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Erik Stam
Marko Hekkert

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Innovation barriers for small biotech, ICT and clean tech firms: Coping with knowledge leakage and legitimacy deficits

Neil Thompson[1]
Andrea Herrmann[1,2]
Erik Stam[3,4]
Marko Hekkert[1]

[1] Innovation Studies Group, Utrecht University
[2] Institute for Social and Economic Research and Policy, Columbia University
[3] Utrecht University School of Economics
[4] EIM Business & Policy Research

Abstract

Innovative high-tech small and medium sized enterprises (SMEs) are thought to be drivers of economic renewal and growth. However, due to their limited size, SMEs face two fundamental innovation barriers: the risk that other organizations appropriate the returns to the newly created knowledge by SMEs (knowledge leakage), and a lack of understanding and recognition of their business on the part of potential stakeholders (legitimacy deficits). Based on a panel study of 196 SMEs this paper shows that biotech, ICT and clean tech firms choose different strategies to deal with knowledge leakage and legitimacy deficits. To prevent knowledge leakage, high-tech SMEs are very selective in choosing their R&D partners and collaborate with basic rather than applied technology developers. Furthermore, to gain organizational legitimacy, high-tech SMEs pursue activities that focus not only on product development but also on generating awareness and understanding of their technologies.

Keywords: high tech SMEs, innovation, R&D collaborations, legitimacy

1. Introduction

There has been a long debate on whether small firms are more innovative than large firms. Some argue that SMEs are crucial for innovation and industrial renewal. However this does not mean that SMEs as a group are more innovative than large firms. They might even be less innovative because of the problems they face with respect to creating, delivering and appropriating new value. In this paper, we focus on the innovative capacities and innovation strategies of small firms in new technological areas. Among a variety of reasons for the general reluctance of SMEs to innovative one dominant issue is the "*knowledge spillover problem*" (Teece, 1986), also known as "knowledge leakage" (Kale et al. 2000). By definition, small firms have a less comprehensive knowledge base than large firms. They are short of resources such as human capital, financial capital, and know-how, which are, however, essential for innovation, and the development of new technologies (Acs & Audretsch, 1987; Garnsey, 1998; Nooteboom, 1994; Vossen, 1998). In order to gain access to these resources, SMEs seek to complement their internal knowledge base through external knowledge (Eisenhardt & Schoonhoven, 1996; Jarillo, 1989; Lipparini & Sobrero, 1994; Tyler & Steensma, 1998; Yli-Renko, Autio, & Sapienza, 2001). For example, they partner with universities, research institutes, or other firms with the aim of developing innovations through R&D collaborations (Kelley, Peters, & O'Connor, 2009; Powell, Koput, & Smith-Doerr, 1996; Soh, 2003). At the same time, such collaborations bear the risk that R&D partners diffuse the jointly discovered knowledge without ensuring that the involved SME benefits from it. Knowledge spillover problems or knowledge leakage are a general problem that SMEs face as soon as they seek to innovate, with small biotechnology firms providing an ideal-typical examples of ventures coping with this innovation barrier.

In addition to the general problem of knowledge spillovers, SMEs developing technologies whose applicability is still unclear to the broader public face a specific problem of *organizational legitimacy* (Suchman, 1995). All firms need to gain organizational legitimacy in the eyes of potential stakeholders, such as financiers, employees, suppliers, and customers, otherwise they will not be able to acquire resources from, or sell their products to, them. Yet, whenever few prior examples of firms exist that have successfully marketed a new technology, actions of firms in this area are perceived as risky, pioneering, or illegitimate – whether or not this is actually the case (Rao, Chandy, & Prabhu, 2008; Singh, Tucker, & House, 1986; Stinchcombe, 1965). While there certainly are exceptions to this rule, SMEs seem to have generally less organizational legitimacy than large firms, simply because small firms have a more limited numbers of stakeholders which already have placed trust into their business. Small ventures developing new alternative-energy technologies are a typical example of ventures facing the problem of legitimacy acquisition.

Given the knowledge spillover problem in general and the legitimacy-acquisition problem in particular, it seems surprising that existing SMEs in new technological areas are able to innovate successfully at all. Yet, to be able to compete in high tech industries, it is certainly vital for small firms to be innovative. But which strategies enable SMEs to overcome the innovation barriers related to acquiring external knowledge on the one hand, and legitimacy on the other? Do SMEs developing technologies with a reduced risk of knowledge leakage choose different collaboration strategies than SMEs advancing technologies with high spillover risks? And do SMEs active in technologies that are less well understood by the public seek to gain legitimacy through different channels than their counterparts, active in well understood technology areas? Or do all ventures developing new technologies use the same approaches to prevent knowledge leakage on the one hand, and to gain legitimacy on the other?

