The influence of the knowledge base of different actor types upon the technological expectations of technological development

A quantitative research applied for the Dutch photovoltaic sector

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Abstract

The aim of this research is to empirically examine the relationship between the knowledge base of actors and the technological expectations of future subsidized projects. Including the notion that different actor types possess different knowledge bases, this research uses three actor types as an interaction term for the knowledge base and its influence upon the future expectations. These three actor types are Knowledge Institutes (KIs), Large Enterprises (LEs) and Small and Medium Enterprises (SMEs).

With insights from the evolutionary and organizational theory, we hypothesised that the basic and applied knowledge bases of different actor types are positively related to the technological expectations of future subsidized projects. The basic knowledge base was measured through the keywords of scientific articles. The applied knowledge base was measured by the keywords of patents. The technological expectations were measured by the keywords of the project applications of actors. The hypotheses are tested using the PV technology as case study.

The results show that the knowledge bases of actors are negatively related with the technological expectations of future subsidized projects. Furthermore, the basic knowledge base and the applied knowledge base of KIs are dominant in expectation forming compared to LEs. For SMEs, the results show that scientific publications and patents have not a significant influence on the expectation forming in future subsidized projects.

Keywords: basic knowledge base, applied knowledge base, technological expectations, technological development, photovoltaic

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1. Introduction

Due to the increased energy consumption, depletion of fossil fuel sources and associated climate issues there is a growing interest in the development of renewable energy sources (Jager, 2006; Defaix et al., 2012). Photovoltaic (PV) energy is a promising renewable energy technology that contributes to tackling those problems. However, the current PV cells are expensive and have a low efficiency, which makes it difficult to compete with the incumbent locked-in energy technologies (Negro et al., 2009). Therefore, the Dutch government introduced innovation subsidies to stimulate the development of PV technology (Agentschap NL, 2011).

The Dutch government design such innovation policy to shape innovation processes (Hekkert et al., 2007). An innovation process includes the development of a technology and its interaction within the system in which it is embedded (Smits and Kuhlmann, 2004; Klein Woolthuis et al., 2005; Bergek et al., 2008). Technological development is not an autonomous process; therefore management of technological change is necessary. Innovation policy programs design and implement these management processes. In the projects subsidized by the Dutch Government, different actor types are collaborating within the technological innovations system (Edquist, 1997; Hekkert et al., 2007) and are responsible for raising, maintaining and controlling technological expectations (van Lente and Bakker, 2010). In the literature, technological expectations are defined as "real time representations of future technological situations and capabilities" (Borup et al., 2006, p. 286). The subsidized projects enunciate expectations about the direction in which a technology develops (van Rijnsoever, 2012) and these expectations should draw back on to the knowledge base of the actors.

According to Dosi (1982), the direction in which a technology develops is explained by technological trajectories. A technological trajectory is defined as "the pattern of normal problem solving activity on the ground of a technological paradigm" (Dosi, 1982, p.152). Dosi (1982) explains that technological trajectories provide a path whereby actors innovate within a specific technology in attempt to improve the current functioning of a technology. Also, Castaldi and Dosi (2006) explain path dependency as a process where past decisions or beliefs of a technology determine the present and future technological developments. Thus, "history matters" in the development of a technology.

Technological trajectories provide insight in the technological development on a system level. However, it is the actor within the system who develops and produces the new technologies. Actors accumulate prior knowledge and experiences over time, which is also known as the knowledge base (Cohen and

Levinthal, 1990; Rogers, 2010). Within innovation systems different actor types are present such as Knowledge Institutes (KIs), Large Enterprises (LEs) and Small and Medium Enterprises (SMEs) (Edquist; 1979; Freeman, 1995). Each actor type has different aims; hence their knowledge bases vary. The main aim of KIs is to develop knowledge, whereas the main aim of firms is to apply knowledge (Geuna and Nesta, 2006).

Previous studies in the field of technological trajectories and path dependency are focused on the history of technological developments (Frenken et al., 1999; Castaldi and Nuvolari, 2003; Verspagen, 2005; Genus and Coles, 2008). Cohen and Levinthal (1990) explain the importance of the knowledge base in the development of a technology. However, those studies provide no insight in the role of expectations upon the future development of the technologies. The expectation literature explains that expectations give direction to search and development activities (van Lente and Rip, 1998; van Lente and Bakker, 2010). Also, Konrad (2006) explains that expectations have influences upon technological development. Geels and Raven (2006) explain that shared expectations create stable technological trajectories. Those studies enlighten the importance of expectations in the development of a technology. However, no insight is provided into how expectations of technological forecasting are come into being. This research aims to address the gap by examining the influence of actors' knowledge base upon the technological expectations within a policy context. Hence, the following research question is defined:

"How does the knowledge base of different actor types influence the technological expectations of future subsidized projects?"

To answer the research question, keywords of publications and patents are analysed to get insight in the knowledge base of different actor types participating in the Dutch PV sector. This study focuses on the relation between the knowledge bases of different actors and the technological expectations of the Dutch PV sector. The Dutch PV sector case is exemplary for this research because the sector is developing rapidly. Also, the government supports this technology to accelerate the technological development and the Netherlands Enterprise Agency documented the PV related projects applications well. The outcome of this research is of interest for policy makers since they have would benefit when getting insight in how the direction of technological development is influenced.

The further outline of this research is as follows. First the theory is elaborated. Thereafter the methodology is described. Finally the results are discussed and a conclusion is drawn from this research.

