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The role of organizational knowledge integrators in large R&D projects

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Abstract

One of the challenges interorganisational collaborations face is the managing of knowledge transfer from one technological stage to another. This paper stresses that an organizational knowledge integrators can be an important partner in knowledge transfer in large R&D projects. The paper defines the knowledge integrators as partners in a project who utilize the knowledge created in specific technological stages, and at the same time the knowledge integrators are responsible of carrying the knowledge from one stage into the next technological stage. The quantitative empirical results show that R&D projects that are in applied research do have a tendency to involve a knowledge integrator. The findings furthermore demonstrate that the partner construction in projects incorporating a knowledge integrator differ from projects without a knowledge integrator by involving external sources such as a competitor, universities, and international partner. Finally projects involving a knowledge integrator do have a tendency to receive more funding.

Keywords: Knowledge integration, knowledge integrator, innovation and R&D projects.

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The role of organizational knowledge integrators in R&D projects

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Abstract

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Introduction

Every year national and international research programs support R&D projects for development of new technologies, often characterized by being far from the market introduction and with extensive development horizons. Each project goes through a series of technological stages from basic to demonstration before project is ready for market introduction. A project application receives funding for one or several technological phase, and in large R&D projects a multitude of actors are involved in formulating the application, but also in developing the technology. A key activity is the sharing of knowledge among the partners in the project; but vertical transfer of knowledge and technologies can pose problems (Kogut and Zander, 1992). So the question that is relevant to ask is how can the created knowledge be shared across the stages of technology development? Obviously, the knowledge and insights obtained does not flow automatically, but needs to be carried and transferred by actors (the holders) of the knowledge to other actors in the following project phases.

This paper argues that the core actors ensuring the transfer of knowledge from the current stage of development to the following stages are knowledge integrators. According to Grant (1996) *the primary role of the firm, and the essence of organizational capabilities, is the integration of knowledge.* A knowledge integrator is the actor who will use the knowledge created and subsequently be responsible for integration of the knowledge from one stage into the next. The literature on knowledge integration in interorganisational and cross-functional projects are of vital importance for R&D projects (Huang and Newell, 2003, Berggren, 2011, Enberg et al., 2010, Kogut, 2000). However, despite of this, the recommendations as to how the knowledge can be integrated in collaborative R&D projects is thus far not well-understood (Lindkvist, 2011, Tell, 2011). Hence, what is the role of knowledge integrators in collaborative projects, and how does their role change across different technological stages? The core assertion of this paper is that knowledge integrators are important partners in large R&D projects for two reasons. First, by involving knowledge integrators in R&D projects, the innovation process is likely to become more goal-oriented. Second, involving a knowledge integrator might also lead to more innovation and financial bigger R&D projects. However it is not clear who these knowledge integrators are nor what characterises them.

The aim of this paper is to identify and characterize the role of those who integrate knowledge in R&D projects, also called organizational knowledge integrators. This aim is analysed using the research question:

> *Who are the organizational knowledge integrators in technology-development R&D projects, and what characterises these knowledge integrators?*

The main gap addressed in the paper is that knowledge integration has thus far been analysed at the individual level, but when the context is large R&D projects then its reasonable to assume that knowledge integration is linked to the organizations involved rather than single individuals simply because of the sheer size and importance of the projects. The importance of examining knowledge integrators from an organisational level compared to individual knowledge integrator is twofold. First, to understand why collaborative partnerships and interorganisational relationships are beneficial for innovation and R&D (Ahuja, 2000, Child and Faulkner, 1998, Gulati, 1998, Hagedoorn, 2002), it is important to examine knowledge integration as an organizational capability (Grant, 1996) Second, individual learning and knowledge sharing between individuals enhances organizational learning and in most cases innovative performance (Cohen and Levinthal, 1990). Hence, focusing on the organizational level allows the research to move from an intra-organizational perspective to an interorganizational perspective.

Furthermore, this study contributes to an improved understanding of R&D projects and the interaction between the different partners and technological stages. The contributions of this paper are twofold. First, the results confirm the existence of organizational knowledge integrators on a project level. Not only by showing that projects involving a knowledge integrator have a longer duration, are financial bigger, and are mainly represented in applied research. The results also strongly indicate that projects incorporating a university, competitor, or an international partner tend to involve a knowledge integrator. The second contribution is to the knowledge integration literature. Examining organizational knowledge integrators on a project level contribute to a deeper understanding of how knowledge is transferred from one technological stage to another. Furthermore, the paper uses objective program level quantitative data, which ensures both a longitudinal but also unbiased analytical results. While the existing knowledge integration literature on a project level mainly presents specific qualitative findings (Magnusson and Lakemond, 2011, Söderlund and Tell, 2009) this paper aims for more generalizable results.

The paper proceeds by a conceptualization of the knowledge integrator by discussing the knowledge integration and creative accumulation. After the empirical context, the data and the variables are described. Lastly, the paper discusses the results which lead to a final conclusion.

The theoretical background: Knowledge integration and creative accumulation

The literature on interorganisational relationships has long claimed obvious benefits from incorporating external partners in the innovative project. One of the claimed benefits of working with external partners is exchange of knowledge for the benefits of learning and mutual innovation within the boundaries of the project (Tsai, 2001). However, in such projects one firm typically invites the partners to be involved, what Pisano & Verganti labels a *consortium* structure (2008:4). Furthermore, with increasing research and capital intensity, a larger set of equal partners is typically required to carry the risk and the technological challenges, because the ambition of the project transcends the capacities of single firms. Here there is not necessarily one key partner that coordinates all efforts, but rather a set of partners that interact to first complete the application, identify additional partners and submit the application. Second, to actually to complete the project according to the project description in line with the original ambition once the funds have been obtained. A key activity within such projects is the exchange and integration of newly created knowledge with the differing insights of the individual project partners, and therefore implies a coupling of existing *actor-specific* knowledge with new *collective* knowledge and insights. Willem et al (2008: 371) define knowledge integration as: *include sharing and transferring knowledge, but also the collective application of knowledge in cooperative activities. This integration exists on* *different levels in the organization; namely within teams, subunits, communities, or the organization*.

An example of an intra-firm structure for knowledge integration is illustrated by the processes in cross functional teams, where the team structure stimulate knowledge flows among team members, as well as create a platform for changing and improving these knowledge flows (Magnusson and Lakemond, 2011). The same kinds of processes are observed in interorganizational projects where the team members are external partners with different backgrounds and competence and where the knowledge exchanges between the partners. While it is widely acknowledge that companies should integrate knowledge from external partners to key actors within the firm (DeBresson and Amesse, 1991, Enkel et al., 2009), it is a challenge to understand how the knowledge and the interaction between different partners is integrated in the collaborations (Tell, 2011).