To shed light on these questions, we compare SMEs active in biotechnology (BT), information and telecommunication (ICT), and `clean` technologies (CT) – including alternative

energy and environmental technologies. These comparisons promise most insightful results, because biotech SMEs are most affected by knowledge leakage and clean-tech SMEs are particularly confronted with legitimacy-acquisition problems. ICT firms, in turn, offer most insightful contrasts as they are least affected by both innovation barriers.

Logistic regression analyses based on a longitudinal panel study of 196 high tech SMEs shows that their innovation strategies differ in line with the knowledge leakage and legitimacy problems encountered. Whenever the risk of knowledge appropriation by R&D partners is acute as basic technologies are invented, SMEs selectively choose their collaboration partners and work with basic rather than applied technology developers. The opposite holds for SMEs where the risk of knowledge appropriation is reduced. Similarly, small ventures proceed differently in how they gain legitimacy. While SMEs with high legitimacy focus mostly on product development activities, SMEs with low legitimacy levels engage in activities that promote the understanding of their business and its technology – way beyond mere product development.

To illustrate these points, the remainder of this paper is organized as follows. Section 2 gives an overview over the existing literatures: including the concepts, assumptions, and theories underlying knowledge spillover and legitimacy acquisition problems. Based on these insights, hypotheses are proposed on how SMEs in new technology areas may overcome the respective innovation barriers. Section 3 presents the case selection and data used to analyze these strategies. Section 4 presents and interprets the outcomes of logistic regression analyses and links the results back to the initially proposed hypotheses. Section 5, summarizes and concludes the paper with a discussion of research limitations and suggestions for future research.

2. Knowledge leakage and legitimacy deficits

SMEs in new technological areas have been studied extensively. They have been found to develop more product innovations than large firms (Acs & Audretsch, 1987) and even more importantly, they have been found to develop product innovations that are at least as successful as those of their larger counterparts (Link & Bozeman, 1991). Since they have also been shown to generate new jobs (Acs et al., 2008), innovative SMEs are generally considered a fundamental driver for economic renewal and growth (Baumol, 2002).

SMEs need to acquire resources in order to innovate successfully. Yet, to acquire these resources, SMEs need to convince potential stakeholders of the firm`s legitimacy on one hand (Aldrich & Fiol, 1994; Delmar & Shane, 2004; Zimmerman & Zeitz, 2002) and to make sure that innovation partners do not appropriate their knowledge without adequate compensation (McKelvie & Davidsson, 2009). Given their apparent success in new technological fields, many SMEs must have found ways to overcome these disadvantages. How then do small firms overcome these innovation barriers of knowledge leakage and legitimacy acquisition?

2.1. Selective R&D collaborations: A solution to the knowledge spillover problem

SMEs developing new technologies are confronted with a R&D collaboration dilemma: On the one hand, they are too small to possess all those resources themselves that are needed for innovations (Cohen & Levinthal, 1990). Consequently, innovative SMEs typically seek to complement their internal resources and R&D projects through collaborations with external R&D

partners (Niosi, 2003; Powell et al., 1996)[1]. On the other hand, R&D collaborations give rise to the risk of involuntary knowledge spillovers. While economists point to the positive net effects that result for a society whenever knowledge generated by private R&D initiatives spills over to other economic actors (Acs, Audretsch, & Feldman, 1994; Jaffe, 1986), the risk of involuntary spillovers systematically leads SMEs to under-invest in R&D activities. Hence, SMEs have few incentives to make R&D investments if the chances of capturing the returns on these investments are low (Spence, 1984).

SMEs certainly seek to insure themselves against the risk of knowledge spillover by concluding contracts with their R&D partners, which stipulate the entitlements that are to result for each party from the collaboration. Importantly, though, scholars of `hold-up` situations teach us that it is inherently impossible to determine all features of a future collaboration from its outset (Rogerson, 1992; 777). The reasons are twofold; first, when starting their collaboration, the involved parties may not foresee the necessity of writing certain provisions into the contract, because unpredictable events may occur in the future that change the significance of certain contractual provisions. Second, it is "too costly or too time consuming to write all the relevant details into a contract" (Malcomson, 1997; 1917). Consequently, it is difficult to prevent knowledge spillovers, because it is inherently impossible to define ex ante which precise intellectual property rights shall arise for the involved parties ex post.

It follows that the precision with which contracts can, ex ante, protect future intellectual property rights and, hence, the risk of knowledge spillover varies according to the technologies developed. Whenever R&D collaborations aim at developing basic technologies, whose precise application within a future product is not entirely clear from the outset, the inventions that will be made cannot be protected with precision, that is to say, the outcomes are partly unknown. The opposite holds true for the joint developments of applied technologies, whose future use in a product are so clearly defined that the intellectual property returns on joint R&D investments can be unambiguously assigned to the involved parties. Consequently, SMEs developing applied technologies are less concerned by the risk of knowledge spillovers than firms developing basic technologies.

