers, but also for innovation managers tasked with developing open innovation projects as they seek to appropriately configure the number and types of sources and partners, contingent on the nature of the project and technology.

While this paper has argued for the advantages of project level analyses of open innovation there a limitations to this approach. Firm level measurement and analysis are capable of capturing aspects, which are difficult for a project level analysis to capture. As an example a significant risk of open innovation strategies might involve an overreliance on external sources. One such drawback is the potential limited absorptive capacity (Cohen and Levinthal, 1990), which can arise from overreliance. Overreliance on external knowledge may deteriorate the internal innovation capacities and knowledge necessary to actually search for and integrate the external knowledge. The consequences of this may leave firms both without internal innovation capacities and without the ability engage in open innovation efforts. Such aspects are difficult to capture with project level analyses as this concerns the influence of e.g. breadth on firms overall innovation capacity. As such, firm level analyses of open innovation have their merits and have contributed greatly to the development of this emerging paradigm. None the less, the authors are positive that increasing focus in future research on the project level will help nuance existing insights from firm level, as well as test the concepts introduced and insights provided in this paper.

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7. Appendix

Table 5: Descriptive Statistics Incremental Sample

Variable	Obs	Mean	Std. Dev.	Min	Max
qt_exp_score	8672	4.234.581	3.329.213	0	96.67
breadth	8672	1.226.407	5.810.379	1	34
university_part	8672	.873155	.3328185	0	1
uni_breadth	8672	3.098.363	2.561.865	0	16
knowledge_depth	8672	5.465.406	211.528	1	14
turn_over	8672	.4836255	.4997606	0	1
Size	8672	.4346172	.4957352	0	1
call_id	8672	1.703.413	9.253.537	1	39
Nuts	8672	5.490.414	3.121.489	1	1108

Table 6: Descriptive Statistics Radical Sample

Variable	Obs	Mean	Std. Dev.	Min	Max
qt_exp_score	5314	50.76385	30.43009	0	100
Breadth	5314	9.783591	4.650866	1	28
university_part	5314	.8733534	.332608	0	1
uni_breadth	5314	2.965563	2.379594	0	12
knowledge_depth	5314	4.523146	1.813311	1	10
turn_over	5314	.3998871	.489921	0	1
size	5314	.3477606	.4763044	0	1
call_id	5314	18.84682	8.648426	3	36
nuts	5314	551.904	309.6903	1	1107

Table 7: Variance Inflation Factors

Full Sample		**Incremental Sample**		**Radical Sample**	
Variable	VIF	Variable	VIF	Variable	VIF
turn_over	3.66	turn_over	3.63	turn_over	3.73
size	3.54	size	3.51	size	3.63
breadth	2.98	breadth	2.84	breadth	3.29
knowledge_breadth	2.27	uni_breadth	2.24	knowledge_breadth	2.49
uni_breadth	2.20	knowledge_breadth	2.15	uni_breadth	2.21
university_part	1.35	university_part	1.36	university_part	1.34
call_id	1.09	call_id	1.11	call_id	1.09
nuts	1.00	nuts	1.00	nuts	1.02
Mean VIF	2.04	Mean VIF	2.02	Mean VIF	2.11