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THE INTER-RELATIONSHIPS BETWEEN EXTERNAL R&D, INFORMAL PARTNERSHIPS AND INNOVATION PERFORMANCE

Levan Bzhalava
Friedrich Schiller University Jena
Microeconomics and Business Administration
levan.bzhalava@uni-jena.de

Mette Præst Knudsen
University of Southern Denmark
Department of Marketing and Management
mpk@sam.sdu.dk

Uwe Cantner
Friedrich Schiller University Jena
Microeconomics and Business Administration
uwe.cantner@uni-jena.de

Abstract

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variables come from 2008 Community Innovation Survey (CIS). One year lag is taken in order to avoid endogeneity issues, implying that the dependent variables are taken from 2009 CIS. The survey contains information on the expenses for R&D performed by external actors whether domestic or international and then subsequently used in internal innovation activities. The data analyses show that integration of domestic external R&D in internal innovation activities substitutes the utilization of informal linkages; we could not detect significant relationship between international external R&D and informal linkages. Moreover, the paper demonstrates that a firm acquiring international, rather than domestic, external R&D is more likely to develop high degree of product innovativeness.

Jelcodes:L24,L23

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Abstract

External R&D has become important strategy in product innovation. Yet, little is known how such strategy relates to other types of openness and overall product innovativeness. To study this issue, the paper analysis the following research questions: First, does external R&D substitute or complement the utilization of informal linkages in internal innovation activities? Second, how does external R&D relate to the degree of product innovativeness? The paper uses Danish innovative firms from the manufacturing sector to address the proposed research questions. The independent variables come from 2008 Community Innovation Survey (CIS). One year lag is taken in order to avoid endogeneity issues, implying that the dependent variables are taken from 2009 CIS. The survey contains information on the expenses for R&D performed by external actors whether domestic or international and then subsequently used in internal innovation activities. The data analyses show that integration of domestic external R&D in internal innovation activities substitutes the utilization of informal linkages; we could not detect significant relationship between international external R&D and informal linkages. Moreover, the paper demonstrates that a firm acquiring international, rather than domestic, external R&D is more likely to develop high degree of product innovativeness.

Key Words: Open innovation, domestic external R&D, international external R&D, informal linkages, product innovativeness

JEL codes**: L23, L24**

1. Introduction

The open innovation paradigm introduced by Chesbrough (2003) is one of the current debatable topics in R&D management literature (Laursen and Salter, 2006; Dahlander and Gann, 2010). The new paradigm is described as a process in which organizational boundaries are 'porous' and a firm strongly engages in interaction with external partners for the purpose of advancing knowledge exchange across organizational boundaries (Lichtenthaler, 2008). Although the idea of open innovation is not entirely new –"External collaboration is as old as the first invention" (Grönlund et al, 2010, p. 10) – the interesting new aspect introduced by the open innovation approach is that firms have started thinking about the balance of their internal R&D activities and their degree of openness.

Studying empirically the implications of open innovation, two main types of collaborations are identified in the literature, informal and formal ones (Dahlander and Gann, 2010). In the informal type of openness there are no formal contracts defining the type of innovation projects and ruling how costs and benefits are to be shared; external actors serve as knowledge sources in innovation activities and the respective knowledge flows are labelled as informal linkages (Freitas et al, 2008). In contrast, formal types of openness refer to either the case of developing innovation jointly on a contractual basis or the case of acquiring external R&D; the external actors are then formal collaboration partners or R&D suppliers, respectively. In both cases, activities performed externally the outcome is subsequently transferred back and used in internal R&D.

Independent of whether external knowledge search is done formally or informally, openness is costly for a firm (Katila and Ahuja, 2002). For the integration of external knowledge into internal R&D activities common interface needs to be established that requires absorptive capacity allowing identifying, assimilating and transforming external knowledge for internal purposes (Cohen and Levinthal, 1990). Building up the absorptive capacity is a time consuming and costly process. Due to this issue, negative effect of over searching of external knowledge on innovation performance is recognized (Laursen and Salter, 2006). Kaput (1997) claims that over-searching is not only affected by the 'absorptive capacity problem', but also by the 'attention allocation problem'. When there are many ideas for a firm to choose between, only a few of them will be given the required level of attention and effort to be implemented (Laursen and Salter, 2006). Based on these arguments, a firm may prefer to restrict the diversity types of external collaborations, and to prevent external knowledge over-search in its innovation activities.