Following this reasoning, we hypothesize that SMEs active in basic technologies choose different approaches than SMEs active in applied technologies to deal with the innovation barrier of knowledge spillover. More precisely, we expect to find that

Hypothesis 1. (on the extent of R&D collaborations): SMEs developing basic technologies are more selective when engaging in external R&D collaborations than SMEs developing applied technologies.

Hypothesis 2. (on the form of R&D collaborations): If SMEs developing basic technologies engage in R&D collaborations, they are more likely to choose other developers of *basic* technologies as external collaboration partners, as they face the same risk of knowledge appropriation and have more limited capacities to bring joint discoveries to the market.

[1] It is noteworthy that this necessity for R&D alliances has been studied and explained not only by proponents of the resource-based view, but also by scholars of transaction economics and business strategy (Hoffmann & Schlosser, 2001). While adherents of the resource-based view recognize inter-organizational alliances as a source of synergies due to complementary resources (Ahuja, 2000), transaction economists view alliances as a method to co-ordinate economic activities in scenarios of limited need for control (O. E. Williamson, 1994; O. E. Williamson, 1991). Business strategists, in turn, view alliances more broadly as providing access to knowledge through cooperative efforts that aim to meet the firm's business strategy (Dickson & Weaver, 2011).

2.2. Legitimacy Acquisition: A solution to legitimacy deficits?

In addition to knowledge spillover problems, a growing number of researchers have stressed the acquisition of organizational legitimacy as a key factor for obtaining scarce resources necessary for innovation (Aldrich & Fiol, 1994; Delmar & Shane, 2004; Khaire, 2010; Tornikoski, 2009; Tornikoski & Newbert, 2007; Zimmerman & Zeitz, 2002). In line with Suchman (1995: 574), we understand legitimacy as "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions." A firm`s present and potential stakeholders need to accept the venture as appropriate according to their norms (see Aldrich & Fiol, 1994). Otherwise, they will not be willing to provide necessary resources for activities such as innovation.

To gain legitimacy, firms actively deploy strategies with the aim of generating acceptance and recognition of their business on the part of external constituents (Aldrich & Ruef, 2006; Dowling & Pfeffer, 1975; Golant & Sillince, 2007; Lounsbury, 2001; Massey, 2001; Neilsen & Rao, 1987; Walker & McCarthy, 2010). More concretely, firms seek to build contacts, engage in activities, and invest in building relationships that go far beyond the sheer aim of bringing new products to the market. Rather than focusing interactions with their stakeholders on product-oriented activities, firms strategically choose to interact in ways that also increase their external recognition (Zimmerman & Zeitz, 2002). Examples are the publication of research articles, road shows and presentations at universities. Even the provision of professional education to students and trainees are activities that go beyond the immediate aim of product development and increase a firm`s external recognition (Zimmerman & Zeitz, 2002).

Importantly, though, some firms find it more difficult to gain legitimacy than others. Small firms, in general, have more difficulties raising financial capital and human capital than large firms due to their inability to offer long-term stability and internal labour markets (Aldrich & Auster, 1986). As a consequence, SMEs are generally perceived as less legitimate than large firms. While gaining legitimacy is more difficult for SMEs in general, SMEs in new technological areas face a specific legitimacy deficit problem, because the understanding of a new technology is usually limited amongst potential stakeholders. Whenever a new technology is less understood, SMEs need to deploy strategies that generate legitimacy not only for their individual business, but also for their technology in general.

Following this reasoning, we hypothesize that SMEs differ in how they cope with the innovation barrier of legitimacy acquisition:

Hypothesis 3. (on the extent of legitimacy acquisition): SMEs active in technological fields that are less well understood by potential stakeholders seek to secure legitimacy through a broader variety of means than firms active in technologies that are well understood by potential stakeholders.

Hypothesis 4. (on the form of legitimacy acquisition): SMEs developing products of well understood technologies focus their legitimacy-acquisition strategies on promoting their products, whereas SMEs developing products of less well understood technologies seek to gain legitimacy through activities that create technological understanding and awareness beyond their own products.

3. Methodology and Data

3.1. The Sample

The most insightful data available to assess how innovative SMEs cope with the challenges of knowledge leakage and legitimacy deficits is the EIM "SME technology panel" (cf. De Jong and Freel 2010). The resulting database contains systematic information, collected via computer-assisted telephone interviews in 2005, on various aspects and activities of overall 779 SMEs developing and commercializing technological innovations. As the purpose of the survey was to understand innovation in SMEs, screening questions limited the database to companies that have no more than 500 employees and that have shown to systematically innovate.[2]

To assess possible strategic differences in how innovative SMEs cope with the innovation barrier of knowledge leakage on the one hand, and legitimacy deficits on the other, we focus on SMEs active in biotechnology 30, information and communication technology 125, and clean technologies 41. Clean-tech SMEs are defined as firms that are active in alternative energy (e.g. wind, solar, biomass), soil treatment and environmental technologies.