2. Theory

2.1 Technological development

Within the evolutionary literature, technological change is described as a sequence of radical changes and incremental changes (Dewar and Dutton; 1986; Dosi, 1998; Essletzbichler and Winter, 1999; Rogers, 2010). The radical changes are indicated as the change from one technological paradigm to the next paradigm. A technological paradigm is defined as “a model and a pattern of solution of selected technological problems, based on selected principles derived from the natural science and on selected material technologies” (Dosi, 1982 p.148). The technological paradigms prescribe the directions of technological change to pursue and those to neglect. The incremental changes occur within a technological paradigm along well-defined technological trajectories. Technological trajectories can be seen as a cluster of possible technologies whose boundaries are defined by the technological paradigms (Cohen and Levinthal, 1990). Consequently, the direction of the development of technologies is explained through technological trajectories that are grounded by technological paradigm (Dosi, 1982). Technological trajectories give rise to the formation of expectations on the direction of the development of a technology (technological innovation) (van Geels and Raven, 2006).

Technological innovations are explained by the accumulation of knowledge over time. This knowledge is produced through different modes of learning (Arrow, 1962; Pisano, 1997). The concept path dependency is used as explanatory mechanism for the technological innovation process. Path dependency is a process that is described in the evolutionary literature by Arthur (1989) and David (1985). The authors explain that the development of technologies is a selection process in which specific technologies are excluded and other technologies become further developed. Consequently, past events such as unexpected success of a prototype, the order in which the technologies reach the market and the selection of technologies can stimulate a technology into a dominant direction.

Thus, technological paradigms and trajectories give rise to expectations. Those concepts guide the direction of the future technological expectations of innovations. Within organizations the accumulation of knowledge over time gives insight in the future expectations of the ability to absorb knowledge. In this research, technological expectations of future subsidized project are defined as the dependent variable. The knowledge base of actors is defined as independent variable.

2.2. Technological expectations

Innovation is a future-oriented business with an emphasis on the creation of new opportunities and capabilities (Teece et al., 1997; Borup et al., 2006). The changes in scientific principles do not pre-exist themselves, but are stimulated by visions, imaginations and expectations that have shaped their potential. Such expectations are seen as fundamentally ‘generative’ as they guide activities, provide structure and legitimacy and attract interest and foster investment. Technological expectations play an important role in the development of a technology on different levels of the technological innovation system. On the macro level of the innovation system, expectations can play an important role in mobilizing resources through regulations. At the micro level, expectation can drive an important role in mobilizing resources within engineering groups and in the work of the single scientist or engineer. Technological expectations drive technical and scientific activity, which can be reflected in pilot projects and material tests (van Lente and Bakker, 2010). Expectations are translated into goals, specifications and task divisions (Geels and Raven; 2006). For those goals, projects are developed. Sponsors (i.e. government, private investors etc.) make money and other resources available for those projects and creating space for the search and development activities of the upcoming technology.

2.3. Knowledge bases

The technological paradigms define the physical and technological boundaries, but it is the knowledge base of actors that moves technological trajectories along defined paths (Dosi, 1982). This is explained by the concept absorptive capacity. Absorptive capacity is defined as "a firm's ability to recognize the value of new information, assimilate it, and apply it to commercial ends” (Cohen and Levinthal, 1990, p. 128). According to Cohen and Levinthal (1990), the knowledge base of actors leads to two features of absorptive capacity that will affect innovative performance in an evolving and uncertain environment. First, accumulating absorptive capacity in one period will provide a more efficient accumulation in the subsequent period. The development of absorptive capacity in a specific area determines the direction in which actors can more readily accumulate knowledge in the next period (Cohen and Leventhal, 1990). Second, the possession of related expertise will permit the actor to better understand and therefore evaluate the import of technological advances that provide signals to the direction of the technological development (Cohen and Levinthal, 1989). So, in an evolving environment the absorptive capacity influences the expectation formation. This is because actors can predict, on the basis of the knowledge base, the direction of technological advances. This process of accumulation of knowledge and its effect on expectations formation implies that technological development is path dependent (Cohen and Leventhal, 1990; Boschma, 2005).

Thus, the knowledge base of an actor is an indicator for the past and current state of available knowledge on which new innovations can be derived. The knowledge base of an organization is derived from the basic research and the applied research (Rogers, 2010). According to Rogers (2010), basic research is defined as “the original investigation for advanced scientific knowledge that does not have a specific objective of applying this knowledge to a practical problem” (p.134).

Basic knowledge is often codified in scientific publications (Arrow, 1962; Rosenberg; 1990; Polidoro en Theeke, 2012). In contrast, applied knowledge consists of scientific investigations that are intended to solve practical problems (Rogers, 2010). Applied knowledge is often codified in patents. A patent is an exclusive right granted to anyone who invents any new product or article and claims that right in formal applications (Duardo-Sanchez et al., 2008). Patents are the most important instrument that actors use in order to protect intangible assets and technologies (Teece, 1986; Hall, 2007).

Expectations are grounded in the knowledge base of actors. Also expectations extend the knowledge base of actors. Theories argue that actors develop technologies according to a specific path, therefore it is expected that knowledge bases of actors will match with the technological expectations of future projects in which they are going to participate. The basic and applied knowledge bases differ in function, and therefore the two hypotheses are not combined, as there are other arguments that influence the expectations.

The basic knowledge base is broad and not specifically applied to product or process developments. It is expected that the basic knowledge base of actors is positively related to the technological expectations of future projects. The reason is that the basic knowledge bases give direction to expectations forming since current knowledge determines the direction of accumulation of knowledge. According to Rosenberg (1990), basic research gives an improved ability to select areas of applied research. The direction of technological expectations could be derived of the knowledge base. Therefore, the following hypothesis is formulated:

H1. The basic knowledge base of actors is positively related to the technological expectations of future subsidized projects.