Distinguishing between external R&D and informal linkages, main advantages of the former is to reduce a firm's involvement in innovation activities; once the activities are performed externally, the outcome is subsequently transferred back and used in internal R&D. External R&D may therefore allow a firm to contract out innovation activities that are less important for long term competitiveness in favor of deepening its current knowledge base and expertise. Such knowledge decomposition allows a firm to reduce the costs and risks of internal R&D, and to speed up new product development (Quinn, 1999). Although external R&D promises above mentioned advantages, it puts additional challenges on a firm in terms of knowledge integration. Since a firm does not involve in problem solving activities of external R&D, effective utilization of the knowledge provided by R&D suppliers can be problematic (Takeishi, 2001). To deal with this issue, additional effort may be required in term of developing internal knowledge base. For this purpose, Cassiman and Veugelers (2006) highlight importance of collaboration with university to increase internal knowledge base and to transform external R&D into product innovation. Grimpe and Kaiser (2010) further discuss this issue and come up with the recommendation that high numbers of formal collaborations positively moderates the effectiveness of external R&D on product innovation. While the literature discuss the role of formal collaborations in effective utilization of knowledge provided by R&D suppliers (Grimpe and Kaiser, 2010), little is known whether external R&D substitutes or complements informal linkages used in internal innovation activities.

This paper takes up this issue by analysing the following research questions: First, how does external R&D associate with the utilization of informal linkages in internal innovation activities? Second, how does external R&D relate to the degree of product innovativeness? Our data allows us to differentiate external R&D based on geographical location whether it comes from domestic or international marketplaces. Rather than using standard yes or no questions to identify the use of such instruments, the paper uses the amount of money invested in such activities. This allows us the detailed investigation the inter-relationship between external R&D, informal linkages and product innovativeness.

The findings indicate that domestic external R&D substitute the number of informal linkages used in internal R&D, but we could not detect significant relationship between external R&D and informal linkages. Moreover, the paper shows that a firm acquiring international, rather than domestic, external R&D is more likely to develop product innovation with high degree of product innovativeness.

The rest of the paper is organized in the following way. The next section provides a review of the literature and theoretical arguments for hypotheses development. The database and variables are described in section 3. Section 4 outlines appropriate methodologies for econometric analyses. Section 5 provides estimation results and the last section ends with the discussion and conclusion.

2. Literature Review and Hypothesis Development

2.1 External R&D as a Component of Open Innovation

Main concern of open innovation is to accelerate innovation and to reduce its overall costs (Chesbrough, 2003). Exploration of external knowledge rather than focusing only on internal knowledge is seen as a way to reduce costs of innovation and to speed up new product development. Although external knowledge exploration promises to advance innovation activities, the high degree of openness contains 'pains' that may hurt innovation performance (Katila and Ahuja, 2002; Laursen and Salter, 2006; Grimpe and Kaiser, 2010). Such 'pains' takes place when a firm does not have enough internal expertise to exploit external knowledge, and to apply it for a commercial purpose (Cohen and Levinthal, 1990). This issue is problematic in open innovation which requires balancing internal and external knowledge search (Grimpe and Kaiser, 2010). Thinking how to set R&D boundaries in open innovation, a firm gets instruction from transaction cost economics and resource based view (Dahlander and Gann, 2010).

Fundamental issue in transaction cost economics is how to allocate resources, in our case between internal and external R&D, in cost and risk effective way (Coase, 1937; Williamson, 1975). Based on the theory, external R&D - whether it is domestic or international - is favoured in case of infrequent transactions and low risk of relaying external actors in required knowledge generation process. Resource based view (Penrose, 1959; Wernerfelt, 1984; Barney, 1991) further discuss the resource allocation issue, and come up with the recommendation that the activities generating valuable, unique and non-imitable resources must be kept internally, and supportive activities should be acquired externally (Teece, 1986). In other words, main idea of decomposing innovation activities between internal and external R&D is to contract out activities that are less important for long term competitiveness in favour of specialized core competency defined as activities that gives the firm competitive advantages compared to its competitors (Quinn, 1999). In this way, acquisition of external R&D may influence other types of openness in internal innovation activities. For

instance, Argyres and Silverman (2004) suggest that focusing on narrow innovation challenges inspire the firm to seek less knowledge outside of the organizational boundaries. Moreover, Keupp and Gassmann (2009) argue that risks and costs of innovation activities are one of the main drivers of external knowledge search. These arguments lead us to the question whether external R&D complements or substitutes degree of openness with respect to informal linkages.