These comparisons promise most insightful results as biotech, ICT, and clean-tech firms are affected by the respective innovation barriers to different degrees. Concerning the risk of knowledge leakage, biotech firms are most affected because pharmaceutical applications, resulting from the discovery of new chemical entities, are often hard to foresee and, hence, to protect from appropriation by R&D partners (see Herrmann, 2008; chapter 2). ICT firms, on the contrary, are least affected by possible knowledge leakage as the predictability and, thus, intellectual-property protection of ICT applications is typically high (Ayres & Williams, 2004; Carlaw et al., 2006).

Regarding legitimacy deficit problems, clean-tech firms provide a particularly insightful case as the general understanding of how clean-tech products look like, how they operate, and the profitability is more limited (see Wüstenhagen, Wolsink, & Bürer, 2007). Again, ICT firms allow for most insightful comparisons: despite the frequency of technological innovations, stakeholders of ICT firms generally have a clear-cut understanding how telecommunications are to be used.

3.2. Operationalization

R&D collaboration strategies. The database includes a comprehensive set of indicators that captures all external R&D collaborations of SMEs during the past 3 years. More precisely, the indictors measure whether, or not, an innovative SME has entered into an R&D collaboration with at least one university, research institute, consultancy, university of applied sciences (HBO institutes), supplier, competitor, and customer during the past 3 years. In the survey, the question is stated as: "Over the past three years, which parties has your business collaborated with in innovation projects (select all that apply)?" With the exception of the HBO institutes indicator, all indicators are measured on a scale from 0 to 2: 0 for no collaborations, 1 for collaborations for either home or abroad, and 2 for collaborations both home and abroad.

[2] To identify innovating SMEs, two questions were used. First, respondents had to indicate whether their company has made at least one innovation over the past 3 years. This could be either product -, process-, organizational, or marketing-related innovations defined by the Oslo manual (see OECD, 2005). Secondly, respondents were also included if they have formulated an innovation.

To examine our first and second hypotheses (H1 and H2), we have ordered these indicators from basic to applied R&D collaborations, whereby we considered for each type of R&D collaboration partner whether it is typically associated with developing basic or applied technologies. Accordingly, we classified universities and research institutes as typical collaboration partners in basic R&D projects, whereas we consider suppliers, competitors, and customers as typical collaboration partners in applied R&D projects. Consultancy firms and HBO institutes were classified as an in-between category of neither basic nor applied collaboration partners.

Organizational legitimacy strategies. The database also includes information on the *reasons* why SMEs collaborated with research organizations. In the survey, the question is stated as follows: "The next question is about your company's contacts with research institutes, universities, colleges and research organizations. What opportunities did apply to your business during last year?" All responses are binary: 0 for "no" and 1 for "yes" responses. The possible answers to the question about the aims of SME contacts with research organizations include: outsourcing of R&D; sharing facilities (laboratories, equipment, housing, etc.); recruiting recent graduates; sharing employees (combined part-time appointments); training of employees; use of trainees; joint R&D projects; joint publications; and providing guest lectures, tours, and/ or demonstrations.

In order to examine our third and fourth hypotheses, we consider to what extent the contacts that an SME has with research organizations are used merely to *advance product development*, or to both *advance product development and foster the reputation of a firm and its technology*, or to *only foster the reputation of a firm and its technology*. Following recent research, we consider outsourcing, sharing of facilities, and recruitment as strategies that small firms typically use to develop their products (Huang, Chung, & Lin, 2009; Un, Cuervo-Cazurra, & Asakawa, 2010). On the other hand, we consider joint projects, joint publications, and guest lectures as activities that chiefly aim at giving the firm more credibility and foster the reputation in the eyes of potential stakeholders (Aldrich, 2000; Aldrich & Ruef, 2006). Finally, the sharing and training of employees with, and recruitment of trainees from, research organizations are activities that do both advance a product and foster the reputation of a firm and its technology.