In contrast, the applied knowledge base is often used to gain profit and is made to solve existing problems (Levin et al., 1987; Geuna and Nesta, 2006). This knowledge base is more applied and aims towards improving manufacturing techniques and processes (Rosenberg, 1990; Lim, 2004). The applied knowledge base gives specific insights in the expectation forming. This results in the following hypothesis:

H2. The applied knowledge base of actors is positively related to the technological expectations of future subsidized projects.

2.4. Actors types

As already mentioned, within this research three type of knowledge bases are taken into account: KIs, LEs and SMEs. The distinction between LEs and SMEs is made because larger firms have more resources to invest in R&D and, in turn, smaller firms are credited as more innovative (Chandy and Tellis, 2000; van

Rijnsoever, 2013). SMEs are firms with a maximum of 250 employees, whereas LEs are firms with more than 250 employees (Chandy and Tellis, 2000). According to the literature (Aldrich and Auster, 1986; Teece, 1986; Licht and Zoz, 2002; Blind et al. 2006; Rammer, 2007), actors have different goals wherefore the type of actor has influence upon the composition of the knowledge base. Therefore, the relation between a specific actor type and its effect on the basic and applied knowledge base are further analysed.

2.4.1. Actor types and the basic knowledge base

KIs are most often non-profit institutes that conduct basic research, such as universities or public research institutes (Rosenberg and Nelson, 1994; Laursen and Salter, 2006; Wieczorek and Hekkert, 2012). The main aim of KIs is to produce scientific and technical knowledge (Geuna and Nesta, 2006). KIs can have different forms in outputs (Mowery, 2005), but these outputs are often translated in scientific publications (Rosenberg and Nelson 1994; Rajtenberg, 1995; Henderson et al., 1998; Geuna and Nesta, 2006). The priority is given to the basic knowledge base since it is not the main aim of KIs to commercialise or apply the basic knowledge. Therefore, the basic knowledge base is the main capital of the KIs (Lim, 2004; Geuna and Nesta, 2006).

For LEs, the basic knowledge bases can improve LEs' R&D productivity. This can be explained by the fact that publishing scientific publications may maintain linkages with the scientific community, attract talent, and gives access to external knowledge on which they can build to create innovations (Rosenberg, 1990; Henderson and Cockburn, 1998). Also, firms can demonstrate the merits of their technological innovation to outside parties to succeed (Nelson and Winter, 1982). According to Bijker (1987), scientific publications help to create a shared framework on which their innovation is based (Bijker, 1987). However, in contrast to KIs, LEs publish less scientific publications as this includes that results and knowledge become public good and firms are not willing to share their knowledge to the environment. The relevance of basic knowledge base is for LEs to a lesser extent important in comparison to KIs. Therefore, the following hypothesis is formulated:

H3a. The basic knowledge base of LEs is less positively related to the technological expectations of future subsidized projects than the basic knowledge base of KIs.

To contribute to scientific publications, firms should have developed complementary and co-specialized assets (Teece, 1986; Laursen and Saler, 2006). SMEs have only a limited access to those resources and are less likely to publish scientific publications. SMEs can also profit from their knowledge by keeping their knowledge a secret; this concept is called secrecy (Mansfield, 1986; Leven et al., 1987; Cohen et al., 2000; Nieto and Cano, 2004). For SMEs secrecy leads to less relevance for publishing scientific publications. Therefore, in comparison to KIs, the basic knowledge base of SMEs will give less insights in the future expectations of future projects. This results in the following hypothesis:

H3b. The basic knowledge base of SMEs is less positively related to the technological expectations of future subsidized projects than the basic knowledge base of KIs.

2.4.2. Actor types and the applied knowledge base

According to Geuna and Nesta (2006), KIs are more and more focused on applied knowledge. This can cause delays in replenishing the basic knowledge base. There is substantial literature on how the shift to university patenting has moved universities away from basic research towards applied research (Geuna and Nesta, 2006; Traitenber; 2006; Lemley, 2007). Despite those developments, scientific publications are still mostly used to capture knowledge. This is because the main aim of KIs is still knowledge development instead of commercialisation. Therefore, it is assumed that more scientific articles are published by the KIs than patents are filed.

The applied knowledge base of actors is characterised by high cost and no immediate income (Geuna and Nesta, 2006; Rogers, 2010). The high costs are often caused by patent office fees, translation costs, litigation costs and the cost to monitor potential infringements (Hanel, 2006). LEs have a lot of resources and experiences in house (Chandy and Tellis, 2000). Therefore, LEs have the ability to protect and building up their knowledge base by filling patents (Rammer, 2007; Gredel et al., 2012). LEs prioritise applied knowledge above basic knowledge. For KIs, it is to less extent necessary to protect their knowledge with patents, because their main aim is not to commercialisation. Therefore the applied knowledge base of LEs gives, in comparison to KIs, more relevant representation of the future technological expectations of the projects where they are going to participate. Therefore, the following hypothesis is formulated:

H4a. The applied knowledge base of LEs is more positively related to the technological expectations of future subsidized projects than the applied knowledge base of KIs.

The core business of SMEs is to make profit and it is beneficial to protect their technological applications. However, SMEs have limited resources to invest in knowledge. The high cost of patents discourages SMEs to protect their technology (Hanel, 2006 and Svensson, 2007). According to the OECD (2008), the SMEs often choose to protect their invention normally through secrecy instead of patenting. As KIs are increasingly going to patent their knowledge, it is expected that KIs have more relevance with the technological expectations of future projects. Therefore it is expected that the applied knowledge bases of SMEs have less matches than the applied knowledge base of KIs. This results in the following hypothesis:

H4b. The applied knowledge base of SMES is less positively related to technological expectations of future subsidized projects than the applied knowledge base of KIs.