Although external R&D reduces costs and risks of internal innovation activities, it is characterized in such a way that puts additional challenges on a firm in term of knowledge integration (Takeishi, 2001). Since a firm does not involve in problem solving activities of external R&D, such knowledge integration is often problematic. This issue may become more problematic once geographical distance increases in external knowledge utilization; different cultural values, norms and institutions across countries creates specific learning environment that may increase cognitive distance between local and foreign firms (Kirat and Lung, 1999). In this sense, absorptive capacity plays key role to effectively cooperation with external entities on distance geographical location (Drejer and Vinding, 2007). For the purpose of enriching internal absorptive capacity, open innovation literature highlights importance of increasing integration of external information sources in internal problem solving activities (Gassmann and Enkel, 2006). In this line of reasoning, we assume that a firm acquiring international, rather than domestic, external R&D is more likely to employ the number of informal linkages in its internal innovation activities. Hence, we propose following hypothesis:

> *H1: Other things remaining the same, a firm acquiring international, rather than domestic, external R&D is more likely to utilize the number of informal linkages in its internal innovation activities.*

2.2 External R&D and Product Innovativeness

Having discussed possible relationship between external R&D and the number of informal linkages, in this section we study the overall benefit a firm might expect from external R&D in its product innovation activities. In particular, we are interested to investigate how domestic and international external R&D relate to the degree of product innovativeness.

Distinguishing external R&D based on the geographical dimension, Bertrand and Mol (forthcoming) analyse French innovative firms from manufacturing industry and come up with the recommendation that acquisition of external R&D from foreign rather than domestic marketplace increase likelihood of product innovation. While knowledge spillover is geographically bounded

(Bottazzi and Peri, 2002), one of the main advantages of sourcing knowledge from international marketplace is to tap into global innovation network and to access diversity type of knowledge not available within home market (Rosenkopf and Almeida, 2003; Lahiri, 2005). In this sense, international external R&D may support a firm to supply internal innovation activities by heterogeneous knowledge, which can enhance internal creativity and innovation performance (Nelson and Winter, I982; Cohen and Levinthal, 1990). Lahiri (2005) suggest that once knowledge coming from distance location is effectively integrated in internal R&D, it increases innovation quality, and put the firm in competitive advantage comparing with its competitors relaying only on local knowledge. Moreover, as we have discussed in the previous section, utilization of international, rather than, external R&D may require additional effort in terms of practicing with other types of openness resulting with high variation of new ideas in internal innovation activities. Based on these arguments, we assume that a firm acquiring international, rather than domestic, external R&D is more likely to develop higher degree of product innovativeness. Hence, following hypothesis is proposed:

H2: Other things remaining the same, a firm acquiring international, rather than domestic, external R&D is more likely to develop higher degree of product innovativeness.

3. Database and variables

The empirical part of the paper is based on Community Innovation Survey (CIS) implemented in Denmark[1]. The CIS is conducted on the enterprise level and gives a broad variety of information on innovation activities such as internal and external R&D expenditures, the number of information sources used in innovation, the types of internal R&D - whether it is basic, applied research or development work, R&D employment structure and different types of product innovations, etc.

The independent variables, which are domestic and international external R&D, share of scientists and technical workers in total R&D employment, firm size, etc, come from 2008 CIS. One year lag is taken in order to avoid endogeneity issue implying that the dependent variables which are informal linkages and product innovativeness are taken from 2009 CIS. By merging 2008 and 2009 CIS data files we get 667 observations. We delete non-product innovative firms from the sample (resulting in 294 observations) to study the factors relating different level of product innovativeness. In the empirical analysis we restrict our attention on the manufacturing sector.

[1] The paper acknowledges the access to the Danish CIS data from the Danish Statistical Office.

3.1 Dependent variables

The paper presents three level of analysis. In the first place, we examine the factors (such as innovation objectives, characteristics of internal innovation activities, etc.) that may associate with external R&D and informal linkages strategy. The paper operates with two dependent variables. The first, *external R&D*, is binary variable taking the value one if a firm purchase external R&D from external entities. The second, *informal linkages*, stands for the number of information sources employed in internal innovation activities (Freitas et al, 2008). The CIS lists nine possible information sources – suppliers, customers, competitors, private consulting organizations, universities, other public research institutions, conferences, scientific journals, and industrial organizations. The respondents were asked to evaluate the importance of each of these sources on a four-point scale, ranging from low (0) to high (3). We simply added up the nine information sources so that each firm gets a zero when no information sources are used, and twenty-seven, when all sources are used with high intensity.

In the next regression analysis, we are interested to study whether the acquisition of external R&D complements or substitutes the utilization of informal linkages in internal innovation activities. Similarly to the first level of analysis, the dependent variable - *informal linkages* - refers to the number of information sources used in internal innovation activities. We simply added up all information sources so that the variable gets value between zero and twenty-seven. Moreover, we use different methodology to construct the variable for the number of informal linkages - each information source is coded as a binary variable, zero for 0-1 scale and one for 2-3 scale (Freitas et al, 2008). After adding up all the information sources, firms get a zero when no information sources are used and nine, when all sources are utilized.