Control variable. Among all possible determinants that influence how SMEs cope with knowledge and legitimacy acquisition problems – other than a meticulous selection of R&D partners and strategic interactions, age provides the strongest alternative explanatory variable. In line with research into corporate age, younger SMEs can be expected to be more affected by knowledge spillover problems than older SMEs, because the latter have had more time to address this difficulty (e.g. with developing complementary assets, or knowledge about appropriating value). Younger SMEs can be expected to be more affected by legitimacy acquisition problems than older SMEs, as the latter have had the time to build up legitimacy (Clegg, Rhodes, & Kornberger, 2007; Elsbach & Sutton, 1992). We therefore control for corporate age.[3]

[3] It should be noted that four outlier cases were included in the original database as three biotech ventures and one clean tech venture were older than 90 years. Since the inclusion of these outliers would have distorted the normality of distribution, we excluded these cases from the analyses.

Table 1a: R&D collaborations of SMEs with high vs. low knowledge-appropriation risks: two sample t-tests

	SMEs with Low Knowledge- Appropriation Risk ICT (N=125)				SMEs with High Knowledge- Appropriation Risk BT (N=30)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
R&D Collaboration w.								
Universities***	**0.56**	0.700	0	2	**1.30**	0.702	0	2
Research institutes**	**0.34**	0.553	0	2	**0.70**	0.702	0	2
Consultancy	**0.31**	0.545	0	2	**0.40**	0..675	0	2
HBO institutes in NL***	**0.31**	0.465	0	1	**0.10**	0.305	0	1
Suppliers	**0.68**	0.655	0	2	**0.90**	0.803	0	2
Competitors	**0.24**	0.498	0	2	**0.33**	0.661	0	2
Customers***	**0.90**	0.645	0	2	**1.63**	0.615	0	2
Controls								
Age	**16.83**	14.43	6	109	**15.92**	8.36	7	45

*** significance level greater than 99%
** significance level greater than 95%
* significance level greater than 90%

Table 1b: Legitimating strategies of SMEs with high vs. low legitimacy deficits: two sample t-tests

	SMEs with Low Legitimacy Deficits ICT (N=122)				SMEs with High Legitimacy Deficits CT (N=41)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Awareness								
Outsourcing*	**0.18**	0.386	0	1	**0.32**	0.471	0	1
Sharing Facilities**	**0.11**	0.32	0	1	**0.29**	0.461	0	1
Recruitment*	**0.32**	0.468	0	1	**0.20**	0.401	0	1
Share employees	**0.14**	0.348	0	1	**0.12**	0.331	0	1
Training	**0.14**	0.348	0	1	**0.10**	0.300	0	1
Trainees	**0.58**	0.495	0	1	**0.51**	0.506	0	1
Joint Projects***	**0.37**	0.484	0	1	**0.66**	0.480	0	1
Joint Publications***	**0.18**	0.386	0	1	**0.41**	0.499	0	1
Guest lectures	**0.31**	0.465	0	1	**0.39**	0.494	0	1
Controls								
Age	**16.94**	14.54	6	109	**18.28**	11.39	7	51

*** significance level greater than 99%
** significance level greater than 95%
* significance level greater than 90%

Comparison of means. In table 1a and 1b, we provide an empirical overview over differences in mean values for both sets of indicators. We also performed simple t-tests to assess whether mean differences are statistically significant. Following hypothesis H1, we expect biotech SMEs, which are more exposed to the risk of knowledge appropriation by R&D partners than ICT SMEs, to be very selective in choosing external R&D collaborations. At first sight, table 1a indicates that SMEs with a high risk of knowledge appropriation collaborate generally more with external R&D partners – with the exception of Dutch HBO institutes – than SMEs with low knowledge-appropriation risks. This finding suggests that the need to collaborate with R&D partners is

stronger for basic technology developers than their fear that jointly discovered knowledge could be stolen. When looking at table 1a more closely, however, we note that several indicators are not statistically significant. In other words, the extent to which biotech SMEs collaborate more with external R&D partners than ICT firms is relatively marginal. Differences in the external of R&D collaborations are only significant for projects with universities and research institutes, HBO institutes in the Netherlands, and customers. In other words, SMEs with high knowledge-appropriation risks seem, indeed, rather selective in choosing their R&D partners.

According to hypothesis H2, we expect that those biotech firms engaging in external R&D collaborations are mostly cooperating with other developers of *basic* technologies. Overall, the mean comparisons seem to support this hypotheses to the extent that SMEs with a high risk of knowledge appropriation collaborate more with basic technology developers, namely universities and research institutes, and less with applied technology developers, such as HBO institutes. R&D collaborations with customers constitute the only exception that is not in line with H2, as biotech SMEs collaborate more with these applied technology developers than ICT firms.

Following hypotheses H3, we expect that clean-tech SMEs, which overall enjoy less legitimacy than ICT SMEs, are more active in trying to gain legitimacy for their business than ICT firms. In particular, H4 suggests that they engage more substantially in activities raising technology-awareness than in sheer product-developing activities. With the exception of the extent to which SMEs share facilities with research organizations, the empirical evidence presented in table 1b about the interactions of SMEs and research organizations with the aim of completing joint projects and joint publications seem to support both hypotheses at a 95% significance level.