Knowledge integration processes stimulate the combination and recombination of knowledge into new combinations. These new combinations are discussed in Schumpeter's analysis of innovation and economic change (Schumpeter, 1939). The new combinations create innovation, which are also called creative accumulations (Granstrand, 1998, Bergek et al., 2011, Breschi et al., 2000). Creative accumulation is a process where companies explore innovation built on established knowledge. From a knowledge-based view the term, accumulation, implies that innovation is competence-enhancing rather than competence-destroying if it is created on previous knowledge rather than substituting for it (Granstrand et al., 1997, Bergek et al., 2011). Such processes are especially needed in research and capital-intensive R&D projects with high technological complexity that transcends technological disciplines and multiple areas of expertise where actors and areas of expertise are required to interact in new ways to develop improved technological performance.

Research and capital-intensive R&D projects rely on existing knowledge to develop new knowledge. Therefore, this paper argues that creative accumulation is the foundation of such research and capital-intensive R&D projects. It is also important to emphasize that creative accumulation cannot be accomplished in isolation (Bergek et al., 2011).

The above discussion implies that knowledge integration is about sharing and transferring knowledge, but also the application of knowledge for the collective, namely the joint R&D project. The processes of integrating knowledge are driven by key actors in each project and the complexity in these projects can be high due to the number of actors and their dependence on each other (Carlile and Rebentisch, 2003). The key actors in a R&D project can be a knowledge integrator.

Who is the knowledge integrator?

This paper posits that a knowledge integrator is *a partner in a R&D project who is responsible of implementing the knowledge created in the project into the next stage of the technological development*. It is important to emphasize that the knowledge integrator is the actor who will use the knowledge created and the knowledge integrator might also have an monetary interest, but in the energy sector where R&D can be regulated, it may not always be the final interest to commercialize the development and introduce it to the market, but only to employ it. The knowledge integrator in the R&D projects is not always a university or a customer, but may differ with the project description, the project aim etc. Part of the problems in researching knowledge integrator is therefore linked to the problem of identifying the actual knowledge integrator. How does the knowledge integrator distinct from the other partners in a project? A knowledge integrator can take form of a company or a university, but when a partner takes form as a knowledge integrator, the organizational role in a R&D project changes. Going from being a partner in a project to being a knowledge integrator means that the knowledge integrator is responsible and has en interest of taking the knowledge to the next stage of technology development. The other partners in the project might also have an interest but they might not have capabilities or knowledge of taking the created knowledge to the next technological phase.

When discussing the role of knowledge integrators in interorganizational projects, it is pertinent to investigate whether knowledge integrators are significant in driving R&D projects towards innovation. To create innovation, the partners in a R&D project span different knowledge areas, and they combine their own knowledge with insights from other technical areas. As a result the firms test and adapt their innovations by mobilizing the knowledge from the partners in the collaboration. To ensure the best possible result of the R&D process, one could argue that the combination of partners in the R&D project is highly relevant. This paper investigates who the knowledge integrator is and when the role of the knowledge integrator is important in regards to technology stages. Incorporating a knowledge integrator can result in an innovation process with technological stages that is not continuously interrupted or perceived as stages of entity, but more of a flow of knowledge where the knowledge integrator integrates the created knowledge in every stage. By integrating the knowledge integrator in R&D projects, the innovations process might become more efficient and thereby more goal-oriented in a technical sense. As a result of the knowledge integrator, the technology might at the end of the innovation process be utilized, because the technology from the beginning is more focused and one may argue that the knowledge integrator keeps the innovation on the track.

Hypotheses

As explained above, external sources of knowledge are important to a firms new innovation activities (Inkpen and Tsang, 2005). To stimulate extensive knowledge sharing between different actors in R&D projects, whether hitherto un-experienced new firms or large established ones, public funding for R&D activities are increasingly linked to demonstration of knowledge sharing within these projects (Abramovsky et al., 2009). A Research and Technology Organizations[1] (RTO) is an advanced technology group, who has a pre-defined role to bridge the research environment e.g. universities with industry. In the literature, these companies are also defined as *knowledge brokers,* because their function is to intermediate knowledge between two entities (Hargadon, 1998). In a

[1] The literature often speaks of Research and Technology Organizations (RTO's). The European organization for RTO's, EARTO, characterize the role of a RTO as: *RTOs occupy nodal positions within innovation eco-systems, bringing together key players across the whole innovation chain, from fundamental to technological research, from product and process development to prototyping and demonstration, and on to full-scale implementation in the public and private sectors* (www.earto.eu). In Denmark, RTO's are labeled GTS (**G**odkendt **T**eknologisk **S**ervice) for Approved Technological Service.

university and industry collaboration, a knowledge broker could be a RTO that mediate between the two parties. An advantage with inclusion of a RTO is that the institution consists of experts that understand both the academic perspective and the industrial view, and can thereby communicate and link the parties and help the communication flow between them (Hoegl and Schulze, 2005, McEvily and Zaheer, 1999). An obvious assumption is therefore that a RTO is a knowledge integrator! But compared to the knowledge integrator, the RTO is often not motivated by its own strategies to use the results of the R&D projects, because their function is to *facilitate* the process rather than *engaging in own innovation* activities (Howells, 2006) and therefore to build their own profits from process facilitation rather than innovation *per se*. A knowledge integrator is defined to use the knowledge created in the projects and has therefore an interest in bringing the knowledge to the next innovation stages to build own long run profits from the R&D project. A further question is therefore whether knowledge integrators may even substitute for RTOs? It is imaginable, that the knowledge integrator may communicate with the different partners in the projects, because they are the ones who will bring the knowledge into the next stage. Hence, a RTO can be a substitute for a knowledge integrator, if a knowledge integrator is not incorporated in a project.

H1: Projects incorporating a knowledge integrator are less likely to have a RTO in the project, compared to projects without a knowledge integrator.