3. Method

3.1. Research design

The hypotheses are tested in the context to the field of PV technology. PV technology is one of the most promising technologies to generate sustainable and valuable power from renewable resources (Kamp et al., 2009). The Dutch PV market has observed some fluctuations over the years (Negro et al., 2009). However, since 2002, the PV sector is emerging in the Netherlands. The total accumulated installed capacity of PV capacity amounts 27 MW in 2002 and increased towards 650 MW installed cumulative capacity in 2013 (IEA, 2013).

This research uses the PV technology as case study, since it is an upcoming renewable technology (Negro et al., 2009; Kamp et al., 2009; Negro et al., 2012). A lot of development focuses on the product and process developments in order to improve the efficiency and reduce the price of PV technology (Defaix and Sark, 2012; Ecofys, 2012) The PV technology is a high-tech sector in which much knowledge is stored in knowledge bases (Verbong and Geels, 2007; Negro et al., 2009; Negro et al, 2012; Verhees et al., 2013).

Furthermore, the PV technology requires a niche market in which they become protected from direct market selection (Rip and Schot, 2002; Bakker et al., 2012). The Dutch government has approximately invested 49.9 million euros in the PV industry (Netherland Enterprise Agency, 2014). The funds are dispersed over projects, which include different actors. This policy measure articulates expectations of the direction of the renewable technologies. The project applications, which include different types of actors, give insight in the technological expectations of the future subsidized projects.

3.2. Data collection

The following information was collected for the dataset:

- Project applications for PV technologies of the Netherlands Enterprise Agency: keywords, actors, actor type, title and year.

- Patent data of PV technologies (for each actor present in the project applications): keywords, actor type, title and year.

- Scientific publications about PV technologies (for each actor present in the project applications): keywords, actor type, title and year.

To gather this information, multiple data sources were used. Firstly, for the project applications data is used from the Netherlands Enterprise Agency, which is the executive agency of the Dutch Ministry of Economic Affairs. The Netherlands

Enterprise Agency has constructed a database in which project applications are gathered for PV energy technology between the year 2005 and 2013. The project applications available in the database are the projects subsidized by the Netherlands Enterprise Agency. Thus, the project applications are based in the policy context. In the project applications of the Netherland Enterprise Agency, a description is provided about the future technical specifications and capabilities. Those project applications are real-time representations of future technological situations of the PV energy technology; therefore it corresponds with the concept technological expectations. The database contains 92 innovation projects for the PV energy technology. Those innovation projects include 209 unique actors. In table 1 an overview is provided of the number of firm types. In this table, SMEs accounts for the majority of the firm types (75.1%), followed by KIs (13.4%) and LEs (15.0%).

Secondly, Web of Science is used for collecting scientific articles of actors about PV energy technologies. Web of Science is an international scientific literature database in which a lot of disciplinary science is included (Web of Science, 2013). This database is used to investigate the scientific articles that are published by organizations. The search string is defined as follows: TS=(photovoltaic* OR solar cell) AND OO=(actor name). The reason for this query is that all technologies related to photovoltaic or solar cells should be included in the dataset. Therefore, this query is not too narrow, because it is not focused on a specific technology like for example “thin film” or “multi-crystalline”. On the other side this query is not too broad because it is focused on articles of actors related to photovoltaic and not on other technologies. The timeframe is set between 2002 and 2013, because the development of PV technology was limited in the Netherlands before 2002 (IEA, 2007). Put of the results from this query, the abstracts and features of the publications were read in order to check whether the articles met the following requirements: photovoltaic must be related to technologies and at least one author of the articles has to be located at the “actor name”. Web of Science contains 2048 scientific articles that are published by 44 actors that are included in the project requests. Some actors co-authored scientific articles, which explained the mismatch when adding up the articles. Web of Science provides the keywords of the scientific publications. In table 1 an overview is provided of the amount of firm types. In this table KIs accounts for the majority of the firm types (79.5%), followed by LEs (15.8%) and SMEs (4.7%).

Thirdly, Espacenet is used to gather patent data. This database is the European patent register for more than 90 countries and offers access to more than 80 million patent documents, containing inventions and technological developments (Espacenet, 2013). This database is used because it gains the highest scores on data coverage in comparison to other patent databases (Patent information news, 2013). In this research we searched on the classification codes Y02B10/00, which query includes “the integration of renewable energy sources in buildings”. The sub categories (Y02b10/10, Y02b10/12 and Y02b10/14) include respectively Photovoltaics, Roof systems for PV cells and PV hubs. Also a search is done on the classification code Y02E10/50 that includes Photovoltaic energy. The patent outcome of the subcategories (Y02E10/52, Y02E10/54, Y02E10/541, Y02E10/542, Y02E10/543, Y02E10/544, Y02E10/545, Y02E10/546, Y02E10/548, Y02E10/549) is analysed. This is for the timeframe of 2000 till 2013. This search in Espacenet yielded 27 actors holding 125 patents. In table 1 an overview is provided of the number of firm types. In this table, LEs accounts for the majority of the firm type (86.8%), followed by SMEs (16.0%) and KIs (15.2%).

Table 1: Overview of the number of actors, articles and patents by actor type.