It is however important to note that the results presented in tables 1a and 1b are preliminary as the respective types of collaboration and legitimacy activities are not controlled for each other. The relative importance of a particular activity for overcoming knowledge spillover and legitimacy acquisition problems will only become visible when other activities and age characteristics are held constant. In other words, tables 1a and 1b does not show which differences between the respective R&D-collaboration and legitimacy-acquisition types are the strongest ones – when controlled for the strength of differences between the respective other collaboration and legitimacy-acquisition types. To gain more systematic insights into how SMEs cope with innovation barriers, we perform logistic regression analyses in the next section.

4. Analyses

To empirically analyze our hypotheses, three sets of binary logistic regressions were conducted for both sets of indicators. More precisely, we test the following models for the R&D collaboration indicators on the one hand, and the legitimacy indicators on the other. Model 0 assesses the explanatory power of each independent variable separately: Hence, it regresses each independent indicator separately on the respective sample groups of firms that are, or are not, affected by knowledge spillover and legitimacy acquisition problems respectively (dependent variable). Model 1 is the most comprehensive model, because it includes all independent variables on collaboration and legitimacy acquisition strategies, as well as age, in order to measure their relative explanatory power. Model 2 is the most parsimonious model as it includes only those independent variables that turned out to be significant in model 1. Consequently, the binary logistic regression analyses of model 1 for knowledge spillover and legitimacy deficit difficulties respectively can be expressed as follows:

Strategies to cope with knowledge spillover problems:

$$\text{Odds}_{\text{high risk SME / low risk SME}} = \frac{\text{prob}_{\text{high risk SME}}}{\text{prob}_{\text{low risk SME}}} = e^{\beta 0 + \beta 1\, x1 + \beta 2\, x2 + \beta 3\, x3 + \beta 4\, x4 + \beta 5\, x5 + \beta 6\, x6 + \beta 7\, x7}$$

where

- SMEs with high risk of knowledge appropriation = Biotech firms
- SMEs with low risk of knowledge appropriation = ICT firms
- x_1 = R&D collaborations of SMEs with public research organizations
- x_2 = R&D collaborations of SMEs with consultancies
- x_3 = R&D collaborations of SMEs with HBO institutes in the NL
- x_4 = R&D collaborations of SMEs with suppliers
- x_5 = R&D collaborations of SMEs with competitors
- x_6 = R&D collaborations of SMEs with customers
- x_7 = corporate age

Strategies to cope with lack of legitimacy

$$\text{Odds}_{\text{low legitimacy SME / high legitimacy SME}} = \frac{\text{prob}_{\text{low legitimacy SME}}}{\text{prob}_{\text{high legitimacy SME}}} = e^{\beta 0 + \beta 1\, x1 + \beta 2\, x2 + \beta 3\, x3 + \beta 4\, x4 + \beta 5\, x5 + \beta 6\, x6 + \beta 7\, x7 + \beta 8\, x8 + \beta 9\, x9 + \beta 10\, x10}$$

where

- low legitimacy SME; or SME with high legitimacy problem = CT firms
- high legitimacy SME; or SMEs with low legitimacy problem = ICT firms
- x_1 = collaborations with the aim of outsourcing projects to a research organization
- x_2 = collaborations with the aim of sharing facilities with a research organization
- x_3 = collaborations with the aim of recruitment from a research organization
- x_4 = collaborations with the aim of sharing employees with a research organization
- x_5 = collaborations with the aim of training together with a research organization
- x_6 = collaborations with the aim of recruiting trainees from a research organization
- x_7 = collaborations with the aim of doing joint projects with a research organization
- x_8 = collaborations with the aim of doing joint publications with a research organization
- x_9 = collaborations with the aim of guest lectures at a research organization
- x_{10} = corporate age

It should also be noted that for the regressions on knowledge spillover problems, the variables `collaboration with universities´ and ´collaboration with research institutes´ were combined into one index, entitled public research organizations (PROs). The reason is of a statistical nature: Correlation analyses revealed that both indicators are substitutes and, therefore, strongly correlated. In order to avoid multicollinearity problems in the regressions on knowledge spillover problems, a single variable was coded. This new variable was coded 0 whenever an SME collaborated neither with universities nor with PROs, it was assigned a value of 1 whenever

SMEs collaborate either with universities or with PROs, and it was coded 2 for SMEs collaborating with both universities and PROs.