Mansfield (1998) have shown that around 10% of new products and processes introduced by companies would not have been developed (or only with great delay) without the involvement of academic research. Furthermore, it is found that university and industry (U/I) interactions can be very important in regard to science-based technologies (Meyer-Krahmer and Schmoch, 1998, Beise and Stahl, 1999), in particular these have been shown to be strongly correlated with generating patents, products, and spin-off companies (Gulbrandsen and Smeby, 2005). In R&D projects where a university is incorporated it is important that the partners in the projects gain value from the collaboration and that the industrial partners understand that it is research and not commercial products and development that universities excel in (Rosenberg and Nelson, 1994). This also means that successful U/I collaborations require that universities needs to be motivated in research that industry also considers valuable and industry must be made aware of employing the types of research that universities are producing (Santoro and Chakrabarti, 2002). According to Inzelt (2004), universities and research institutes can be the primary source for R&D collaboration if the companies need them, and innovation policy program are important in facilitating such collaborations in R&D projects. A project, where a knowledge integrator is involved requires that the knowledge integrator interacts with the other partners including universities to establish creative accumulation. Especially in technology-based R&D projects on the program level, the probability of university participating in a project is high. Another argument is that if a project is only a university focused project a knowledge integrator might not be incorporated in the project. To go from basic research to applied research indicates that partners with an interest besides basic research are incorporated in the project (Ranga et al., 2003) and that potential partner could be a knowledge integrator.

H2: Projects incorporating a knowledge integrator are more likely to involve a university compared to projects not incorporating a knowledge integrator.

Different partners and their knowledge can complement a company's internal knowledge and thereby increase the innovative performance of a company. But what happens in a R&D project when a partner is a competitor? Cooperation among competitors is analysed and argued to be advantageous because the companies' resources and capabilities can be combined and used in competition against other competitors (Bengtsson and Kock, 2000). Further, an important reason for including competitors is that they have the same insights about market needs and the same fundamental knowledge needed to serve the same market, and therefore the basis for collaboration and mutual understanding should be obvious. But according to Bleeke & Ernst (1995), the combination of cooperation should not include competitors for the reason that this combination has a tendency to fail, because the competitors will work against each other. From a strategic point of view, Bengtson & Kock find that *R&D activities can be carried out in cooperation with competitor, but when it comes to launching a new product; competitors choose to compete to distinguish the products from each other* (Bengtson & Kock, 2000:424). Further, the risks of including competitors in projects can be poor exchangeability and it can make the process of exchange much more difficult, expensive, confining and risky while it can also offer many benefits (Perks and Easton, 2000). Child & Faulkner (1998) argue that it is important that the partners not only complement each other, but that they actually need each other. In this way, the competitors can prevent working against one another, because they are dependent on each other's competences and knowledge. Examining the advantages and the disadvantages of collaborating with competitor one may argue that R&D projects incorporating knowledge integrators might choose to take the chance of collaborating with a competitor despite the disadvantages. If the main goal is creative accumulation by using different sources of knowledge, a competitor in a R&D project might result in creating something unique that might benefit the whole industry. With other words, projects incorporating a knowledge integrator might incorporate a competitor compared to projects not incorporating a knowledge integrator, because the R&D projects are more focused on the creative accumulation process rather than the mistrust that can result in failure. This leads to the third hypotheses:

H3: Projects incorporating a knowledge integrator are more likely to include a competitor compared to projects not incorporating a knowledge integrator.

As innovation becomes more and more open (Chesbrough, 2004) and knowledge transcends and flows freely across borders, it becomes more and more common that R&D projects involve international partners. To incorporate the best competences and knowledge in R&D project, it is likely that this is found in an international rather than a domestic setting. The reason for this is that these international partners might be leading actors in specialised research areas and their knowledge and resources can make them indispensable in a particular R&D project. R&D projects with international partners make it possible to do global exploration and generate value by drawing on resources of all the international partners. Collaboration with international partners is not only an industrial phenomenon as the importance of international collaboration is also increasing in the scientific world (Luukkonen et al., 1992). The likelihood of international partners in R&D projects incorporating knowledge integrators might be higher than projects not incorporating a knowledge integrator. The reason for this is that knowledge integrators seek partnerships where the exchange of knowledge exists and where the possibility for creative accumulation is greatest. Working with international partners makes it possible to create unique creative accumulation. At the same time a knowledge integrator is focused on employing the results, and therefore responsible of implementing this in the next stage.

> ***H4: Projects incorporating a knowledge integrator are more willing to work with an international partner compared to projects not incorporating a knowledge integrator***

R&D projects can be very financial costly and the level of risk may be high (Rosenberg, 1990), but on the other hand successful R&D can lead to sales growth (Granstrand, 1998). Basic research at universities is based on *generalisation on a restricted number of variables, and results in publications and reproducible experiments* (Pavitt, 1991:11). On the other hand, applied research is a combination of research and development, testing, production, engineering with the goal of seeking potential application by combining these research results with company assets. The gap between science (university, public research, laboratories ect.) and industry (industrial and service activities) has received a lot of attention in the context of growing importance of knowledge, technological competiveness and innovation (Ranga et al., 2003). U/I collaboration is a widely studied area that confirms the significance of U/I exchange of knowledge especially when the projects are basic research (Dasgupta and David, 1994, Salter and Martin, 2001). According to Chiesa and Manzini (1998) in the early stages of research and development as in basic research, the collaboration should favor knowledge exchange. When moving from basic research, applied research collaborations are usually conducted with other partners from the market such as suppliers, competitors, customers etc[2]. A great deal of the research that is supported by government is applied, or practically oriented, and the focus is on solving general social, technical or economic problems using the competences of science (Pavitt, 2001). Many R&D projects funded by public resources are based on the Triple Helix model, where academia and industry go together supported by a governmental institution (Etzkowitz and Leydesdorff, 2000), and these kinds of projects are not basic research but applied research. Therefore one may argue that R&D projects in applied research including a market integrator collaborates more with universities compared R&D projects in basic research. The market integrator is most likely interested in research that has an applied approach rather than basic research. This leads to the final hypotheses:

> **H5: Projects in applied research incorporating a market integrator are more likely to collaborate with university partners compared to projects in basic research incorporating a market integrator**

The following section will present the empirical setting of the paper.

[2] http://stats.oecd.org/glossary/detail.asp?ID=120

Empirical Setting

The Empirical setting of this research is R&D projects funded by a Danish transmission company (TSO) called Energinet.dk. The energy sector utilizes relative large and financial demanding projects where they are constructed in a way where there are different actors assembled in projects. These actors are partners in a project and together most of them finance half of the amount of the project and apply for funding for the rest of the amount. An example of this could be a project that wants to develop a new technology that can produce sustainable energy. When a project with this mission is formed, partners can often be universities with the latest knowledge about the technology, different suppliers of equipment and electricity companies that in the end has to use the technology and implement the innovation in the energy system.