	Number of actor	Number of articles	Number of patents
KI	28	1895	19
LE	24	377	86
SME	157	111	20
Total	209	2048	125

3.3. Measurement

3.3.1. Dependent variable

The technological expectations of future subsidized project applications are measured by analysing the content of project applications available in the database of the Netherlands Enterprise Agency. In those project applications, a description is provided on what the expected outcome is of future projects of actors. It is therefore assumed that insight in project applications corresponds with the expectations of the direction of the future PV technology for the actors present in the project. For the project applications no keywords were available. By using qualitative coding, those keywords were manually derived from the project applications (Gibbs, 2007). This analysis is based on a few steps. First, the summary was analysed for the keywords of the project applications to determine the subject and main aim of the project application. The keyword list of the scientific publications was used to derive the keywords from the project applications. Second, the section of technological innovativeness of the project applications was investigated. The words including concepts of the PV technological innovations were selected. Then, a table was made with the keywords and keywords with the same meaning were clustered. Words that had basically the same meaning were recorded as one keyword. Those tables were controlled by experts in the field of PV technology from the Netherlands Enterprise Agency. In Appendix A, an overview is given of the keywords.

3.3.2. Independent variables

The knowledge base of actors includes the basic and applied knowledge base. The basic knowledge base is measured by the accumulated keywords of scientific research publications over the years. The reason is that the knowledge base is built up over the years. The keywords available in the scientific publications indicate the direction in which an actor increases its knowledge base. This is because scientific publications reflect the new scientific knowledge in a technological field (Polidoro and Theeke, 2012).

The applied knowledge base is measured by the accumulated keywords of patents actors possess in the field of PV technology. A patent gives therefore direction to which direction a technology can be developed. Organizations protect their intellectual property by applying patents with the thought that it provides commercial benefits (Teece, 2003). As specific patents have no standardised keywords, the keywords were qualitatively derived on the same manner as the keywords of the project applications. The keywords list of project applications, scientific publications and patents uses the same wording. In total there were 362 keywords (see Appendix A).

3.4. Data analysis

The data is analysed via logistic regression analysis using the statistical program SPSS. This software is designed to handle large amount of data and make statistical analyses (Bryman, 1994). Prior to the analysis, the data from the project applications, scientific publications and patents were collected in one data set. The total number of observations in the data is 14173. A filter was applied when an actor (1) did not participate in a project application, (2) published no scientific publication and (3) filed no patents in a specific year.

Technological expectations of future subsidized project application, is a nominal variable since the keywords could be present (1) or not present (0) in the project applications for an actor. The knowledge base is measured by the keywords of scientific publications and patents. For each actor in each year the occurrence of a keyword is examined. From this data hypotheses 1 and 2 are tested.

For testing hypotheses 3 and 4 interaction terms were added to in the model. Scientific publications were interacted with the three actor types. Also an interaction term was provided for the patents and the three actor types. Adding an interaction term to the model changes the interpretation of all coefficients (Vocht, 2004). If there was no interaction term, then the patents should interpreted as the unique effect of the patents on project applications. However, the interaction means that the effect of the patent on project applications is different for the type of organization. This results in the following regression model:

$$\ln\left[\frac{p}{1-p}\right] = B_0 + B_1 S + B_2 Pa + B_3 S * actor\ type + B_4 Pa * actor\ type \quad [1]$$

Where P is the probability of the occurring of keywords of technological expectations in future subsidized projects. Scientific publications are displayed with S, whereas the patents are displayed as Pa. B_0 is the model interception at y-axis, B_3 is the regression coefficient of the variable scientific publications and B_2 is the regression coefficient of the variable patents. B_3 and B_4 are the regression coefficients for respectively the scientific publications the patents of each actor type. The control variables are the years and the type of organizations. Also, there is controlled for the keywords and the number of patents and publication an actor possess each year[1].

[1] In the model is controlled for the number of scientific publication and patents an actor possess each year. This is done because e.g. universities have more chance to have a lot of knowledge in-house, since the knowledge base is much larger.

4. Results

Table 2 shows the results of the logistic regression analysis. The regression values for the scientific publications and the patents are statistically significant (p<0,01). The Nagelkerke R square is good for the model (0.824). This indicates a strong relation between the dependent and independent variables.

Table 2: Results of logit regression analysis with the dependent variable technological expectations of future subsidized projects.

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

Keywords of project applications	Variables	Specification	Model
Control variables	Year	2005	1.107***
		2006	0.215
		2007	0.523**
		2008	0.297
		2009	-0.893**
		2010	0.0451
		2012	0.666**
		2013	Ref
	Actor type	LE	2.910***
		SME	29.738
		KI	Ref
Independent variables	Basic knowledge base	Scientific publications	-0.119***
	Applied knowledge base	Patents	-2.149***
	Basic knowledge base	LE* scientific publications	-3.580***
		SME* scientific publications	-31.655
		KI* scientific publications	Ref
	Applied knowledge base	LE* patents	-3.009***
		SME* patents	-32.086
		KI* patents	Ref
Model indicators	Cox and Snell		0.616
	Nagelkerke R		0.824***
	McFadden		0.695
	-2 Log Likelihood (final)		1,858.808***
	Number of Obs.		14,173

4.1. Scientific publications and patents

In the regression analysis, there is a significant relation between the keywords of scientific publications and the project application keywords (p<0.01). Additionally, there is a significant relation between keywords of patents and project application keywords (p<0.01). However, the regression coefficients indicate that both relationships are negative. This does not support hypothesis 1 and 2. This indicates that actors that possess scientific publications and patents in the same field as a specific project application are less likely to participate in project with the same keywords. This means that it is not necessary to have a matching knowledge base in order to participate in project applications of the Netherlands Enterprise Agency. Thus, in the selection process of actors for a specific project, the knowledge base of actors is not a likely selection criterion. This may result in a low innovative outcome of the project as there is no optimal knowledge available (Nootenboom et al., 2007), compared to when there where actors active with a knowledge base matching with the project applications.