At the end, we study how domestic and international external R&D relate to the degree of product innovativeness. To measure the degree of novelty in product innovation, respondents were asked whether firms introduced product new to their current market or new the worldwide (the survey also contains information whether a firm introduced product innovation that is already known on the market. While this strategy is related more to imitation than product innovation resulted from the innovation activities, the variable is excluded from the regression analyses). The high degree of product innovativeness is measured as a share of sales from world new product, whereas low

product innovativeness refers to share of sales from product new to a firm's current market. They are continues discrete variables and fall between zero and one.

3.2 Independent variables

Having discussed the dependent variables, we turn our attention to the independent ones. In the first level of analysis, to explain the characteristics of firms relaying external R&D and informal linkages in innovation activities, we take the type of internal R&D, diversity of internal R&D employment, innovation objectives, firm size and industry characteristics as independent variables. All the independent variables, except the type of internal R&D, come from 2008 CIS; the survey does not contain information on the characteristics of internal R&D, therefore the variable is taken from 2009 CIS. To measure the characteristics of internal innovation activities, respondents were asked whether they invested in basic, applied or development work; the variables have binary outcomes. *Basic research* is defined as an experimental or theoretical work undertaken primary purpose of gaining new knowledge without any specific application. *Applied research* stands for an experimental or theoretical work to gain new knowledge that has direct specific or commercial application. *Development work* is the systematic work, drawing on existing knowledge gained from research. The basic research does not provide enough positive observation. Hence, we do not expect the variable to be significant in the regressions; we put the line instead of the coefficient.

Table I - Descriptive statistics

Variable names	Obs.	Mean	Std. dev.	Min	Max
Low degree of Product innovativeness	294	0.15559	0.2675	0	1
High degree of Product innovativeness	294	0.08204	0.2210	0	1
Informal linkages (2009)	294	5.39115	2.2122	0	9
Log (informal linkages) (2009)	294	3.1906	0.2014	2.4849	3.5835
Informal linkages (2008)	294	4.77891	2.67502	0	9
Domestic external R&D	294	0.30414	0.42841	0	1
International external R&D	294	0.15163	0.31663	0	1
Share of scientist	294	0.42417	0.34949	0	1
Share of technical workers	294	0.2494	0.2721	0	1
Basic research	294	0.0816	0.2742	0	1
Applied research	294	0.3605	0.4809	0	1
Development work	294	0.7176	0.4508	0	1

To measure the diversity of internal R&D employment, we use Blau index (Blau, 1977) referring to the following formula – $(1-\sum P_i^2)$, where P stands for the proportion of each category workers in total R&D employment and i refer to a number of categories. 2008 CIS differentiates three types of R&D workers: scientific, technical and others. Each of the categories stands for the share of total R&D employment.

To define *innovation objectives*, respondents were asked to evaluate the important of the following objectives in company's innovation activities: Increase the range of goods or services, replace outdated products or workflows, increasing flexibility in the production of goods or services, increase capacity in the manufacturing of goods or services. The answers are scaled between 0 (no) and 3 (high). In order to identify the variables with similar information content we conduct component factor analysis, which suggests one factor of innovation objectives. Since the concept of the variables is different, we decided to estimate each of the variables independently than to present all of them in one factor.

Moreover, in the regression analyses we add control variables relating to firm size and industry characteristics. *Firm size* is measured by the logarithm of the number of employees. In our sample 20 percent are micro firms (9-50 employees); 45 percent represents small sized firms (50-250 employees), 17 percent are medium sized firms (250-500 employees), and 17 percent are large sized firms (more than 500 employees). To control the industry characteristics a firm operates in, we constructed three groups: *Low-tech industry* if a firm belongs to NACE 15, 16, 17, 18, 20-22; *Medium-tech industry* - 24, 25, 26, 27, 28, 29; *High tech industry* - 30, 31, 32, 33. Firms across industries are distributed in the following way: 19 presents comes from low tech industry; 57 percent from medium tech industry, and 22 percent from high tech industry. Based on the groups we introduce industry dummies in regression analyses. Medium tech industry is taken as benchmark variable. The variables relating firm size and industry characteristics are also control in the next regression analyses.