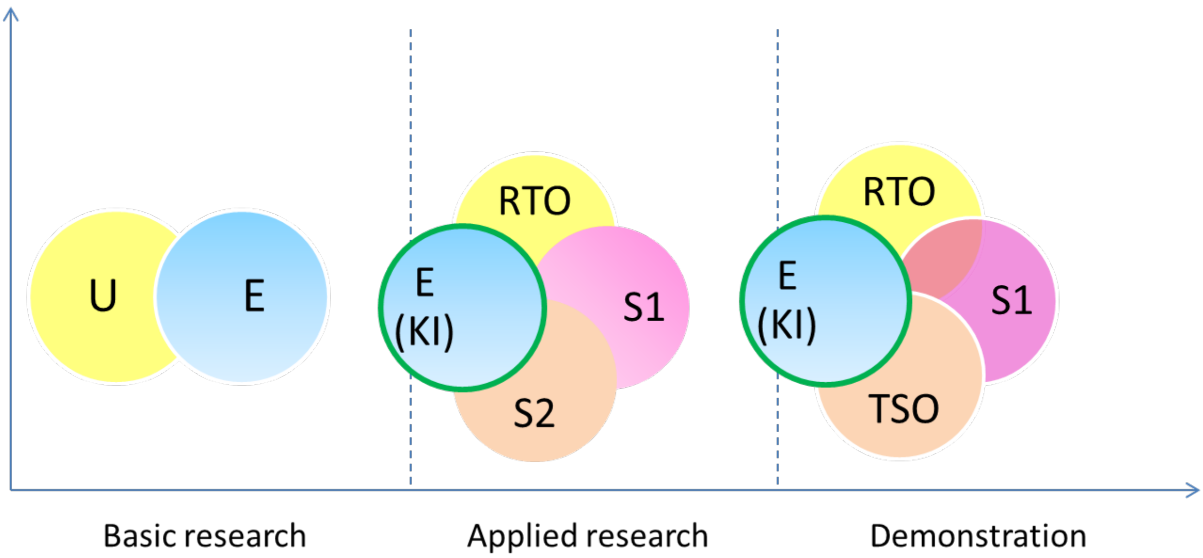

Figure 1: *The knowledge integration process across technological development phases*

Figure 1 illustrates an example of knowledge integrators in a R&D project. A R&D project do often start at basic research and over time it evolves to other technological stages such as applied research and demonstration. A project can first consist of a university (U) and an energy company (E) that will finally implement the innovation. In other words, the energy company is responsible of implementing the knowledge. Moving the R&D project into the next phase called applied research, other partners might become involved in the project such as suppliers of components (S1 and S2), RTO, and the energy company is still in the project, brining knowledge created from basic research into the next phase. Therefore the energy company is the knowledge integrator (E (KI)) and the green circle symbolize that the energy company is the knowledge integrator in the project. Going from applied research to demonstration, new partners might join the project such as a transmission company (TSO), and the knowledge integrator will take the knowledge from applied research and is responsible of implementing the knowledge in the demonstration stage.

Data collection

The data used in this study consists of 401 funded projects from 1988 to 2008. The dataset was compiled in 2008 by the energy program with the purpose of evaluating the program and the funded projects. The aim of the dataset was to provide a comprehensive overview of all the projects that were initiated under the PSO program in its 10 year lifetime. The list of projects is updated to 2008 range and is not updated subsequently.

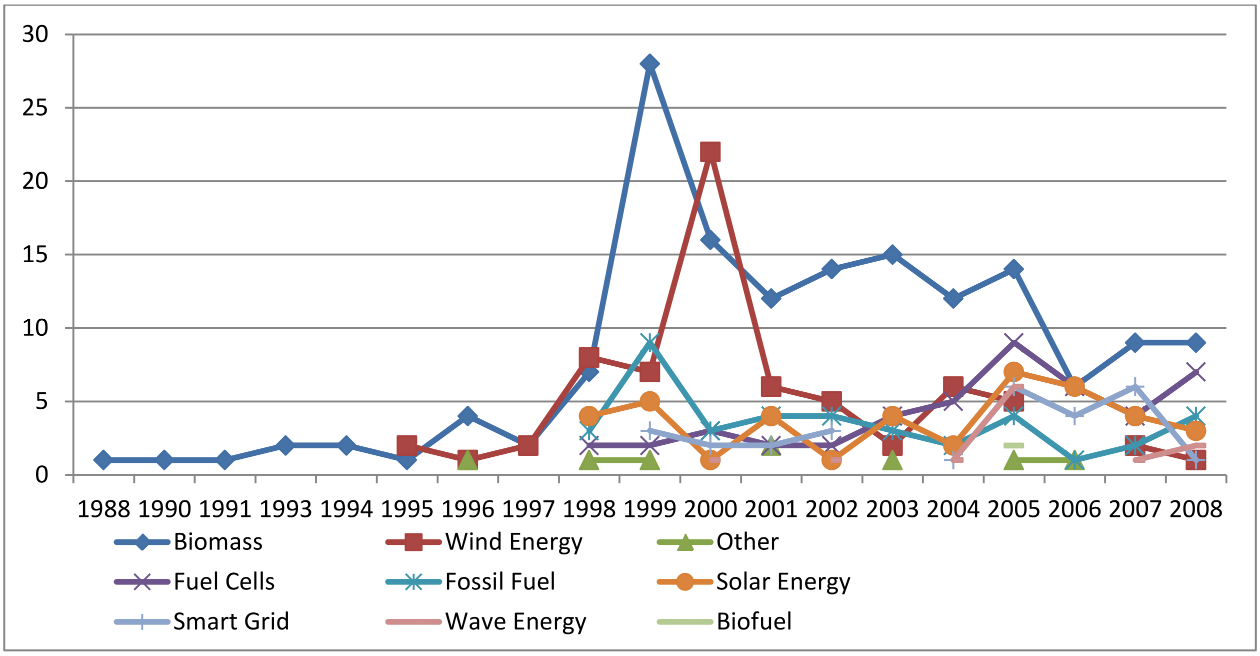

Figure 2: The amount of funded projects from 1988-2008 divided in energy areas

Figure 2 illustrates the number of projects funded by Energinet.dk from 1988-2008 divided in energy areas. It illustrates that the energy areas such as biomass and wind energy have been financial supported a great deal for many years, but the number of funded projects in these areas has declined. A reason for why these projects have received much public funding is due to the political regulations over the years. As the energy areas becomes more and more commercial, the public support declines as the program only supports upcoming technologies. The figure also shows that an energy area as fuel cell is increasing. This is also because of the political support shown by the Danish government. Furthermore with the goal to understand the evaluation process of the projects, an observation study was made which includes the evaluation of 36 projects.