Furthermore, scientific publications are less negatively related to the keywords of the project applications in comparison to patents. This indicates that keywords of scientific publications do match more with the project application keywords in comparison to the keywords of patents towards the project application keywords. An explanation for this outcome is that scientific publications are more used in innovation projects than the knowledge represented by patents. Another reason is that actors can use patents for fencing instead of using their knowledge in the projects (Cohen et al. 2000; Leten et al., 2010).

4.2. Actor types and knowledge bases

In table 2, the interaction term is provided in the model of scientific publications and patents with the three types of actors. Wherein KIs are the reference organizations. The addition of those interaction terms to the final model improves the model in terms of the Nagelkerke R and the significance of the scientific publications[2,3].

4.2.1. Actor types and the basic knowledge base

The analyses show that the keywords of the scientific publication published by LEs, compared to the reference variable KI, have a significant (negative) relation with the keywords of project application (B=-3.580; p<0.01). This supports hypothesis 3a. This can be explained by the fact that KIs benefit more from scientific publications, since their main aim is knowledge development, and this does not apply for LEs.

The analysis shows that scientific publications published by SMEs, compared to the reference variable KI, have no significant influence upon the keywords upon the project applications (B= -31.655; p>0.05). This means it cannot be concluded whether the basic knowledge base of SMEs is less positively related to the technological expectations of future subsidized projects than the basic knowledge

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[2] This is shown in Appendix B, where the model is run without interactions terms (R=0.527; for scientific publications B=-0.026; p >0.05).

[3] The model is also run with a filter where only keywords of patents and keywords of project applications match, and another model with a filter where only keywords of scientific publications and keywords of project applications where taken into account. This results in an insignificant relation of patents upon the project applications. Since this did not improve the model, those models are left out of the analysis (for patents B= -19.867; p>0.05) (Appendix C and D).

bases of KIs**.** A likely explanation is that SMEs have too little observations (N=1490)[4]. Since they own less patents in comparison to the number of SMEs that are present in the project applications (table 1), it can indicate that there is insufficient statistical power to produce a significant result. The little observations can also be explained by the secrecy mechanisms SMEs use. Keeping their knowledge secret, results in less scientific publications.

4.2.2. Actor types and the applied knowledge base

For the applied knowledge base, the analysis shows that the keywords of the patents of LEs are more negatively related with the technological expectations of future subsidized projects than the keywords of the patents of KIs (B=-3.009, p<0.01). This does not support hypothesis 3b. This indicates that LEs possess fewer patents that match with the keywords of future subsidized projects in which they participate. This can be explained, as firms can use patents for creating blocking fences that impede the development of competing alternative (Cohen et al., 2000; Leten et al., 2010). This hampers new entrants in the technology field, because it is difficult to 'invent around' the patent fences. Since patents are not often used in practice, this should be the reason for the less positively relation with the technological expectations of future subsidized projects. For universities, competition plays to a lesser extent a role, therefore they are more willing to share the patents in a project.

For SMEs, the applied knowledge base has no significant influence upon the technological expectation of future subsidized projects. Therefore it cannot be concluded whether the applied knowledge base of SMEs is less positively related to the technological expectations of future subsidized projects than applied knowledge bases of KIs. An explanation for this insignificant result could be that SMEs own less patents compared to the number of SMEs available in the project applications. A likely explanation of the low number of patents is again that SMEs do not invest in patents as they use secrecy to gain competitive advantage. Also, some SMEs do not patent knowledge at all due to a limited number of innovations (Blind, 2006). Besides, it appeared that SMEs are uncertain about the patentability of their innovations (Masurel, 2002).

In sum, there is less substantive relation with the keywords of the scientific publications and patents upon the keywords in project applications. Scientific publications have the least negative effect upon the occurrence of the same keywords in project applications. KIs do have the most matches with their keywords in their knowledge base and the keywords of project application in which the KIs participate. These results indicate that KIs are dominant in expectation forming. For SMEs, the results show that scientific publications and

[4] This seems a lot but each actor is good for 362 observations.

patents have not a significant influence on the expectation forming in future subsidized projects.

5. Conclusion

In this paper, the following research question was studied: "*How does the knowledge base of different actor types influence the technological expectations of future subsidized projects?*" Insights from evolutionary literatures and organizational learning are used to give insight in how the knowledge bases of actors match with the content of project applications.

The results show that the basic and applied knowledge base of actors is negatively related with the technological expectations of future subsidized projects. This means that the knowledge bases of the actors do not forecast the technological expectations of future projects. The basic knowledge base of actors is less negatively related with the technological expectations of future projects compared to the applied knowledge base. This implicates that the basic knowledge base has more influence on the expectations forming of future projects than the applied knowledge base.

Furthermore, the results show that the basic knowledge base of KIs is more positively related to the technological expectations of future subsidized projects compared to the basic knowledge base of LEs. This implicates that the basic knowledge base of KIs is of more relevance for forecasting the technological expectations of future projects. This can be explained by the different goals of the actors. KIs' main goals are the development of knowledge, and for LEs the main goal is to commercialise knowledge. For the basic knowledge base of SMEs there was no significant influence upon the technological expectations. It is likely that SMEs do not invest in scientific publications as they use secrecy to gain competitive advantage. Their main aim is not to publish scientific articles for knowledge development.