4.1. How SMEs cope with knowledge spillover problems

Table 2 reports the results obtained from binary logistic regressions on collaboration choice strategies of SMEs. Overall, these results confirm our findings reported in table 1a and, hence, hypotheses H1 as well as H2. With regard to H1, let us remember that biotech firms, which are at risk of knowledge appropriation by external R&D partners, were found in table 1a to collaborate selectively with certain types of R&D partners. This is confirmed by model 1 of table 2: Exp(B) values indicate that, when collaboration with PROs increases, the odds ratio is 2.63 times as large and, therefore, SMEs are 2.63 more times likely to be biotech rather than ICT ventures with limited knowledge appropriation risks. On the other hand, when collaborations with HBO institutes increase then SMEs are 0.16 less times likely to be biotech firms with high knowledge appropriation risks. Lastly, an increase in collaboration with customer results in SMEs being 7.58 more times likely to be biotech than ICT ventures. This indicates that SMEs faced with knowledge-appropriation risks are, indeed, very careful in selecting their R&D partners. Overall, we interpret this finding in support of hypothesis H1.

Table 2: R&D collaborations of SMEs with high knowledge-appropriation risks: binary logistic regression

0 = SMEs with Low Knowledge-Appropriation Risk (ICT)		Model (0)		Model (1)		Model (2)	
1 = SMEs with High Knowledge-Appropriation Risk (BT)		B	Exp(B)	B	Exp(B)	B	Exp(B)
	Intercept			-4.92***		-4.64***	
	Public research organizations	1.20***	3.33***	.96**	2.63**	.94**	2.55***
	Consultancy	.26	1.29	.44	1.55		
	HBO institutes in NL	-1.41**	.25**	-1.85**	.16**	-1.70**	.18**
	Suppliers	.46	1.58	.31	1.36		
	Competitors	.30	1.35	-.11	.89		
	Customers	1.90***	6.70***	2.03***	7.58***	2.01***	7.44 ***
	AGE	-.01	.99	-.02	.98	-.01	.99
N				129		129	
R^2				0.457		0.449	

**** significance level greater than 99%*
*** significance level greater than 95%*
** significance level greater than 90%*

Furthermore, the results of table 2 provide partial empirical support for hypothesis H2: SMEs exposed to the risk of knowledge appropriation typically collaborate with basic research organizations (i.e. PROs), whereas SMEs that are less exposed to this risk are more likely to collaborate with applied technology developers (i.e. HBO institutes). Model 2 shows that the when collaboration with PROs increases, SMEs are 2.55 more times likely to be biotech ventures, and they are 0.18 less times likely to be biotech firms whenever SMEs collaborate with an HBO institute. The only exception to the rule formulated in H2 are R&D collaborations with customers, where biotech firms collaborate more strongly than ICT firms. The reason may be that biotech firms need to test their drugs on patients before new drugs can be brought to the market. Hence,

the strong extent of collaboration with customers might be a peculiarity of the biotech industry rather than an indication of how basic technology developers seek to avoid knowledge spillovers.

Finally, it is noteworthy that differences in the age of ICT and biotech SMEs are so small that they only come out as statistically significant at a 0.1 level in the most parsimonious model (no. 2). This indicates that SMEs choose different approaches to cope with knowledge spillover problems by carefully choosing their R&D partners – and less so because they are of a certain age. The relative insignificance of corporate age compared to distinct collaboration strategies offers further support to hypotheses H1 and H2. To conclude, our analyses of solutions to knowledge spillover problems provide empirical support that SMEs developing basic technologies seek collaboration with basic research organizations, whereas SMEs developing applied technologies more often seek collaborations with applied research organizations.

4.2. How SMEs cope with legitimacy deficits

Having assessed how SMEs cope with knowledge spillover problems, let us turn to the second innovation barrier studied in this article: legitimacy problems. The results obtained from the logistic regression analyses on legitimacy acquisition strategies are presented in table 3. In line with our findings from table 1b, these results provide support for both hypotheses 3 and 4. Accordingly, both models 1 and 2 indicate that clean-tech SMEs, which generally enjoy less legitimacy than ICT SMEs, engage in a broader variety of activities – focusing not only on product development but also on increasing the reputation and understanding of their business in general.

Table 3: Legitimating strategies of SMEs with high legitimacy deficits: binary logistic regression

0 = SMEs with Low Legitimacy Deficits (ICT)		Model (0)		Model (1)		Model (2)	
1 = SMEs with High Legitimacy Deficits (CT)		B	Exp(B)	B	Exp(B)	B	Exp(B)
	Constant			-1.90***		-2.02***	
	Outsourcing	.75*	2.11*	.22	1.25		
	Sharing Facilities	1.16***	3.19***	.97*	2.64*	.86*	2.37*
	Recruitment	-.66	0.52	-.81	.44	-1.02**	.36**
	Share employees	-.15	0.86	-.89	.41		
	Training	-.40	0.67	-.48	.62		
	Trainees	-.28	0.75	-.27	.76		
	Joint Projects	1.19***	3.30***	.89*	2.45*	.88**	2.41**
	Joint Publications	1.17***	3.22***	.99**	2.69**	.82*	2.27*
	Guest lectures	.35	1.42	-.07	.93		
	AGE	.01	1.01	.02	1.02	.02	1.02
N				162		162	
R2				0.216		0.129	