Dependent variable: Knowledge integrator

The main dependent variable used is the knowledge integrator variable. The researchers engaged external experts to assist in identifying knowledge integrators based on actor identities. As all partners are named in an application with name and address, the key challenge is primarily to identify whether a particular partner in fact is a knowledge integrator or not in each stage of the project. To ensure a credible assignment, the researchers developed a tool and a description and carefully informed the experts about the tool and the particular conceptualization of knowledge integrators before they coded each partner in each project application with either a 1 (for yes) or a 0 (for no). The experts are highly knowledgeable not only about energy technologies in a broader sense, but in particular one of the experts is very experienced with the PSO program (from which the applications are drawn) and has also in earlier periods been associated with some of the projects on an administrative level. Today one of the experts is still working within some of the technology areas underlying the projects. The person therefore has the knowledge and expertise to evaluate if the knowledge integrator was in fact part of the projects. However, the researchers further cross-checked with a second expert to validate the coding of the expert. This validation resulted in a revision of the codings, based on a discussion with each of the experts on the cases where there were disagreements on the coding. In total the researchers revised 401 cases.

Knowledge integrators in the energy sector	Description	Knowlegde integrator type
Suppliers of energy	This category includes companies that supply materials to energy production. Some of the companies can also produce electricity. Examples of companies are Shell and DONG Energy A/S.	Market integrator
Producers of energy (electricity and district heating)	The category includes producers of electricity and district heating. Examples of companies are EPZ Holland, Vattenfall A/S, Nordborg Kraftvarmeværk etc. These companies produce electricity and district heating.	Market integrator
Transmission and distribution (energy companies – monopoly)	In this category includes utilities and transmission companies. E.g. Energinet.dk is a transmission company who owns all the natural gas transmission system and the 400 kV electricity transmission system.	Market integrator
Trade and sales (energy companies)	National utilities are included in this category. They trade and sell electricity on the market. E.g. Dong Energy A/S.	Market integrator
Suppliers of plant and components	Companies in this category are different suppliers of components and plants. It can be all from a national wind turbine producer to a local blacksmith shop.	Market integrator
Other private companies	This category includes companies that do not directly supply components but their service is still beneficial for the projects. An exampel is Eurofins Steins Laboratorium A/S which is an authorized an accredited to perform analysis in agriculture, dairy and food. Their service might be useful in fuel cell projects.	Market integrator
Advisers and consultants	Advisers and consultants are incorporated in the projects to supply their knowledge and expertise. The category includes normal consultant companies like Rambøll A/A to more specialized institutions with chemical expertise.	Science integrator
Universities and research institutions	The category includes national and international universities and research institutions.	Science integrator
RTO (Approved technological service institutes)	RTO – Advanced Technology Service Institutes is a network consisting of nine independent Danish research and technology organisations. They support innovation and constitute the core of the technological infrastructure in Denmark.	Science integrator
Public authority	This category includes public institutions like a municipality or DMI who provides meteorological information and forecasting in Denmark.	Societal integrator
Politicians	Other national or international research programs are included in this category.	Societal integrator
NGO (non-governmental organizations) and industry association	The category includes NGOs but also industry associations that supports the Danish energy industry.	Societal integrator
Investors (funds etc.)	Investors like firms or fund who want to support projects are included in the category.	Societal integrator
Other research programs	Other national or international research programs are included in this category.	Societal integrator
Households	This category includes household and end users of electricity. Projects that are near market introduction can benefit from incorporating the end users.	Societal integrator

Table 1: Description of the different potential knowledge integrators in the R&D projects.

Before the identification of the knowledge integrators was undertaken, a catalogue with all the actors in the dataset was produced. The following actors in the catalogue were divided into different groups (see *table 1* for descriptions).

After coding each of the knowledge integrators in each project, the expert coded *who* the knowledge integrator is by applying the typology of knowledge integrators in the energy sector (*table 1*). The reason why the 15 categories were formed in such detail was to clarify the role of the knowledge integrator and to highlight the diverse nature of the knowledge integrators. After the expert coded the knowledge integrators into these 15 different categories, the categories were further summarized into three main categories: market integrators, science integrators and societal integrators (*see table 1*).

Market integrators include integrators with knowledge about and direct contact with the market; producers, suppliers and component companies in the energy sector.

Science integrators include integrators with knowledge about technical science and basic research; universities and other research institutes. Advisors and consultants are also included in this group because they often have an area of expertise that equals that of science institutions.

Societal integrators include a broader range of actors in the energy sector, including public authorities, politicians, NGOs etc. This group is characterized by their explicit role outside the technical field of the energy sector. They consume, regulate, lobby etc. Their interests are derived from a community-oriented perspective rather than technical or market perspectives.

For the first analyses (hypotheses 1-4), the dependent variable *knowledge integrator* is simply coded as a dichotomous variable (knowledge integrator yes/no).

The variables, market integrator in applied research and basic research

For the last part of the analyses (H5), the dependent variable is dichotomous and shows market integrators in applied and basic research (e.g. *market* integrator in *applied* research vs. other type of integrators in other stages). When the expert identified the knowledge integrator, the registration of the knowledge integrator was done coincident, followed by a recoding of the identification variable taking into account the innovation stage. It was not possible to include all the knowledge integrators in the variable, but 79.2% of the identified knowledge integrators are included. The reason why the paper only looks at one integrator type is due to large representation of the market integrator type in the sample.

To conduct regression analyses of knowledge integrators, the paper applies logistic regression.

Independent variables

RTO

As mentioned before, a Research and Technology Organization (RTO), i.e. a network which supports innovation and constitutes the core of the technological infrastructure. These institutes are incorporated in projects when the scope of the project is applied research or even commercial. The variable explains if a RTO institute is incorporated in the project (0/1).

International partners

When talking about innovative R&D projects, the level of innovation and research can be so demanding that national sources are not enough. The energy program supports projects that have other partners than national ones especially if the partners' expertise is quite unique. This variable explains if an international partner is incorporated in the project. The reason why the number of international partners might be relatively low is because the projects are longitudinal. The variable is a dichotomous variable.