The applied knowledge base of LEs is less positively related with the technological expectations than the applied knowledge base of KIs. An explanation of this result is that LEs use sometimes patents for fencing and not for applying the knowledge to new technological innovations. The applied knowledge base of SMEs did not show a significant relation with the technological expectations of future subsidized projects. A likely explanation is that SMEs make more use of secrecy instead of patenting.

Thus, the basic and applied knowledge base of KIs are dominant in expectation forming compared to basic and applied knowledge base of LEs. For SMEs, the results show that scientific publications and patents have not a significant influence on the technological expectation forming in subsidized projects applications.

6. Discussion

6.1. Theoretical implications

As argued in the introduction, this study is the first to explicitly link the role of the knowledge bases of different actor types to technological expectations using a quantitative approach. The negative relation between the concepts knowledge base and technological expectations indicates that the underlying theories do not apply in the policy innovation context. A recommendation is to investigate the knowledge bases of actors within non-subsidized projects, if those projects are present. It is likely that actors, due to a lack of knowledge, will participate earlier in subsidized projects than in self-paid projects. In this way, they avoid the risks if projects will fail.

Also, this research contributed to the literature about organizations and technological expectations. This research demonstrated that the basic knowledge bases of KIs are more positively related with technological expectations than the basic knowledge base of LEs. This is in line with Geuna and Nesta (2006), who explain that KIs have more relevance with basic knowledge bases. However, further research can focus on the influence of the changing pattern of the knowledge bases of KIs. According to Bekkers (2010) KIs are more and more patenting knowledge; this development shifts the basic knowledge base towards applied knowledge base. Future oriented research can focus on the knowledge base developments of KIs and its influence on expectations forming.

6.2. Policy implications

The results indicate that the knowledge bases of actors should vary from the subsidized project applications in order to participate in subsidized project application. However, it can also be supposed that the knowledge bases do not fit well to the project applications they participate in. Therefore, a policy implication is that the Netherlands Enterprise Agency can take the contents of actors' knowledge bases more into account while assessing project applications of actors. This could result in a more efficient use of the available knowledge in the sector. Nootenboom et al. (2007) explained this by the concept of cognitive distance: for an optimal innovative performance the gap between the knowledge of actors should be not too broad but also not too narrow for a specific technological innovation. In addition, this research only included approved project application are included in this research. It is of interest to investigate the match of the rejected project applications with the knowledge bases of the actors.

Another policy implication is that the Netherlands Enterprise Agency can take more project partners form abroad into account. Nowadays, almost exclusively Dutch actors are involved in the projects. Technological innovations are not bound to the borders of a country (Hekkert et al., 2007). International collaboration within project application could give more insight in the expectations of the development PV sector. Also, by collaborating with other countries, Dutch actors can exchange knowledge and co-develop products or processes with each other (Gulati, 1998; Powell, 1998; Schilling and Phelps, 2003). Further research should investigate the influence of focussing on international collaboration within the PV sector.

6.3. Limitations

This research suffers from two limitations. The first limitation is the measurement of concepts. We chose to operationalize the basic and applied knowledge bases through scientific publications and patents. This knowledge is codified. However also tacit knowledge is part of the basic and applied knowledge base (Pavitt, 1989). Tacit knowledge is non-codified knowledge, which is important to understand the knowledge underlying scientific publications and patents (Pavitt, 1989; Haruyama, 2009). This is not included in the data. Therefore, it is likely that the content of knowledge bases is not fully complete. However, in this research it is assumed that the majority of the knowledge is captured in patents and scientific publications. Another limitation of measuring concepts is that the keywords for the patents and project application were qualitative determined in this research. The reason for this was the absence of keywords. It is likely that by repeating this research by other authors, some keywords of the patents and scientific publications could differ from the ones derived in this research. In order to increase the reliability of this research (Yin, 2003), the keywords of the project applications and patents were reviewed by an expert in the field of PV technology from the Netherlands Enterprise Agency[5]. Also, a detailed description of how the keywords are derived from the project application and the patents are elaborated in the method.

The second limitation is the generalizability. This research takes only in account the subsidized projects by the government. There is a possibility that this research missed unsubsidized projects. Although there is a large dependency on governmental funding in this sector, there cannot be excluded that projects are missing. Also this analysis is valid for subsidized projects in the Dutch PV sector between 2005-2013, based upon the knowledge bases of the period 2002-2013. For generalization, further research is necessary on different technologies and in different countries.

[5] The expert who reviewed the keywords is Otto Bernsen. He is a specialist within the field of PV technology.

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Appendix A. Keyword list

Table 3 provides the keyword list of the scientific publications, patents and project applications. In total there are 362 keywords derived.

Table 3: Keyword list.

Keywords
1DPhotonic crystal
3 4 multijunction solar cell
3 4 photonics
3 4 semiconductor materials
3 5 Multi junction solar cells
Absorber layers
Absorption
Ag
Al
Al2O3
ALD Atomic Layer deposition
ALD Al2O3 film
ALD SiO2 layers
Angle selective
Annealing
Anode
Antireflection layer
APCVD Atmospheric Chemical Vapor Deposition
a-si
a-Si:H
AU
Back contacted
Backend serial interconnection
Bandgap
Bandgap energy
Bismuth Bi
Building envelope
Building integrated photovoltaic BIPV
Bulk heterojunction cell
Cadmium
Carboxyl
Cast wafer
CDSbuffer
Cell assembly
Cell voltage
Cells
Ceramic
Cerium
CIGS