**** significance level greater than 99%*
*** significance level greater than 95%*
** significance level greater than 90%*

More specifically, the most parsimonious model (no.2) shows that the likelihood that an SME has a high rather than a low need for legitimacy acquisition is 98.63% higher whenever a

firm shares facilities with a research organization, 98.59% higher whenever an SME carries out joint projects, and 98.73% higher whenever a firm publishes together with a research organization.[4] We consider these results as a confirmation of hypothesis 3, as low legitimacy SMEs generally pursue a broader variety of aims when collaborating with research organizations than high legitimacy SMEs.

In line with hypothesis 4, the results of table 3 also suggest that clean-tech SMEs, whose technologies are generally less well understood than those of ICT firms, engage in more activities that do not aim at developing a product in the first place but rather generate awareness and understanding for their firm and its technology. While there are no systematic differences in the behaviour of high and low legitimacy SMEs regarding activities that do both develop a product and generate awareness, SMEs with a high need for legitimacy acquisition are significantly less likely to engage in activities that only seek to develop a product. Accordingly, model 2 indicates that low legitimacy SMEs abstain from fostering product development by recruiting employees from research organizations (Exp. B = .36). Instead, SMEs with low legitimacy aim to legitimate their technology and activities through joint publications (Exp. B = 2.27) and joint research projects with research organizations (Exp. B = 2.41). The only exception to the rule formulated in hypothesis 4 is that the odds of an SME having low rather than high legitimacy are 98.63% higher for firms that engage in sheer product-development activities by sharing facilities with PROs.

Similar to our results on knowledge spillover problems and solutions, we find that corporate age does not significantly influence how SMEs are affected by legitimacy acquisition problems when outliers are taken into account. In sum, we conclude that, despite the innovativeness of both sample groups, SMEs pursue legitimation strategies that are more product oriented whenever they already enjoy high levels of legitimacy, whereas their legitimation strategies are technology and business oriented whenever SMEs have low legitimacy levels.

5. Discussion and conclusions

In this study, we have examined how SMEs cope with two fundamental innovation barriers: knowledge leakage and legitimacy acquisition. Our analyses of one of the most comprehensive datasets on innovative SMEs have shown that SMEs developing basic technologies deal differently with the risk of knowledge leakage than SMEs in applied technology areas. Overall, SMEs in basic technological areas are very selective when choosing external R&D partners. More concretely, we found that SMEs developing basic technologies, which are generally more affected by the risk of knowledge appropriation by R&D partners, are more likely to collaborate with partners that are also active in basic technologies, because such collaborations reduce the risk of involuntary knowledge spillover. Furthermore, our analyses indicate that innovative SMEs pursue different legitimating strategies, depending on the acceptance and recognition of their technology among potential stakeholders. SMEs developing technologies whose usefulness is generally well understood focus on product development activities, whereas SMEs developing less accepted technologies typically focus on technological legitimating activities that go beyond mere product development.

Like most studies, our research is not without limitations. First, the list of innovation barriers we study is certainly not exhaustive. Innovative SMEs face more obstacles than this article could examine with the necessary depth. We therefore decided to focus on two particularly severe innovation barriers: knowledge leakage and the lack of organizational legitimacy.

[4] Given that the independent variables is binary, the percentage change in odds for each unit increase in the independent variable are calculated using the formula: 100 – (exp(B) – 1).

Consequently, our work should be seen as a complement to other studies of innovation barriers rather than an exhaustive discussion of all difficulties that innovative SMEs encounter.

Second, even though the database used is a comprehensive, large-scale, and randomly selected source of information, we acknowledge that the database consists of self-reported data, which may reflect some biases in the views of founders and owner-managers. Thus, scholars wishing to corroborate, or refute, our findings may want to use alternative data sources. In particular, qualitative insights into the causal mechanisms that lead innovative SMEs to select certain innovation partners, or to engage in specific legitimating activities, would be desirable.

Third, the operationalization of both knowledge leakage and organizational legitimacy deficits may be debatable. Since technological characteristics of ventures are at the basis of firms` difficulties to acquire know-how and gain legitimacy, we used their technological field as proxies for the extent to which they are affected by the respective innovation barriers. While we believe that the choice of these technological fields represents best how innovative SMEs are affected by knowledge leakage and legitimacy deficits, other scholars may wish to test our findings on the basis of alternative indicators for the respective innovation barriers.

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