Table II - Correlation Table

	Variable names	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	High degree of product innovativeness	1.000													
2	Low degree of product innovativeness	-0.072	1.000												
3	Informal linkages (2009)	0.035	0.040	1.000											
4	Informal linkages (2008)	0.027	0.009	0.236	1.000										
5	Domestic external R&D	-0.042	0.035	-0.165	-0.0553	1.000									
6	International external R&D	0.144	0.033	-0.096	-0.0597	-0.128	1.000								
7	Log(firm size)	0.040	-0.133	-0.307	-0.1058	0.122	0.269	1.000							
8	Share of scientist	0.150	-0.069	-0.137	0.0534	0.139	0.117	0.139	1.000						
9	Low tech industry	-0.014	0.040	0.079	0.1019	-0.125	-0.058	0.128	-0.095	1.000					
10	High tech industry	0.039	0.090	-0.095	0.116	-0.024	-0.006	-0.104	0.238	-0.269	1.000				

11	Share of technical workers	0.022	0.012	-0.054	0.083	0.193	0.125	0.105	-0.198	-0.107	0.015	1.000			
12	Basic research	0.139	-0.005	-0.055	0.006	0.071	0.144	0.177	0.061	-0.147	0.074	0.123	1.000		
13	Applied research	0.214	-0.044	-0.258	-0.038	0.058	0.251	0.381	0.155	-0.069	0.064	0.183	0.345	1.000	
14	Development work	0.108	0.097	-0.148	0.038	0.121	0.192	0.233	0.289	-0.163	0.163	0.220	0.187	0.339	1.000

In the second level of analysis, the main explanatory variables are domestic and international external R&D. The survey contains information on the expenses for R&D performed by external actors whether domestic or international and then subsequently used in internal R&D. *Domestic external R&D* refers to expenses for R&D performed by external actors located in Denmark – such as other parts of the business group, other companies, approved technological service institute, universities and colleges, other public research institutions. *International external R&D* stands for the expenses for R&D performed by external actors located abroad - such as other parts of the business group, other companies and universities or other public research institutions. We divide expenditure for domestic external R&D by total external R&D expenditure (i.e., domestic and international external R&D). Similarly, international external R&D refers to the share of international external R&D expenditure in all external R&D spending. In the regression analysis, we also control other factors that could relate to organizational decision to utilize the number of informal linkages in internal innovation activities. These variables are the type of internal R&D, firm size and industry characteristic. The variables are explained at the beginning of this section when we discuss the independent variable for the first level of analysis.

In the final regression, similar to the second level of analysis, external R&D is differentiated based on geographical location whether it comes from domestic or international marketplaces (the variables are explained in the previous paragraph). Moreover, the share of scientists and technical workers in total R&D employment are taken as independent variables. In the regression, we also control for the number of informal linkages to check whether high number of information sources used in internal R&D relates significantly to the degree of product innovativeness. The variable (informal linkages) comes from 2008 CIS data. Each information sources is coded as a binary variable, zero for 0-1 scale and one for 2-3 scale (Freitas et al, 2008). After adding all the information sources, firms get a zero when no information sources are used and nine, when all sources are used.

4. Econometric models

The dependent variables, in the first level of analysis, are external R&D and informal linkages. The former has binary outcome; to model the variable we use Logit regression (Cameron and Trivedi, 2005). The second dependent variable is informal linkages, which has count outcome - ranging

from zero to twenty-seven. After logarithm transformation, we use OLS regression to model informal linkages. In the second level of analysis, we use the same method to estimate informal linkages. In addition to this, we have variable, informal linkages, with the values ranging between zero and nine. The variable is normally distributed, and it allows us to use OLS regression. Moreover, since informal linkages ranging from zero to nine is count variable we use count data methods. Usually, the starting point of a count data analysis is Poisson model (Cameron and Trivedi, 2005). However, Poisson model is too restrictive and may not be able to cope with over-dispersion and excess zeros problems. Over-dispersion 'leads to grossly deflated standard errors and grossly inflated *t* statistics' (Cameron and Trivedi, 2005, p. 670). Therefore, we check whether our data is free from such problems. The variable does not show over-dispersion and excess zeros problems; variance is smaller than mean (see table I). Also, the variable contains very few zeros. Hence, Poisson model fits well to our data.

In the final estimation, we are interested to investigate how domestic and international external R&D relates to product innovativeness. We have two dependent variables: low and high degree of product innovativeness. They are continues discrete variables and fall between zero and one. Since the dependent variables contain high number of zeros, the left-censored Tobit model is used to adequately account for this specific feature of our data.

5. Estimation results

Table III presents regression analysis for external R&D and informal linkages. The results demonstrate that both applied research and development work positively and significantly relate to external R&D with the level of significance increasing towards development work. In contrast, applied research negatively associates with the number of informal partnerships. No significant relationship is found between the development work and the number of informal partnerships. The estimation results suggest that those firms concentrating on applied research and development work are more likely to supplement internal innovation activities with external R&D rather than informal linkages. Basic research contains very few positive observations; therefore the estimations do not give significant results, and hence the table shows lines instead of the coefficients.