University

University involvement in R&D projects is quite relevant in early stage R&D projects where the technology is relatively new. Many of the R&D projects in the energy sector incorporate universities because they have the newest research and technological expertise. This variable explains if a university is incorporated in a project and it is a dichotomous variable.

Competitor

In public funded R&D projects it is not unlikely that competing actors are part of the same project. This constellation is usually found in projects where the goal is to create a technological platform. This variable explains if there are competing partners in the project. The variable is dichotomous (competing actor(s)/no competing actor(s))

Applied research

Applied research primary goal is to solve practical problems opposite basic research where the problems are theoretical. In R&D projects in applied research do often combine the theoretical aspects with practical aspects and that is why the projects often consist of partners from the academia and industry. The variable is coded as a dichotomous and coded as applied research projects (1) compared to projects in basic research and demonstration (0).

Duration

Some of the projects that started in 2005 or later are registered with the year that the projects were announced to finish in their application. So for some of the projects registered some years before 2008 it might be possible that the end year is the factual year if the projects experienced some problems that may have caused a delay, the end year might have been changed. The variable is dichotomous and 1-5 years (0) and 6-12 years (1).

Size (LN)

The full amount of financial resources used on R&D projects by Energinet.dk from 1988 to 2008 is 1.093.291.238 billion Danish kroner. The variable size is constructed by summing up the amount of funding each year and thereafter the percentage of each project's funding was calculated. The variable is continuous variable shown is as logarithm because the original variable was skewed.

Size of an energy area (LN)

The full amount of financial resources used on R&D projects by Energinet.dk from 1988 to 2008 is divided into what each energy area that have received funding through the years. The variable size of energy area is constructed by summing up the amount of funding from each energy area and thereafter the percentage of each project's funding in the given area was calculated. The variable is continuous variable shown is as logarithm because the original variable was skewed.

Control variables

The control variables used in this paper are: Wind energy, solar energy and fuel cell energy. The reason why these have been chosen compared to other technologies as biomass or fossil energy is because wind, solar and fuel energy represent technologies on different stages on the development stage. Wind and solar energy are a relatively mature and commercial technology but Denmark has not given solar energy the same focus as the wind energy. Fuel cell energy is a relatively new technology that is still immature compared to wind and solar energy.

Wind energy

Wind power is the conversion of wind energy wind into electricity through wind turbines. The variable is coded as a dichotomous variable that illustrates fuel cell technology compared to other technologies (biomass, wave energy, solar energy, fuel cell, fossil energy, and smart grid).

Fuel cell energy

This variable shows how many of the projects are in the fuel cell technology area. Fuel cell technology is a conversion of chemical energy into electricity. Hydrogen is a common fuel, but other fuel sources such as natural gas and alcohol (e.g. methanol) are also used. The variable is coded as a dichotomous variable that illustrates fuel cell technology compared to other technologies (biomass, wave energy, wind energy, solar energy, fossil energy, and smart grid).

Solar energy

Solar energy is the conversion of sunlight into electricity. The variable is coded as a dichotomous variable that illustrates fuel cell technology compared to other technologies (biomass, wave energy, wind energy, fuel cell, fossil energy, and smart grid).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Knowledge Integrator	1	-,055	,045	,089	.241**	.235**	.152**	.100*	.164**	.135**	-,004	,021	-,018	-,007
2. Market integrator in applied research		1	-.456**	-,030	,000	-.178*	,003	.863**	-,099	-,130	-.268**	-,039	-.159*	-.151*
3. Market integrator in basic research			1	-,019	-,110	.269**	-,101	-.528**	.231**	.158*	,128	,042	,081	-,037
4. RTO				1	,077	,090	-,003	.123*	,040	,052	,018	-,041	-.120*	.139**
5. International Partner					1	,093	.119*	,073	,068	,014	,000	-,056	-,029	.118*
6. University						1	.128*	-.156**	,033	.161**	.259**	,028	,097	-,081
7. Competitor							1	,060	-,018	,059	.105*	-,085	.144**	-,086
8. Applied research								1	-.119*	-.128*	-.214**	,069	-.125*	-,016
9. Duration									1	.332**	,064	-,086	-.121*	-,034
10. Size LN (the whole amount of funding)										1	.531**	-.181**	.194**	,035
11. Size LN (Energy area)											1	-,013	.152**	.100*
12. Wind Energy												1	-.168**	-.157**
13. Fuel Cell Energy													1	-.124*
14. Solar Energy														1

*Table 2: Correlation matrix of the variables (***p<.001, **p<.05, *p<.1)*

Identifying the knowledge integrator and their role

The purpose of the section is to identify who the knowledge integrators are in the R&D project within the energy sector. The empirical results show that minimum one knowledge integrator is involved in 62% of the projects (*table 3*). A first observation from the table is that R&D projects in the energy sector do incorporate organizational knowledge integrators, but not who the knowledge integrators are. To describe who the knowledge integrators are, the names and addresses were linked with their type and these are illustrated in *table 4*.

	Frequency	Percentage
No knowledge integrator in the project	151	38.0
Minimum 1 knowledge integrator in the project	246	62.0
Total	397	100.0

Table 3: Incorporation of the knowledge integrator

The reason why more than one knowledge integrator can be identified in a project is that the project can embrace different technological areas e.g. when producing an electrical car, three potential knowledge integrators can be identified: an electricity company produces the charger for the car; a supplier of car parts, and the end-consumer for the car. If the project is in the stage of applied research, all the knowledge integrators can carry the knowledge to the next step in the technology stage, called demonstration.

The total number of knowledge integrators is 313 indicating that not all projects have knowledge integrators involved (min=0; max=3 and mean=1.28).

As *table 4* illustrates, almost half of the knowledge integrators are producers of energy (49.5%). The producers of energy have a more general role in the energy system as they are the potential users of the final innovations created in the R&D projects. These companies are heavily involved in programs especially in regards to R&D projects that are politically regulated. Suppliers of plant and components are also a group that is quite strongly represented (23.9%).