CIS
Coating
Composite material
Concentrator
Construction
Contacts
Conversion materials
Copper
Core Shell absorber
Crystal
Crystal lattice
Crystalline Silicon photovoltaic
CVD Chemical Vapor Deposition
DC
DCAC conversion
Deposition
Deposition rate
Deposition technique
Dielectric layer
Doping
Downconversion
Dye
Dye sensitized solar cell DSSC
Efficient
Electricity
Electro active layer
Electrochemical deposition
Electrolysis
Electrolyte
Electrons
Emitter
Encapsulation
Energy production
Energy technology
Enhancement
Flexible photovoltaics
Fluorescent
Fresnel lens
Fullerene
Gallium
Glass substrate
Glassfoil
Gridparity
Heterojunction
High efficiency
Homogeneity
Homojunction
Impurities
In2S3

Indium
Ingot casting
Inkjet printing
Inline
Integrated functionality
Integration
Interdigated
Interferention
Intermediate Reflector IR
Ion Implantation
Junction formation
Light scattering
Light spectrum
Light trapping
Liquid crystal
Low deposition temperatures
Lowband gap polymers
Lowcost production
Luminenscent solar concentrator LSC
Materials
Metallisation
Micromorph
Module production
Morphologies
Multicrystalline silicium
Multicrystalline silicon
Multijunction
Nano crystal
Nano crystals
Nano layer
Nano particle
Nano structured cell
Nano tubes
Nano wire
Nip structure
ntype
Optical active layer
Optical losses
Optical modelling
Organic Photovoltaic OPV
Passivation
PECVD
Phosphor
Photo electric chemical cell
Photon
Photonic crystals
Photosensitive
Photovoltaic cell
Photovoltaic system

Pigment
Pigments
p-i-n
Plasma oscillation
Plastic
Polar side groups
Polymer solar cell
Polymere layer
Power optimizer
Power output
Prism
ptype
PV module
PV systems
Quantum cutting
Quantum dots
Radiation
Radical flux
Rearside passivation
Rearside processing
Reflection layer
Rolltoroll
Scaling
Selective emitter
Semiconductor
Shading
Silanes
Silicon
Single junction
SiO2
Si
Spraying
Stabalized morphology
Stability
Stack
Stack layers
String
Subbandgap
Substrate
Super lattices
Surface passivation
Suspended Particle Device SPD
Tandem cells
TCO
Thermal
Thermal Oxidation
Thermo electric converters
Thickness
Thin film

TiO2layer
Titanium
Tracker
Transparant
Upconversion
Wafer based silicon technologies
Wavelength selective
Zinc oxides

Appendix B. Model run for basic and applied knowledge base

In table 4 the logistic regression of the independent variables the keywords of scientific publication and the keywords of patents and the dependent variable technological expectations. In this logistic regression only the scientific publications and patents are included. The interaction term actor type is disregarded. The results show that the influence of the scientific publications is not significant.

Table 4: Results of logic regression analysis with the dependent variable kewords of project applications.

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

Keywords project applications	Variable	Specification	Model
Control variables	Year	2005	-0.081
		2006	-1.383
		2007	0.055
		2008	-1.606
		2009	-1.192
		2010	-0.865
		2012	0.312
		2013	Ref
	Actor type	SME	-2.01*
		LE	0.164
		KI	Ref
Independent variables			
	Basic knowledge	Scientific publications	-0.026
	Applied knowledge	Patents	-10.472***
Model indicators		Cox and Snell	0.277
		Nagelkerke	0.527***
		McFadden	0.435

Appendix C. Model run for basic knowledge base

In table 5 the results of the logistic regression analysis are provided wherein only the influence of the keywords of the scientific publication is taken into account. This shows that the keywords of scientific publications are still significant related to the expectations of future subsidized project applications. However, it is still a negative relation.

Table 5: Results of the logic regression analyis with only the independent variable scientific publications

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

Keywords project applications	Variable	Specification	Model
Control variables	Year	2005	1.259
		2006	0.317***
		2007	0.523
		2008	0.398*
		2009	-1.015***
		2010	0.057
		2012	0.711**
		2013	Ref
	Actor type	SME	18.63
		LE	3.469***
		KI	Ref
Independent variables	Basic knowledge	Scientific publications	-0.103***
	Basic knowledge	SME* scientific publication	-18.631
		LE * Scientific publications	-3.469***
		KI * scientific publications	Ref
Model indicators		Cox and Snell	0.614
		Nagelkerke	0.826***
		McFadden	0.701
Intercept Only		-2 Log Likelihood	5,661.83
Final		-2 Log Likelihood	1,665.274***

Appendix D. Model run for applied knowledge base

In table 6 the results of the logistic regression analysis are provided wherein only the influence of the keywords of the patents is taken into account. This shows that the keywords of patents are not anymore significant related to the expectations of future subsidized project applications.

Table 6: Results of the logistic analysis with only the independent variable patents

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

Keywords project applications	Variable	Specification	Model
Control variables	Year	2005	-0.273
		2006	-2.744
		2007	-2.008
		2008	-2.744*
		2009	-1.66
		2010	-1.193
		2012	0.29
		2013	Ref
	Actor type	SME	0.542
		LE	-12.249
		KI	Ref
Independent variables	Applied kowledge base	Patents	-19.867
	Applied knowledge base	SME* Patents	-8.536
		LE * Patents	-13.082
		KI * Patents	Ref
Model indicators		Cox and Snell	0.508
		Nagelkerke	0.967***
		McFadden	0.952
Intercept Only		-2 Log Likelihood	2,089.969***
Final		-2 Log Likelihood	1,991.433