Table III – Estimation Results for External R&D and Informal Partnerships

	Logit	Logit	Logit	Logit	OLS	OLS	OLS	OLS
	1	2	3	4	5	6	7	8
	External R&D	External R&D	External R&D	External R&D	Log(informal linkages)	Log(informal linkages)	Log(informal linkages)	Log(informal linkages)
Basic research	----------	----------	----------	----------	----------	----------	----------	----------
Applied research	0.772**	0.849**	0.706**	0.698**	-0.077***	-0.088***	-0.059**	-0.064**
Development work	1.648***	1.587***	1.661***	1.661***	0.027	0.032	0.022	0.019
Diversity of internal R&D employment	0.726	0.589	0.620	0.620	0.088*	0.100*	0.099*	0.084*
Low-tech-industry	0.240	0.332	0.265	0.265	0.047	0.032	0.0388	0.034
High-tech-industry	0.971**	0.963**	0.961**	0.961**	-0.010	-0.013	-0.014	-0.026
Log (firm size)	0.536***	0.493***	0.509***	0.491***	-0.032***	-0.025**	-0.026***	-0.025**
Inno obj: increase range of goods	-0.270*				0.037***			
Inno obj: replace outdated product		-0.292*				0.047***		
Inno obj: increase flexibility			-0.187				0.051***	
Inno obj: increase capacity				-0.187				0.056***
Constant	-4.898***	-4.530***	-4.720***	-4.702***	3.223***	3.162***	3.132***	3.127***
LR chi2(9)	82.66***	82.75***	80.67***	80.67***	8.66***	9.61***	9.67***	10.76***
Pseudo R2	0.2366	0.238	0.232	0.232	0.1866	0.2017	0.2152	0.232

Note: *, ** and *** denote significance at a 10%, 5% and 1% level respectively

Moreover, the paper finds that the diversity of internal R&D employment does not relate significantly to external R&D, but associates positively with informal linkages. It implies that diversity of internal skill allows firms to engage in the number of external information search available outside of the organization boundaries rather than to complement internal innovation activities by external R&D. Moreover, the estimation result shows that the size variable has a positive and significant correlation with external R&D, but negatively and significantly associates with informal linkages. It is surprising that large firms employ less external knowledge sources in innovation processes in the form of informal linkages. One possible explanation can be that large firms in Denmark may be more sensitive to acquire external R&D than to employ the number of informal linkages in internal innovation activities. For instance, Brusoni et al. (2001), Chesbrough (2003a) and Prencipe (1997, 2000) suggest that the last decades large companies have started to organize entire projects internally, but they are responsible for developing only sub technologies. In this sense, it might be case that firms acquiring external R&D utilize less information sources in innovation activities. Moreover, the results indicate that firms from high tech industry purchase external R&D, and combining internal and external R&D more intensively compared to the medium tech industry. In high and medium tech industries, the number of informal linkages employed in innovation activities does not differ significantly from each other. The dummy for low tech industry does not provide significant signs in any of the regressions. The innovation objectives such as increasing range of goods and replacing outdated products decrease the likelihood of the firms pursuing external R&D. Other innovation objectives such as increasing capacity and organizational

flexibility do not provide significant results. In contrast, all of the innovation objectives positively and significantly relate to informal linkages.

Table IV contain Poison and OLS regressions; the Models present very similar results. In the regressions domestic external R&D is significantly and negatively associated with informal linkages. We could not detect a positive and significant relationship between international external R&D and the number of informal linkages. It implies that knowledge search strategy toward domestic, rather than, international external R&D substitutes the number of informal linkages used in internal innovation activities. Hence, the estimation results do not confirm our *first hypothesis*.

Table IV – Estimation Results for Informal Linkages

	Poisson regression	OLS	OLS
	1	2	3
	Informal linkages (0-9)	Informal linkages (0-9)	Log(Informal linkages (0-27))
Basic research	----------	----------	----------
Applied research	-0.1471**	-0.7604***	-0.0746***
Development work	0.0107	0.0419	0.0083
Domestic external R&D	-0.1342**	-0.7305***	-0.0754***
International external R&D	- 0.0550	-0.3318	-0.0218
Log (firm size)	-0.0639***	-0.3468***	-0.0367***
Low-tech-industry	0.0231	0.1213	0.0420
High-tech-industry	-0.0933	-0.4789	-0.0505
Constant	2.1278***	7.0252***	3.4223***
LR chi2(9)	41.05***		
Pseudo R2	0.1158		
F (5, 280)		9.61***	8.98***
R2		0.1817	0.1638

Note: *, ** and *** denote significance at a 10%, 5% and 1% level respectively

At the end, the paper studies the relationship between external R&D and product innovations. In the *Second hypothesis*, it was argued that a firm acquiring international, rather than domestic, external R&D is more likely to develop high degree of product innovativeness. The empirical results demonstrate that domestic external R&D positively and significantly associated only with low degree of product innovativeness, whereas international external R&D positively and significantly relates both low and high dimension of product innovativeness (see Table V). It implies that firms purchasing external R&D from foreign, rather than, from local market are more likely to develop high quality of product innovation. The estimation results confirm proposed hypotheses.