Identification of knowledge integrators	Number	Percent
Suppliers of Energy	5	1.5
Producers of energy (electricity and district heating)	154	49.5
Transmission and distribution (energy companies -monopoly)	10	3.1
Trade and sales (energy companies)	16	5.1
Suppliers of plant and components	75	23.9
Other private companies	5	1.5
Advisers and consultants	17	5.4
Universities and research institutions	23	7.3
RTO (Approved technological service institutes)	4	1.2
NGO and industry association	2	0.6
Public authority	1	0.3
End users/Households	1	0.3
Total	313	100

Table 4: The total number of knowledge integrators divided into categories

The majority of knowledge integrators are market integrators (*table 5)*. The market integrators are the main drivers for production and selling of electricity in the energy sector, and they benefit by entering R&D projects. Science integrators gain knowledge and research by entering into interorganizational R&D projects, but they may not share the same need for participation since the universities are publicly owned and already has funding for some research activities. Societal integrators are represented with only 1.27 %, which is by far the smallest group compared to the other integrator groups. The societal integrators may be less represented, because the majority of projects in the dataset are mainly basic or applied research projects. If the projects were orientated towards the end of the technological development stage such as market introduction (*figure 1*) potentially the share of societal integrators would be larger.

	Frequency	Percent
Market integrators	265	84.66
Science integrators	44	14.05
Societal integrators	4	1.27
Total	313	99.98

Table 5: Knowledge integrators divided into groups

Knowledge integrators across technological development stages

An interesting aspect that was raised with the market, science and societal knowledge integrators is whether these in fact are distributed equally across the technological R&D process. One could assume that science integrators would be more frequent in basic research, whereas market integrators would be more prevalent in the demonstration stage.

	Basic Research		Applied Research		Demonstration	
Market integrators	42	72.41%	154	87.5%	60	88.2%
Science Integrator	15	25.8%	22	12.5%	7	10.2%
Societal Integrator	1	1.7%	0	0	1	1.4%
Total	58	99.9%	176	100%	68	99.8%

Table 6: Integrator groups across different technological development stages

Table 6 shows the knowledge integrator groups divided across the technological stages. Here it is observed that market integrators are presented in all the technological stages. Market integrators such as producers of energy, i.e. companies that produce electricity and district heating, are often represented in the applied research stage (52.2% not shown in *table 6*), which implies that these companies are interested in relatively new upcoming energy research. As expected above (see *table 6*), *science* integrators are heavily represented in basic compared to applied and demonstration stage. It is also important to mention that 72.8 % of projects have a private company, who is responsible for the project and 20.1% is a university (not shown in the table). This implies that many of the R&D projects are driven by private companies.

Knowledge integrators on a project level

To understand the concept of a knowledge integrator, it is relevant to look at projects incorporating a knowledge integrator from a project level. *Table 7* contributes to give a fundamentally understanding on how the projects distinct when they are incorporating a knowledge integrator, and how they are constructed. In the following, an analysis of projects with knowledge integrators is provided using logistic regression analysis. The model (*table 7*) has a fit with a Nagelkerke R^2 at 0.073 and a significance level of the overall model at 0.002. The model includes duration of the project, size and if the projects are in applied research. As controls, the paper uses wind, solar and fuel cell energy. The Hosmer & Lemeshow test is not significant, implying that the model is trustworthy.

	Knowledge Integrator on a project level	Knowledge integrator on a partner level
Duration	1.444**	1.542**
Size (LN)	.170*	.112
Applied research	.523**	.605**
University		1.067***
International partner		2.491***
RTOs		.267
Competitor		1.611**
Wind energy	.215	.206
Solar Energy	-.023	-.061
Fuel cell Energy	.058	-.147
Nagelkerke R2	.073	.238
Cox & Snell R2	.054	.175
-2 Log Likelihood	486.021a	429.830a
Hosmer & Lemeshow	.643	.204
Number of observations	382	377

*Table 7: Logistic regression for projects incorporating a knowledge integrator on a project level and on a partner level (***p<.001, **p<.05, *p<.1)*

The results show that the longer the duration of a project, the higher the probability of a knowledge integrator is involved in the project. The bigger a project is the higher is the probability that a knowledge integrator is incorporated in the project and projects in applied research to have a high tendency to involve a knowledge integrator.

To sum up, on a project level R&D projects that have a long duration, a higher budget and do applied research are more likely to incorporate a knowledge integrator. *Table 7* contributes to give a fundamentally understanding on how the projects distinct when they incorporate a knowledge integrator, and how they are constructed. In the following, an analysis of projects with knowledge integrators on a partner level (see table 7) is provided using logistic regression analysis.

Knowledge integrators on a partner level

Table 7 also shows the results of a logit regression concerning *hypothesis 1-4*. The model has a good fit with a Nagelkerke R^2 at 0.238 and a significance level of the overall model at 0.000. The variables; duration, applied research, university, competitor, international partner, have a significant effect (0.05, 0.001) on projects involving a knowledge integrator compared to projects not incorporating a knowledge integrator. No effect can be detected by the variables RTO, size and the control variables; wind, solar and fuel cell energy. Those projects that involve at least one university as a partner increase the likelihood that the project also incorporates a knowledge integrator (*confirming hypothesis 2*).The results also confirm hypotheses 3 and 4 by showing that projects that include international partners or competitors increase the likelihood of the projects also involving a knowledge integrator. In addition the model shows that projects in applied research have a strong tendency to involve a knowledge integrator and the duration of projects do have a tendency to be longer when involving a knowledge integrator.

Market integrator in applied and basic research

The regressions in *table 8* show two logit regressions used to test *hypothesis 5*. Nagelkerke R^2 is .157 and .145 and the significance levels of the models are 0.003 and 0.001. The variables used in the regression are university and duration, and they have a significant effect (0.05) on projects involving a market integrator in basic research compared to projects not incorporating a market integrator.

	Market Integrator in basic research	Market integrator in applied research
Size (LN)	.174	-.121
University partner	1.522**	-.611*
Duration	1.592**	-.665
Wind energy	.916	-.819*
Solar Energy	.106	-1.785**
Fuel cell energy	1.107	-1.540**
Nagelkerke R2	.227	.159
Cox & Snell R2	.132	.119
-2 Log Likelihood	134.291a	231.709a
Hosmer & Lemeshow	.712	.915
Number of observations	184	184

Table 8: Market integrator in basic and applied research (***p<.001, **p<.05, *p<.1)

The results demonstrate that when a university is connected to a project in applied research the likelihood of a market integrator being involved is significant and negative. Therefore, when a project in applied research involves a university, the likelihood that a market integrator is involved decreases. The paper can therefore not accept *hypothesis 5*. The results also show that projects in basic research that involves a university are more likely to incorporate a market integrator. The control variables show that projects in applied research in the area of wind, solar and fuel cell energy the likelihood of incorporating a market integrator is negative.