Table V – Estimation Results for Product Innovativeness

	Tobit regression	
	Low degree of product innovativeness	High degree of product innovativeness
	1	2
Informal linkages (0-9)	-0.0049	0.0125
Share of scientists	-0.1355*	0.3327***
Share of technical workers	0.1182	0.1796
Domestic external R&D	0.1341**	-0.0489
International external R&D	0.1823**	0.2452**
Log (firm size)	-0.0227	0.0237
Low-tech-industry	0.0766	-0.0786
High-tech-industry	0.1289	0.0038
Constant	0.1075**	-0.6523***
LR chi2(7)	12.36*	28.31***
Pseudo R2	0.0935	0.1610

Note: *, ** and *** denote significance at a 10%, 5% and 1% level respectively

Moreover, the paper shows that the structure of internal R&D employment may also matter when a firm strives for the high quality of product innovation. For example, the share of scientific workers in total R&D employment positively relates to high degree of product innovativeness, but negatively related to low innovativeness dimension. The share of technical workers does not relate significant neither low nor high degree of product innovation. With respect to the firm size and industry dummies, surprisingly none of them indicates significant relationship with innovativeness variables.

6. Conclusion

The paper contributes to the current debate about the relationship between external R&D and product innovation. To study the issue, we present three levels of analyses. In the first place, we discuss the factors relating to external R&D and informal linkages. Second, the relationship between external R&D and the number of informal linkages are explained. At the end, we scrutinize the inter-connection between external R&D and product innovativeness. Our data allows us to differentiate external R&D based on geographical location whether it comes from domestic or international marketplaces. Rather than using standard yes or no questions to identify the use of such instruments, the paper uses the amount of money invested in such activities. This gives us possibility to investigate on a more detailed how external R&D relates to informal linkages and the degree of product innovativeness. Distinguishing external R&D based on a geographical dimension, we find that strengthening knowledge search strategy toward domestic external R&D substitutes

utilization of informal linkages in internal innovation activities. It implies that engaging in different types of external collaboration is costly for a firm, and in this sense, managers restrict external knowledge outreach in innovation activities. Moreover, we find that firms relaying international, rather than, domestic external R&D are more likely to develop high degree of product innovativeness that can compete at the global market. The findings suggest that utilization of international external R&D may allow firms to tap into global innovation network to access diversity type of knowledge not available within home market; relaying only local knowledge sources may not be enough to compete at the global market in terms of product innovation.

While the paper has important implication, explaining how the domestic and international external R&D relate to the degree of product innovativeness, it has also several limitations. First of all, since innovation processes often take longer than one year to result in a marketable product, one year lag might be too short to study input and output relationship in innovation activities. Also, our database is cross sectional and does not allow us to examine changes in variables over time; to study the effect of external R&D on product innovation. Moreover, for future research its vital that inter relationship between external R&D and product innovation to be studied in more detail. In particular, one should look at the external R&D whether it comes from research institutions/university, competitors, suppliers or consulting company. External R&D coming from research institution/university rather than other external entities may contain more basic knowledge that can play key role in enhancing the degree of product innovativeness. Such analyses will allow for a better understanding of how domestic and international external R&D influence on product innovation. While in the paper we argue that firms acquiring external R&D from international, rather than, from local market are better off in product innovation, it might be case that riskier R&D project to be contracted out in close proximity rather than on distance location. In this sense, purchasing external R&D from close proximity can be also crucial to develop product innovation that could compete on the global market.

References:

Argyres, N. S. And Silverman, B. S. 2004. Organizational Structure and the Development of Corporate Technological knowledge. Strategic Management Journal, 25: 929-958

Barney, J. B., 1991. Firm resources and sustained competitive advantage, Journal of Management, 17: 99-120.