Knowledge integrator and funding

The regression *table 9* shows an OLS regression of the project's funding and knowledge integrator. The table shows that knowledge integrators do have a tendency to be incorporated in projects that have been given a larger funding from the program. Longer duration of a project increases the likelihood of increased funding and projects in applied research have a negative significant on funding when the funding is a percentage from a specific energy area. Table 9 also show that projects in solar and fuel cell energy have a tendency to get a high amount of funding, but projects in wind energy have a decreasing amount of funding compared to other projects.

	Size of an energy area LN (the percentage of funding given to a project in a specific energy area)	Size LN (the percentage of funding given to a project)
Knowledge Integrator	.013	.202*
Duration	.176	1.335***
Applied research	-.513***	-.148
Wind energy	.185	-.361**
Solar energy	.610**	.200
Fuel cell energy	.693**	.820***
N	382	382
R^2	.075	.184
Significance	.000	.000

*Table 9: OLS regression on the amount of funding given to a project in percentage on a specific energy area and from the whole amount of funding (***p<.001, **p<.05, *p<.1)*

Discussion

This paper has shown that organizational knowledge integrators are important in energy research programs. 62% of the R&D projects have incorporated a knowledge integrator. Three groups of knowledge integrators: market integrators, science integrators, and societal integrators were identified of which the largest group is market integrators (88.2% of the integrators). Basic and applied research projects were represented by science integrators, whereas market integrators were heavily represented in applied research and demonstration stages of the projects.

The analyses showed that the longer the duration of a project, the higher the probability of a knowledge integrator is involved in the project. This might indicate that having a knowledge integrator incorporated in a project might make the project more complex which can result in the duration of a project becomes longer. On the other hand, the size of a project in terms of funding increases when having a knowledge integrator in a project which might indicate that the projects incorporating a knowledge integrator are big innovative projects or the complexity of the project makes the project more expensive. The findings also show that projects in applied research are likely to incorporate a knowledge integrator. Projects in applied research tend to have a more practical approach which might attract knowledge integrators that have the knowledge and monetary interest to take the projects to the next step in the development process.

On a partner level, projects that involve an international partner also have a higher tendency to incorporate a knowledge integrator. Here the knowledge integrator may bridge national and international partners and again stimulate knowledge sharing across not only organizational but also geographical boundaries. The results may also be in line with innovation processes becoming more open (Chesbrough, 2004) and therefore needing further mechanisms to transfer international knowledge. Furthermore, the openness in projects with a knowledge integrator is further confirmed when examining if a competitor is in a project. The result supports that projects including competitors increase the likelihood that a knowledge integrator is involved. Technological uncertainty may also be a significant reason for forming an interorganizational R&D project with competitors or international partners. According to DeBresson & Amesse (1991), interorganizational relationships arise because of strong uncertainties and by collaborating the partners can spread the risk across all partners. The findings also show that projects with a university the likelihood of a knowledge integrator being in the project is high. In general the findings support the research by Arora and Gambardella (1990) who find that innovation should be considered as “network” of interorganisational relations.

Focusing particularly on the market integrator, the findings demonstrate that projects in applied research with a university embedded in the project do have a stronger tendency *not* to incorporate a market integrator. On the other hand, projects in basic research with a university involved in the project do involve a market integrator. These results contradict the literature where the industry partners are more often represented in applied research than in basic research. So why is it that projects in basic research involving universities also include market integrators, whereas the same collaboration form is not seen in applied research? The partners in a basic research project are primarily universities and sometimes companies who has an interest and has absorptive capacity (Cohen and Levinthal, 1990) to understand basic research. When a sector is technology-driven as in the energy sector, the standard level of technical expertise for a market integrator might be higher than in other industries. Therefore, a knowledge integrator in applied research does not *need* the research competence from the universities, because they are already capable of bringing the basic research towards applied research, but they are not capable of creating basic research itself.

The findings also show that projects that overall received a large amount of funding to have a tendency to incorporate a knowledge integrator. The reason for this may be that in the process of evaluation of the projects, the evaluators might unconsciously consider if a partner who can bring the project into the next step is involved in the project. From these results one may argue that projects incorporating a knowledge integrator tend to get more funding. The results also show that the longer duration of a project increases the likelihood of increased funding. This makes good sense that longer projects receives larger funding than shorter projects, but R&D projects in the energy sector do have a tendency to have a long time horizon because of the complexity of the innovation. Projects in applied research have a negative significant effect on funding. The reason for this may be that applied research compared to basic research or demonstration is relatively more low-cost. Basic research can be costly with expensive equipments and right facilities to facilitate technical demanding experiments. Demonstration can also be very expensive when projects scale up and test innovations in real life constellations.

Conclusion

This paper observed that organizational knowledge integrators are less acknowledged in the literature than individual knowledge integrators. Hence, the main purpose of this paper is to investigate the role of organizational knowledge integrators in collaborative projects, and to characterise the projects and partners that may stimulate the use of organizational knowledge integrators. The empirical results confirm the existence of organizational knowledge integrators, and in fact find an abundance of these in energy-technology projects. The main findings of the descriptive analyses demonstrated that out of the three groups of knowledge integrators, the largest group of knowledge integrators in the R&D projects is market integrators. Furthermore, the empirical results confirm that that the involvement of knowledge integrators differs across the technology stages. Knowledge integrators are more often represented in applied research. Examining the projects on a partner level, projects incorporating a competitor, an international partner or a university partner are more likely to involve a knowledge integrator in the R&D projects. From this it is observed that projects involving a knowledge integrator have a strong tendency to involve external sources of knowledge. The findings of this paper also show that looking at only one integrator type, projects in applied research with a university tend not do involve a market integrator however the opposite was found in basic research. Finally, projects that receive a larger amount of funding tend to incorporate a knowledge integrator. This might indicate that projects involving a knowledge integrator might be more likely to receive funding than projects not incorporating a knowledge integrator. The empirical setting of this paper is large R&D projects from the energy sector, but these results might be generalised to other high technical demanding technical areas such as the information and communications technology (ICT) sector.

Limitation

The paper is limited by a possible lack of important aspects or core aspects in the data collection. The data is based on a set of project applications that were formulated to obtain external funding rather than for academic research. Furthermore, the paper does not consider the degree of involvement of the knowledge integrator in projects, neither is it possible to compare these results in an international context or with other research programs in different technological areas. Further research could examine other sectors and investigate how the role of knowledge integrators might differ across different sectors. Further research should also look more into how knowledge integrators affect innovative performance in R&D projects.

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