Bertrand, O. and Mol, M. J. The antecedents and innovation effects of domestic and offshore R&D outsourcing. Forthcoming in Strategic Management Journal

Bottazzi, L. and Peri, G. 2003. Innovation and spillovers in regions: Evidence from European patent data. European Economic Review, 47(4): 687-710

Brusoni, S. Prencipe, A. and Pavitt. K. 2001. Knowledge Specialization, Organizational Coupling, and the Boundaries of the Firm: Why DoFirms Know More Than They Make? Administrative Science Quarterly, 46(4): 597-621

Cameron, A. C. and Trivedi, P. K. 2005. Microeconometrics - Methods and Applications. Published in the United States of America by Cambridge University Press, New York. www.cambridg e.org /9780521848053

Cassiman, B. and Veugelers, R. 2006. In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition, Management Science, 52(1): 68-82.

Chesbrough, H. W. 2003. Open Innovation - the New Imperative for Creating and Profiting from Technology, Boston, USA.

Coase, R. H. 1937. The Nature of the Firm. Economica 4(16): 386-405.

Cohen, W. M. and D. A. Levinthal. 1990. Absorptive Capacity: A New Perspective on Learning and Innovation. Administrative Science Quarterly, 35 (1): 128-153.

Dahlander, L. and Gann, D. M. 2010. How open is innovation? Res. Policy, doi:10.1016/j.respol.2010.01.013.

Drejer, I. and Vinding, A. L. 2007. Searching Near and Far: Determinants of Innovative Firms' Propensity to Collaborate Across Geographical Distance. Industry and innovation 14(3): 259-275

Freitas, I. M. B, Clausen, T. H. Fontana, R. and Verspagen, B. 2011. Formal and informal external linkages and firms' innovative strategies. A cross-country comparison. Journal of Evolutionary Economics 21:1, 91-119.

Grönlund, J. Ronneberg, D. and Frishammar, J. 2010. Open Innovation and the Stage-Gate Process: A Revised Model For New Product Development. California management Review, 5 (3): 106-131.

Grimpe, C. and Kaiser, U. 2010. Balancing Internal and External Knowledge Acquisition: The Gains and Pains from R&D Outsourcing. Journal of Management Studies, 47:8

Katila, R. and Ahuja, G. 2002. Something Old, Something New: A Longitudinal Study of Search Behavior and New Product Introduction. Academy of Management Journal, 45 (6): 1183-1194.

Keupp, M. M. and Gassmann, O. 2009. Determinants and archetype users of open innovation. R&D Management 39 (4).

Kirat, T. and Lung, Y. 1999. Innovation and Proximity: Territories as Loci of Collective Learning Processes. European Urban and Regional Studies 6: 27

Kogut, B. and Zander, U. 1992. Knowledge of The Firm, Combinative Capabilities and The Replication of Technology. Organizational Science, 3(3).

Koput, K.W. 1997. A Chaotic Model of Innovative Search: Some Answers, Many Questions. Organization Science, 8(5): 528-542.

Lahiri, N. 2005. Geographic Distribution of R&D Activity: How Does It Affect Innovation Quality? Academy of Management Journal, 53(5): 1194–1209.

Laursen, K. and Salter, A. 2006. Open for Innovation: The Role of Openness in Explaining Innovation Performance among U.K. Manufacturing Firms, Strategic Management Journal 27 (2): 131-150.

Levinthal, D. and March, J. 1982. A model of adaptive organizational search. Journal of Economic Behaviour and Organization, 2: 307-333.

Lichtenthaler, U. 2008. Open Innovation in Practice: An Analysis of Strategic Approaches to Technology Transactions. IEEE Transactions on Engineering Management, 55(1): 148-157.

Nelson, R. R. and Winter, S. G. 1982. An Evolutionary Theory of Economic Change. Cambridge, Mass: Harvard University Press.

Penrose, E. 1959. The Theory of the Growth of the Firm. New York, Oxford University Press Inc.

Prencipe, A. 1997. Technological capabilities and product evolutionary dynamics: A case study from the aero engine industry. Research Policy, 25: 1261-1276.

Prencipe, A. 2000. Breadth and depth of technological capabilities in complex product systems: The case of the aircraft engine control system. Research Policy, 29: 895-911.

Quinn, J. B. 1999. Strategic Outsourcing: Leveraging Knowledge Capabilities. Sloan Management Review; 40 (4): 9

Quinn, J. B. 2000. Outsourcing Innovation: The New Engine of Growth. Sloan Management Review; 41(4): 13

Rosenkopf, L. and Almeida, P. 2003. Overcoming Local Search through Alliances and Mobility. Management Science, 49 (6): 751-766

Takeishi, A. 2001. Bridging Inter- and Intra-Firm Boundaries: Management of Supplier Involvement in Automobile Product Development. Strategic Management Journal, 22: 403-433

Wernerfelt, B., 1984. A resource based view of the firm, Strategic Management. Journal, 5: 171-180.

Williamson, O. E. 1975. Markets and Hierarchies: Analysis and Antitrust Implications. New York, The Free Press.